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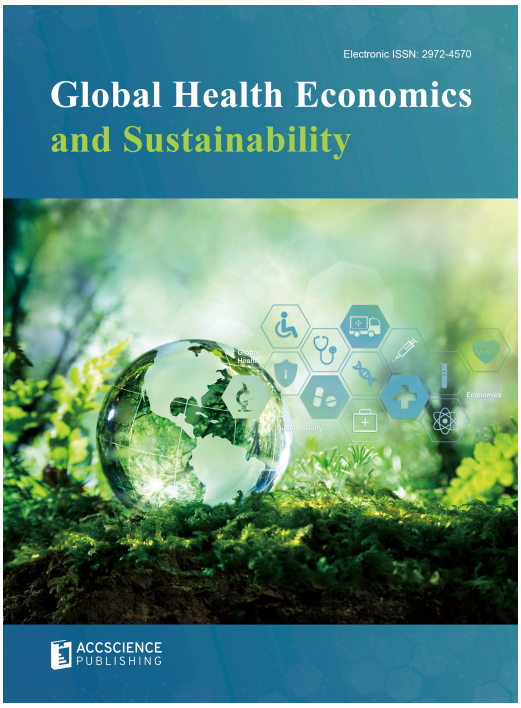

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AccScience Publishing
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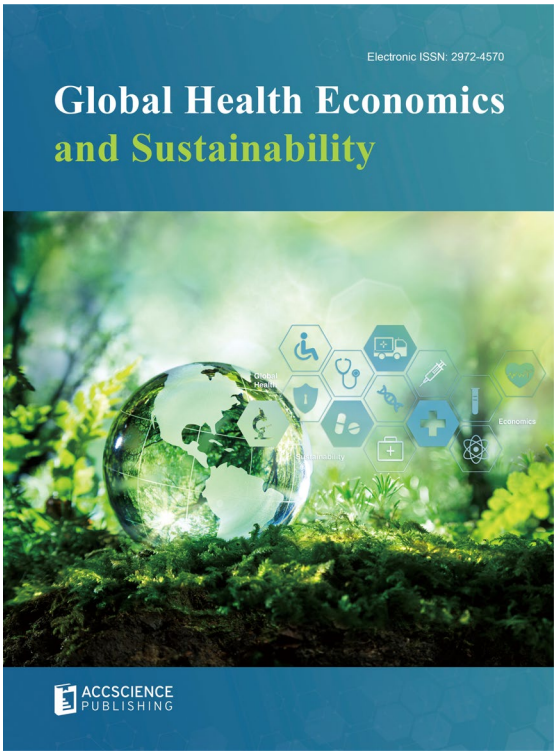

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Global Health Economics and Sustainability

REVIEW ARTICLE

Enhancing flow states in neurodivergent individuals through cognitive network integration

Piper Hutson* and **James Hutson**

Department of Art History, AI, and Visual Culture, College of Arts and Humanities, Lindenwood University, Saint Charles, Missouri, United States of America

Abstract

This article explores the concept of "flow" in the context of neurodivergence, focusing on the interaction between the default mode network (DMN) and task-positive networks (TPNs), particularly in conditions such as autism spectrum condition (ASC) and attention-deficit/hyperactivity disorder (ADHD). Flow, a state of deep immersion and focused engagement, is associated with enhanced performance and satisfaction across activities. The DMN, typically active during rest and self-referential thinking, interacts uniquely with TPNs during flow states, creating a dynamic balance crucial for sustained focus and reduced self-referential thinking. Neurodivergent individuals often exhibit distinct DMN activity patterns, which affect their capacity for achieving flow. For instance, individuals with ADHD may experience flow in stimulating tasks, whereas those with ASC may achieve it in areas of deep interest due to their intense focus. This paper examines the expertise-and-release model in creative flow and transient hypofrontality as a potential mechanism facilitating flow in neurodivergent individuals. It also proposes strategies to enhance flow through personalized cognitive training, specialized task environments, and technology-assisted interventions, aiming to harness neurodivergent strengths and accommodate unique cognitive profiles. This comprehensive analysis deepens understanding of neurodiversity and offers practical applications for improving quality of life and performance in neurodivergent populations.

Keywords: Neurodivergence; Flow state; Default model network; Task-positive networks; Transient hypofrontality; Expertise-plus-experience model

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***Corresponding author:**
Piper Hutson
(phutson@lindenwood.edu)

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1. Introduction

The concept of "flow" refers to a state of complete immersion and focused engagement in an activity, often resulting in enhanced performance and enjoyment. Investigating whether neurodivergent individuals experience flow more frequently due to connections with the brain's default mode network (DMN) requires reviewing the scientific literature on both flow states and neurodivergence. The DMN is a network of brain regions that are typically more active when a person is at rest and not focused on the external environment, such as during daydreaming, self-referential thought, and mind-wandering. Key regions include the medial prefrontal cortex, posterior cingulate cortex, and angular gyrus (Raichle, 2015). Studies continue to elucidate DMN's role and its interactions with task-positive networks (TPNs), underscoring its relevance in neurotypical and

neurodivergent populations. Current research has also highlighted the stability and consistency of DMN activity across different cognitive states. For example, studies have shown that the DMN remains highly stable during resting-state conditions, preserving its functional integrity over extended periods (Beason-Held *et al*., 2009). In addition, the network's deactivation patterns during task engagement are well documented, showing a significant reduction in activity in regions such as the posterior cingulate and medial prefrontal cortex when individuals switch from rest to cognitively demanding tasks (Pfefferbaum *et al*., 2011).

In neurodivergent individuals, the DMN shows distinct connectivity and activity patterns. For instance, those with autism spectrum condition (ASC) often exhibit atypical DMN connectivity, affecting cognitive processing and attention mechanisms (Wang *et al*., 2021). Similarly, individuals with attention-deficit/hyperactivity disorder (ADHD) may struggle to regulate network activity, leading to challenges with sustained attention and increased mind-wandering (Di & Biswal, 2014). These unique activity patterns can significantly impact their experience of flow states. Research suggests that efficiently switching between the DMN and TPNs is crucial for entering flow states, facilitating the intense focus and reduced self-referential thinking characteristic of flow (Beason-Held *et al*., 2009).

Neurodivergent individuals often experience heightened states of flow while performing activities that align with their interests and strengths (Heasman *et al*., 2024). For example, those with ASC can achieve deep flow states in areas of special interest due to their intense focus and dedication (Greicius *et al*., 2004; Wassner, 2024). Conversely, individuals with ADHD find flow in highly stimulating and engaging tasks that capture their attention, although they might struggle with maintaining flow in less engaging activities (Broyd *et al*., 2009; Ogrodnik *et al*., 2024). Neurodivergence, including conditions such as ASC, ADHD, and dyslexia, refers to variations in brain structure and function that affect attention, perception, and cognitive processing in unique ways (Broyd *et al*., 2009). Flow states often involve a balance between the DMN and TPNs, which are active during focused attention and goal-directed tasks. During flow, the DMN typically deactivates, whereas TPNs exhibit heightened activity, indicating a dynamic interplay between these networks (Pfefferbaum *et al*., 2011).

Although neurodivergent individuals exhibit unique DMN activity patterns, the relationship between neurodivergence and flow remains complex and understudied (van den Engh, 2024). Some neurodivergent individuals achieve flow more readily in specific contexts due to their distinct cognitive and attentional profiles (Savickaite, 2024). However, this phenomenon is not only attributable to the DMN but also to the interplay between various brain networks and individual characteristics (Greicius *et al*., 2004). Further research is essential to fully understand how different types of neurodivergence impact the ability to achieve and sustain flow states, considering both strengths and challenges associated with each condition (Heasman *et al*., 2024).

Given the distinct neurocognitive profiles of neurodivergent individuals and their unique DMN activity patterns, it is crucial to examine how these variations affect their ability to achieve and sustain flow states. This study aims to investigate the complex relationship between neurodivergence, the DMN, and flow through a comprehensive analysis of existing research and innovative, neurodivergent-focused approaches. By exploring the dynamic interaction between the DMN and TPNs while considering the roles of transient hypofrontality and cognitive expertise, this research seeks to provide deeper insights into the mechanisms that promote flow in neurodivergent individuals. The findings have the potential to guide the development of personalized cognitive training, specialized task environments, and advanced technological tools, enhancing the quality of life and performance of neurodivergent individuals. This study not only deepens our understanding of neurodiversity but also provides practical applications to foster optimal cognitive and creative engagement in diverse populations.

2. DMN, TPNs, and flow

The DMN and TPNs are crucial components of brain function, interacting dynamically to support various cognitive processes. The DMN, primarily active during rest and internally focused activities, includes regions such as the medial prefrontal cortex, posterior cingulate cortex, and angular gyrus (Fajardo-Valdez *et al*., 2024). In contrast, TPNs, active during goal-directed tasks, involve regions such as the dorsal attention network and executive control networks (Uddin *et al*., 2009) (Figure 1). The interaction between the DMN and TPNs is characterized by competitive dynamics, where activation in one network typically corresponds with deactivation in the other. This antagonistic relationship facilitates the brain's ability to switch between rest and task-focused states. For instance, studies have shown that DMN activity decreases during task engagement, whereas TPNs exhibit increased activity (Pfefferbaum *et al*., 2011; Seeburger *et al*., 2024). This modulation is essential for efficient cognitive functioning, allowing for adaptive responses to environmental demands.

Flow state, characterized by complete immersion and focused engagement in an activity, involves a dynamic balance between the DMN and TPNs (Fischman, 2023).

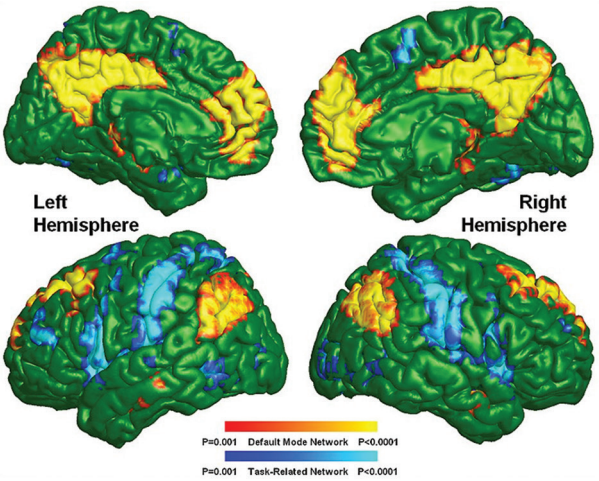

Figure 1. Default mode and task-related brain activity maps in healthy individuals (Shim *et al.*, 2010)

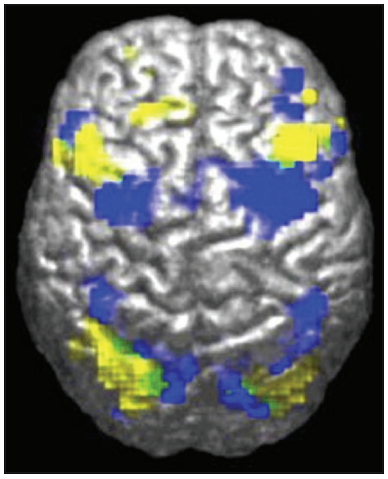

Figure 2. fMRI-derived image showing differences in brain activity between individuals with autism and control groups (Ralph-Axel Müller, 2004)
Abbreviation: fMRI: Functional magnetic resonance imaging.

Achieving flow relies on effective switching between these networks, enabling intense concentration and reduced self-referential thoughts (Beason-Held *et al.*, 2009; Parvizi-Wayne *et al.*, 2024). During flow, DMN deactivation minimizes distractions, whereas enhanced TPN activity sustains attention and performance. Neuroimaging studies have highlighted the functional connectivity between these networks. Task-related functional magnetic resonance imaging (fMRI) analyses show that DMN regions, such as the posterior cingulate cortex and medial prefrontal cortex, decrease activity during cognitive tasks, corresponding with increased activity in TPN regions such as the dorsal attention network (Picó-Pérez *et al.*, 2023; Vatansever *et al.*, 2015). These findings underscore the brain's capacity for dynamic reconfiguration, vital for cognitive performance.

Neurodivergent individuals, including those with autism and ADHD, exhibit distinct DMN and TPN connectivity patterns (Curtin *et al.*, 2023). For instance, individuals with ASC may show atypical DMN connectivity, affecting attention and cognitive processing (Wang *et al.*, 2021) (Figure 2). Conversely, those with ADHD often struggle with regulating DMN activity, leading to challenges with sustained attention and increased mind-wandering (Di & Biswal, 2014; Duke, 2023). Figure 2 illustrates these differences, clearly labeling DMN and TPN regions. The *p*-values in the figure indicate statistically significant differences in connectivity patterns, linking observed brain activity to functional outcomes in cognitive tasks. Understanding the interaction between the DMN and TPNs is essential for developing strategies to enhance cognitive and creative engagement. Research into these interactions during flow states can inform interventions that optimize performance in neurotypical and neurodivergent individuals. For instance, tailored cognitive training programs aimed at improving the ability to switch between the DMN and TPNs may facilitate flow states, thereby boosting cognitive function and creativity (Callara *et al.*, 2023; Uddin *et al.*, 2009).

Future research should further explore the mechanisms underlying DMN and TPN interactions, particularly in the context of neurodivergence (De La Serna *et al.*, 2021). Investigating how different types of neurodivergence affect the ability to achieve and sustain flow states will offer deeper insights into the strengths and challenges associated with these conditions. This research is crucial for developing personalized interventions that enhance cognitive and creative potential across diverse populations (Heasman *et al.*, 2024). By deepening our understanding of the DMN, TPNs, and their roles in flow states, we can better support individuals in achieving optimal cognitive performance and creative engagement, ultimately improving their quality of life and productivity. Investigations into domain expertise and intuitive processes have been part of these approaches.

3. Expertise-plus-release model in neurodivergent individuals

The expertise-plus-release model of creative flow, as proposed by the authors, suggests that reaching a state of flow in creative activities requires both deep expertise in a specific domain and the ability to relinquish conscious control, allowing spontaneous and intuitive processes to take over. This model aligns with research on the interaction between the brain's DMN and TPNs (Santarnecchi *et al.*, 2018; Yuan *et al.*, 2021). The DMN is associated with internally focused

activities such as daydreaming, envisioning the future, and considering others' perspectives (Carroll, 2020). Researchers found that the DMN facilitates creative thinking by enabling individuals to access their extensive knowledge base and form novel connections (Lopata *et al*., 2022; Zhuang *et al*., 2023). During reflection and incubation, experts may engage the DMN, integrating and reorganizing information engaged during tasks requiring subconsciously (Davidson, 2020; Raichle, 2015). TPNs are focused attention and active problem-solving (Hamilton, 2024). For experts, TPNs enable the application of learned skills and knowledge to specific tasks (Lesourd *et al*., 2024). The ability to switch efficiently and quickly between the DMN and TPNs is crucial for creative flow, allowing experts to harness their deep knowledge while engaging in focused, goal-directed activity (Hamilton, 2024; Vatansever *et al*., 2015).

The concept of "release" involves relinquishing conscious control, allowing intuitive and spontaneous processes to guide action (Chowdhury *et al*., 2024). This can be related to neurodivergent experiences and their unique brain connectivity patterns. Individuals with ADHD, for instance, often struggle with sustained attention and inhibitory control, which can lead to spontaneous and divergent thinking (Senkowski *et al*., 2024). This spontaneity may facilitate the release aspect of creative flow, particularly during engaging and stimulating tasks (Nejati *et al*., 2023). The hyperfocus observed in some individuals with ADHD can contribute to deep immersion in activities they find especially interesting, enhancing their potential for entering a creative flow (Wotruba *et al*., 2014).

Conversely, individuals with ASC might experience intense focus and deep engagement in areas of special interest, which can support the expertise component of creative flow. Their capacity for deep immersion in a topic can lead to significant creative insights (Horgan *et al*., 2023). The release aspect may be facilitated by their unique cognitive processing styles, which often involve less reliance on social conformity and more on original thought patterns (Greicius *et al*., 2004; Rządeczka *et al*., 2023). For neurodivergent individuals, the interplay between expertise and release is shaped by their unique brain functioning. They often develop deep expertise in areas of personal interest, with intense focus and dedication resulting in a rich knowledge base – critical for the expertise component of creative flow. This expertise is further supported by their ability to engage deeply with content, driven by their unique cognitive profiles and brain network activity (Bailey, 2023; Di & Biswal, 2014).

Although both ADHD and ASC can involve intense focus, the nature and triggers of this focus differ significantly. In ADHD, hyperfocus is often spontaneous and linked to novel, stimulating, or personally engaging tasks. This intense focus can emerge unpredictably and may shift rapidly based on interest levels (Wotruba *et al*., 2014). In contrast, individuals with ASC typically experience deep, sustained focus on specific areas of special interest. This focus is more stable and consistently tied to long-term passions and expertise (Horgan *et al*., 2023). The cognitive processes underlying this engagement also vary: ADHD-related hyperfocus is often driven by reward sensitivity and the need for stimulation, whereas ASC-related focus aligns more closely with a preference for routine, order, and depth of exploration (Di & Biswal, 2014; Greicius *et al*., 2004). Understanding these differences is crucial when examining how each condition impacts creative flow. Both groups can reach deep immersion, but the pathways and tasks that trigger it are distinct, reflecting their unique cognitive and neural profiles.

Neurotransmitter imbalances play a significant role in shaping the distinct cognitive profiles of ADHD and ASC, directly affecting DMN and TPN activities. In ADHD, dopamine pathway dysregulation is a central feature, leading to challenges with attention, impulsivity, and executive functioning. Moreover, reduced dopamine levels, especially in the prefrontal cortex, impair focus and the ability to switch effectively between the DMN and TPN, contributing to attentional variability (Volkow *et al*., 2009). In contrast, ASC often involves serotonin pathway alterations, impacting social cognition, mood regulation, and sensory processing. Serotonin imbalances contribute to the rigid, repetitive behaviors and intense focus on specialized interests characteristic of ASC, further influencing how these individuals engage with DMN and TPN networks (Schauder *et al*., 2015). Understanding these neurotransmitter differences is crucial for comprehending how flow states differ between ADHD and ASC. Dopamine's role in reward processing and motivation may drive spontaneous, hyperfocused states in ADHD, whereas serotonin's effect on routine and stability supports the sustained, methodical focus seen in ASC. These neurochemical differences highlight the need for tailored interventions that address each condition's unique neural dynamics, optimizing their ability to achieve and sustain flow.

Neurodivergent traits, such as divergent thinking and unique problem-solving, may enhance the ability to release conscious control and engage in intuitive processes, fostering spontaneous connections and novel ideas (Maw *et al*., 2024). Neurodivergent individuals may experience less inhibition from social norms and expectations, enabling greater creative freedom and exploration (Spreng, 2012). The expertise-plus-release model of creative flow is linked to these networks, with neurodivergent individuals

possibly experiencing this interplay in a unique manner. Their distinct cognitive profiles and brain network activity can both support and challenge their ability to achieve creative flow. Neurodivergent strengths in developing expertise and engaging in spontaneous, intuitive thinking can facilitate the creative flow state, making them potentially more adept at achieving flow in their areas of interest (Norris, 2023; Uddin *et al*., 2009).

4. Transient hypofrontality and flow

Other considerations regarding flow in neurodivergent populations involve transient hypofrontality, a phenomenon in which there is a temporary reduction in prefrontal cortex activity, including areas such as the superior frontal gyri, during high flow states (Khalil & Demarin, 2024). This concept is crucial for understanding how neurodivergent individuals might experience creative flow differently. Exploring transient hypofrontality within the context of the expertise-plus-release model, neurodivergence, and brain network dynamics offers valuable insights into flow mechanisms. The theory suggests that during flow, there is a temporary downregulation of the prefrontal cortex, which handles higher-order cognitive functions such as self-monitoring, planning, and decision-making. This reduction facilitates greater focus on the task at hand, allowing immersion without self-consciousness or overplanning (Dietrich, 2003; Parvizi-Wayne *et al*., 2024). In addition, reduced prefrontal activity can decrease cognitive inhibition, enabling freer, more spontaneous thinking and the generation of novel ideas (Lloyd-Cox, 2024).

The superior frontal gyri, part of the prefrontal cortex, is involved in self-awareness, executive functions, and integrating sensory and cognitive information (Tondelli *et al*., 2024). During flow states, decreased activity in these regions can facilitate deep immersion and seamless integration of actions and awareness (Chen & Mokmin, 2024). This dynamic is particularly relevant for neurodivergent individuals, who often exhibit different baseline activities and connectivity patterns in the prefrontal cortex and other brain regions, shaping their flow experiences (Megari *et al*., 2024). For instance, individuals with ADHD often exhibit reduced activity and connectivity in the prefrontal cortex, impacting executive function and attention regulation. This baseline hypofrontality may make it easier for those with ADHD to experience transient hypofrontality and enter flow, particularly in stimulating, engaging tasks (Faraone & Radonjic, 2023). Their tendency toward hyperfocus in areas of interest further supports this process (Carter *et al*., 1998). Similarly, individuals with autism display atypical connectivity patterns between the prefrontal cortex and other brain regions, affecting information processing and focus. The deep immersion in special interests common in ASC may be linked to a mechanism similar to transient hypofrontality, where reduced prefrontal activity enables intense focus and creative flow (Blumberg *et al*., 1999; Desaunay *et al*., 2023).

Combining an understanding of the expertise-plus-release model with transient hypofrontality offers a deeper understanding of how neurodivergent individuals achieve creative flow. Neurodivergent individuals often develop deep expertise in areas of personal interest, supported by their unique cognitive strengths. This expertise forms the foundation for entering flow states, as it provides a rich knowledge base to draw upon (Bailey, 2023). The intense focus and dedication required for expertise can naturally lead to transient hypofrontality, where deep engagement reduces prefrontal activity (George *et al*., 1995). Transient hypofrontality facilitates releasing conscious control and engaging in spontaneous, intuitive processes. For neurodivergent individuals, reduced prefrontal activity enhances their ability to let go of self-monitoring and enter flow (Djebbara *et al*., 2024). "Divergent thinking," a common neurodivergent trait, aligns with reduced cognitive inhibition during transient hypofrontality, enabling greater creative freedom (Dietrich, 2003; Peterson & Pattie, 2024). Divergent thinking is a cognitive process used to generate creative ideas by exploring many possible solutions in a spontaneous, free-flowing manner. Therefore, transient hypofrontality is a key mechanism that explains how neurodivergent individuals achieve and sustain flow. By temporarily reducing prefrontal cortex activity, they focus more deeply on tasks, enhancing creativity and immersion. This process, combined with the expertise-plus-release model, offers insights into neurodivergent experiences and highlights the potential for leveraging their strengths in achieving optimal performance and flow (Table 1).

5. Recommended next steps

Using knowledge of the brain's DMN, transient hypofrontality, and the unique cognitive profiles of neurodivergent individuals, several innovations can be developed to help them achieve more frequent and sustained flow states. Ayaz & Dehais (2021) suggest that these innovations include personalized cognitive training programs and advanced technological applications, each designed to leverage strengths and address challenges faced by neurodivergent individuals. Tailoring cognitive training to the specific needs and strengths of neurodivergent individuals can significantly enhance their ability to switch between the DMN and TPNs, fostering conditions conducive to flow (Chacón, 2021). Such programs might include gamified apps that offer exercises to improve attentional control, working memory, and executive functions, with adaptive difficulty levels to

Table 1. Integrating neurodivergence, brain networks, and flow: a framework for enhancing cognitive engagement

Concept	Role in neurodivergence	Interaction with flow state	Potential applications
DMN	Influences internal thought processes and self-referential activities; atypical in neurodivergence, affecting connectivity and function.	Deactivation is crucial during flow to reduce distractions and enhance focus; poor regulation may impede flow in neurodivergent individuals.	Tailored cognitive training to enhance the switch between DMN and TPNs.
TPNs	Engaged during goal-directed activities; requires effective management, which can be challenging in neurodivergent individuals.	Activation supports attention and engagement during flow; effective coordination with DMN is essential for maintaining flow.	Development of environments and tools that optimize task engagement for neurodivergent individuals.
Transient hypofrontality	Reduces activity in the prefrontal cortex, potentially beneficial for those with executive function challenges.	Facilitates creative and immersive experiences by lowering barriers to spontaneous thought during flow.	Use of neurofeedback and biofeedback to train brain regions involved in flow to manage their activity more effectively.
Expertise-plus-release model	Leverages deep knowledge and the ability to release control, which can be particularly powerful for neurodivergent individuals with focused interests.	Enables harnessing of skills and knowledge effortlessly, combined with the capacity for innovation and creativity in flow states.	Implementing educational and professional development programs that align with personal interests and strengths.

Abbreviations: DMN: Default mode network; TPNs: Task-positive networks.

maintain engagement and promote flow. For instance, neurofeedback training has shown promise in enhancing cognitive functions by providing real-time feedback on brain activity, helping individuals learn to control the activation of specific brain regions (Hosseini *et al*., 2016).

Individuals with both ASC and ADHD represent a unique population in terms of DMN and TPN processing, as the coexistence of these conditions can create complex interactions between brain networks. Research indicates that the overlap of these conditions may intensify difficulties in switching between the DMN and TPNs, leading to challenges in sustaining focus as well as persistent mind-wandering or hyperfocus (Hosseini *et al*., 2016; Chacón, 2021). The combination of ASC's intense, specialized focus and ADHD's impulsivity and attentional variability produces distinct cognitive patterns that differ from those seen in individuals with only one condition. However, the neural mechanisms driving these interactions remain underexplored, representing an important area for future research. Studying how dual-diagnosed individuals process the DMN and TPNs could provide insights into personalized interventions tailored to this unique cognitive profile. Addressing this gap could lead to the development of tailored cognitive training and neurofeedback programs that consider the combined effects of both ASC and ADHD, offering more effective strategies for enhancing flow states.

Creating environments that minimize distractions and provide optimal stimulation levels can help neurodivergent individuals enter flow states. These environments can be both physical and virtual. Sensory-friendly workspaces with adjustable lighting, noise levels, and ergonomic furniture create comfortable settings that reduce sensory overload and promote deep focus. For example, sensory-friendly environments have proven effective in various therapeutic settings, enhancing individuals' ability to concentrate and engage with tasks (Yoshida *et al*., 2014). In addition, developing tools that help neurodivergent individuals organize tasks and manage time according to their natural rhythms and cognitive preferences can be highly beneficial. Intelligent task management software that uses artificial intelligence to suggest optimal scheduling, break times, and task sequences based on user performance patterns and preferences can boost productivity and flow. Such tools can align with the specific needs of neurodivergent individuals, enhancing workflow and task management (Vinogradov *et al*., 2012).

Utilizing biofeedback and neurofeedback technologies can help neurodivergent individuals monitor and modulate their brain activity in real time, fostering conditions conducive to flow. Wearable devices that track brainwave activity, heart rate variability, and other physiological indicators can offer feedback and guided exercises to help users achieve a state of relaxed focus. Neurofeedback enhances cognitive and emotional regulation by enabling individuals to self-regulate brain activity through operant conditioning (Fink *et al*., 2023). With insights from these technologies, targeted interventions can be developed. Educational and training platforms that tap into the deep interests of neurodivergent individuals can foster engagement and flow in learning activities. Personalized learning platforms that allow users to explore subjects at their own pace through interactive multimedia content tailored to their interests and learning styles can significantly enhance the learning experience. These platforms make learning more enjoyable and effective by aligning with the unique cognitive strengths of neurodivergent individuals (Jiang *et al*., 2017).

Developing software and apps specifically designed to help neurodivergent individuals enter flow states can be highly effective. Techniques such as guided meditation, focus-enhancing soundscapes, and structured work sessions can help maintain focus and promote flow. For instance, apps offering guided meditation to reduce prefrontal cortex activity, focus-enhancing music, or binaural beats can help users achieve and sustain flow (Masterpasqua & Healey, 2003). Beyond targeted apps, implementing adaptive programs in workplaces and educational institutions that recognize and accommodate the unique needs of neurodivergent individuals can enhance their ability to achieve flow. Flexible work arrangements, such as remote work, customizable tasks, and support for hyperfocus sessions, can enable neurodivergent individuals to work in ways that best suit their flow states, boosting productivity and job satisfaction (Friedrich *et al*., 2015). Building supportive communities and networks can also provide encouragement, resources, and shared strategies for achieving flow. Online forums, support groups, and mentorship programs where neurodivergent individuals share their experiences, tips, and techniques for entering and sustaining flow states can be invaluable, fostering community and provide valuable insights into achieving and maintaining flow (Butnik, 2005).

Using virtual reality and augmented reality to create immersive environments can help neurodivergent individuals focus and engage deeply with tasks. Virtual reality applications that simulate ideal work or learning environments, offering immersive and interactive experiences, can enhance concentration and flow. These technologies can be customized to the needs of neurodivergent individuals, making tasks more engaging and enjoyable (Ramot *et al*., 2017). Supporting ongoing research into the neural mechanisms of flow and the specific needs of neurodivergent individuals is essential for developing new insights and innovations. Funding interdisciplinary projects that explore the intersections of neuroscience, psychology, and technology can lead to new tools and strategies for enhancing flow in neurodivergent populations. Such research can foster effective interventions and support systems, ultimately improving the quality of life of neurodivergent individuals (Trambaiolli *et al*., 2020). By leveraging these innovations, we can create environments and tools that help neurodivergent individuals harness their unique strengths, achieve flow more often, and unlock their full creative and cognitive potential.

6. Conclusion

The exploration of flow states in neurodivergent individuals highlights the complex interplay between the DMN, TPNs, and transient hypofrontality. Neurodivergent conditions such as ASC and ADHD present unique brain activity patterns that can challenge and enhance the ability to achieve flow. The expertise-plus-release model emphasizes the importance of deep domain knowledge and the ability to relinquish conscious control, enabling creative and focused engagement. Understanding these neural mechanisms paves the way for tailored interventions and innovative approaches designed to foster flow more effectively in neurodivergent populations.

Personalized cognitive training programs, specialized task environments, and advanced technological tools such as neurofeedback and biofeedback devices offer promising pathways for supporting neurodivergent individuals. Aligning these interventions with their unique cognitive profiles and leveraging their strengths can create environments conducive to achieving and sustaining flow. Moreover, adaptive work and study programs, interest-based learning platforms, and community support networks can further enhance their ability to maintain deep focus and engagement across various activities.

Ongoing research into the neural underpinnings of flow and the development of targeted interventions will continue to enhance our understanding and ability to support neurodivergent individuals. These efforts have the potential to unlock the full creative and cognitive capabilities of these individuals, resulting in improved performance, satisfaction, and quality of life. By embracing these insights and innovations, we can better accommodate the diverse needs of these individuals, fostering environments where they can thrive and reach their highest potential.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

REVIEW ARTICLE

A cross-sectional comparative analysis of quality of life and cost-effectiveness for retrospective dialysis and kidney transplant patients

Mohammad Akil Shaikh, Yogesh Raval, Ghadir Mohemmad, Kushal Parekh, and Kiran Dudhat*

Department of Pharmacology, School of Pharmacy, RK University, Rajkot, Gujarat, India

Abstract

Dialysis, including hemodialysis (HD) and peritoneal dialysis, is initiated when kidney function deteriorates to a glomerular filtration rate below the normal range. In addition, dialysis manages renal failure through diffusion and ultrafiltration but does not completely replace kidney function. Conversely, kidney transplantation involves replacing a diseased kidney with a healthy donor kidney, offering restored kidney function and improved quality of life (QoL). Herein, this review compares the QoL and cost-effectiveness of dialysis versus kidney transplantation for patients with end-stage renal disease (ESRD). Transplant recipients generally report better physical and mental well-being, higher independence, and greater overall life satisfaction compared to dialysis patients. Economically, kidney transplantation, despite its high initial costs, proves more cost-effective in the long run due to reduced ongoing healthcare expenses. Dialysis, particularly in-center HD, incurs higher long-term costs. The findings advocate prioritizing kidney transplantation for eligible ESRD patients while also emphasizing the need for improved support for dialysis patients.

Keywords: Quality of life; Cost-effectiveness; Kidney transplant; Dialysis; End-stage renal disease

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***Corresponding author:**
Kiran Dudhat
(kiran.dudhat@rku.ac.in)

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1. Introduction

1.1. General overview

Dialysis and kidney transplants are both very crucial conditions for patients with renal failure. They are connected with the renal failure state and significantly impact the individual's quality of life (QoL) worldwide. Dialysis can be classified as (i) hemodialysis (HD), where blood is filtered by an external machine, and (ii) peritoneal dialysis (PD), whereby a dialysis solution is used to assist the abdominal cavity by acting as a natural filter. However, dialysis cannot completely replace kidney function, instead merely assisting with diffusion and ultrafiltration. In contrast, a kidney transplant is a type of medical procedure that replaces a diseased kidney through surgery with a healthy kidney from a deceased or living donor.

1.2. Prevalence of kidney diseases

The prevalence of kidney transplant patients declined during the COVID-19 pandemic but increased to 25,487 in 2021 after a slight decline in 2020. In 2022, the United States

of America (USA) reported a record-breaking 25,498 kidney transplants, a 3.4% increase from 2021. In 2023, the USA reported 46,632 kidney transplants, an 8.7% increase from 2022 and a 12.7% increase from 2021 (Ferhatoğlu *et al*., 2019).

Liyanage *et al.* (2022) observed substantial variation in chronic kidney disease (CKD) prevalence (7.0–34.3%) across Asia, with an estimated 434.3 million people affected across the eastern, southern, and southeastern regions. The highest disease burden was observed in China and India, accounting for 299.9 million cases (Liyanage *et al*., 2022).

1.3. Objective of the review

This review aims to compare QoL metrics (e.g., physical function, mental health, and social functioning) between dialysis and kidney transplant patients (Parker & Molzahn, 2017), as well as analyze the economic impact and cost-effectiveness of dialysis versus kidney transplantation over a retrospective duration (Kiberd & Keown, 2014). The findings of this review could help healthcare providers recommend the most effective treatment option based on the QoL (Miller & McLachlan, 2016) and improve patient outcomes and healthcare efficiency, benefiting both patients and healthcare systems.

2. Dialysis

2.1. HD

HD is a therapeutic procedure that uses the extracorporeal circulation of a patient's blood to ameliorate azotemia, fluid, electrolyte, and acid-base abnormalities associated with uremic syndrome (Ye *et al*., 2020).

2.1.1. Application of HD

The most common application of HD is for patients with CKD who have progressed to end-stage renal disease (ESRD). HD reduces the workload on the heart and prevents pulmonary edema (Shtepa *et al*., 2022). One of the most critical applications of HD is the management of hyperkalemia (excessive potassium in the blood), which can cause dangerous heart rhythms. HD effectively lowers potassium levels, preventing life-threatening complications (Shtepa *et al*., 2022).

2.1.2. Indications of dialysis

Indications for dialysis or acute HD include failure of fluid administration, diuretic or vasodilator therapy, inability to initiate adequate diuresis, failure of conventional therapy to control the biochemical and clinical manifestations of acute uremia, life-threatening fluid overload, hyperkalemia, and acidosis (Shtepa *et al*., 2022).

2.1.3. Principles of HD

HD operates on the principle of diffusion and ultrafiltration. The components of HD are displayed in Figure 1.

2.2. PD

PD is a renal replacement therapy used for patients with stage 5 or terminal CKD, characterized by a significantly reduced glomerular filtration rate (GFR). Unlike HD, PD uses the peritoneal membrane for the exchange of solutes and water between blood in the peritoneal capillaries and a dialysate solution instilled into the peritoneal cavity.

2.2.1. Peritoneal physiology

The peritoneal membrane is a serous membrane lining the abdominal cavity and covering the abdominal organs. It consists of a layer of mesothelial cells, a basement membrane, and underlying connective tissue, including blood vessels and lymphatics. The mesothelial cells form a barrier between the peritoneal cavity and the underlying tissues, suggesting a crucial role in the permeability and function of the peritoneal membrane.

The peritoneal membrane facilitates the exchange of solutes and fluids between the blood and the dialysate through diffusion and convection mechanisms. During PD, the membrane acts as a filter, allowing waste products and excess fluids to pass from the blood into the dialysis fluid, which is then drained from the peritoneal cavity.

2.2.2. Application of PD

PD was initially utilized for acute kidney injury (AKI), providing a means to eliminate toxins and maintain fluid balance in critically ill patients. At present, PD is increasingly applied in various clinical settings. It serves as a long-term renal replacement therapy for individuals with CKD, enabling home-based treatment and enhancing QoL. PD is particularly favored for pediatric patients due to its gentler nature and the convenience of home management. In addition, PD can help preserve residual kidney function more effectively than HD, leading to improved patient outcomes. Furthermore, PD's association with fewer fluctuations in blood pressure and fluid balance makes it suitable for patients with cardiovascular complications (Amerling *et al.*, 2003).

2.2.3. Indications of PD

PD is particularly suitable for patients with ESRD who require long-term renal replacement therapy. In addition, PD can be used in cases of AKI, especially when HD is not feasible, and for patients with hemodynamic instability. For patients who face difficulties establishing or maintaining vascular access for HD, PD offers convenience and

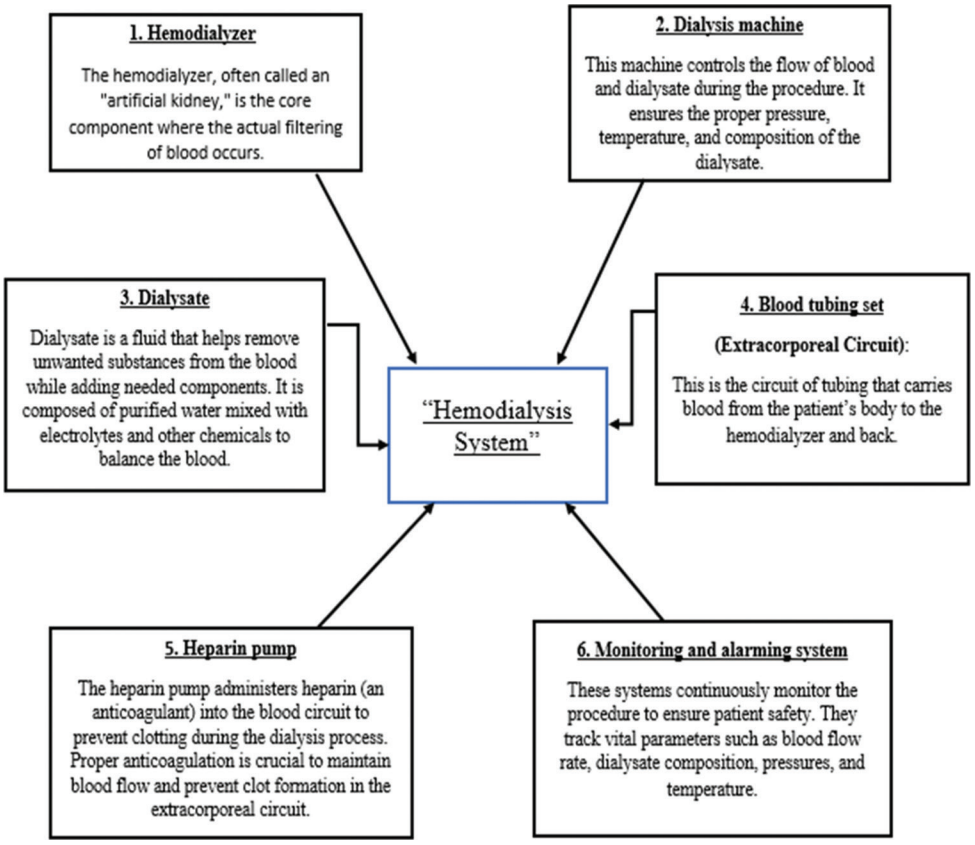

Figure 1. Components of a hemodialysis system

flexibility, enabling home-based treatment and reducing the need for hospital visits, making it an attractive option (Amerling *et al.*, 2003).

2.2.4. Principles of PD

The mechanism of PD is similar to that of HD, but PD uses the peritoneum as the membrane for solute exchange. This process relies on the peritoneum's natural ability to filter blood and remove waste products (Mehrotra *et al.*, 2016). The efficiency of PD depends on the transport characteristics of the peritoneal membrane, including surface area, permeability, and thickness (Mehrotra *etal.*, 2016). Ultrafiltration is the removal of fluid driven by osmotic pressure created by the dialysate. The volume of fluid removed can be adjusted by changing the concentration of osmotic agents in the dialysate. Conversely, the clearance of solutes (e.g., urea and creatinine) is influenced by the dialysis solution composition and dwell time (Mehrotra *et al.*, 2016).

However, not all patients are suitable for PD. Factors, such as peritoneal membrane function, patient compliance, and anatomical considerations, determine patient suitability (Alscher, 2005). The common complications of PD include infections (peritonitis), catheter problems, and issues related to fluid balance (Alscher, 2005).

2.2.5. Factors affecting efficiency and physiological aspects of PD

The permeability of the peritoneal membrane is influenced by its surface area and the size of the pores in the mesothelial cells. Permeability variations affect how effectively solutes and fluids are exchanged (Stachowska-Pietka *et al.*, 2015). Nonetheless, chronic exposure to dialysis solutions, especially those with high-glucose concentrations, can lead to inflammation and fibrosis, subsequently reducing membrane permeability over time (Stachowska-Pietka *et al.*, 2015). Besides that, the efficiency of PD is influenced by the dialysate composition, including its osmotic agents. High-glucose concentrations can increase ultrafiltration but may also lead to adverse effects on the peritoneal membrane over time (Stachowska-Pietka *et al.*, 2015).

2.3. Comparison between HD and PD

Among ESRD patients, PD and HD remain the two major dialysis modes, with their respective indications and contraindications, depending on the patient's medical

condition, lifestyle, and therapeutic goals. In general, PD is preferred over HD in the following aspects:

(i) Cost-effectiveness: In most healthcare systems, PD is cheaper than HD, requiring less specialized staff, equipment, and space for its administration (Stachowska-Pietka *et al*., 2015).
(ii) QoL: Studies have demonstrated that in most situations, patients with PD have improved QoL compared to those on HD. This can be attributed to the greater flexibility, independence, and fewer dietary and fluid restrictions offered by PD (Alscher, 2005).
(iii) Contraindications: For patients with severe peripheral vascular disease that precludes the creation of reliable vascular access, HD may not be feasible. Patients with severe cardiovascular conditions, such as unstable angina or recent myocardial infarction, may face risks that make HD unsafe or less effective. A lack of suitable vascular access or inadequate blood flow can serve as a contraindication (Murdeshwar & Anjum, 2020).

3. Kidney transplant

Kidney transplantation has greater survival rates than dialysis. In the USA, post-transplantation results have improved over time, with current 1-year allograft and patient survival rates over 90% (Wang *et al*., 2016). According to studies, kidney transplantation is associated with a lower death rate and a higher QoL than chronic dialysis treatment (Tonelli *et al*., 2011).

3.1. Indication

The prevalence of ESRD is increasing, with diabetes and hypertension being the leading causes. Additional causes of CKD and ESRD include pre-renal (e.g., chronic or acute ischemia), intrinsic renal (e.g., glomerulonephritis and focal-segmental glomerulosclerosis), and post-renal (stones, tumors, strictures, or neurogenic bladder, leading to increased pressure, kidney damage, and eventually renal failure) factors. Patients with stage 4 CKD, characterized by GFR < 30 mL/min/1.73 m^2, should be referred to a nephrologist for further management and consultation on kidney failure and treatment options, including transplant (Abramyan & Hanlon, 2024).

3.2. Contraindications

The contraindications of kidney transplantation are key factors that may disqualify a patient from being a viable candidate.

Despite ongoing progress in diagnostic and therapeutic procedures, infections remain a serious and sometimes fatal complication among kidney transplant recipients. According to the United States Renal Data System, over 19,000 people received successful kidney transplants between 1983 and 2006. In the following 9 years, almost 2,700 people with functional transplants died. Cardiovascular disease was the major cause of mortality, accounting for 34.6%, followed by infections (19.5%). The 1st year following kidney transplantation is particularly hazardous, with deadly infections exceeding 30% (Dasdelen & Grebe, 2017).

Cancer is another common cause of mortality and morbidity among kidney transplant recipients after cardiovascular disease. Oncogenic viruses, immunosuppressive medications, and alterations in T-cell immunity can contribute to the increased risk of new and recurring malignancies in transplant recipients (Au *et al*., 2018).

3.3. Preparation

3.3.1. Patient selection

From the moment, a patient is diagnosed with ESRD, the selection of potential candidates is strongly dependent on collaboration within a multidisciplinary team, led by established protocols and standard practices (Marroquin, 2019). Obesity (body mass index > 30 kg/m^2) is linked to poor wound healing and a higher risk of developing diabetes following transplantation. According to a systematic review and meta-analysis, obesity is associated with delayed graft function (relative risk [RR]: 1.41) and an increased risk of death from cardiovascular disease (RR: 2.07), particularly in patients who underwent a kidney transplant before 2000 (Tepel *et al*., 2022a, Tepel *et al*., 2022b).

3.3.2. Donor selection

Determining the best living or deceased donor for a patient with ESKD is an important decision for kidney transplant programs. Personalizing donor kidney selection for a given recipient might provide significant long-term benefits, especially when numerous donors are available. The relative probability of transplant failure (return to dialysis or patient mortality) for Expanded Criteria Donor (ECD) kidneys was predicted to be 1.7 times higher than that of Standard Criteria Donors (SCD). The Kidney Donor Profile Index (KDPI) was introduced in 2014 as a more objective assessment of graft quality, replacing the ECD and SCD classifications. The KDPI is derived from the Kidney Donor Risk Index (KDRI), which represents the percentage of donors in a reference population (as determined annually by the Organ Procurement and Transplantation Network) with a KDRI score equal to or lower than the donor's. The KDPI is calculated using factors, such as donor age, ethnicity, creatinine levels, history of hypertension or diabetes, cause of death,

height, weight, hepatitis C virus status, and donation after circulatory death status, subsequently followed by patient selection (Gabolde *et al.*, 2001).

3.4. Organ preservation

Maintaining graft viability between explantation and implantation is critical for ensuring both early and long-term kidney function after transplantation. Machine perfusion is a recent method that reduces the risk of delayed graft function, with pulsatile machine perfusion displaying particularly better results.

4. Significance of this study for clinical decisions and framing healthcare policies

4.1. Clinical decisions

4.1.1. Personalized management

Knowledge on the impact of dialysis compared to that of kidney transplantation on QoL enables the development of relevant treatment strategies that conform to the patient's preferences. For example, patients who view long-term QoL as more valuable than other factors may select transplantation, as data have demonstrated that transplantation produced improved outcomes (Raimann & Kuhlmann, 2016).

4.1.2. Informed patient counseling

Based on the results of QoL and cost-effectiveness, clinicians can inform patients of all available options, enabling better-informed decisions. This is particularly valuable in shared decision-making, where patient preferences and expectations are considered (Raimann & Kuhlmann, 2016).

4.1.3. Risk-benefit assessment

Based on the state of a patient's health, age, lifestyle, and other factors, clinicians can evaluate the risks and advantages of dialysis over transplantation. For instance, a 60-year-old patient with an early-stage or less comorbid condition would benefit from transplantation, regardless of the current QoL, as they have higher chances of improved QoL in the future (Raimann & Kuhlmann, 2016).

4.1.4. Resource allocation in clinical settings

Resource allocation in clinical settings allows for the comparison of cost-effectiveness, ensuring proper utilization of resources by healthcare providers. For instance, if an analysis indicates that transplantation offers long-term cost benefits compared to non-transplant options, hospitals may need to allocate more transplant-related resources or programs to enhance donor-alternative matching (Raimann & Kuhlmann, 2016).

4.2. Healthcare policies

4.2.1. Informing healthcare resource allocation

Cost analysis can be valuable for policymakers when making funding arrangements and decisions. There are potential opportunities for policy improvement that could bring additional benefits to the field. For instance, if transplantation is found to be cheaper in the long run, there could be ways to increase patients' access to transplantation centers and decrease the overall costs (Hays & McClellan, 2018).

4.2.2. Developing treatment guidelines

Assessments of QoL and costs can contribute to the production of guidelines that comprise best practices in the treatment of various diseases to improve compliance by health organizations. For instance, these criteria may recommend transplantation as the preferred choice for eligible patients, based on positive cost-effectiveness and QoL indicators (Hays & McClellan, 2018).

4.2.3. Overall impact

By understanding the benefits of QoL and the cost-effectiveness of dialysis and kidney transplantation, more effective clinical decisions and policies can be implemented. This, in turn, places both the patient and the healthcare system in a better position to achieve optimal health outcomes, patient satisfaction, and resource utilization (Olsson & Helgesson, 2019; Kumar & Sharma, 2020).

5. Technological advancements in kidney dialysis and transplant patient monitoring

5.1. Telemedicine

Telemedicine refers to the practice of providing medical care remotely using technology, which can include a range of tools (Santosh *et al.*, 2024), as follows:

(i) Video consultations: Patients and healthcare providers can have virtual face-to-face appointments through video calls, allowing for real-time interaction and consultation without needing to be physically present in the same location.
(ii) Phone consultations: Medical advice and follow-ups can be conducted over the phone, which is useful for patients who may not have access to video technology or prefer voice communication.
(iii) Mobile health apps: These applications can offer services such as appointment scheduling, medication reminders, and access to health information.

With this technology, physicians (nephrologists or transplant specialists) can provide virtual consultations, which reduce the burden of travel and increase access to

care, particularly for patients in remote areas, ultimately enhancing patient QoL (Santosh *et al*., 2024).

5.2. Digital health tools

Mobile health apps that track dialysis schedules, medication adherence, dietary intake, and symptom management can empower patients to take control of their care, leading to better disease management and improved QoL (Santosh *et al*., 2024).

Online support communities can provide platforms for patients to connect and share experiences, fostering emotional support and better connection with the physician and ensuring patient adherence to therapy (Santosh *et al*., 2024).

5.3. Robotics and automation

Robotic systems that automate certain aspects of dialysis (e.g., preparation and monitoring) can reduce human error and increase the efficiency of the process, thereby enhancing patient safety and reducing operational costs (Santosh *et al*., 2024).

In kidney transplantation, robotic-assisted surgery can lead to less invasive procedures, shorter recovery times, and potentially fewer complications, improving QoL and reducing hospital costs (Santosh *et al*., 2024).

5.4. Genomics and personalized medicine

Advances in genomics can personalize treatment strategies based on individual genetic profiles. Personalized medicine, or precision medicine, tailors medical treatment to the individual characteristics of each patient, primarily using genetic profiling and biomarker identification. This approach allows healthcare providers to understand how genetic variations influence disease risk and treatment responses. For kidney transplant patients, personalized immunosuppressive therapies can reduce rejection rates and side effects.

Santosh *et al*. (2024) discussed how genetic factors contribute to the susceptibility and progression of CKD, highlighting the importance of understanding the genetic basis of the disease. They emphasize the potential for genomics to enable personalized treatment approaches, tailoring interventions based on an individual's genetic makeup. In addition, they explored the possibility of using genomic data to identify biomarkers that can improve early diagnosis and risk assessment in CKD (Gordon & Sehgal, 2000).

6. Cost-effectiveness of the two therapies

6.1. Kidney transplant

A kidney transplant involves surgically placing a healthy kidney from a donor into a patient with ESRD, thereby restoring normal kidney function and significantly improving QoL.

The primary advantage of a kidney transplant is its cost-effectiveness. While the upfront costs of transplant surgery and post-operative care can be high, long-term costs are often lower than dialysis due to the reduced need for frequent treatments and hospitalizations. In addition, kidney transplants significantly improve patient QoL compared to dialysis, evidenced by better health, increased energy levels, and greater freedom compared to the constraints of dialysis. Transplant patients also have better survival rates than those on dialysis, particularly with well-matched living donors (Rosselli *et al*., 2015).

However, the procedure carries surgical risks, including complications related to anesthesia and rejection of the transplanted kidney. Moreover, patients must take immunosuppressive drugs to prevent rejection, which can lead to increased vulnerability to infections and other health issues. Notwithstanding, there is a significant shortage of donor organs, leading to long waiting times for transplants (Rosselli *et al*., 2015).

6.2. Dialysis

Dialysis is a procedure that artificially removes waste and excess fluid from the blood when the kidneys can no longer perform these functions. As discussed, there are two main types of dialysis (HD and PD), each with their respective advantages and disadvantages.

Dialysis can be started quickly without the need for surgery or a waiting period for an organ donor. In addition, patients can choose between in-center HD and home-based PD, providing some control over treatment schedules. Compared to kidney transplants and surgical interventions, dialysis generally involves fewer immediate health risks (Rosselli *et al*., 2015).

Nonetheless, dialysis is often more expensive over time due to the need for regular treatments (usually 3 times a week for HD) and ongoing medical care. Besides that, patients may experience fatigue, dietary restrictions, and limitations on travel and activities due to the frequency of treatments (Rosselli *et al*., 2015).

7. QoL analysis of patients

7.1. QoL analysis of dialysis patients

The QoL of dialysis patients was assessed using the Kidney Disease QoL-36 survey, which evaluates the overall health of patients undergoing the dialysis procedure. This survey includes various questions about the patient's health and daily life, helping the physician or the interviewer to identify potential challenges the patient faces with dialysis.

This survey has a score range of 0–100, with higher scores indicating better QoL. Clinically, this survey can guide treatments by incorporating patient-reported outcomes, providing better patient monitoring of symptoms and therapy outcomes. Ultimately, it helps to correlate these factors, leading to improved patient QoL (Maglakelidze *et al*., 2011).

7.2. QoL analysis of kidney transplant patients

Unlike the survey for dialysis patients, the questionnaire for kidney transplant patients includes various categories, such as physical health, mental health, financial condition, daily life experience, and medication change. The scoring typically ranges from 1 to 5, with higher scores indicating better QoL. The total score, when summed, reflects the overall well-being in that area (Maglakelidze *et al*., 2011).

7.3. Inclusion criteria

The inclusion criteria were as follows: (i) adult participants diagnosed with hypertension and diabetes mellitus who had undergone kidney transplants or dialysis at least 6 months – 1 year prior; and (ii) participants with a stable medical condition.

7.4. Exclusion criteria

The exclusion criteria were as follows: (i) individuals who have received kidney transplants before starting dialysis to maintain homogeneity within the dialysis group; and/or (ii) those who are unwilling to participate or have recently undergone major surgeries or complications that might affect their current QoL or cost-effectiveness metrics.

8. Significance of the analysis of dialysis and kidney transplants

8.1. Impact on the hospital sector

8.1.1. Policy formulation

This analysis is instrumental in convincing hospitals to make policies that emphasize kidney transplant programs, as they not only boost patient success but also prove to be cost-effective. Achieving this requires establishing more transplant centers and enhancing pre- and post-transplant care systems to better serve a growing number of patients (Sarhan *et al*., 2021).

8.1.2. Financial planning

Cost analysis between dialysis and transplantation can better support hospital financial planning by allocating budgets to treatments that have the biggest effect on patient outcomes and long-term cost-effectiveness. This approach also helps in supporting long-term financial planning by focusing on sustainable investments, such as expanding transplant programs, even when they are more costly upfront but garner more significant savings over time. These insights can also support the justification of seeking supplementary funds or investment to ensure the efficient utilization of resources (Sarhan *et al*., 2021).

8.2. Clinical significance

The clinical significance of this analysis lies in its potential to improve patient outcomes by providing a comparative analysis of the QoL between dialysis and transplant patients. For instance, if a study indicates that transplant patients experience significantly better QoL, this could justify prioritizing transplants to enhance patient satisfaction and long-term health outcomes (Van Mil *et al*., 2024).

The findings by Van Mil *et al*. (2024) can improve patient care by providing evidence-based recommendations. For example, if one establishes that kidney transplants offer far greater QoL compared to dialysis, clinicians may be more likely to recommend transplantation earlier in the process of treatment (Van Mil *et al*., 2024).

9. Future advancements in the field of the analysis of the QoL of patients

QoL assessment is a relatively new field in patient care, more so for patients suffering from chronic diseases or undergoing long-term treatment processes. In this regard, future improvements are most likely to emanate from technological advances, more holistic and patient-centered assessment tools, and growing interest in personalized medicine, some of which are discussed in this section.

9.1. Digital health and wearable technology

Monitoring physical and psychological health is anticipated to be conducted by wearable devices and mobile health apps, where the patient's wearable continuously records data on various QoL metrics. These assessments are expected to be timelier and more accurate (Swan, 2012). Health practitioners can also make more informed decisions regarding patient care by integrating wearable technology data into electronic health records, providing a more comprehensive view of the patient's health (Swan, 2012).

9.2. Utilization of artificial intelligence (AI) and machine learning

The use of AI and machine learning algorithms can predict potential QoL outcomes based on a patient's prior records, selected treatment plan, and real-time data; proactive clinical and scientific treatments can also be included to enhance QoL prediction (Cohen *et al*., 2021). Other implications of natural language processing in the deep analysis of patient-reported outcomes arise from various

Table 1. Studies comparing the metrics/variables of interest

Study	Study design	Population characteristics	Evaluated metrics	Key findings
Abdi *et al.* (2022)	Cost-benefit analysis; case study	Patients in Iran with CKD	Cost of transplant; willingness to pay; BCR; NPV	Average cost of transplant: $877.4; BCR: 5.39; NPV: $3855; willingness to pay significantly affected by income, insurance, and ESRD duration
Ferhatoğlu *et al.* (2019)	Retrospective analysis	Kidney transplants in Istanbul (n=100); donor mean age: 44.05 years; primary disease: diabetes (36.4%) and hypertension (15.6%)	Vascular variations; ischemia times (warm and cold); post-operation complications; anastomosis preference	Mean warm ischemia: 1.82 min; cold ischemia: 40.25 min; complication: ureter anastomosis stenosis (4.1%); preferred anastomosis: End-to-end (57.2%)
Iqbal *et al.* (2020)	Comparative study	Transplant patients versus CKD patients with/without dialysis; QoL assessed across four groups: CKD patients with dialysis, without dialysis, healthy controls, and transplant recipients; (age range: 34–49 years)	QoL scores: Physical, social, energy, and pain	Transplant recipients had the highest QoL scores, some comparable to healthy controls

Abbreviations: CKD: Chronic kidney disease; QoL: Quality of life; ESRD: End-stage renal disease; BCR: Benefit cost ratio; NPV: Net present value.

sources, such as unstructured reports of patient diaries, social media, or even clinical notes. These insights provide more comprehensive and valuable contributions to understanding QoL (Cohen *et al.*, 2021).

9.3. Personalized and precision medicine

In the future, QoL assessments may be personalized to specific patient needs, preferences, and conditions. Questionnaires and adaptive testing techniques could then be modified based on the information provided by the patients (Alonso *et al.*, 2004). Genomic and biomarker integration with QoL assessments can also guide personalized treatment according to the characteristics of patients to enhance QoL (Alonso *et al.*, 2004).

9.4. Holistic and multidimensional assessment

Future QoL assessments could include additional QoL dimensions, expanding QoL tools beyond indicators of physical and mental health to encompass social determinants of health, environmental factors, and spiritual well-being (Mihalopoulos *et al.*, 2022). The incorporation of patient-generated health data within QoL measurements would enable a complete and comprehensive description of the patient's life, accounting for daily activities, stress factors, and social interactions (Mihalopoulos *et al.*, 2022).

9.5. Telemedicine and remote monitoring

Telemedicine can be used for remote QoL assessments, enabling more frequent and consistent evaluations, particularly for rural or underserved patients. Remote monitoring of symptoms and side effects through telemedicine allows for real-time adjustments of the treatment plan, optimizing patient QoL (Kaufman *et al.*, 2019).

9.6. Big data and longitudinal studies

Big data analytics applied to large-scale QoL datasets can uncover trends and correlations that may influence health policy decisions and personalized treatment plans (Swan, 2012). Longitudinal QoL tracking improvements in data collection and analysis will enable long-term QoL monitoring with remarkable efficiency, facilitating the study of the chronic impact of diseases and their treatments (Swan, 2012).

10. QoL of patients reported in previous studies

This review and meta-analysis compared the QoL between kidney transplant recipients and dialysis patients from various studies. The results are summarized in Table 1, aligning with our inference; transplant recipients consistently experienced a better QoL across various areas, such as physical functioning, emotional well-being, and social interactions (Iqbal *et al.*, 2020).

11. Conclusion

In comparison with dialysis, kidney transplantation offers more clinical advantages in QoL and is more cost-effective for patients with ESRD. Transplant patients experience significantly better QoL, including improvements in physical and emotional well-being, independence, and overall life satisfaction, compared to dialysis patients. The nature of dialysis treatment, especially HD, is complicated and taxing, which naturally leads to a lower QoL. Although kidney transplantation incurs higher initial expenses, it is more economical over time due to reduced ongoing medical expenses and improved QoL. Conversely, dialysis, particularly in-center HD, incurs higher long-term expenditures due to its ongoing requirement for treatment.

These findings strongly support prioritizing kidney transplantation for eligible patients. However, healthcare systems must focus on improving the care and support of dialysis patients to enhance their QoL.

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Global Health Economics and Sustainability

PERSPECTIVE ARTICLE

Achieving universal health coverage in Sub-Saharan Africa through the reformation of mental health financing

Emmanuel Otieno[1,2*], Tabeta Seeiso[3], Jeninah Businge[1], Grace Kimera[4], and Edward Sempira[5]

[1]Department of Health Economics, School of Public Health, Gudie University Project, Kampala, Uganda

[2]Chieftaincy of Medical Services, Uganda Peoples' Defence Forces, Kampala, Uganda

[3]Department of Nursing, Scott College of Nursing, Maseru, Lesotho

[4]Department of Counseling and Addiction, Life Back Foundation Uganda, Kampala, Uganda

[5]Department of Clinical Psychiatry, Life Back Foundation Uganda, Kampala, Uganda

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Mihajlo Jakovljevic M.D. Ph.D. MAE

***Corresponding author:**
Emmanuel Otieno
(otienomdc@gmail.com)

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Abstract

Insufficient financing is limiting mental health services for universal health coverage (UHC) in sub-Saharan Africa (SSA). Without ambitious steps to enhance mental health services, UHC will fall far below its historical agenda; however, adequate mental health financing could strengthen governments' capacity to provide additional budgetary resources. This paper aims to identify potential strategies for more equitable and sustainable mental health financing in SSA. Using Uganda as a key example, we provide a contextual analysis and highlight current gaps. We draw parallels with successful countries and discuss recommendations for engagement from the global mental health community. This perspective focuses on health systems, mental disease burden, and macro-fiscal situation. Drivers of fiscal space for health indicate prospects to boost mental health budgets for socioeconomic development. Governments should conduct consistent mental health investment cases and expedite fiscal space for aggressive taxation to health reforms.

Keywords: Financing; Mental healthcare; Fiscal space; Universal health coverage; Health insurance, Uganda

1. Introduction

Fiscal space for mental health continues to be a driver for socioeconomic growth. In sub-Saharan Africa (SSA), mental health has eroded significantly during the past several decades. In 2019, close to one billion people suffered from mental disorders, 82% of whom were estimated to be in low- and middle-income countries (LMICs). In contrast, nearly one in four people globally suffered from a mental disorder by 2022 (Kestel, 2022). In SSA, poor funding reduces access to care, leading to high treatment gaps and out-of-pocket expenditures. Pervasive income inequality, lack of employment, and growing poverty are other main drivers for the soaring mental disorders, which are compounded by ongoing political and social distress. The determinants of

mental health are a multilayered construct with diverse dimensions, including political, economic, and social. These dimensions usually lie outside the remits of the health system. The historic lack of adequate investment and prioritization in mental health, insecurity, education, food, employment, income inequality, and living standards have all been associated with poor mental health; thus, the promotion of mental health is multisectoral. The feasible measures for reforms to offset such determinants vary. Such measures include transforming mental health services with explicit human rights-based approaches; building responsive, resilient, and sustainable primary health systems; supporting employment policies and programs to help acquire, retain, or regain jobs; and legalizing social welfare sustainable systems. For example, in Belgium and Canada, multisectoral approaches beyond mental health care have been examined regarding housing, educational, and employment support to patients (Van Rensburg & Brooke, 2023). In Poland, mental health centers have been incorporated into the local communities, emphasizing patient-centeredness, societal integration, and accessibility (Korolkiewicz *et al*., 2024). Furthermore, France and New Zealand have integrated a mental health people-powered model within a well-being framework (McGorry *et al*., 2022). Other successful multisectoral initiatives have been reported in Burkina Faso, Ghana, Kenya, Nigeria, Malawi, South Africa, and Zimbabwe, with greater involvement of families in providing care, use of herbal medications, rituals, and prayers in mental illness recovery (Van der Zeijst *et al*., 2023). This situation contributes to positive therapeutic outcomes, cost savings, close income gaps, and unemployment. Close to 28% of countries do not have a separate budget for mental health, and 36% of these countries spend <2% of their health budget on mental health, far below the 12% recommended by the World Health Organization. Indeed, Uganda and Lesotho are not unique.

A Lancet Commission report on mental health indicates that mental disorders will cost the global economy 16 trillion US dollars (USD) by 2030. The economic value associated with poor mental health is estimated at 5 trillion and 1 trillion USD from lost productivity (WHO, 2022). The global cost of care is projected at 387 USD billion annually for depression and anxiety (Arias *et al.,* 2022). The estimated cost of mental disorders in Africa is 30.3 billion USD (UNICEF, 2021), whereas for East Africa, 4% of its gross domestic product (GDP) is estimated to be lost in productivity (Arias *et al.,* 2022).

Studies show that every 1 USD invested in mental health is estimated to return 4 USD in improved health and productivity (The Lancet Global Health, 2020); however, interventions targeting severe mental disorders may show promise in improving productivity in LMICs (Lund *et al*., 2024). In SSA, the cost of intervention is small for a package of depression, alcohol abuse, epilepsy, and schizophrenia at 3 – 4 USD per capita every year, except in South Africa at 13.3. In upper-middle-income countries (Jamaica, Marshall Islands, Mauritius, North Macedonia, Saint Vincent and the Grenadines, and South Africa), the cost is 6 – 8 USD. Upper-middle-income countries allocate around 5% of their health budget to mental health, contrary to 0.5% for LMICs. For low-income countries (LICs) and LMICs to achieve basic mental health services delivery, LICs would need to increase funding fivefold, and LMICs would need to double their allocation. In the global South, countries such as Uganda, where poverty, disease, and ignorance are common, demand for resolute mental health care can seem a luxury inaccessible to many.

A Ugandan Mental Health Study in 2022 reported that 32% of adults suffer from mental disorders, ranking Uganda among the top six countries in Africa, with 14 million people suffering from mental problems (Kaggwa *et al*., 2022). Suppose these 14 million affected people interact with at least two other individuals. This situation potentially translates to the entire nation of 45 million people being affected directly or indirectly by mental health. The surge will profoundly impact Uganda because there are limited facilities for mental health care. Only one national referral mental hospital (Butabika) exists. The facility staffing is presently at 50% from the proposed 86% and yet the number of patients accessing for services is increasing mostly the inpatients. Thus, the bed occupancy rate of 212% is a challenge. More so, primary care is inadequate to address mental health concerns. Despite the health sector reforms deliberated on for over three decades, little attention has been paid to mental health financing. Mental health is allocated 1% of the health budget in Uganda, a country without a National Health Insurance Scheme. Undoubtedly, the call for reforms demands a shift in mental health financing; thus, the need for mental health services is palpable.

In pursuit of the African Agenda 2063, financing reforms could positively impact mental health coverage by increasing mental health funding and using existing funds effectively. Furthermore, improving financial structures and integrating mental health into the budgets and programs of ministries, departments, and agencies, including off-budget programs in a harmonized method, requires high prioritization by development actors to integrate mental health into their projects. They must also prioritize mental health in global financing partnerships and design health financing systems relevant to universal health coverage

(UHC) through prepayment approaches. These prepaid sources, through tax-funding and social health insurance schemes, increase health revenues. Finally, innovative finance mechanisms such as social impact bonds for mental health should be fostered. Countries with a high level of public health investment have low out-of-pocket payments and a high level of financial risk protection compared with other countries, which promotes access to mental health care. For example, out-of-pocket spending in Botswana is 8% of the total health expenditure, compared to Uganda (42%); thus, Botswana has more efficiency and equity in the health sector.

2. Regaining the reform momentum

Uganda's Third National Development Plan (NDPIII) 2020/2021 – 2024/2025, does not mention mental health care services, indicating the gaps in the existing sectors' harmonization framework and implying that mental health is not a priority. This omission implies that the right to health for all is still a challenge and a trend also witnessed in other SSA countries. The mental health treatment gap in SSA is alarmingly high at 98.8% (Saade *et al*., 2023). More disturbingly, 85% of Ugandans with mental disorders are not seeking care at all, potentially attributable to the high costs of treatment as a deterrent. Moreover, worsened by income inequality where the wealthiest 10% of the population receives 35.7% of the national income, the poorest 10% earns 2.5%, and the poorest 20% earns 5.8%. Subsequently, the proportion of Ugandans who receive mental health care is unacceptably low.

In private health care, consultation costs 60,000 to 365,000 Ugandan shillings (UGX) (15.87 – 96.55 USD) per session. Private medical schemes for prepayment insurance coverage limits are capped at 1,000,000 – 6,000,0000 UGX (264.54 – 15,872.34 USD) for in-patients and 500,000 – 1,500,000 UGX (132.27 – 396.81 USD) for outpatients per year. Multiple therapy sessions over an extended period render many patients, particularly young people and those from the lower-income quintile, unable to bear such a financial burden. This situation exposes them to catastrophic expenditures, especially if they have comorbid conditions. This trend implies that access to healthcare is a privilege for a few individuals, undermining UHC's vision; hence, healthcare as a commodity remains scarce for low-income families.

3. Setting benchmarks for the SSA

Most countries' health systems in SSA were inherited from colonialism; consequently, their premise is reactive, not preemptive. The human resource shortage for mental health is another gray area demanding financing reform. Across SSA, the ratio of psychiatrists to population is below the WHO's recommendation of 1:10,000, creating significant challenges for achieving UHC and meeting sustainable development goals. Momentum has been increasingly prioritizing mental health in the global health agenda, which is evident from the specific provisions for mental health in the Sustainable Development Goals and the integration of mental health into the Global Declaration on UHC at a UN high-level meeting in 2019. The ratio of psychiatrists per 100,000 is high in upper-middle-income countries compared to SSA: 4.6 in Singapore (Ministry of Health Singapore, 2022) and 1.2 in Malaysia (Fernandez, 2022). Comparatively, Uganda has only 53 psychiatrists countrywide, that is, 0.12/100,000 (Kaggwa *et al*., 2022). The number of other mental health-care workers per 100,000 people in Uganda is estimated at 0.1 psychologists, 0.04 other medical doctors, 0.2 psychiatric clinical officers, 0.01 social workers, 0.78 nurses, 0.01 occupational therapists, and 6.4 psychiatric nurses. Training more psychiatrists requires integrating psychiatric care with primary care, increasing clinical capacity with digital patient management systems, and shifting some responsibilities to allied healthcare workers. Such a workforce would be adequate, efficient, and equitably distributed.

Several sub-Saharan countries, such as Uganda, Kenya, and Tanzania, have proposed various tax proposals to generate more revenues; however, political apathy persists in taxing commercial determinants of health, which can be used for mental health investment. Subsequently, such apathy tends to worsen prevailing financing approaches to mental ill-health situations. The tax base that has not been explored for investment in health includes the sugar-sweetened beverage industry, plastic shopping bags, and the gambling and betting industry. Other culprits that could be targeted to fund mental health programs are the tobacco and alcohol industries. Taxing these industries based on profitability, their position in exasperating poor mental health, and their lack of accountability in financing countries' mental health programs to date needs reform. Such taxation strategies could alleviate the health financing gap; thus, there is still a fiscal space for aggressive taxation, which could benefit mental health.

Uganda's proposed national health insurance scheme, which is relevant to UHC, is an opportunity to promote health equity and improve mental health; however, there is a need to scale the integration of mental health in all sectors. Such integration requires robust government leadership that finance ministries can facilitate as part of a strategic and cross-governmental approach.

From a macroeconomic stability perspective, the context of financing mental health is malleable. The policy

shift of fiscal space increase to 5% of GDP going to the mental health sector may yield primarily to doubling the per capita expenditure on health (Okwero *et al*., 2010), potentially increasing mental health service coverage by nearly 40% – 80%. Such a proactive approach by governments would ensure that patients have better, more affordable buffers, cushioning them from financial hardship rather than expanding social safety nets following a crisis. Cognizant of this, mandatory health insurance in Egypt, Morocco, Gabon, Ghana, Zambia, Mali, Rwanda, Tanzania, and Togo receives budget transfers or public subsidies (ISSA, 2023).

From a systemic level, policymakers must empower the sector with professional planners at all levels to lead the process under the auspices of the National Development Plan to realize reforms. Moreover, catalytic funding should be provided in those contexts where governments cannot find this fully in support of a UHC-based approach. Countries could also pursue creating mechanisms by multilateral or bilateral partners to mobilize new financing, including from the private sector, at affordable terms, such as public-private partnerships (PPPs) for domestic resource mobilization in the US. Venture capital (VC) companies invested a record-breaking 637 million USD in more than 60 mental health-oriented companies in 2019 to improve mental healthcare (Shah & Berry, 2021). Therefore, it is desirable to support the SSA mental health innovation ecosystem for digital health care of mental illnesses through VC investments. However, SSA's inadequate pooling of VC hinders the rise of private-profit start-up investment and makes it harder to increase funding to the health sector. Also, the PPPs can mainstream mental health insurance to provide population-based (rather than beneficiary-based) services. Ultimately, this situation ensures financial risk protection for people living with mental illness. Policy support can help countries meet their needs as they undertake important reforms by shifting and transitioning from input to output-based financing (performance and revenue retention), which can be implemented at facility levels; however, their implementation needs regulation and oversight mechanisms.

Case-to-case management of public health facility issues could be implemented, involving actual costing from facilities and interactions with key actors to attain UHC. In the Netherlands and France, health-care purchasing and payment options are engaged in integrated and chronic mental health care (Polin *et al*., 2021). Consumer organizations were integrated into care planning and provision systems in Scandinavian countries. For example, Norway developed a strong community-decentralized care system that integrated community mental health-care centers, including in-patient services outside the hospital premises. Furthermore, it developed municipality networks for providing social care for mental illness. Norway has Europe's most facilitated mental health sector and the highest professionalism and human resource levels. In contrast, the Benelux countries (Belgium, the Netherlands, and Luxemburg) developed integrated care systems with a vast network of health and social services financed by social health insurance on a not-for-profit basis. For example, Belgium established a hospital-centric community-based system founded on partnerships and proactive outreach planning. This approach was accompanied by the forming of regional mental health networks within the national mental health ecosystem. (Salvador-Carulla, 2021).

4. Enhancing leadership and investment in mental health

Nonetheless, reforms are often overlaid on existing systems, risking further fragmentation and mixed signals to stakeholders. Therefore, countries should systematically and explicitly embed such adjustors in their reform strategies. We suggest strategies for engaging stakeholders, including governments, non-government organizations, and the private sector, including advocacy techniques, community participatory frameworks, partnership models, and stakeholder analysis approaches. First, advocacy could involve engaging influential mental health advocates who serve as goodwill "ambassadors" and champions among their peers and the target audiences to advocate for systemic changes and build visibility and sustainability of mental health services. Second, engaging community participation through leaders helps establish conditions for dialog and implement linkages in the community to foster ownership, for example, designing mental health awareness campaigns through sports and school health programs. Third, routine sharing of inputs and outcomes through partnership to improve mental healthcare in the community, for example, the partnership model of anti-stigma activities in Singapore has been conducted by the Institute of Mental Health, Health Promotion Board, statutory boards of state psychiatric institutions, National Council of Social Service, and not-for-profit organizations, such as the Singapore Association for Mental Health and Silver Ribbon Singapore.

Given that stigma is a significant barrier to accessing mental health care, in our view, strategies to reduce stigma include the promotion of mental health advocacy, litigation, and awareness. These should embrace inclusivity and culturally sensitive practices that address stigma and other disparities, thus promoting equitable access to services. Shahwan *et al*. (2022) proposed a framework that includes (1) raising mental

health awareness, particularly among youth predisposed to increased challenges and whose attitudes are more pliable by dispelling misconceptions and demystifying mental illness. Their framework also includes (2) promoting social contact through the delivery of testimonies by individuals who have lived the experience offering their experiential wisdom in challenging stigma to a target community, (3) advocacy by influential figures or groups, and (4) legislation of anti-discriminatory laws. Finally, interest must be garnered in needs and support for care through stakeholder analysis and mobilizing opportunities for change. For example, the Ugandan civil society is noted as having low levels of interest in mental health services compared to international agencies. This situation contrasts Ethiopia, South Africa, and Nepal (Makan *et al*., 2015).

A policy framework could be implemented to track mental health investments with a marker for countries to monitor and evaluate progress toward the established benchmarks. Despite the uniqueness of each country that enables its socioeconomic development path, a framework for implementing the suggested reforms would encompass a similar process. Such a process would support analytical and technical health financing efforts, informed dialogues, evidence-based policy decisions, awareness campaign drives, associated administrative and institutional strategic actions, and multi-sector involvement. Urban healthcare must be analyzed differently from rural settings, as the context, interventions, patterns of care, and performance indicators vary (Perkins *et al.*, 2019). First, this policy would determine prospects for improved mental health mainstreaming, inspiring the inclusion of mental health objectives or indicators within projects that may not have otherwise included them, undoubtedly marking direct mental health projects. Second, it would advance accountability and transparency. A similar marker or methodology could track cross-sectoral mental health financing changes from development actors and inspire its expansion. Third, governments must foster lasting support networks such as reinforcing responsible gambling for health and conducting facility outreaches for realistic financial ceilings in budgeting to meet the increasing demand. Such a roadmap for the health landscape underlines the transformative power of targeted policy reforms. Finally, to engage in effective policy solutions, policymakers must be clear on the political aspects that may negatively affect such reforms, thus gaining political buy-in to achieve sustainable investment cases for mental health care.

5. Conclusion

We suggest mobilizing a set of actions across multiple stakeholders, including fiscal expansion strategy, health insurance coverage, statutory mental health levies, multisectoral approaches, stakeholder analysis, private sector participation, and governance for UHC. Closing these gaps could create space and drive real change in the health sector. The SSA, including Uganda, must learn from successful contexts that could serve as models. The Benelux countries, Italy, Scandinavian countries, Singapore, and the United Kingdom have successfully implemented financing reforms to provide actionable insights and inspire valuable potential pathways for mental health reform. The challenge is to attain national adoption of such models in the face of poor funding and infrastructure. Given the much-needed investment in many SSA countries on health, urgent action is needed to prioritize financing mental health reforms, enhance fiscal space for health, and support from stakeholders to provide lower-cost financing and grants. The financing pressures on health could transform into a mental health crisis with fundamental implications for socio-development and missing opportunities for achieving UHC. Thus, the global community must act to avoid this outcome.

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Author contributions

Conceptualization: Emmanuel Otieno, Jeninah Businge
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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

PERSPECTIVE ARTICLE

Are random price generators useful for health policy processes and analysis? effectiveness of random price generators in health policy processes and analysis

Christine C. Huttin[1,2]*

[1]Department Business and Economics, University Aix Marseille, IAE School of management, Aix en Provence, France

[2]Endepusresearch, R&D Operations, Cambridge, Mass, United States of America and Endeplux, Luxembourg

Abstract

This paper discusses why using random price generators in an economic model for medical markets may be useful. It summarizes the different steps for the development of the model and describes an original contribution of the physicians' choice model with random drug prices applied to Type 2 diabetes in the US. Pharmaceutical markets have been supply-driven to boost life science and medical technologies; however, with the widening inequalities inside national health systems and the global agenda for universal health coverage, more economic research is being done to strengthen the analysis of demand for healthcare services. Research, especially, examines more disaggregated levels of demand systems to understand the heterogeneity of physicians' choices and better capture patient needs. It can also be an approach to calibrate supply and demand adjustments in medical markets. This paper argues that choice modeling is particularly relevant, using random price generators in a structural model where a demand approach is useful. If validated by additional experimental studies, this first study by Professors Huttin & Hausman (2021) could be used in advanced value assessment frameworks. Random price generators on medical markets could also be tested with additional models that fit oligopolistic market structures (e.g., models for differentiated product markets such as the Berry–Levinsohn–Pakes model). It may also help with a policy analysis process that addresses major disruptive transformations of market dynamics, evolving boundaries in science, fast digitalization, and artificial intelligence-based information systems.

Keywords: Choice model; Medical markets; Randomness process and nature; Random price generators; Mixed logit models

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***Corresponding author:**
Christine C Huttin (christine.huttin@univ-amu.fr; chxyinfo@endepusresearchinc.com)

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1. Introduction

This paper continues a series of methodological contributions to develop an economic model for medical markets, especially suited for structural models of markets such as the US. The use of random price parameters for medical products and services is

a recent development; other pricing methods, especially revealed-preference methods (e.g., hedonic pricing), have prevailed in valuation methodologies used for macroeconomic models over contingent valuation methods (e.g. Appendix A1; United Nation [UN], 2003). They proved to be statistically reliable in market dynamics of liberal economies and health systems primarily using price mechanisms. The concept of randomness is not new in medicine and life sciences. It has been used for modeling in population studies and their evolution (e.g., breeding populations are randomly combined in pairs to produce offspring). Scientists such as epidemiologists and biostatisticians have used Markov chains models for disease progression (e.g., Bernoulli's principle for simple cases or Monte Carlo models).

Using random parameters in statistical models for economic analysis of medical markets is also widespread; however, generating random prices is quite recent for medical products and services. This paper discusses the implication of the experimental research for an economic physicians' choice model initiated by Huttin & Hausman (2021) on patients with Type 2 diabetes. In their study, random prices were generated for drug prices on an analytical dataset for Type 2 diabetes. Their paper also explained the main methodological steps. The project provided encouraging results on such an approach; it implemented the recent econometric specification tests on a mixed logit (ML) model at an individual level, proposed by Burda *et al.* (2012) and Hahn, Hausman & Lustig (2020), it complements the generalization of Hausman & McFadden tests for the Multinomial Logit Model (1984). Random generators for drug prices were computed for this ML model. Such development may help to move beyond latent class models, existing ML model statistics, and additional applications to other models for oligopolistic markets.

Limitations of this approach have been discussed, especially concerning the development of pricing methods such as algorithmic pricing in the context of digitalization and mobile economics (Huttin & Hausman, 2021). Further development of other choice models using random pricing is also needed for a validated simulated tool, especially with comprehensive user cases on choice sets of medicines, devices, or procedures, and applied to analytical datasets from different national or regional contexts.[1]

2. Why is it useful to include randomness in modeling for policy-aiding tools in health?

2.1. Nature randomness and development of economic models for health

One of the main arguments for using randomness to study nature is that it is a useful process to achieve neutrality (Sunstein, 2019), which is important for policymakers, especially when using "nature nudging" as a policy-aiding tool.

Nature randomness may change at any time, so using random variables in modeling with a process approach may fit more data on population health. Economists have run analyses using random parameters for variables in models for health or medical markets for a long time; however, this paper shows the possible interest of random prices in an economic model for physicians. The methodological steps of this experimental user case are tested on a statistical model for the Type 2 diabetes market in the USA. This type of economic model aims to strengthen the analysis of the demand side of a medical market to better represent the heterogeneity of physicians' preferences at the individual level.

Figure 1 provides the different types of statistical models used to analyze this medical market; it lists predictive disease econometrics, especially from Professor Huttin's previous studies and more recent projects for oligopoly markets.

The current milestone aims to provide a comparative analysis of study results for the latest approaches: choice models with random price generators and Hierarchical Bayesian analysis with shrinkable estimators. According to the structural models for national economies, facing open boundaries of science and new players disrupting traditional game rules, these approaches can contribute to calibration methods for adjusting supply and demand for medical markets.

2.2. Experimental research in other sectors: A useful resource for the use of random generators in healthcare markets

Experimental research using random parameters has expanded greatly, especially in transportation research and finance. Studies using random parameters usually show very good results in such fields, especially in transportation research, marine research, and energy (Glenk *et al.*, 2020), comparing valuation methods such as random parameters logit and latent class models. Systematic reviews may help further milestones for more comprehensive user cases in healthcare markets with such an approach; however, they are out of the scope of this paper.

The sharing economy also leads to studying the preferences of consumers and populations when adjusting to the new economy. These include workers' preferences for co-working spaces and hours in labor markets, new alternative sharing models on bicycle or car sharing in transportation research, preferences for quality and choice of genetically modified food in nutrition studies, and preferences between electric and hybrid cars in automobile markets.

[1] Grimmett and David Stirzaker (2020) provide a good review of random processes for interested readers.

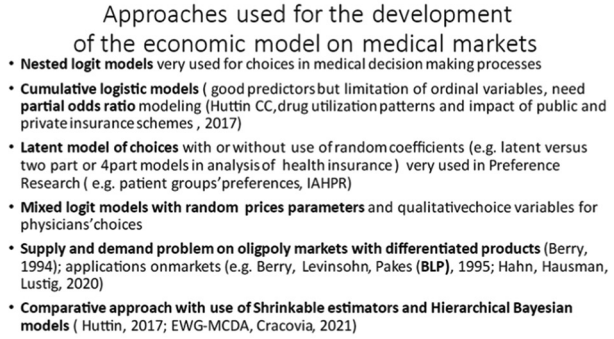


Figure 1. Approaches used for the development of the economic model on medical markets
Source: Extracted from Prof Huttin CC 's communication at Euro conference, July 3–6th, ESPOO, Finland, 2022 (with permission of Prof Huttin CC-ENDEPUSresearch, Inc).
Abbreviation: IAHPR: International academy of health preference research.

As research is increasing in all these fields, the methodological discussions around using random generators and simulated studies are growing and will benefit the development of such an approach for analyzing medical markets. Some methodological issues and limitations discussed in the next section were identified in the original study by Huttin & Hausman (2021) of the physician choice model on type 2 diabetes.

3. Original physician choice models using random drug price parameters: Promising results for medical markets?

The economic model development for medical markets and the statistical studies on analytical datasets extracted from the US National Ambulatory Medical Care Survey used different approaches. The data were transformed to run ML models using random price parameters.

The main statistical model used in three chronic conditions (asthma, hypertension, and Type 2 diabetes) were cumulative logit models using socioeconomic predictors and proxy for insurance profiles based on the classification from the administrative data set on insurance types and payment types. The studies were useful in identifying the main socioeconomic predictors and the impact of types of insurance profiles; however, such models also require additional partial odds ratio testing.

Figure 2 presents the study results and illustrates the issue of odds ratio testing.

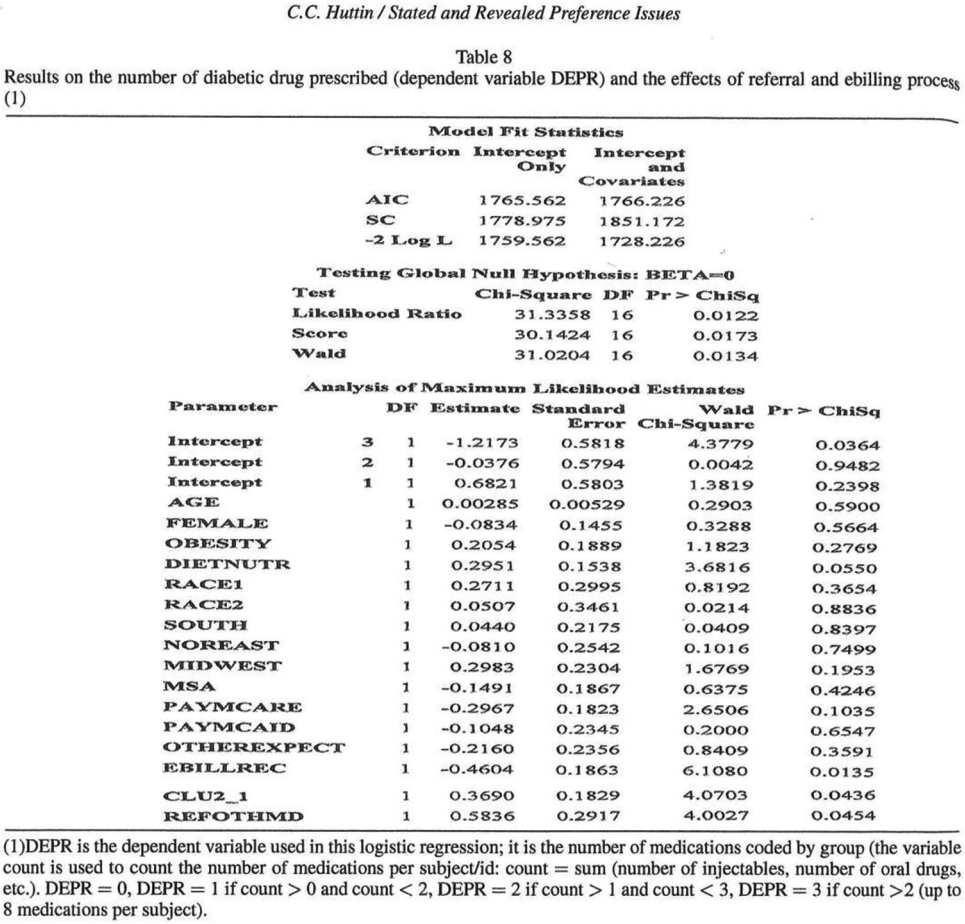
In such models, several types of random variables have been used. For instance, in the study on Information and Communication Technologies (ICT) diffusion in primary care, some random variables were used (as interaction terms in some runs), capturing the effects of electronic billing and insurance plans. They controlled whether the computerization process affected enrollees according to their plans: Medicare and Medicaid enrollees versus commercial insurance (study run with the Glimmix SAS procedure) (Huttin, 2017).

However, approaches with random parameters also tend to outperform latent class models in analyzing heterogeneity in medical markets; Zhou & Bridges (2019) also studied treatment heterogeneity regarding diabetes. Therefore, using random price generators can be viewed as a new milestone on random parameters in a choice modeling approach for physicians.

The ML model uses a combination of two random parameters for prices and three non-random parameters for demographic variables: age, gender, and obesity. The statistical estimates for the three non-random parameters were estimated predictors from the previous studies using cumulative logistics. These variables were used in the baseline model for simulations of the ML model.

The randomization of prices was performed using an Excel formula around some prices collected with Redbook for the main drug classes of the three categories; this experiment helps to identify workable random price parameters to import into the database; several experiments on the generation of such random variables have been tested as well as two sequences Halton and uniform; issues of correlation between the number of draws and number of sequences should be addressed for larger scaled studies (Mariel & Meyerhoff, 2018; Ellis *et al.*, 2019), however for the original study, it did not create issues and the model could converge with draws limited to 200. Price parameters with interaction terms were introduced to represent enrollees on public versus private insurance plans in the US. This approach may be extended to include Medicaid patients and additional classifications of Medicare patients with supplemental plans versus or in combination with commercial plans; however, in further studies, additional classifications or more complex cost-sharing arrangements required more extensive datasets and samples to comprehensively represent public and private plans.

The ML model was run with a STATA procedure called "asmixlogit" and then imported into Matlab for comparison between simulated data and the original data from the analytical dataset on diabetes. The different steps of the study are described in two papers by Huttin & Hausman (first a technical note at MIT in 2018 and a published paper in 2021) and Hahn, Hausman & Lustig (2020), the study was presented at a joint ISPOR/IAHPR conference in 2019 in Basel.



C.C. Huttin / Stated and Revealed Preference Issues

Table 8
Results on the number of diabetic drug prescribed (dependent variable DEPR) and the effects of referral and ebilling process (1)

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	1765.562	1766.226
SC	1778.975	1851.172
-2 Log L	1759.562	1728.226

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	31.3358	16	0.0122
Score	30.1424	16	0.0173
Wald	31.0204	16	0.0134

Analysis of Maximum Likelihood Estimates

Parameter		DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	3	1	-1.2173	0.5818	4.3779	0.0364
Intercept	2	1	-0.0376	0.5794	0.0042	0.9482
Intercept	1	1	0.6821	0.5803	1.3819	0.2398
AGE		1	0.00285	0.00529	0.2903	0.5900
FEMALE		1	-0.0834	0.1455	0.3288	0.5664
OBESITY		1	0.2054	0.1889	1.1823	0.2769
DIETNUTR		1	0.2951	0.1538	3.6816	0.0550
RACE1		1	0.2711	0.2995	0.8192	0.3654
RACE2		1	0.0507	0.3461	0.0214	0.8836
SOUTH		1	0.0440	0.2175	0.0409	0.8397
NOREAST		1	-0.0810	0.2542	0.1016	0.7499
MIDWEST		1	0.2983	0.2304	1.6769	0.1953
MSA		1	-0.1491	0.1867	0.6375	0.4246
PAYMCARE		1	-0.2967	0.1823	2.6506	0.1035
PAYMCAID		1	-0.1048	0.2345	0.2000	0.6547
OTHEREXPECT		1	-0.2160	0.2356	0.8409	0.3591
EBILLREC		1	-0.4604	0.1863	6.1080	0.0135
CLU2_1		1	0.3690	0.1829	4.0703	0.0436
REFOTHMD		1	0.5836	0.2917	4.0027	0.0454

(1)DEPR is the dependent variable used in this logistic regression; it is the number of medications coded by group (the variable count is used to count the number of medications per subject/id: count = sum (number of injectables, number of oral drugs, etc.). DEPR = 0, DEPR = 1 if count > 0 and count < 2, DEPR = 2 if count > 1 and count < 3, DEPR = 3 if count >2 (up to 8 medications per subject).

Figure 2. Examples of results on disease econometric studies using a cumulative logit model (Huttin, 2017)
Source: Huttin, 2017. *Reprinted with permission of IOS Press-SAGE group, Copyright C, 2017 Technology and Health Care Journal, IosPress.*

Table 1 presents an example of the result of the specification test comparing two and three choices of drug sets and the coefficients for the two random price variables: prices for Medicare enrollees and prices for all population enrollees. As shown, prices for these diabetes drugs were similar for Medicare patients under the choice of two (alternatives 2 and 3) versus three alternatives (alternatives 1, 2, and 3), contrary to the coefficients associated with the other price parameters for the sampled population.

4. Design of health policy-aiding tools in the context of digitalization and mobile economics

The pricing of services in digital economics, such as platforms and mobile economics, differs significantly from conventional pricing theories. For example, Huttin's (2012) first paper on mobile pricing highlighted how health/biological data pricing could be modified along the value chain between significant data providers, such as big pharma or some big tech companies, and data users and acquirers. Such modifications are especially affected by additional market characteristics, such as constraints imposed by technical wireless capacities or other infrastructures (e.g., 3G, 5G, or 6G).

At this point, the random price parameters were used in the baseline physicians' choice model. The disease econometric study (presented in Figure 2) included the computerization of medical records in the design of the analytical dataset. It uses partitioning and clustering algorithms for the impact of ICT diffusion on electronic billing variables and variables on types of information computerized in electronic medical records (documentation such as open notes, nurses' notes, and reports for public health).

Digitalization also transforms how various layers of information are processed for reminder systems and decision aids. For instance, layers of information from the cognitive architecture of the decision-making ruling system help adjust mechanisms of influence or persuasion; however, in this user case, the healthcare organizational

Table 1. Examples of results with random price generators on a medical market

Results of the tests Main parameters on three and two alternatives	Full model with three alternatives (alternatives 1, 2, and 3)	Restricted choice set (alternatives 2 and 3)
Age × alternative 1 (at least one oral agent)		
Age × alternative 3 (no drug)		
Obesity × alternative 1		
Obesity × alternative 3		
Sex × alternative 1		
Sex × alternative 3		
Price	−2.4270	2.8546
Price × Medicare	0.4438	0.4227

Source: Extracted from Huttin & Hausman, 2021 *Reprinted with permission of Gudapuris, Copyright 2021, Gudapuris.*

level inside the economic system is not part of the study, which targets individual-level data (providers of care and/or patients).

The impact of digitalization on a macro-model is complex and challenges the architecture of health information systems. It depends on layers of information for marketing intelligence tools in market access and counter-detailing techniques[2] professions use to grow awareness with comparative information on various products and services. Moreover, multi-stakeholders are now engaged in such processes (e.g., value assessment frameworks from ISPOR). Other dimensions of digitalization in biopharma value chains or the medical informatics of health systems also transform biopharma R&D operations, manufacturing, and delivery of services, especially after the boost of the COVID-19 pandemic.[3]

Additional risks and uncertainties for economic models must be considered:

- Transformations in information technology (IT) lead to different issues around the control and security of information processing; primary care settings are usually not equipped and often rely on the medical informatics of hospitals or stronger health networks.
- Algorithmic system designs increasingly enhance, supplement, or partially substitute human interactions and tasks; however, the change process to control the impacts of fast digitalization and mobile computing on providers of care, patients' behaviors, and health systems is under-researched.
- Software developers play a critical role in designing templates and generating new IT platforms that change the rules of the games and impact price competition and nudging policies.
- IT has transformed the implementation of survey instruments and data generation totally or partially; thus, random parameter generators may depend on online systems of instant individual-level data.

Therefore, implementing decision tools designed with implicit and explicit pricing and cost of care information (e.g., cost sensitivity simulators using discrete choice experiments and reversed conjoint models) depends on how digitalization impacts the implementation of the survey instruments, data generation, and software development.

5. Limitations and further developments

This paper promotes the use of more knowledge of the structure of the demand system for medical markets since the move toward personalized medicine also means an extreme heterogeneity of the demand and requires a better representation of patient needs in a context where current trends of technological change lead to singularity (Kurzweil, 2005).

The experimental study was performed with random price generators, and parameters were used for one type of choice model, the ML model. The area of stratification economics covers methodological developments, especially in various approaches for multi-attribute choice models. Further experiments could compare results between ML and different versions of latent class logit models and the latest development combining random parameters and reducing the number of classes in latent class models.

Useful economic models have also examined the structure of a demand system in oligopolistic markets (Berry, 1984; Berry & Haile, 2014), which are often market characteristics of medical markets. Such a model uses the mean of consumer utility to compute market shares in different market segments (the mean utility method); Berry *et al.* (1995; the BLP model) successfully applied

[2] Counter detailing techniques with psychological "cost cues" from behavioral economics help better understand decision shifts and identify restraints due to financial restrictions with big societal impact and significant effect on disease severity.

[3] See, for instance, ICT diffusion in global value chains for pharmaceuticals (data extracted from TiVa Dataset within a collaboration between Prof Huttin and OECD-Science and Technology directorate, 2020).

it to the car industry. Research is ongoing on the BLP model, for possible computation on analytical datasets for medical markets. This type of business research helps quantify changes in cross-price elasticities between market segments and may also be useful for other policy-aiding tools, especially in the case of mergers, for instance, in gene sequencing.

Different extensions of multilevel demand systems may also be useful, including dynamic random coefficient logit applications in the health sector in longitudinal medical claims databases. Other contributions include research on comparative estimators, e.g., on simulated maximum likelihood (Park & Gupta, 2012), generalized methods of moments estimators (Berry *et al*., 1995), and recent interfaces to adjust to the latest forms of such models, e.g., in Python see, Colon & Gortmaker (2020) or STATA technical notes.

Incorporating choice modeling with microdata into macroeconomic models may be helpful for healthcare budget forecasting (Soekhai *et al*., 2019; Vass *et al*., ISPOR Interest Group report, 2022), aiding in considering the heterogeneity of preferences. Random price generators in such a demand model may fit the US medical markets with strong oligopolies or monopsonies and large demand heterogeneity. Globally, many countries do not use a demand approach and prefer to set the rules with governmental agencies (such as health technology assessment agencies, using techniques like quality-adjusted life year and threshold adjustments). Therefore, this approach to strengthening the demand system does not automatically apply to regulated health systems with health technology assessment agencies, such as Nice in the UK or other European systems, using conventional pharmacoeconomics or economic evaluation methodologies.

Controversies among economists also exist on contingent valuation methods or stated-preference studies for health service research; however, they are increasingly used in health care studies, especially for revisions of welfare contracts (e.g., review of contingent valuation methods, ISPOR task force report) (Hauber *et al*., 2016). Discrete choice experiments can very well operationalize the responses of various actors to financial changes or variations of access to care according to types of barriers. They help target the different needs of subpopulations of patients and limit the overuse of medical services.

Additional supply and demand parameters in structural models help address broader consumption behavior changes. Strengthening the demand system may shift the priority setting from technology-driven medical systems, usually more induced by supply (Evans, 1974; Sina Shih & Tai-Seale, 2012; Chen *et al*., 2023), and may lead to different public policies, especially with science and technology.

Introducing more demand-side parameters in healthcare is a scientific challenge, even if predictive econometrics in some diseases improves quickly. The advances in genomic medicine raise expectations toward precision medicine and personalization of clinical pathways. Scientific discoveries (especially genome-wide association studies) are promising. For instance, modeling monogenic diseases leads to beneficial causal inference relationships with genetic predictors, but monogenic diseases do not represent many diseases.

Moreover, the growth of complexity may limit the advance of models using genetics as predictors, especially for disease econometrics. Asthma genetics is a good example, where the discovery process in asthma genetics has expanded quickly and led to reliable associations with genetic biomarkers and beneficial asthma drug therapies. However, the complexity of the interactions, especially gene-gene interactions and epigenetic modifiers according to geographical sites, has slowed the predictability of models, including genetic predictors in this disease. Controversies remain between geneticists and biologists (Huttin, 2015) with such evolving scientific advances. Only system biologists may be able to capture the role of gene-gene interactions and epigenetic modifiers' influence on outcomes of chronic diseases such as asthma and its complications (e.g., chronic obstructive pulmonary disease) in the future (see also Appendix A2).

Despite current scientific limitations and new uncertainties, it is relevant to strengthen the demand function with a better understanding of individual choices and not only market products and services. Moreover, as longevity challenges welfare economic theory, it also shows the interest in using micro-macro modeling in evolving value frameworks.

6. Conclusion

In health policies, the cost-benefit analysis framework, including for evidence in development, is very used, especially in countries with strong health technology assessments. This paper proposes approaches to strengthen the demand system in medical markets using choice modeling techniques and random price generators.

Reliable metrics are needed for advanced value frameworks and evolving multi-stakeholders impact assessments to complement existing thresholds used in cost-benefit analysis, for example, incremental cost-effectiveness ratios (Solow & Pezalla, ISPOR Value assessment framework, 2018). Decision tools using cost and price information rely on cognitive architecture and

financial information systems with implicit and explicit information implemented in the correct settings and modes of enforcement (Sunstein, 2016).

Integrating individual levels and microdata to represent the heterogeneity of demand (and patient needs) is usually achieved through choice modeling (Abaluck & Gruber, 2013). Random price parameters in structural models seem promising for structural models fitting complex, competitive markets such as the US medical market. It may also be helpful when there is a disruptive transformation of market dynamics and more open boundaries in sciences.

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Conflict of interest

The author declares no competing interests.

Author contributions

This is a single-authored article.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Not applicable.

Further disclosure

Part of the results from figures and tables are extracted from communications at conferences. EWG-MCDA meets twice a year; it is a European working group and is in EURO society. All the results were presented at Euro in Helsinki. Usually, the EWG helps to prepare main conference.

Figure 2 is an extract from my own article in Technology and HealthCare, only authors need to agree for tables.

Table 1 is no problem since I mentioned that in the Archives of Health Sciences, it is an open access journal, and the authors keep copyrights.

The original econometric paper and the original case study on diabetes Type 2 are published in articles cited in this paper; there are no other direct contributors in this health policy-oriented paper.

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Appendix

Appendix A1. Stated-preference and revealed-preference studies

Contingent valuation methods are also called stated preference studies. They include different methods, such as conjoint valuation, willingness to pay, or ability to pay (see UN pricing methodologies, 2003). Usually, they are used in health care at the individual level or for minorities or subgroups of the populations to analyze large heterogeneity in preferences. However, incorporating such microdata, often based on intentional rather than real or effective data in macroeconomic models, remains controversial. Fusion studies with both types of types are limited in healthcare (SP-RP modeling). Discrete choice modeling can use either intentional or real data (when they exist); it is used in healthcare systems to adjust the preferences of providers and patients or in population studies. The growth of digital markets also generates additional methods to analyze their impact on medical markets, such as recent algorithmic pricing methods and neural networks used by big tech players (e.g., Amazon); however, it is out of the scope of this paper

Appendix A2. Data models and econometrics

Economic model development must also incorporate the fast pace of technological changes (e.g., AI and biotech or genomic revolutions). Such changes may require additional decision points with economic markers for payers, impacting various cost-sharing mechanisms for patients and their dependents. Moreover, fast scientific discoveries in genomic medicine push the frontiers of discovery on humans, with changes in coding, decoding, and re-coding DNA, for example, regenerative medicine or recent R DNA technologies to fight the COVID-19 pandemic (e.g., BioNTech/Pfizer or Moderna Vaccines). Machine learning techniques also accelerate using DATA models with genetic and biological variables and clinical, epidemiological, or socioeconomic predictors used by econometricians. Data models introduce other types of uncertainties: potential biases (e.g., data from geographical sites that do not automatically match people's ancestry), non-obvious interpretation, transferability of study results, and uncertain biomarkers in some genetic disease models (issues of reliability of early detection techniques).

Therefore, a more comprehensive framework for decision-making processing and selection of alternatives is required; additional theories may be helpful, for instance, the C-K theory proposed by Hatchuel *et al.* (2012) and Colorni & Tsoukias (2018)

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PERSPECTIVE ARTICLE

Combating HIV among youths in Sub-Saharan Africa through inclusive health education

Ibrahim Khalil Ja'afar* and **Usoro Udousoro Akpan**

Department of Public Health, Warwick Medical School, University of Warwick, Coventry, United Kingdom

Abstract

The human immunodeficiency virus (HIV) epidemic among youths in Sub-Saharan Africa underscores the exigency for effective prevention education programs tailored to their needs. This article examines barriers hindering HIV prevention efforts for youths in the region and proposes strategies for developing more inclusive and impactful health education interventions. Despite the challenges faced by HIV-positive adolescents, comprehensive youth-friendly services remain limited. Impediments such as stigma, poverty, and lack of health-care infrastructure obstruct HIV prevention. Access to information and services, negative attitudes of service providers, and scarcity of youth programs present challenges. The article discusses approaches such as involving youth in program design, establishing community advisory boards, mobilizing community health workers, integrating services, engaging schools, employing gender-sensitive methods, and advocating supportive policies. These strategies aim to enhance cultural sensitivity, community engagement, and accessibility of education for all youths. Sustained commitment through ongoing funding, monitoring, capacity building, and multisectoral collaboration can empower youths with the knowledge and support needed to curb their long-term risk of HIV.

Keywords: HIV; Youth; Sub-Saharan Africa; Health education; Strategies; Barriers

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Mihajlo Jakovljevic M.D. Ph.D. MAE

***Corresponding author:**
Ibrahim Khalil Ja'afar
(Ibrahimkhaliljaafar@gmail.com)

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1. Introduction

Combatting human immunodeficiency virus (HIV) among youths in Sub-Saharan Africa through inclusive health education is crucial due to the high prevalence of HIV cases in this demographic group (Abate *et al.*, 2020). Despite the challenges faced by young people infected by HIV in Sub-Saharan Africa, there is a lack of comprehensive health services tailored to their needs.

Factors influencing access to youth-focused sexual and reproductive wellness programs have been identified, emphasizing the importance of understanding these factors to improve programmatic interventions. In addition, addressing sexual risk behaviors in HIV-positive young people is vital, and interventions to reduce such behaviors have been studied in Sub-Saharan Africa (Toska *et al.*, 2017).

Barriers toward access to HIV prevention programs for young people in rural areas have not been extensively explored, indicating a gap in understanding and addressing these challenges (Ssali, 2023). Factors such as school attendance, movement, and employment should be considered when examining the risk of HIV infection among young people in Sub-Saharan Africa.

Formal education has been associated with a decreased risk of HIV transmission among youths, emphasizing the role of education in HIV prevention efforts. Inclusive education has been shown to enhance the health situation of individuals in Sub-Saharan Africa, underscoring the importance of education in improving health outcomes (Kouladoum, 2022). The relationship between education and HIV risk is multifaceted, with various studies indicating that higher levels of education can correlate with reduced HIV risk behaviors, although this relationship can vary by context and demographic factors. Education, particularly in the context of HIV prevention, plays a crucial role in shaping individuals' knowledge, attitudes, and behaviors regarding sexual health, which in turn influences their vulnerability to HIV infection. Research indicates that individuals with higher educational attainment often possess better knowledge about HIV transmission and prevention methods. For instance, studies have shown that women with higher education levels are more capable of understanding HIV infection dynamics and are less likely to engage in risky sexual behaviors (Zoung-Kanyi Bissek *et al.*, 2011). Furthermore, a correlation exists between educational attainment and the likelihood of being HIV positive, with lower educational levels being associated with higher HIV prevalence (Alvarez-Uria *et al.*, 2012).

Inclusive education plays a critical role in addressing these risk determinants by fostering a supportive environment that promotes sexual health knowledge, self-efficacy, and healthy relationships (Andrew & Andrew, 2020; Phillips *et al.*, 2020). Programs that incorporate family involvement and peer support have shown effectiveness in reducing risky behaviors among youths (Cordova *et al.*, 2014; Wilson *et al.*, 2012). Moreover, educational interventions that are culturally sensitive and tailored to the specific needs of at-risk populations can significantly enhance health literacy and empower youth to make informed decisions regarding their sexual health.

Effective adolescent sexual and reproductive health education programs are essential for addressing HIV prevention among youths in Sub-Saharan Africa. Assessing violence against youth and understanding the prevalence of HIV in the region are critical for developing targeted interventions (Currie *et al.*, 2021).

2. Barriers to effective HIV prevention and education among youth in Sub-Saharan Africa

A study by Mody *et al.* (2024) have demonstrated that some HIV prevention interventions have had limited success due to challenges such as poor health-care infrastructure and social stigmatization. For example, interventions targeting rural youths often face additional barriers in terms of access to information and community resources.

Furthermore, barriers such as negative health-care provider attitudes and a lack of youth-friendly services have been identified as significant hindrances (Ijaiya *et al.*, 2024). More targeted interventions in areas with high poverty levels have been shown to reduce HIV risk, but these efforts need sustained support.

Obstacles hindering the effectiveness of HIV prevention and education efforts among youth in Sub-Saharan Africa are multifaceted and encompass various cultural, socioeconomic, and institutional barriers. These challenges have significantly impacted the success of interventions aimed at curbing the spread of HIV in the region.

Cultural factors play a significant role in shaping attitudes toward HIV prevention and education. The stigma surrounding HIV/AIDS remains a pervasive issue, leading to discrimination and fear of disclosure among youth. Socioeconomic factors also pose barriers to effective HIV prevention among youth in Sub-Saharan Africa. High levels of poverty and unemployment, particularly among young people, limit access to health-care services and information.

Institutional challenges further impede HIV prevention efforts. Limited health-care infrastructure and resources affect the delivery of prevention services, including testing and counseling (Asaolu *et al.*, 2016).

Access to information and health-care services is a critical issue in HIV prevention among youth. Barriers to utilizing HIV prevention services, such as negative attitudes among health workers, lack of skills, and limited availability of youth-friendly services, hinder effective interventions (Ssali, 2023).

3. Inclusive health education strategies to control HIV among youths in Sub-Saharan Africa

To develop more inclusive and effective health education programs for youth in Sub-Saharan Africa, a variety of approaches and methodologies can be implemented. These strategies may involve curriculum development, community engagement, technology utilization, and ensuring cultural sensitivity and accessibility to all youths in the region.

- *Youth engagement:* Involving youths in the design and execution of HIV prevention programs is essential. Approaches such as substantial engagement, where youth have decision-making authority, can result in more effective and pertinent interventions (Johnson *et al.*, 2024)

- *Community advisory boards:* Establishing community advisory boards can promote community engagement and ensure that health programs are culturally sensitive and responsive to local needs (Khan, 2024)
- *Utilizing community health workers:* Harnessing the role of community health workers in HIV care can enhance access to health services and education, particularly in underserved areas (Mwai *et al.*, 2013)
- *Integration of services:* Combining sexual and reproductive health services with HIV programs can broaden the reach and impact of interventions, addressing multiple health needs simultaneously (UNAIDS, 2023)
- *School engagement:* Collaborating with schools to integrate health education into the curriculum can reach a large number of youths and ensure comprehensive coverage of key health topics (Gasparri *et al.*, 2022)
- *Gender-sensitive approach:* Designing programs that account for gender differences in health knowledge and behaviors can address specific needs and challenges faced by young men and women (Barr *et al.*, 2024)
- *Policy advocacy:* Advocating for policies that support youth-friendly health services, education, and employment opportunities can foster an enabling environment for youth development and health promotion (Bedingar *et al.*, 2024).

4. Conclusion: Moving forward with sustainable solutions

Combating HIV among youths in Sub-Saharan Africa will require sustained, collaborative, and innovative efforts from all stakeholders. The high burden of HIV in the region underscores the urgent need for effective, youth-friendly prevention education programs. While various barriers have hindered past interventions, the proposed strategies discussed provide a way forward to develop more inclusive, tailored, and sustainable solutions. Ongoing commitment through sustained funding, community engagement, and capacity building of local partners will be critical to successfully curb the HIV epidemic among youths over the long term. Promoting multisectoral collaboration and implementing evidence-based, gender-sensitive interventions can help address the diverse circumstances that fuel risk. Continual monitoring and evaluation coupled with adaptive program design will further strengthen HIV education and ensure it meets the evolving needs of young people. With coordinated action and focused commitment from governments, organizations, and communities, more inclusive and responsive health education can empower youths to protect themselves from HIV infection and realize better health and socioeconomic outcomes across Sub-Saharan Africa.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

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ACCSCIENCE PUBLISHING

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ORIGINAL RESEARCH ARTICLE

Assessing the adequacy of health facilities for the aging population in Indian cities

A.H. Sruthi Anil Kumar[1]*, Nawaj Sarif[2], and Papai Barman[1]

[1]Department of Family and Generations, International Institute for Population Sciences, Mumbai, Maharashtra, India

[2]Department of Migration and Urban Studies, International Institute for Population Sciences, Mumbai, Maharashtra, India

Abstract

India, a developing country and currently the most populous nation, has been experiencing a rapid and unpredictable increase in the proportion of its older population. The healthcare system is already struggling to meet the needs of the current population, and the rising number of older adults is expected to further strain resources. Therefore, this study aimed to investigate the distribution of the older population in Indian cities and their access to advanced health facilities. The study uses data from Census of India, 2011, which is the latest census data available. A Health Facilities Index was developed to assess the availability of health facilities, and a geospatial approach was adopted to determine aging patterns and access to health facilities across cities. Despite similar aging trends, health infrastructure was unevenly distributed across cities. The study revealed that advanced health facilities were concentrated in specific areas, primarily metropolitan cities, whereas smaller cities lacked adequate health facilities and accessibility. Therefore, improving health infrastructure in smaller cities to match that in larger ones should be prioritized. The findings highlight a notable infrastructure gap in Indian cities, which presents a significant challenge to achieving healthy aging in the country.

Keywords: Population aging; Aging cities; Healthcare infrastructure; Health-care facilities

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***Corresponding author:**
A.H. Sruthi Anil Kumar
(shrutz91@gmail.com)

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1. Introduction

Rapid reductions in fertility and mortality rates have led to global population aging (United Nations, 2019; 2022). Population aging refers to the increasing proportion of older persons, internationally defined as those aged 65 and above and defined in India as those aged 60 and above. The lower age threshold in India corresponds with the country's traditionally lower life expectancy at birth. Globally, the total fertility rate (TFR) declined from 5.0 in 1950 – 1955 to 2.3 in 2021; this rate is projected to further decline to 2.1 by 2050 (United Nations, 2022). At the same time, life expectancy at birth has increased from 47 years in 1950 – 1955 to 72.8 years in 2019, an increase of 25.8 years. It is expected to reach 77.2 years by 2050. This combination of decreasing fertility and increasing life expectancy has produced a demographic dividend and also accelerated population aging globally (United Nations, 2019; 2022). However, intercountry variations in the pace of fertility and mortality decline have resulted in

differing levels and trends of population aging globally (United Nations, 2017).

According to the World Population Aging Report (2020), 9.3% of the global population (7.75 billion in 2020) was aged 65 or above in 2020, amounting to approximately 745 million older persons. Projections indicate that the share of older persons will increase to 16% by 2050. The data and projections also highlight that of the growing number of older persons aged 60 or 65 and above, a significant proportion will be in developing nations (United Nations, 2020).

1.1. Aging in India

India has experienced significant changes in fertility and mortality in recent decades. The average number of children per woman (TFR) in India decreased from 5.9 in 1961 to 2.0 in 2019 – 2021 (International Institute for Population Sciences, 2020; Rele, 1987), a reduction of 3.9 children per woman. This fertility decline occurred alongside significant mortality improvements: life expectancy at birth in India increased from 42.0 years in 1961– 69.7 years between 2015 and 2019, an increase of 27.7 years (Technical Group on Population Projections, 2019a; United Nations, 2019). These changes have led to a demographic dividend in India, although the pace of aging varies significantly across states.

According to the 2011 Census of India, 8.3% of the population, or 98.5 million persons, were aged 60 and above. Projections show that this share will increase to 11.5% (163.2 million) by 2026 and 15% (228 million) by 2036 (Technical Group on Population Projections, 2019b). The extent and pace of population aging will differ substantially across states and population groups, as shown in census data, surveys, and projections (Office of the Registrar General and Census Commissioner, 2011; 2019; National Family Health Survey 5). Table 1 outlines population aging in India since 1981 and provides projections till 2036.

Using census data and population projections, researchers have observed that population aging in India varies across states and population groups (Bhagat & Kumar, 2011; Dhar Chakrabarti, 2001; Dommaraju, 2016). According to the 2011 Census of India, the share of the older population ranges from 7% in Manipur to 12.6% in Kerala. The states with the highest shares of older persons are Kerala (12.6%), Goa (11.2%), Tamil Nadu (10.4%), Punjab (10.3%), Himachal Pradesh (10.2%), and Maharashtra (9.9%). However, as the population size varies considerably across states, the actual number of older persons also differs. For example, in Uttar Pradesh, India's most populous state with 200 million people in 2011, the proportion of the older population is only 7.7%; however, this value amounts to 15.4 million persons. In contrast, Kerala, despite having the highest proportion of the older population, has only 4.2 million older individuals.

Table 1. Progress in population aging in India (1981 – 2036)

Year	Number of persons aged 60 and above (in millions)	Percent of the total population	Old age dependency ratio
1981	43.1	6.3	12.0
1991	56.6	6.8	12.2
2001	76.6	7.5	13.0
2011	101.5	8.4	13.8
2021	137.9	10.1	15.7
2026	163.2	11.5	17.6
2031	193.8	13.1	20.1
2036	228.0	15.0	23.1

Note: Data for 1981 – 2011 are based on census data. Projections for 2021 – 2036 are from the Registrar General and Census Commissioner (2019).

Table 2 provides estimates of gender and rural–urban differences in population aging for 2021. To generate these estimates, we used the projected total population of India for 2021 and its age distribution, the projected urban population for 2021, and the age distribution of rural and urban populations as obtained from the NFHS 5 report. Using this information, Table 2 presents the estimated percentage and number of older persons in India in 2021. According to these data, in urban areas, the proportion of the older population is the same among men and women (11.6%), whereas in rural areas, this proportion is lower among women (11.4%) than among men (12.4%). The estimated number of older individuals in India is 84.6 million men and 76.2 million women. However, if we use the projections used by the Census of India, the corresponding figures are slightly lower at 67.1 million (9.6%) and 70.9 million (10.7%), respectively.

1.2. Impact of population aging on health

By 2050, nearly one-fifth of the world's population will be aged 60 and above (United Nations, 2017). In India, the proportion of the older population is expected to rise from 8% in 2015 – 20% by 2050 (UNFPA, 2017). This shift necessitates strategic planning to address present and upcoming problems related to healthy aging (Adlakha *et al.*, 2020). The UN's Sustainable Development Goal 3 of "Good health and well-being," alongside the World Health Organization's (WHO's) focus on "Healthy Aging," emphasizes the importance of understanding the country's aging structure, health profile, and available health facilities (WHO, 2015).

Table 2. Percentage and number of persons aged 60 and above by sex and place of residence, India (2021)

	Urban		Rural		Total	
	Male	Female	Male	Female	Male	Female
Percent aged 60 and above	11.6	11.6	12.4	11.4	12.1	11.5
Total population (in millions)	246.3	228.8	452.7	433.6	699.0	662.4
Population aged 60 and above (in millions)	28.6	26.5	56.1	49.4	84.6 (67.1)	76.2 (70.9)

Note: Computed using the percentage of persons aged 60 and above as obtained from the NFHS 5 (2019–2021) and the projected population by sex and place of residence for 2021 (Registrar General and Census Commissioner, 2019).

India has witnessed a rapid rise in its older population. In 2014, the growth rate of the country's older population was 3 times higher than that of its overall population (Arokiasamy, 2016). With this unprecedented aging population, the health profile of older adults has also undergone significant changes (Agarwal *et al*., 2016). In India, 95% of older persons have at least one chronic illness (Karmakar *et al*., 2014 and Naushad *et al*., 2016). Non-communicable diseases have become a predominant health concern among older adults, and the burden of these diseases has steadily increased over the years (Devadasan, 2006; Yadav & Arokiasamy, 2014). A study by Jayakrishnan (2016) based on the NSSO survey conducted between January and June 2014 highlighted that the proportion of ailing older adults has increased over the last 10 years.

Forty percent of the Indian population is expected to live in urban areas by 2030. However, issues related to the accessibility and affordability of healthcare services are increasing (Rao & Peters, 2015). While most large cities may offer better healthcare facilities, many small cities struggle to provide adequate services. Goli *et al*. (2011) observed differences in development indicators and healthcare facilities across cities. According to Rao & Peters (2015), a higher concentration of healthcare providers is found in more urbanized areas, yet access to healthcare is not uniform across all urban regions. Most advanced healthcare systems and treatment facilities are concentrated in major cities, leading to differences in healthcare systems and delivery structures. Therefore, large and small cities differ in terms of health facilities and accessibility.

Although the proportion of the older population is similar across cities (Census of India, 2011), smaller cities often face challenges in providing timely and sufficient health-care coverage for older adults, particularly in dealing with age-related health conditions. This situation considerably impedes city administrators and the government in ensuring health coverage, especially for the older population. India launched the National Urban Health Mission to address these issues in 2013, with the prime objective of "healthy cities with good health facilities." However, many urban planners in India have yet to prioritize the creation of age-friendly cities (Adlakha *et al*., 2020).

Despite improvements in health facilities over the years, smaller cities continue to lag behind major cities in terms of health facilities. People living in smaller cities have to travel great distances to receive quality treatment. This gap in healthcare access between cities must be examined. Previous literature focused on disparities between rural and urban areas as well as slum and non-slum populations, with limited attention given to differences in health facilities and other development indicators between cities (Garg & Karan, 2009; Zare *et al*., 2018). This study aims to examine the distribution of the older population across Indian cities and investigate their access to advanced health facilities.

2. Data and methods

While recent national-level surveys exist in India, none provide data for all cities. Thus, this study used data from the Census of India (2011), which is the most recent census available and offers age group-wise population data for Class I cities. In addition, data on health facilities were obtained from the Town Directory (2011), which provides city-level information. Data on the older population (those aged 60 and above) were also collected from the Census C-14 (City) table for both 2001 and 2011. In total, 492 cities were included in this research. The share of the older population was calculated by dividing the number of older adults by the total population. In addition, we estimated the share of the older population for 2021 using the exponential growth method.

To assess the available health facilities in Class I cities, a Health Facilities Index (HFI) score was calculated. This score considered factors such as the number of hospitals, doctors, paramedical staff, and hospital beds. A composite score was computed for each city, with equal weight assigned to all indicators. The mean distance to these health facilities was also calculated. Furthermore, variations in the share of the older population were analyzed based on city size and civic status. Similarly, available health facilities were compared with the aging scenario in these cities and

categorized by size and status.

The ArcGIS software was used to map the share of the older population across Indian cities. We projected the share of the older population for 2021 and created an inventory map displaying the available health facilities in each city and the average distance to them. Hotspot analysis was also performed to identify the major hotspots of aging in India. The list of indicators and subindicators used to compute the HFI is given below:

Indicators of health facilities	Subindicators used (Per 000 population)
1. Government Hospital	a. Number of Allopathic Hospitals
2. Allopathic Government Hospital Alternative	b. Number of beds
3. Dispensary/Health Center	c. Number of doctors
4. T.B. Hospital/Clinic	d. Number of paramedical staff
5. Nursing Home	
6. Mobile Health Clinic	
7. Others	

3. Results

3.1. Aging pattern in Indian cities

Figure 1 illustrates the distribution of the older population across different city sizes. The older population in million-plus cities grew from 4.8 million in 2001–10.3 million in 2011. Other cities had a smaller share of older persons compared with million-plus cities. Cities with <200,000 population had 2.9 million older adults, those with populations of 200,000 – 500,000 had 3.5 million, and those with populations of 500,000–1 million had 2.5 million older residents. This increase in the number of older persons was more pronounced in million-plus cities but slightly lower in other small cities between 2001 and 2011.

The share of the older population increased across different city sizes between 2001 and 2011, with the highest increase observed in cities with populations between 500,000 and 1 million persons. Notably, smaller cities had a slightly higher share of older adults compared with larger cities. Cities with populations of <1 million had 8.2% of adults aged 60 and above, whereas million-plus cities had a population of 7.9% older adults. The study also highlights a significant variation in the distribution of the older population across cities with various civic statuses. Census towns had the lowest proportion of older people (5.5%), whereas municipalities had the highest (9.3%). The proportion of the older population was found to increase across all types of cities between 2001 and 2011 (Table 3).

Regional variations in the distribution of the older population in Class I cities are depicted in Figure 2. In 2001, most cities had an older population of < 8%. However, states such as Kerala, Tamil Nadu, and West Bengal exhibited a higher share of more than 10%. A rapid increase in the older population was observed between 2001 and 2011 across cities. The percentage of the older population is expected to increase above 14% in many cities across the country. Significant concentrations of the older population will be observed in states such as Kerala, Tamil Nadu, West Bengal, Punjab, Delhi, and Maharashtra and cities such as Thiruvananthapuram, Palakkad, Hugli-Chinsurah, Khardah, South DumDum, Uttarpara Kotrung, and Nabadwip.

Hotspot analysis reveals the geographic hotspots for the older population in India (Figure 3). The southernmost and eastern parts of India emerge as the primary hotspots, with a 99% confidence level. These areas house a high proportion of the older population and are surrounded by cities with similar numbers of older adults. Conversely, the northern regions, including Punjab, Haryana, Uttar

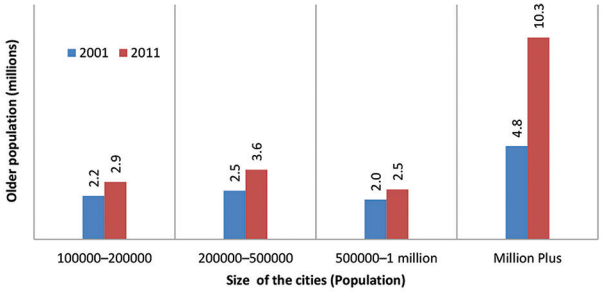

Figure 1. Older population by city size in 2001 and 2011, computed using data from the Census of India (2001 and 2011)

Table 3. Share of older population by city size and civic status in India, 2001 – 2011

Characteristics	2001	2011
City size		
100,000 – 200,000	6.9	8.2
200,000 – 500,000	6.9	8.3
500,000 – 1 million	6.5	8.2
Million plus	6.5	7.9
Civic status		
Census Town	3.6	5.5
City Municipal Council	6.4	8.1
Municipality	7.6	9.3
M. Council	6.7	8.3
M. Corp	6.6	8.0
Others	6.0	7.0

Note: Computed by authors from Census of India data 2001 and 2011.

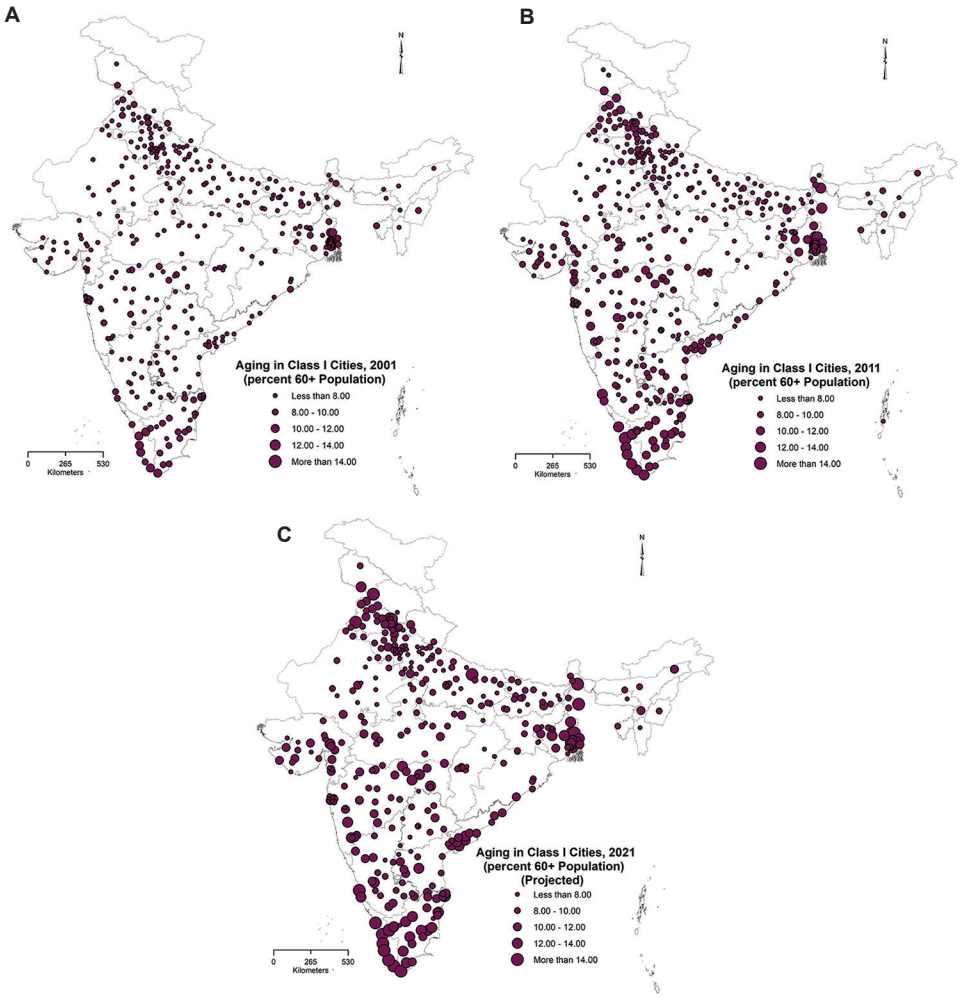

Figure 2. Share of older population aged 60 years and above in 2001, 2011, and 2021 (predicted) computed by authors using data from Census of India, 2001 and 2011
Note: (A) Older population share in 2001, (B) older population share in 2011, and (C) predicted older population share in 2021.

Pradesh, and Rajasthan, form a cold spot. The share of the older population in central India shows no significant clustering and is thus statistically insignificant.

3.2. Aging and health facilities in Indian cities

Health facilities in Indian cities are primarily associated with population size. Figure 4 illustrates that cities with larger populations have more and better health facilities, whereas cities with smaller populations tend to have fewer advanced health facilities. This trend is evident across the data.

There is a gap between the proportion of the older population and health facilities across Class I cities of different sizes. Table 4 shows that while the share of the older population is relatively similar across cities of different sizes, health facilities are unevenly distributed. Although the million-plus cities have a slightly lower percentage of the older population, they have better health facilities. In contrast, smaller cities have fewer health facilities although their share of the older population is higher.

The share of the older population and the availability of health facilities vary among cities with different civic statuses (Table 4). Municipal Corporations stand out for having better health facilities despite an 8% share of the older population. In contrast, census towns, *nagar panchayats*, and municipal councils show low HFI scores despite having a considerable proportion of the older population. Notably, municipalities have the highest share of older adults (9.3%), yet their HFI score remains very low (0.01).

Figure 5 highlights the insufficiency of health facilities with respect to population aging in Indian cities. It is evident that only a few major cities, such as Jaipur,

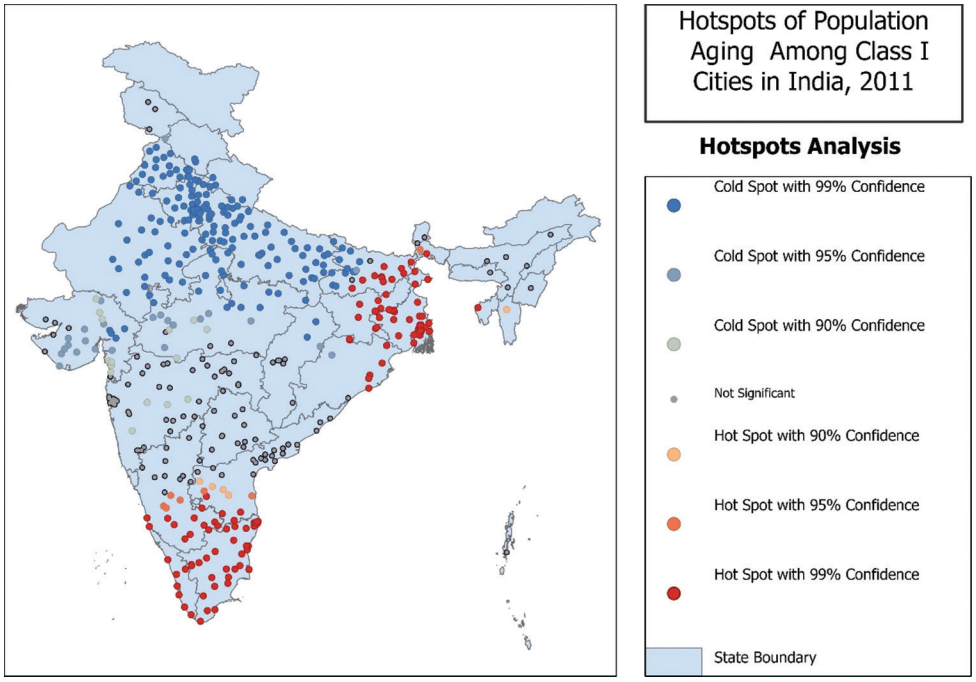

Figure 3. Hotspots of older population concentration among Class I cities in India, 2011 computed by authors using data from Census of India, 2011

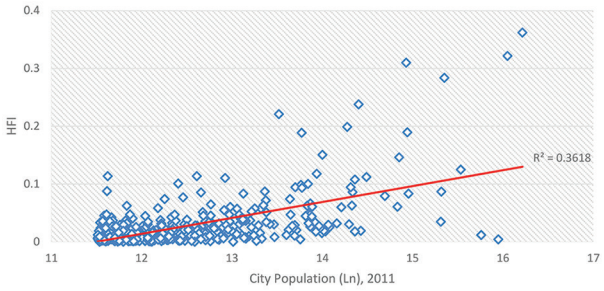

Figure 4. Relationship between the population size (natural log) of cities and the HFI score, 2011 computed by authors using data from Census of India, 2011

Bangalore, Chennai, Mumbai, Pune, Kolkata, and Delhi, have adequate health facilities relative to their aging populations. In contrast, many cities that have experienced rapid population aging in the last decade lack health facilities. Emerging aging cities in states such as Kerala, Tamil Nadu, and West Bengal, which already have a higher older population, are particularly lacking in terms of health facilities. Therefore, improving health facilities in such cities is crucial for ensuring healthy urban aging.

This examination of the health facility infrastructure across various Indian cities has generated certain noteworthy findings (Figure 6). Larger cities such as Bengaluru, Delhi Municipal Corporation, Mumbai, Jaipur, Chennai, Bhopal, Thiruvananthapuram, Agra, and Guwahati demonstrate high HFI scores, indicating that they possess the necessary resources and infrastructure to meet the healthcare needs of their populations, particularly older adults. Conversely, in cities with lower HFI scores, older adults are required to travel significantly long distances to access healthcare. This is especially true for cities in Uttar Pradesh, Bihar, and parts of Madhya Pradesh, Maharashtra, and Gujarat. In contrast, cities in Kerala and Tamil Nadu offer more accessible health facilities, with shorter travel distances.

Table 4. Comparison of the older population share and mean Health Facilities Index, 2011

Characteristics	Share of older population	Mean HFI
City size		
100,000 – 200,000	8.2	0.01
200,000 – 500,000	8.3	0.02
500,000 – 1 million	8.2	0.04
Million plus	7.9	0.09
Civic status		
Census Town	5.5	0.01
City Municipal Council	8.1	0.02
Municipality	9.3	0.01
M. Council	8.3	0.02
M. Corp	8.0	0.1
Others	7.7	0.03

Note: Computed by authors using the Census of India data, 2001 and 2011.
Abbreviation: HFI: Health Facilities Index.

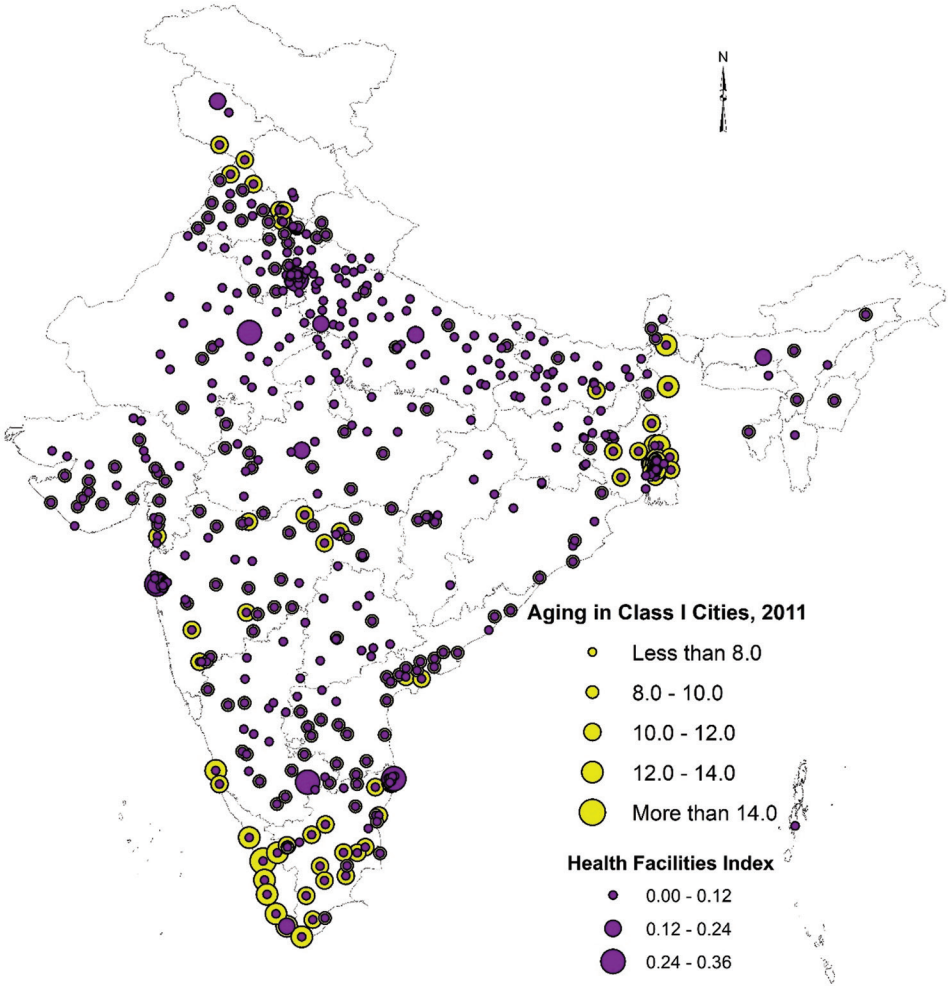

Figure 5. Share of older population and available health facilities in Class I cities in India, 2011

4. Discussion

This study aimed to investigate the relationship between population aging and the availability of health facilities in Indian cities. While much research has focused on aging populations at the state level, few studies have investigated the city-level situation. This study found that Indian cities house a significant share of the older population, with this share increasing rapidly in the last decade. However, there are substantial regional disparities in health facilities, with many cities struggling with inadequate healthcare infrastructure and personnel. As the proportion of older adults rises, the current healthcare infrastructure will prove to be inadequate to meet the mental and physical well-being needs of older adults (Jeste *et al*., 2016).

The study compared the distribution of the older population with the availability of health infrastructure, such as hospitals and medical staff, revealing notable regional disparities. Smaller cities tend to have poorer health facilities compared with larger cities despite having similar proportions of older adults. As India's demographic structure evolves, it is essential to plan and prepare for the future needs of its aging population (United Nations, 2020). The study underscores the need for policies and programs targeting the older population and for further research on the changing patterns of aging in urban areas. Urban planning should focus on creating age-friendly environments to meet the needs of the older population.

As the population continues to age, adequate planning for the health and well-being of older people becomes crucial (Gardener & Lemes de Oliveira, 2020; Noroozian, 2012). However, there are significant regional differences in the availability of health facilities across India. While urbanization is often associated with development, it is important to recognize that different urban areas are at varying stages of development. Previous research has

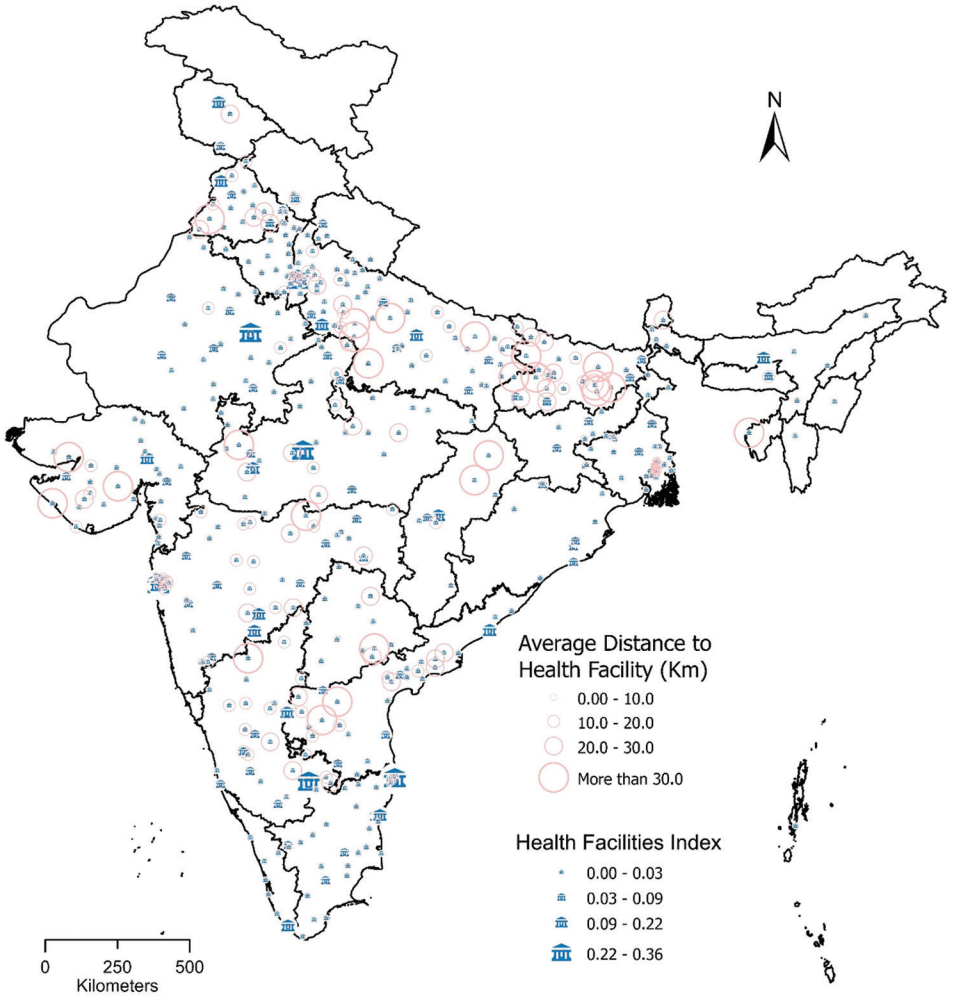

Figure 6. Existing health facilities and average distance to the health facilities among Class I cities in India, 2011 computed by authors using data from Census of India, 2011

highlighted the lack of healthcare facilities in rural areas, but this study emphasizes the need to investigate the extent of healthcare facilities in urban centers in India, specifically in cities.

This study examined the distribution of the older population alongside the availability of health infrastructure, including hospitals, hospital beds, and healthcare personnel, across various cities in India. The findings indicated that a significant number of Indian cities have inadequate health infrastructure and personnel (Ajitha *et al.*, 2022). Moreover, regional differences in the concentration of the older population were observed among Class I cities, with higher concentrations in the northern, southern, and eastern parts of India.

Larger cities generally have advanced health facilities, whereas smaller cities experience a lack of adequate facilities although they house similar proportions of older adults. Therefore, it is essential to improve health infrastructure in smaller cities as much as in larger ones. The study also highlighted significant variations in healthcare infrastructure, services, and travel distances to health facilities (Bhan *et al.*, 2017; Hoof *et al.*, 2018).

In addressing health inequities, alternative approaches must be considered. During the COVID-19 pandemic, telehealth practices expanded rapidly and were widely adopted across the globe, reshaping health-care delivery and presenting new opportunities for achieving health equity (Kobeissi & Hickey, 2023). In India, the healthcare system was on the verge of collapse during the pandemic, but telehealth, which allows for remote treatment, played a crucial role in maintaining access to healthcare (Rajkumar *et al.*, 2023).

With the increasing number of older individuals and the rising prevalence of chronic, lifestyle-related, and long-term diseases, there is a pressing need for telehealth

solutions to address the escalating healthcare demand in India. Telehealth has bridged the healthcare access gap in recent times, especially for those with chronic conditions (Bhatia, 2021), offering a possible solution for reducing healthcare inequalities. However, telehealth services alone cannot fully address healthcare service delivery. Telehealth is also most effective for initial consultations, triage, and follow-up care (Raj Westwood, 2021). An approach that combines telehealth and enhanced healthcare infrastructure is essential, particularly for older adults who prefer to stay at home while maintaining access to necessary healthcare resources (Markert *et al*., 2021).

Emphasizing the development of telehealth services, alongside meticulous planning for their effective implementation, can improve healthcare delivery. The integration of telehealth with enhanced infrastructure can contribute to the improvement of India's primary healthcare system in the future (Maroju *et al*., 2023).

While this study provides valuable insights into the adequacy of health facilities for India's aging population, it is not without limitations. The data analyzed herein are obtained from the 2011 Census of India as the new census is yet to be conducted; thus, the estimates may not fully reflect the current situation.

5. Conclusion

This study examines the distribution of the aging population and the inadequacies in healthcare infrastructure, including hospitals, hospital beds, and essential healthcare personnel, across a wide range of Indian cities. The findings underscore the critical shortage of basic health facilities, competent staff, and vital resources in numerous cities across the country.

The study finds notable regional disparities in the distribution of the older population among Class I cities. Larger urban centers benefit from well-equipped, advanced health facilities, but smaller cities, despite having similar proportions of older residents, face persisting inadequacies. This discrepancy requires immediate attention.

Given these significant findings, it is crucial to enhance the quality of healthcare services in smaller cities, ensuring that older adults in these cities have access to the same resources and capacities as those in larger cities. The absence of appropriate healthcare alternatives poses a major challenge to the entire Indian healthcare system. A broad approach is necessary to prepare for the demographic changes that will accompany the aging population. A comprehensive strategy should be formulated to support individuals in aging healthily.

Thus, prioritizing the development of healthcare infrastructure in smaller cities to match that in larger ones is essential. Telehealth also plays a vital role in addressing healthcare inequities and must be a focus. The inadequacies in health infrastructure remain a significant challenge in India, and preparedness for demographic shifts should be a top priority. Facilitating healthy aging is key to long-term success and may also boost economic development. By promoting healthy aging, we can unlock the potential for productive aging and capitalize on the economic benefits that come with it.

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Conflict of interest

The authors declare they have no competing interests.

Author contributions

Conceptualization: All authors
Formal analysis: A.H. Sruthi Anil Kumar, Nawaj Sarif
Methodology: All authors
Writing – original draft: All authors
Writing – review & editing: All authors

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The present study used the secondary data collected from the Census of India, 2011. The town directory data are freely available for use. The dataset can be downloaded from https://censusindia.gov.in.

Further disclosure

The paper has been deposited in a preprint server (doi: https://doi.org/10.1101/2024.03.15.24304353).

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Factors influencing direct payment exemption in the user fee elimination project in the Far North of Cameroon

Sali Aristide Dama[1], Alice Ketchaji[2], Dorcas Kamguem Keng[3], Laura Ladouce Yanguem[4], and Godfroy Rostant Pokam Djoko[4]*

[1]Department of Sociology, Anthropology, and Social Sciences for Development, Faculty of Arts, Letters and Humanities, University of Maroua, Maruoa, Cameroon

[2]Department for the Control of Diseases, Epidemics and Pandemics, Ministry of Public Health, Yaoundé, Cameroon

[3]Department of Public Health, School of Health Sciences of the Catholic University of Central Africa, Yaoundé, Cameroon

[4]Research Unit of Applied Biology and Ecology, Department of Animal Biology, Faculty of Science, University of Dschang, Dschang, Cameroon

Abstract

On January 1, 2020, the State of Cameroon instituted a policy to eliminate direct payments by people living with human immunodeficiency virus (PLHIV). However, limited data are available on the implementation of this policy. This study aims to identify the determinants of the improper implementation of this policy by healthcare providers. To this end, a cross-sectional study was conducted with 164 medical and paramedical staff involved in the care of PLHIV. Data were collected using a Google Forms questionnaire and administered in health facility forums. Determinants were assessed using multiple logistic regression analysis. The study found that the job profile of a doctor or pharmacist (odds ratio adjusted [AOR] = 9.64 [95% confidence interval (CI): 2.32 – 44.09]; $p = 0.002$), access to policy guidelines (AOR = 2.81 [95% CI: 1.02 – 7.86]; $p = 0.045$), perception of the policy's impact on quality of care (AOR = 4.26 [95% CI: 0.79 – 26.95]; $p = 0.034$), and the context of working in a system in which the policy is partially effective (AOR = 4.0 [95% CI: 1.53 – 11.08]; $p = 0.005$) significantly increased the chances of improper practices related to policy implementation. Awareness-raising and capacity-building strategies must be developed to policy implementation by healthcare providers in Cameroon. The policy of "user fees elimination" marks the first step toward universal health coverage, and this study also provides a basis for reflection to facilitate its optimal implementation.

Keywords: Policy; Free; User fees elimination; Human immunodeficiency virus/acquired immunodeficiency syndrome; Far North; Cameroon

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***Corresponding author:**
Godfroy Rostant Pokam Djoko
(godfroydjoko@gmail.com)

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1. Introduction

Living with human immunodeficiency virus (HIV) entails particularly high disease-related healthcare costs that can seriously affect individuals' health and well-being (Whiteside, 2002). Thus, people living with HIV (PLHIV) represent a particularly

vulnerable population. Access to free healthcare in the context of HIV denotes a success of the political, ethical, and medical fight against acquired immunodeficiency syndrome (AIDS) (Gilks *et al*., 2006; Souteyrand *et al*., 2008). However, PLHIV is sometimes required to make direct payments, especially in sub-Saharan African countries, for publicly provided healthcare services such as consultations, laboratory tests, and drugs to treat opportunistic infections (Boyer *et al*., 2009).

Many developing countries have introduced cost-recovery policies since the Bamako Initiative of 1987, charging patients new fees at points of delivery. Indeed, this initiative was recommended as a means of increasing healthcare financing and improving access to primary healthcare and public health services (Chabot, 1988). Notably, more than half of the total healthcare expenditures of households in most low- and middle-income countries are out-of-pocket payments. Nations in sub-Saharan Africa that bear the heaviest burden of the HIV/AIDS pandemic are included among these countries (Langenbrunner & Alexander, 2005).

However, the introduction of out-of-pocket payments positively affects healthcare utilization when it is accompanied by measures to ameliorate the supply of care and allow for greater provider autonomy. The decentralized management of direct payments at the provider level constructively influences staff motivation and results in better quality of care (Mathauer *et al*., 2017). Nevertheless, numerous studies show that the need for direct payment by patients reduces access to care and treatment for the poorest individuals (Mehdi, 2015) and decreases their compliance with treatment (Mills *et al*., 2006). In the context of HIV, late treatment or the lack of adherence to antiretroviral (ARV) treatment can deteriorate individuals' health and lead to an increased risk of virus transmission. Thus, the demand for direct payments from PLHIV for certain treatments represents a major public health issue that can exert deleterious effects on the health of the population.

Therefore, it is imperative to remove financial barriers if we desire to achieve, albeit much belatedly, the goal of "universal access to comprehensive prevention programs, treatment, care and support" for HIV/AIDS by 2010, as adopted by the 192 member states of the United Nations General Assembly (United Nations, 2006). Thus, many African countries have developed free healthcare policies aimed at increasing access to care and improving the overall health of their most vulnerable populations. Cameroon has also adopted the policy of exempting PLHIV from making out-of-pocket payments. This policy was instituted by the Ministry of Public Health on January 1, 2020, to ensure free healthcare to strengthen public access to HIV care services. An initiative labeled "user fees elimination" (UFE) has been effectively implemented nationwide with the support of numerous partners since January 2020 (Minister of Public Health, 2021).

The Far North region of Cameroon is characterized by high levels of poverty, poor infrastructure, and limited access to health services and presents unique challenges that can exacerbate the problems associated with the effective application of this policy (Minister of Public Health, 2020). Indeed, unlike other regions of Cameroon with more favorable socioeconomic conditions and infrastructure, the Far North confronts specific obstacles that complicate the exemption of user fees. Thus, analyzing the shortcomings in this region can highlight local particularities, help us adapt policies accordingly, and deliver valuable lessons to ameliorate implementation in similar contexts.

This study aims to determine the causes of faulty practices in the implementation of the policy of exemption from direct payments by providers influencing the care of PLHIV in the Far North region. The results of this study represent a part of a larger plan to raise awareness among healthcare providers in the Far North region vis-à-vis the importance of offering the service package under the free-of-charge policy. In addition, the UFE policy marks the first step toward universal health coverage; thus, we hope that this study will provide a basis for reflection on how best this initiative can be executed.

1.1. Theoretical framework

Analysis of the social relevance of selective free healthcare highlights the crucial importance of values, such as equity, solidarity, and access to health, in the evaluation of public policies. This analysis reveals how values are used to justify the behaviors of social actors and how they affect their perceptions of the stated policy. This study's examination of values to understand the reception of this public policy instrument illustrates how values can represent powerful indicators of the social representations of actors. This approach is based on the theory of ideational processes, which postulates that people's values and ideas exert a significant causal influence on public policy formulation processes (Béland, 2009). This theory posits that the social representations and personal beliefs of actors influence their policy choices and affect instituted reforms by shaping the way policies are perceived and implemented. The theoretical framework of this research aligns with this conception and is based on the analysis of social representations to examine how the beliefs and values of actors influence their interpretations of policies and reforms. Hence, this study offers an in-depth understanding of the impact of values on public policy.

2. Methodology

2.1. Setting and study period

The study was conducted between June 1 and August 31, 2022, in 22 health districts in the Far North region, one of the ten regions of Cameroon. It is located in the north of the country between latitudes 10° and 13° North and longitudes 14° and 16° East, and its population of 2,721,500 inhabitants are spread over an area of 34,246 km^2 (Minister of Public Health, 2020). The Far North region encompasses six divisions, 47 subdivisions, and 30 health districts. It also shares a long border with Chad and Nigeria. Its landscape is characterized by wooded savanna, grassy savanna, and steppe depending on the season.

2.2. Study design and population

This quantitative, cross-sectional, descriptive, and analytical study was conducted with a population of medical and paramedical staff members irrespective of gender and grade working in direct contact with patients for at least 6 months in a selected health facility.

2.3. Sample size and procedure

The minimum sample size was calculated using the Lorenz formula, assuming a precision of 5%, a 95% confidence interval (CI), and a value for the prevalence of the main indicator equal to 12.1% taken from the UFE 2021 regional supervision report. Thus, this study included 164 participants recruited through the non-probability convenience sampling technique. A total of 103 health facilities across 22 health districts were selected for analysis based on the number of patients on ARV treatment and the implementation of the UFE project. This selection procedure was adopted to limit potential selection bias and guarantee the representativeness of our sample.

2.4. Data collection techniques and tools

Data were collected through a survey administered to staff members employed at the selected health facilities. A Google Forms questionnaire was deployed in health facility forums. Control measures were put in place to guarantee data quality and avoid duplication. For instance, we configured Google Forms to limit multiple responses from the same participant by activating the option of only one response per email address and activated the data validation feature. Initially, we pretested the questionnaire on a dozen participants, after which we noted their completion times and assessed their comprehension of the questions. The collected data primarily concerned sociodemographic variables and queried staff knowledge and practices apropos the implementation of the UFE service package.

2.5. Operational definition of variables

The dependent variable of this study was set as the "practice of the direct payment exemption policy" and was evaluated on a scale of 0 – 10 based on participant responses to questions on staff practices related to the implementation of the UFE service package. Participants who were found to implement ≤5 of the 10 UFE service packages available in the health facilities were deemed to perform improper (bad) practice, and those who implemented between six and 10 service packages were considered to establish a beneficial (good) practice.

2.6. Data processing and analysis

Data collected through Google Forms were compiled and analyzed using the Rstudio analysis software version 4.2.4. We used Microsoft Office Word and Excel 2013 to prepare the tables. We calculated descriptive statistics for all variables considered in this study. We determined the associations between the dependent variable "practice of direct payment exemption policy" and the independent variables using binary logistic regression analysis, and all variables with a $p < 0.05$ in the bivariate analysis were deemed candidates for multivariate analysis. The discrete indicators were estimated through a significance level of alpha (α) = 0.05, and associations were considered significant at a $p < 0.05$. Notably, we used specific tests adapted to the nature of the data and verified the conditions of normality for the p test performed for the bivariate analysis. We examined the distribution of the data to ensure conformity with the hypotheses of the utilized statistical tests.

3. Results

3.1. Participant characteristics

Table 1 presents the distribution of the study participants by age, gender, level of education, type of health training, function, department, and length of time in the system. The table shows that the participants most represented the age group of 30 – 39 years (73.6%), with an average age of (35.90 ± 8.41) years. Men were slightly more numerous than women (58.5% vs. 41.5%). Most respondents had completed a secondary school education (53.7%), worked in a regional hospital (35.4%), were psychosocial assistants (59.1%), were attached to the HIV/AIDS unit (56.1%), and had worked in the facility for ≤3 years (47%).

3.2. The UFE direct payment exemption policy in practice

Table 2 shows the practices adopted by medical and paramedical staff in the Far North region with regard to the UFE policy. It shows that the majority of healthcare providers have put in place targeted measures for the management of HIV-positive pregnant women, people living with HIV

Table 1. Sociodemographic characteristics of participants

Variables	Terms and conditions	Absolute frequency	Relative frequency (%)
Age group (years)	20 – 29	33	20.1
	30 – 39	81	49.4
	40+	50	30.5
Gender	Female	68	41.5
	Male	96	58.5
Educational levels	Primary	1	1.8
	Secondary	88	53.7
	University	77	44.5
Health training	Integrated health center	55	33.5
	District medical center	7	4.3
	District hospital	44	26.8
	Regional hospital/Annex regional hospital	58	35.4
Function	Psychosocial assistant	97	59.1
	Nurse/caregiver	31	18.9
	Sanitary medical technician	20	12.2
	Doctor/pharmacist	16	9.8
Related department	Home/Care	11	6.7
	Administration	24	14.6
	Laboratory	4	2.4
	Medicine/pharmacy	33	20.1
	HIV care unit	92	56.1
Duration in the system	≤3 years	77	47
	4 – 6 years	46	28
	≥7 years	41	25

Abbreviation: HIV: Human immunodeficiency virus.

(PLHIV) and children. The most common practices include prenatal consultations for pregnant women, medical record management for PLHIV, and targeted screening tests for pregnant women, young children and adults. Complementary tests, such as blood counts (CBC) and urinalysis, are also frequently carried out to monitor the health status of HIV-positive pregnant women. In addition, a large number of providers offer free blood glucose, viral load and sputum cytobacteriology tests, to enhance patient care.

Figure 1 shows the nature of UFE policy practices adopted by medical and paramedical staff members in the Far North region. The figure clarifies that 31.1% of staff exhibited bad practices and 68.9% displayed good practices.

3.3. Sociodemographic determinants of bad practices

Table 3 presents the results of the bivariate analyses of the sociodemographic determinants of bad practices exhibited by medical and paramedical staff in the Far North region in relation to the direct payment exemption policy. This table illuminates that working in an integrated health center (odds ratio [OR] = 2.5 [95% CI: 0.53 – 17.45]; $p = 0.033$) or in a regional hospital (OR = 2.16 [95% CI: 0.02 – 7.85]; $p = 0.042$) as a doctor or pharmacist (OR = 6.60 [95% CI: 2.17 – 22.77]; $p = 0.001$) significantly increased the chances of exhibiting bad practices apropos the direct payment exemption policy of the UFE project.

3.4. Determinants of bad practices vis-à-vis the direct payment exemption policy based on staff knowledge

Table 4 shows the results of the determinants of bad practices related to the direct payment exemption policy according to staff knowledge. This table elucidates that the chances of exhibiting bad practices vis-à-vis the direct payment exemption policy of the UFE project increased significantly when participants had never heard of the exemption policy (OR = 3.17 [95% CI: 1.17

Table 2. Direct payment exemption policy practices under the user fees elimination project

Variables	Absolute frequency	Relative frequency (%)
Free prenatal consultation for pregnant women		
No	28	17.07
Yes	136	82.93
Free medical booklet for PLHIV		
No	31	18.90
Yes	133	81.10
Free targeted screening test for adolescents and adults		
No	9	5.49
Yes	155	94.51
Free CBC in HIV+pregnant women		
No	65	39.63
Yes	99	60.37
Free urine testing in HIV+pregnant women		
No	44	26.83
Yes	120	73.17
Free creatinemia in HIV+pregnant women		
No	77	46.95
Yes	87	53.05
Free blood glucose testing for HIV+pregnant women		
No	45	27.44
Yes	119	72.56
Offer free viral load		
No	18	10.98
Yes	146	89.02
Cytobacteriological examination of sputum free of charge for patients with signs of tuberculosis impregnation		
No	33	20.12
Yes	131	79.88

Abbreviations: CBC: Complete blood count; HIV: Human immunodeficiency virus; PLHIV: People living with human immunodeficiency virus.

– 8.85]; $p = 0.023$), did not possess guidelines or receive guidance on the policy (OR = 4.20 [95% CI: 2.11 – 8.62]; $p < 0.001$), worked in a health facility without a UFE focal point (OR = 3.74 [95% CI: 1.88 – 7.67]; $p < 0.001$), believed that the exemption policy did not improve the quality of care for PLHIV (OR = 6.85 [95% CI: 2.69 – 19.13]; $p < 0.001$), worked in a health facility that did not effectively implement the exemption policy (OR = 7.72 [95% CI: 2.92 – 21.51]; $p < 0.001$), worked in a health facility in which the implementation of the exemption policy was only partially effective (OR = 4.12 [95% CI: 1.86 – 9.50]; $p < 0.001$), or believed that the exemption policy did not improve the retention of patients in care at the health facility (OR = 4.51 [95% CI: 22.06 – 10.17]; $p < 0.001$).

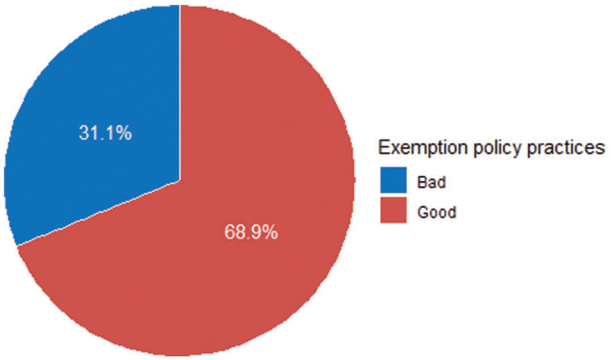

Figure 1. Direct payment exemption policy practices undertaken by medical and paramedical staff

3.5. Multivariate analysis of independent predictors of bad practices adopted by staff members vis-à-vis the direct payment exemption policy

Table 5 displays the results of the multivariate analyses performed on the previously significant variables to control for confounding factors and identify independent predictors of bad practices adopted by medical and paramedical staff in the Far North region apropos the direct payment exemption policy. The table illuminates that being a doctor or pharmacist (Odds ratio adjusted [AOR] = 9.64 [95% CI: 2.32 – 44.09]; $p = 0.002$), not possessing policy guidelines (AOR = 2.81 [95% CI: 1.02 – 7.86]; $p = 0.045$), believing that the exemption policy did not improve the quality of care for HIV patients (AOR = 4.26 [95% CI: 0.79 – 26.95]; $p = 0.034$) and working in a health facility in which the exemption policy was partially effectively implemented (AOR = 4.0 [95% CI: 1.53 – 11.08]; $p = 0.005$) significantly increased the chances of adopting bad practices vis-à-vis the direct payment exemption policy of the UFE project.

4. Discussion

The absence of equivalent studies in this area precludes comparisons of our results with specific previous findings. However, the results obtained from the available and collected primary field data in this study allow certain interpretations that are detailed in subsequent paragraphs.

Our investigation revealed that overall, 31.1% of the participating medical and paramedical staff members exhibited bad practices related to the direct payment exemption policy outlined under the UFE project. This result can be explained by the lack of training and awareness among medical and paramedical staff concerning the exemption procedures and eligibility criteria. In addition, the presence of financial incentives or other advantages

Table 3. Sociodemographic determinants of bad practices exhibited by medical and paramedical staff vis-à-vis the direct payment exemption policy: Bivariate analysis

Explanatory variables	Fee waiver policy practice		OR (95% CI)	*p*-value
	Bad	Good		
	(*n*=51)	(*n*=113)		
Age group (years)				
20 – 29	14 (27.45)	19 (16.81)	2.33 (0.90 – 6.11)	0.079
30 – 39	25 (49.02)	56 (49.56)	1.43 (0.65 – 3.29)	0.374
40+	12 (23.53)	38 (33.63)	1	
Gender				
Female	17 (33.33)	51 (45.13)	1	
Male	34 (66.67)	62 (54.87)	1.61 (0.81 – 3.27)	0.175
Educational levels				
Primary	1 (1.96)	2 (1.77)	1	
Secondary	17 (33.33)	71 (62.83)	0.47 (0.04 – 10.65)	0.557
University	33 (64.71)	40 (35.40)	1.69 (0.15 – 37.37)	0.673
Health training				
Integrated health center	15 (29.41)	40 (35.40)	2.5 (0.53 – 17.45)	0.033*
District medical center	5 (9.80)	2 (1.77)	1	
District hospital	14 (27.45)	30 (26.55)	0.19 (0.02 – 1.01)	0.067
Regional hospital/Annex regional hospital	17 (33.33)	41 (36.28)	2.16 (0.02 – 7.85)	0.042*
Functions				
Psychosocial assistant	24 (47.06)	73 (64.60)	1	
Nurse/caregiver	8 (15.69)	23 (20.35)	1.04 (0.39 – 2.57)	0.928
Sanitary medical technician	8 (15.69)	12 (10.62)	2 (0.70 – 5.43)	0.177
Doctor/Pharmacist	11 (21.57)	5 (4.42)	6.60 (2.17 – 22.77)	0.001**
Related departments				
Home/care	3 (5.88)	8 (7.08)	1	
Administration	9 (17.65)	15 (13.27)	1.60 (0.35 – 8.7)	0.556
Laboratory	3 (5.88)	1 (0.88)	8 (0.70 – 203.37)	0.120
Medicine/Pharmacy	14 (27.45)	19 (16.81)	1.96 (0.47 – 10.21)	0.376
HIV care unit	22 (43.14)	70 (61.95)	0.85 (0.22 – 4.13)	0.822
Duration in the structure				
≤3 years	27 (52.94)	50 (44.25)	1	
4 – 6 years	11 (21.57)	35 (30.97)	0.57 (0.24 – 1.27)	0.181
≥7 years	13 (25.49)	28 (24.78)	0.84 (0.36 – 1.87)	0.677

Abbreviations: CI: Confidence interval; HIV: Human immunodeficiency virus; OR: Odds ratio.

linked to the granting of exemptions could have created perverse incentives for staff members to irregularly grant exemptions. Indeed, shortcomings in control and monitoring mechanisms for program implementation, along with coordination and management difficulties at the institutional level, may have contributed to the scale of the detected malpractices. A comprehensive remedial approach is required to remedy this situation and ensure improved application of the rules of the UFE program. This holistic corrective methodology should incorporate staff training, reinforce supervision processes, and revise incentives.

Conversely, participants working as doctors or pharmacists were significantly associated with bad practices exhibited by medical and paramedical staff in relation to the UFE direct payment exemption policy. This result can be explained by the fact that these healthcare professionals generally occupy positions of responsibility

Table 4. Determinants of bad practices vis-à-vis the direct payment exemption policy according to staff knowledge: Bivariate analysis

Explanatory variables	Fee waiver policy practice		OR (95% CI)	*p*-value
	Bad	Good		
	(*n*=51)	(*n*=113)		
Heard about the UFE				
Yes	41 (80.39)	105 (92.92)	1	
No	10 (19.61)	8 (7.08)	3.17 (1.17 – 8.85)	0.023*
Information channel				
Training	36 (83.72)	95 (89.62)	1	
Posters/media	7 (16.28)	11 (10.38)	1.66 (0.57 – 4.56)	0.33
Knowledge of the definition of UFE HIV				
Yes	44 (86.27)	103 (91.15)	1	
No	7 (13.73)	10 (8.85)	1.62 (0.55 – 4.50)	0.356
Knowledge of free medical services				
Yes	48 (94.12)	112 (99.12)	1	
No	3 (5.88)	1 (0.88)	1.62 (0.86 – 142.19)	0.097
Possession of guidebooks on the UFE policy				
Yes	18 (35.29)	78 (69.03)	1	
No	33 (64.71)	35 (30.97)	4.20 (2.11 – 8.62)	<0.001***
Existence of a UFE focal point in the health facility				
Yes	17 (33.33)	73 (65.18)	1	
No	34 (66.67)	39 (34.82)	3.74 (1.88 – 7.67)	<0.001***
Opinion on the UFE policy				
Useful	46 (90.2)	113 (100)	1	
Useless	5 (9.8)	0 (0.0)	3e+07 (1.6e – 41-NA)	0.987
Improved quality of care for PLHIV after UFE project implementation				
Yes	35 (68.63)	105 (92.92)	1	
No	16 (31.37)	8 (6.93)	6.85 (2.69 – 19.13)	<0.001***
Implementation of the UFE project in the health facility				
Totally	12 (23.53)	68 (60.18)	1	
Partially	14 (47.06)	34 (30.09)	4.12 (1.86 – 9.50)	<0.001***
Not at all	15 (29.41)	11 (9.73)	7.72 (2.92 – 21.51)	<0.001***
Improved patient retention after UFE policy implementation in your health facility				
Yes	31 (60.78)	99 (87.61)	1	
No	20 (39.22)	14 (12.39)	4.51 (2.06 – 10.17)	<0.001***
Provision of free services for patients in the health facility				
Yes	48 (94.12)	112 (99.12)	1	
No	3 (5.88)	1 (0.88)	1.3 (0.72 – 2.11)	0.984

Abbreviations: CI: Confidence interval; HIV: Human immunodeficiency virus; OR: Odds ratio; UFE: User fees elimination.

and have greater decision-making power about granting exemptions. Thus, they are favorably positioned to abuse the system; notably, they can grant unjustified exemptions to certain patients. Moreover, their levels of training and medical expertise grant them considerable influence and credibility with other staff members. Thus, it becomes easier for them to legitimize non-compliant practices. Therefore, it is essential to target these key groups in raising awareness and escalating control measures to improve the honest application of the exemption policy.

Table 5. Independent predictors of bad practices adopted vis-à-vis the direct payment exemption policy: Multivariate analysis

Explanatory variables	Fee waiver policy practice	AOR (95% CI)	*p*-value
	Bad (*n*=51)		
Health training			
Integrated health center	15 (29.41)	0.23 (0.01 – 2.80)	0.248
District medical center	5 (9.80)	1	
District hospital	14 (27.45)	0.34 (0.02 – 4.34)	0.401
Regional hospital/annex regional hospital	17 (33.33)	0.54 (0.04 – 6.87)	0.626
Functions			
Psychosocial assistant	24 (47.06)	1	
Nurse/caregiver	8 (15.69)	1.39 (0.43 – 4.29)	0.565
Sanitary medical technician	8 (15.69)	3.22 (0.97 – 10.60)	0.051
Doctor/pharmacist	11 (21.57)	9.64 (2.32 – 44.09)	0.002**
Heard about the UFE policy			
Yes	41 (80.39)	1	
No	10 (19.61)	1.33 (0.33 – 5.31)	0.682
Possession of guidebooks on the UFE policy			
Yes	18 (35.29)	1	
No	33 (64.71)	2.81 (1.02 – 7.86)	0.045 *
Existence of a UFE focal point in the health facility			
Yes	17 (33.33)	1	
No	34 (66.67)	1.22 (0.43 – 3.34)	0.692
Improved quality of care for PLHIV after UFE project implementation			
Yes	35 (68.63)		
No	16 (31.37)	4.26 (0.79 – 26.95)	0.034*
Implementation of the UFE project in the health facility			
Totally	68 (60.18)	1	
Partially	34 (30.09)	4.0 (1.53 – 11.08)	0.005**
Not at all	11 (9.73)	1.47 (0.31 – 6.69)	0.610
Improved patient retention after UFE policy implementation in your health facility			
Yes	99 (87.61)	1	
No	14 (12.39)	1.42 (0.34 – 5.25)	0.605

Abbreviations: AOR: Adjusted odds ratio; CI: Confidence interval; UFE: User fees elimination.

Furthermore, the absence of access to policy guidelines significantly increased the chances of medical and paramedical staff adopting bad practices apropos the UFE direct payment exemption policy. This outcome aligns with the findings reported by Ridde *et al.* (2012) and can be explained primarily by the lack of clarity and understanding among medical and paramedical staff about eligibility procedures and criteria when the necessary reference tools are not available to them. Indeed, the absence of these guides deprives staff members of the essential information they require to correctly apply the exemption policy. The lack of due awareness encourages subjective, even arbitrary, interpretation of the rules and can result in non-compliant exemption decisions. Therefore, it is vital to ensure that concerned staff members are provided with clear guidelines and procedures to guarantee the rigorous and consistent application of the exemption policy.

The belief that the exemption policy does not improve the quality of care for PLHIV significantly increased the likelihood of bad practices adopted by medical and paramedical staff vis-à-vis the UFE direct payment exemption policy. This outcome may be explained by the fact that this negative perception of staff members could cause them to attach lesser importance to compliance with eligibility procedures and criteria and make them favor other subjective considerations. In addition, the lack of

confidence of certain professionals in the positive impact exerted by the policy on the quality of care could also engender a feeling of frustration or resistance in them and cause them to bypass established rules. Thus, the perception of the merits and usefulness of the exemption policy could function pivotally in staff motivation and commitment to ensure its rigorous application.

However, working in a health facility in which the exemption policy was only partially effectively implemented was found to significantly increase the chances of medical and paramedical staff exhibiting bad practices vis-à-vis the UFE direct payment exemption policy. This result can be explicated by the fact that in such settings, medical and paramedical staff members could be confronted with a lack of clear guidelines, monitoring, and control, leading them to grant exemptions based on personal interpretations and arbitrary decisions. In addition, the uneven implementation of the policy in a health facility can inculcate a sense of inequity and inconsistency among staff members, causing them to deviate from established procedures.

This study has certain important limitations. The cross-sectional methodology used in this study did not allow us to establish causal relationships between the studied variables and the bad implementation of the direct payment exemption policy. Data were collected through a digital questionnaire, which could have introduced biases linked to the selection of respondents and the quality of the answers obtained. In addition, the sample size of the study (164 medical and paramedical staff) was significant but modest, which could limit the generalizability of the results to all healthcare providers in Cameroon. Finally, the study did not intensively explore other factors that could influence policy implementation practices, such as operational constraints specific to individual healthcare facilities.

5. Conclusion

This study highlights several critical factors that negatively influence the implementation of the policy instituted in Cameroon to eliminate out-of-pocket payments for PLHIV. The results of this study reveal that the type of job (physician or pharmacist), access to policy guidelines, perceptions about the impact of the policy on the quality of care, and the context of working in a system in which the policy is partially effective are all significant determinants of bad practices adopted apropos the studied policy. Targeted strategies must be devised to improve the compliance of care providers with this crucial policy. Efforts should be made to create focused training programs for care providers, improve the communication and dissemination of policy guidelines, and establish regular monitoring and evaluation mechanisms to ensure the effective application of the policy. These measures should be proposed to the government as specific strategies designed to reinforce practices conducive to the success of the free healthcare policy and ensure its implementation to ultimately achieve universal health coverage.

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Conflict of interest

The authors declare they have no competing interests.

Author contributions

Conceptualization: All authors
Formal analysis: Godfroy Rostant Pokam Djoko
Investigation: Sali Aristide Dama
Methodology: Sali Aristide Dama, Godfroy Rostant Pokam Djoko
Writing – original draft: All authors
Writing – review & editing: All authors

Ethics approval and consent to participate

In the context of this study, ethics aimed to ensure the protection of those involved in the research, to ensure the independence of Ethics Committees, and to combat false research. We obtained research authorization from the Far North Regional Public Health Delegate [N°545/1/22/MISANTE/SG/DRSPEN]. Anonymity and confidentiality of information were safeguarded during data collection. The research protocol was approved by a sub-committee of teachers from the Faculty of Letters and Humanities of the University of Maroua.

Consent for publication

Not applicable.

Availability of data

All data used and/or analyzed for this study are available from the corresponding author on reasonable request.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Visualizing the association between climate change and quality of life

Dongli Zhang[1], Wullianallur Raghupathi[1]*, and Viju Raghupathi[2]

[1]Gabelli School of Business, Fordham University, New York, NY, United States of America

[2]Koppelman School of Business, Brooklyn College of the City University of New York, Brooklyn, NY, United States of America

Abstract

This research delves into the global impact of climate change on quality of life. Drawing on country-level data from the World Bank, we utilize visual analytics to examine the association between key climate change indicators such as carbon dioxide (CO_2) and methane emissions, PM2.5 (fine particulate matter) air pollution, annual freshwater withdrawal and quality-of-life variables such as child mortality, immunization against measles, school enrollment, gross domestic product (GDP) growth, unemployment, and others. Key findings suggest CO_2 emissions declined in South Asia and Sub-Saharan Africa. Overall, CO_2 emissions appear to be associated with GDP growth, implying that developed countries are responsible for the overall higher emissions as a result of industrialization. CO_2 emissions are also associated with higher unemployment, signaling that health issues are likely causing absenteeism and staying away from jobs. Finally, CO_2 emission is associated with higher air pollution and higher under-five mortality rates. Simultaneously, immunization rates appear to decline. Another significant finding is that higher air pollution is associated with higher child mortality, particularly in South Asia and Sub-Saharan regions. Generally, emissions and pollution have an adverse impact on quality of life indicators, affirming the urgent need to mitigate climate change. The results aim to foster an understanding of the multifaceted effects of climate change and to support the development of effective policies to bolster resilience and improve life quality in the face of environmental shifts.

Keywords: Air pollution; Climate change; Carbon dioxide emission; Freshwater withdrawal; Gross domestic product; Immunization; Mortality rate; Quality of life

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***Corresponding author:**
Wullianallur Raghupathi
(raghupathi@fordham.edu)

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1. Introduction

Global climate change poses a serious threat to the quality of life as it affects many aspects of human well-being (Dietz *et al.*, 2020; Estoque *et al.*, 2019; IPCC, 2023; Levy & Patz, 2015; Semenza *et al.*, 2011). This research examines country-level data to determine how climate variability correlates with quality of life variables. By leveraging data analytics, the goal is to gain a better understanding of how climate change impacts living standards. These insights are vital for policymakers and researchers in creating strategies to improve resiliency and quality of life amidst environmental changes (Adger *et al.*, 2022; Albouy *et al.*, 2016; Ding & Nunes, 2014; Fan *et al.*, 2018; IPCC, 2023). The investigation

focused on the effects of climate change indicators such as carbon dioxide (CO_2) and methane emissions, PM2.5 air pollution (Ganbat *et al.*, 2020; Huang *et al.*, 2021; Lin *et al.*, 2020; Shekhovtsov *et al.*, 2023), annual freshwater withdrawals (Potemkina *et al.*, 2018), and others on quality of life variables, including mortality rates, immunization against measles, school enrollment, gross domestic product (GDP) growth, and unemployment, among others (Apergis & Majeed, 2021; Ding *et al.*, 2014; Platagea *et al.*, 2019; Semenza, 2014; Testa & Simonson, 1996; Theofilou, 2013; van Daalen *et al.*, 2022).

The analysis of direct impacts helps identify vulnerable populations and critical areas requiring immediate attention. Beyond direct effects, climate change triggers a series of indirect consequences through environmental degradation (Kannan & James, 2009; Pecl *et al.*, 2017). These include, for example, increased greenhouse gas (GHG) emissions which affect public health and socioeconomic stability (Bell *et al.*, 2008; Doherty *et al.*, 2017; Evans, 2019; Gavurova *et al.*, 2021; Hassan *et al.*, 2016; IPCC, 2023; Kinney, 2008; Orru *et al.*, 2017; Spickett *et al.*, 2011). Understanding these chain reactions is essential for developing holistic and sustained climate resilience strategies (Stern, 2006; 2007). The concept of quality of life encompasses many aspects of human experience, including economic, physical, and social well-being (Barcaccia, 2013a; Barcaccia *et al.*, 2013b; Gerson, 1976; Kerce, 1992; Nussbaum & Sen, 1993; Owczarek, 2010; Schipper *et al.*, 1996).

Climate change has a profound impact on, for example, climate policies that aim to reduce CO_2 emissions, possibly influencing access to electricity due to the use of fossil fuels in the generation of electricity (IPCC, 2023). Climate change can also compound the difficulty to get adequate immunization because of the spread of diseases (Semenza, 2014; Balbus& Malina, 2009; Beniston, 2002; Haines & Patz, 2004; Kovats *et al.*, 1999; Martens *et al.*, 1997; McMichael, 2009; Wong, 2024). Climate-related food- and water-borne disease risks could increase mortality rates, especially for children under five (Green *et al.*, 2011; Taylor *et al.*, 2013). The number of students enrolled in school may be affected if families prioritize short-term survival over educational opportunities (Anderson, 2010). Climate change could also have a significant impact on food production (IPCC, 2023). The current study provides critical insights into how climate change affects quality of life variables across different countries and regions. By studying various socioeconomic factors such as health, education, and economic stab, researchers can gain an understanding of the broader economic and social impacts (Alborz, 2017; Newman & Noy, 2023; Thomas *et al.*, 2014; Tol, 2009). A key assumption is that climate change indeed has an adverse effect on quality of life. Therefore, our research question is:

> *What are some of the key influencers/drivers in the relationship between climate change and quality of life, at a country level?*

The insights gained from this research can be used to shape strategies by governments and non-governmental organizations to increase resilience against climate impacts toward quality of life. This research contributes significantly to academic discourse and practical discussion on sustainable development. It offers new perspectives for adapting to climate change and fighting it. Understanding the interdependencies between climate change and quality of life is pivotal for crafting resilient economic, education, environmental, and public health policies while simultaneously reducing climate change (Frumkin *et al.*, 2008; Lorenzoni & Pidgeon, 2006; Rocque *et al.*, 2021). Unpacking the association between climate change and quality of life data informs sustainable economic growth models and global climate agreements (Creutzig *et al.*, 2018; Karl *et al.*, 2009; Kravchenko, 2007). Identifying which quality of life variables are most sensitive to climate change helps prioritize resource allocation and international aid (Adger *et al.*, 2022; Erickson, 2017; McMichael, 2009). To date, there are very few empirical studies to examine the association between climate change and quality of life. This exploratory study employs visualization to offer an initial analysis into the topic.

The rest of the paper is organized as follows: Section 2 offers a background discussion for the study. Section 3 discusses the methodology, followed by Section 4 which covers the analysis of the results. Section 5 offers a comprehensive discussion. Section 6 offers the scope and limitations. Section 7 provides conclusions with directions for future research. Finally, section 8 provides implications and recommendations.

2. Climate change and quality of life

Climate change refers to long-term alterations in temperature and weather patterns. While these changes can occur naturally, such as through variations in solar activity or significant volcanic eruptions, human activities have been the dominant cause since the 1800s. This is largely due to the burning of fossil fuels, including coal, oil, and gas (Evans, 2019; IPCC, 2023; Levy & Patz, 2015; United Nations, 2023). Burning fossil fuels releases GHGs that function, such as a blanket around the Earth, trapping heat from the sun, and causing temperatures to rise. The primary GHGs driving climate change are CO_2 and methane (Abbas *et al.*, 2023; Ding & Nunes, 2014;

Erickson & Brase, 2020; Sergeant *et al.*, 2024; Semenza *et al.*, 2011). These emissions result from activities, such as using gasoline to power vehicles or burning coal to heat buildings, clearing land, and deforestation (Karl *et al.*, 2009; Martens *et al.*, 1997; Stern, 2006). The primary sectors responsible for emissions of GHGs include energy, industry, transportation, buildings, agriculture, and land use (Dietz *et al.*, 2020; Fan *et al.*, 2018; Feliciano *et al.*, 2022; IPCC, 2023; Lindroos *et al.*, 2023; United Nations, 2023).

The indirect impacts of climate change extend to an individual's quality of life along the lines of economic stability and social, physical, and mental well-being. Quality of life is defined by the World Health Organization (WHO) as an individual's perception of their position in life, taking into account the cultural and value systems that one is embedded in, as well as the goals, standards, expectations, and concerns (Kelly *et al.*, 2021; World Health Organization, 2012). The concept of quality of life addresses overall well-being, inclusive of positive and negative aspects at a point in time (Aqtam *et al.*, 2023; Byravan *et al.*, 2017; Haas, 1999; Hörnquist, 1982; Luktionov, 2020). Indicators to study quality of life include those that are relevant to material living conditions (such as food, clothing, and shelter) as well as to quality of life (such as environment, education, community, health, governance, life satisfaction, safety, and work-life balance) (OECD, 2011; WHO Quality of Life Group, 1996; WHO, 2012). Traditionally, quality of life was assessed using GDP. However, in recent years, this view has been considered myopic, as it does not cover aspects of a person's current and future living conditions (Brock, 1993; IOM, 1990; Ngan & Khoi, 2020; Ventegodt *et al.*, 2003). While GDP and economic growth remain key for well-being, the goals and aspirations of people are equally important in considering the overall quality of life for a sustainable society (Abbass *et al.*, 2022; Azevedo *et al.*, 2020; Hall *et al.*, 2010; Greco *et al.*, 2020; Kaplan *et al.*,2007; OECD, 2011).

Climate change has a detrimental socioeconomic impact on the quality of life of the population (Fan *et al.*, 2018; Gerson, 1976; Levy & Patz, 2015; Newman & Noy, 2023). Environmental effects such as rising sea levels and saltwater intrusion have forced communities to relocate, while droughts have exposed people to famine. Extreme weather conditions have exacerbated the incidence of food scarcity, droughts, and displacement worldwide (Ebi *et al.*, 2021; Pecl*et al.*, 2017; Tol, 2009; Kravchenko, 2007). The number of people facing acute food scarcity worldwide has increased from 149 million before 2019 (pre-COVID-19), to 333 million in 2023 (post-COVID-19), in countries monitored by the World Food Program. Between 2010 and 2020, the death toll from climate change events was 15 times higher in highly vulnerable regions (Levy & Patz, 2015). Increased exposure to the risks posed by climate change is impeding any progress made in terms of achieving universal sustainable development goals (SDGs) (Albouy *et al.*, 2016; World Meteorological Organization, 2024). The negative impacts of climate change on health range from heat-related or vector-borne diseases to water-borne infections, allergies, malnutrition, respiratory issues, and mental health challenges (Cianconi *et al.*, 2020; Charlson *et al.*, 2021), compared to regions with very low vulnerability (Estoque *et al.*, 2019; Frumkin *et al.*, 2008; Haines & Patz, 2004; IPCC, 2023; Levy & Patz, 2015; McMichael, 2009; Thomas *et al.*, 2014). These environmental and health impacts threaten a wide array of civil, political, economic, social, and cultural rights, including the rights to life, water, food, shelter, health, security, and cultural preservation (Evans, 2019; Kravchenko, 2007).

At the national and regional levels, the groups most vulnerable to the environmental and health impacts of climate change include poor and minority communities, women, children, people with chronic illnesses and disabilities, and those living in regions that are prone to extreme weather and climate (Doherty *et al.*, 2017; Pecl *et al.*, 2017; Thomas *et al.*, 2014; Tol *et al.*, 2009; van Daalen *et al.*, 2022). At the global level also, there is a significant disparity in the effects of climate change on the quality of life. Despite being the lowest contributors to climate change, low-income countries suffer the most impact, while high-income countries which are the highest contributors suffer less severe consequences (Martens *et al.*, 1997). This is because of the inequality in the capacity to adapt to the challenges posed by climate change (Levy & Patz, 2015). As an example, the per-capita GHG emissions in 2004 in developed nations, such as the United States, Canada, and Australia approached 6 metric tons, and those in Japan and Western European countries ranged from 2 to 5 metric tons. In contrast, the overall annual per-capita GHG emissions in developing countries are approximately 0.6 metric tons, and more than 50 developing countries have total annual per-capita GHG emissions of less than 0.2 metric tons (Levy & Patz, 2015).

As global temperature increases, rich countries' economies continue to prosper, but the economic growth of poor countries is seriously impaired more than previously estimated (Stern, 2006; 2007). The consequences for economic growth in poor countries will be substantial if we continue a "business-as-usual" path of increasing CO_2 concentrations and rapid climate change, with poor countries' mean annual growth rate decreasing from 3.2% to 2.6% (Gerson, 1976). Poor countries are likely to suffer a greater negative effect than rich countries from

climate change since they more often experience high temperatures (Levy & Patz, 2015; Newman & Noy, 2023). In addition, their economic growth depends very much on agriculture, natural resource extraction, and other sectors exposed to extreme weather fluctuations. Furthermore, air conditioning, insurance, and other risk-management alternatives are less available in poor countries than in rich countries (Levy & Patz, 2015). Considering the major adverse effects of climate change on various dimensions of quality of life, this study undertakes to shed light on the association between the two and identify the significant variables and linkages. The following section discusses our research methodology.

3. Methods

3.1. Research question and key propositions

The key research question in the current study is to identify key influencers/drivers in the relationship between climate change and quality of life, at a national level.

We address the research question by examining the following propositions in this descriptive-analytic study.

- *Proposition 1: Higher CO_2 emissions are associated with slower GDP growth.*
  CO_2 emissions are a primary GHG source contributing to climate change, which can affect economic dynamics through disruptions in agriculture, health, and disaster-related damages, potentially slowing GDP growth.
- *Proposition 2: Increased air pollution negatively impacts child health.*
  PM2.5, fine particulate matter, is known to be detrimental to health, particularly in children under five. Exposure to high levels of air pollution can lead to severe health issues, increasing mortality rates in this vulnerable group.
- *Proposition 3: Methane emissions correlate with higher under-five mortality rates due to environmental impacts.*
  Methane is a potent GHG that contributes significantly to global warming. Its increase can exacerbate climate change effects such as heatwaves and poor air quality, leading to higher mortality rates among children due to increased susceptibility to respiratory and heat-related illnesses.
- *Proposition 4: Air pollution decreases life expectancy, impacting GDP growth.*
  Chronic exposure to high levels of air pollution can lead to a decrease in life expectancy, affecting the overall health of the workforce. Poor health due to pollution can reduce productivity and, subsequently, GDP growth.
- *Proposition 5: Increased CO_2 emissions correlate with higher unemployment due to economic shifts.*
  As industries adjust to stricter emissions regulations and shifts toward greener alternatives, regions dependent on high-emission industries may experience higher unemployment rates. This transition, while beneficial for the environment, can cause significant economic restructuring and job displacement in the short term.

3.2. Data and variables

The indicators for climate change and quality of life are shown in Tables 1 and 2. The data were retrieved from the World Development Indicators database (https://databank.worldbank.org/) of the World Bank, for countries whose data were available for the period 2010 – 2019. The data were pre-processed to remove missing values. Climate-related variables such as CO_2 emissions and PM2.5 air pollution offer insights into climate change while quality of life indicators, including mortality rates and GDP growth, reflect the societal impacts of climate change (Bennett *et al.*, 2019; Chavez-Baeza & Sheinbaum-Pardo, 2014; Guo *et al.*, 2020; Ścibor *et al.*, 2019). The breadth of data enables robust visualization using the method of visual analytics. Comprehensive data validation and normalization were performed to ensure data integrity. A complete dataset was available for analysis and interpretation.

The selected independent variables offer insights into the multifaceted ways climate change can affect the national quality of life indicators. These variables capture different dimensions of environmental impact, from air and water quality to GHG emissions, which have direct and indirect effects on human and ecological health. Understanding the nuances of these environmental indicators is essential for analyzing their potential impact on a country's economic performance, public health, and social welfare outcomes.

The dependent variables stated in Table 2 are essential for understanding the broader impacts of climate change on societal welfare and economic conditions. They encapsulate key aspects of quality of life, including health, education, employment, and economic productivity. Assessing these variables can illuminate the extent to which climate change affects daily life and can effectively inform policies that are aimed at mitigating its adverse effects. The chosen dependent variables are directly linked to societal markers of prosperity and resilience in the face of climate change.

3.3. Platforms/Tools

Python programming language (Python Software Foundation) was deployed in pre-processing the data to clean out missing variables and refine the data set. Next,

Table 1. Independent variables (climate change)

Variable	Definition	Scale	Type	Example	Control
Methane emissions (kt of CO_2 equivalent)	Total weight of methane gas emission measured in kt of CO_2 equivalent	Ratio	Numerical	16222	No
PM2.5 air pollution, mean exposure (micrograms per cubic meter)	Average concentration of particulate matter smaller than 2.5 microns in the air	Ratio	Numerical	52	No
CO_2 emissions (metric tons per capita)	Average emissions of CO_2 per person measured in metric tons	Ratio	Numerical	0.6	No
Annual water withdrawals (% of internal resources)	Percentage of country's available water resources used per year	Ratio	Numerical	1%	No
Country name	The name of a sovereign state or territory	Nominal	Categorical	Bolivia	No
Year	Calendar year for which the data applies	Interval	Categorical	2015	No
Inflation, consumer prices (annual %)	Annual percentage change in the cost of goods and services	Interval	Numerical	3.2%	Yes
Population total	Total number of people living in a specific area such as a country	Ratio	Numerical	1246847	Yes
Access to electricity (% of population)	Proportion of the population with access to electricity	Ratio	Numerical	95%	No

Table 2. Dependent variables (quality of life)

Variable	Definition	Scale	Type	Example (%)
School enrollment secondary (% net)	Percent of children enrolled in secondary education	Interval	Numerical	77
Unemployment, total (% of total labor force)	Proportion of the labor force that is jobless but seeking employment	Interval	Numerical	4.4
GDP growth (annual %)	Yearly percentage increase in national economic output	Interval	Numerical	1.8
Mortality rate, under i (per 1,000 live births)	Annual deaths of children under five per 1000 live births	Interval	Numerical	4
Access to electricity (% of population)	Proportion of the population with access to electricity	Ratio	Numerical	95
Immunization, measles (% of children aged 12 – 23 months)	Proportion of children between 12 and 23 months who received the measles vaccine	Ratio	Numerical	88
Food production index (2014 – 2016=100)	Measuring food production relative to the base period 2014 – 2016	Interval	Numerical	110

Abbreviation: GDP: Gross domestic product.

Excel (Microsoft Corporation, United States of America) was utilized for reviewing and organizing the refined dataset, reducing the number of variables to a relevant and manageable number. On this dataset, Tableau (Salesforce Inc., United States of America), a visualization tool, was utilized primarily to develop a series of interactive charts, applying the method of visual analytics to illustrate the relationships between multiple variables.

3.4. Visual analytics

The current study is empirical and data-driven and utilizes descriptive analytics as the visualization approach (Börner *et al.*, 2019; Sun *et al.*, 2013) to obtain insight into climate change and quality of life. As an analytic approach, visualization facilitates the analysis of large data sets in real-time (Keim, 2001; Keim *et al.*, 2008; Kohlhammer *et al.*, 2011; Raghupathi & Raghupathi, 2020; Thomas & Cook, 2005; Wong & Thomas, 2004), enabling identification of new patterns and insights (Kohlhammer *et al.*, 2011; Thomas & Cook, 2005, Tufte & Graves-Morris, 1983; Tukey, 1977). This approach is extremely useful in comprehending a phenomenon in-depth (Keim, 2001; Keim *et al.*, 2008; Kohlhammer *et al.*, 2011; Raghupathi & Raghupathi, 2020; Thomas & Cook, 2005). Visualization provides a solution for the issue of information overload by transforming and presenting key highlights that can be used for insightful decisions (Keim, 2001; Thomas & Cook, 2005; Wong & Thomas, 2004). Descriptive analytics is a data-driven approach that analyzes data as-is with no pre-conceived notions (Kohlhammer *et al.*, 2011; Thomas & Cook, 2005). Information is presented using visual graphs and charts, adopting the techniques of categorization, characterization, and aggregation (Raghupathi *et al.*, 2023). The following section discusses the results of the analyses.

4. Results and analysis

The series of charts below collectively provide a descriptive story of the association between climate change and quality of life.

Figure 1 displays the relationship between CO_2 emissions and GDP growth across various regions. The regions of South Asia and Sub-Saharan Africa display a slight decrease in CO_2 intensity with varying GDP growth rates. While in some regions, there is a clear positive relationship between the two; in others it is not so apparent, revealing the complexity of the interplay between climate change and GDP growth.

Figure 2 illustrates a stacked bar chart of the relationship between air pollution levels and child mortality rates across various global regions for the period of study. The intensity of the color denotes the extent of air pollution. The darker the blue, the higher the air pollution. The size of the bar denotes the extent of mortality. The larger the size, the higher the mortality rate. Regions with higher levels of air pollution tended to have higher child mortality rates, which is most evident in Sub-Saharan Africa and South Asia. In contrast, North America showed the lowest air pollution and child mortality rates among the regions presented. The chart underscores the significant regional disparities in both air pollution and child mortality, highlighting the need for targeted environmental policies that will have an impact on mitigating mortality.

Figure 3 displays bar and line charts showcasing the relationship between annual freshwater withdrawals (% of total internal resources) and the food production index. The line represents freshwater withdrawals, while the bars indicate food production index values for each year. Freshwater withdrawals indicate the total water withdrawals as a percentage of the country's total internal resources. The food production index measures the changes each year in the production of edible foods that contain nutrients, relative to the base year 2014 – 2016. Freshwater withdrawal can be for different purposes, one of them being the production of food in agriculture. The demand for freshwater increases worldwide due to factors, such as population growth, economic development, and climate change. The chart shows an increasing trend of freshwater withdrawals up until 2017, followed by a decrease, while the food production index shows an increasing trend, and then a downward spike in 2018. Overall, data generally displayed fluctuating but stable food production rates until a sudden drop in 2018. The steady increase in freshwater withdrawals and the increase in the food production index show the influence on efficient water management in sustainable food production until it reaches a point that upsets the balance between freshwater withdrawals and food production, thus showing the abrupt decrease in food production in 2018.

Figure 4 shows a bar and line chart of access to electricity and average annual GDP growth as a percentage of the population. Despite fluctuations in GDP growth over the years, access to electricity remained consistently

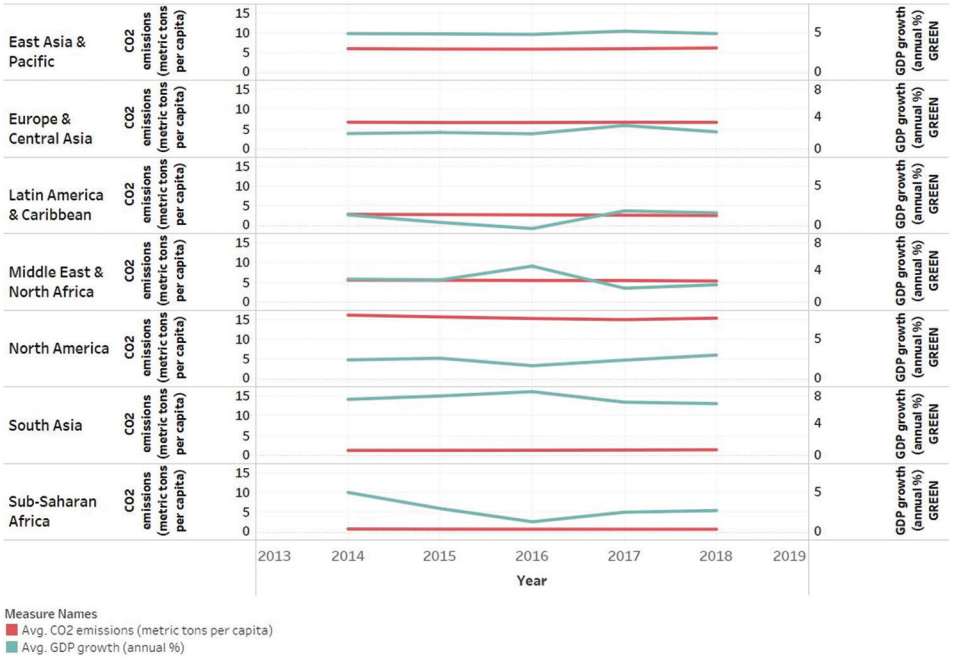

Figure 1. Parallel line graphs of regional analysis of CO_2 emissions and GDP growth
Abbreviation: GDP: Gross domestic product.

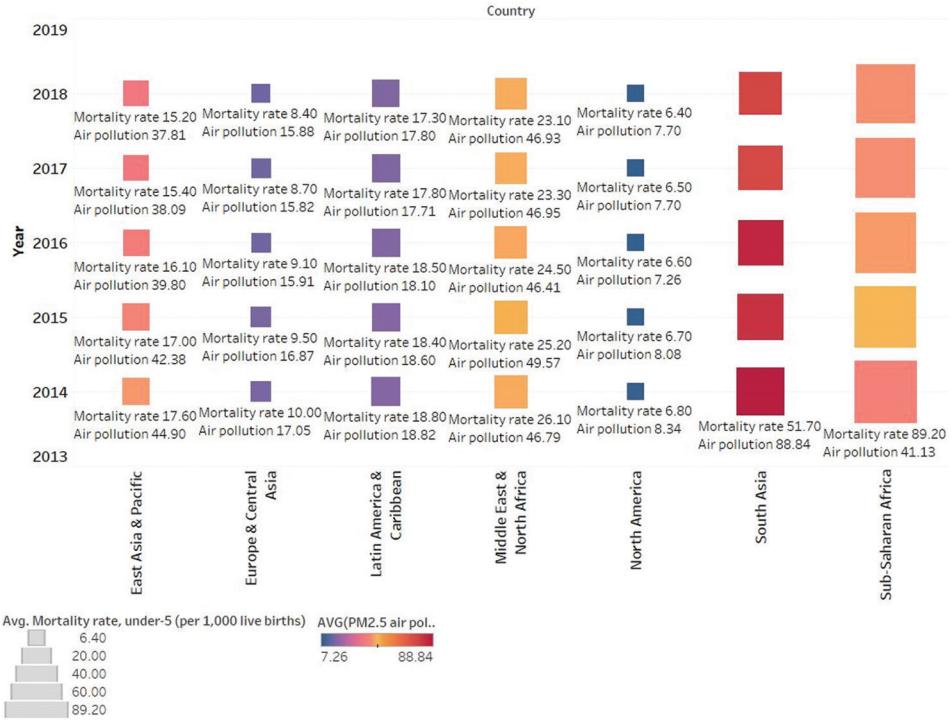

Figure 2. Stacked bar chart of PM2.5 air pollution and child mortality rates by region

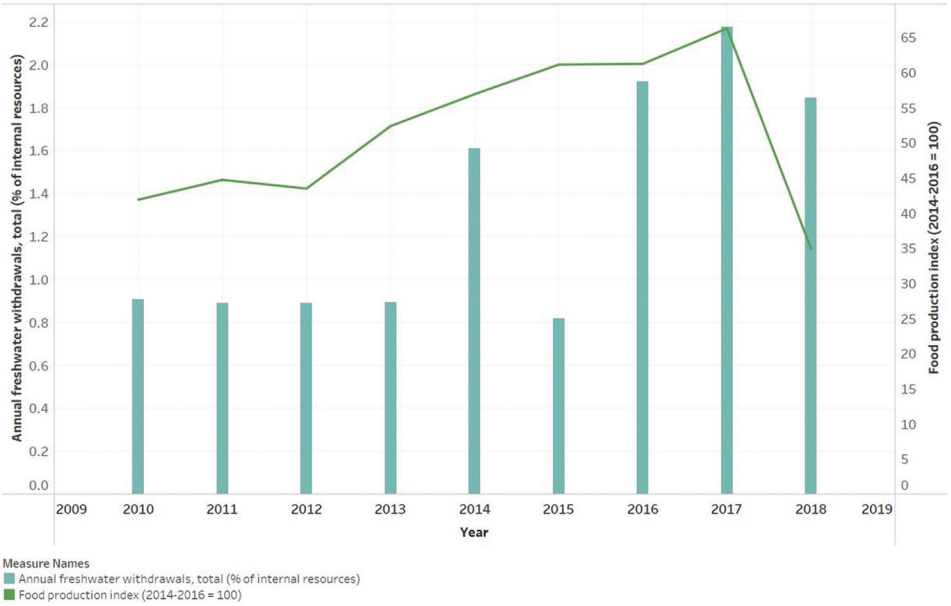

Figure 3. Bar and line charts of annual freshwater withdrawals as a percentage of total internal resources and food production index

high; suggesting that electricity access alone may not directly influence short-term economic growth rates. Except in North America and Europe where access to electricity has been relatively consistent, all regions show increasing access to electricity. The stable high access to electricity with varying GDP growth highlights the need for comprehensive economic strategies that leverage infrastructure to foster sustainable economic development.

Figure 5 above analyzes methane emissions and unemployment rates across global regions comparatively. The bars represent methane emissions in metric tons, while the line depicts unemployment rates. Each bar in the chart represents a region. East Asia & Pacific stands out with very high methane emissions yet maintain a remarkably

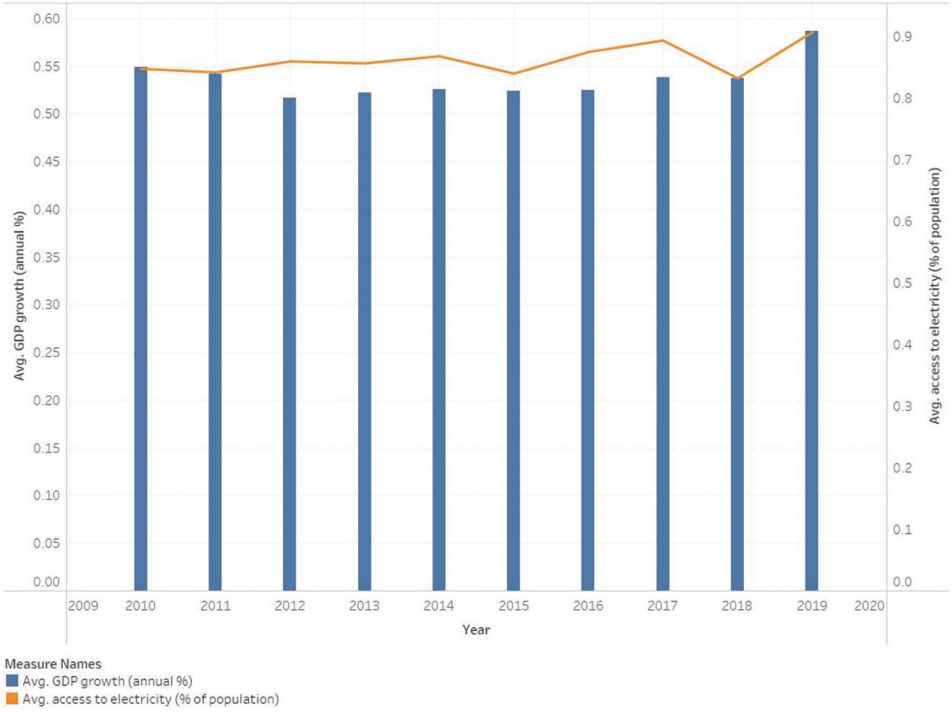

Figure 4. Bar and line chart of access to electricity (% of population) and GDP growth (annual %)
Abbreviation: GDP: Gross domestic product.

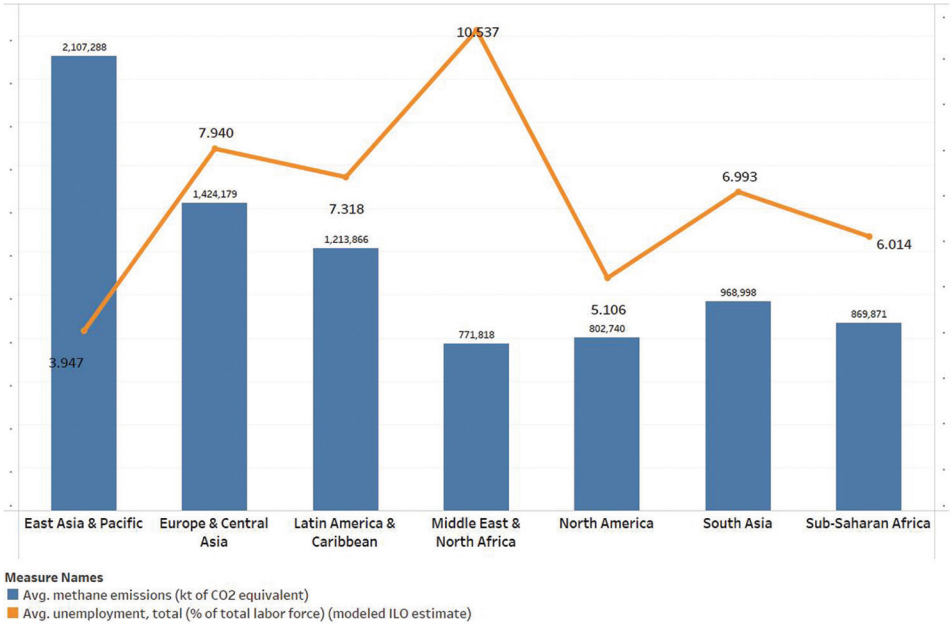

Figure 5. Bar and line chart of methane emissions and unemployment rates across different regions
Abbreviation: ILO: International Labour Organization.

low unemployment rate (3.947%), suggesting a strong and diverse economy that keeps unemployment low despite significant emissions. Middle East & North Africa presents a contrasting scenario. Although methane emissions are the lowest among the regions, unemployment is the highest (10.537%). This discrepancy highlights economic over-reliance on specific sectors and the lack of diversification. In summary, contrary to the expectation that unemployment rates increase with methane emissions, there appears to be no direct correlation between methane emissions and unemployment rates; regions with higher emissions do not consistently have higher unemployment rates. However, there is potential for national policies that should target unemployment along with sustainability goals.

Figure 6 displays a dual-axis line graph illustrating the trends of CO_2 emissions (metric tons per capita) in the blue line, alongside secondary school enrollment percentages (net) in the purple line. Both CO_2 emissions and secondary school enrollment show an upward trend over the years, with an increase in both metrics starting around 2014, suggesting that there was a rise in environmental impact and educational attainment. The parallel rise in CO_2 emissions and school enrollment could imply that regions experiencing economic growth and industrialization – which often lead to higher emissions – are also investing in or benefiting from enhanced educational opportunities. This may highlight the complexity of balancing environmental and developmental goals.

Figure 7 depicts an area chart showing the relationship between inflation, consumer price (annual %) and the food production index, by visualizing the overlap and trends of both variables over the years. Inflation, the consumer price (annual %), is the % of change in the price of a basket of goods and services consumed by households. It is referred to as the consumer price index and is a well-known indicator of inflation. The food production index measures the changes each year in the production of edible food, relative to the base year 2014 – 2016. While the consumer price index relates to food consumption, the food production index relates to food production. Based on the figure, in 2011, where there is a spike in the inflation of consumer prices, there is a decrease in the food production index, which can be due to the result of the pressure from inflation. A drop in inflation leading to a decline in food production indicates that lower inflation is associated with reduced economic activity, which can be construed as adverse impacts on agricultural investments and outputs. Thus, policymakers need to consider how inflation can impact sectors, such as agriculture, particularly with the growing demand brought about by population growth and economic development.

Figure 8 shows a scatterplot of the relationship between average secondary school enrollment rates and access to electricity (% of population). The chart shows that there is a positive association between the two measures and the association is significant (p <0.01). As access to electricity increases, the average secondary school enrollment rate also significantly increases, in all the regions. The strong correlation between increased access to electricity and higher school enrollment rates

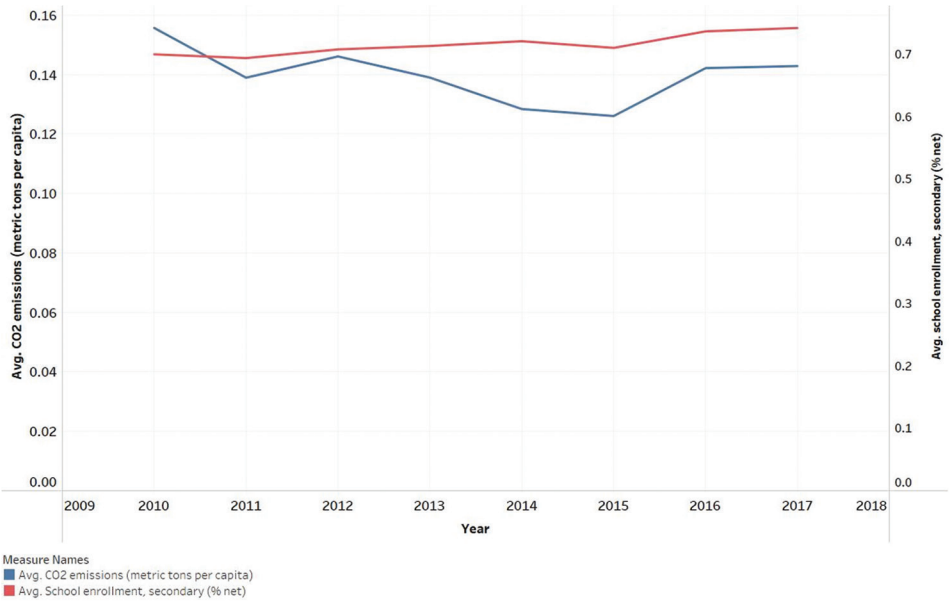

Figure 6. Dual-axis line graph of CO_2 emissions (metric tons per capita) and secondary school enrollment (% net)

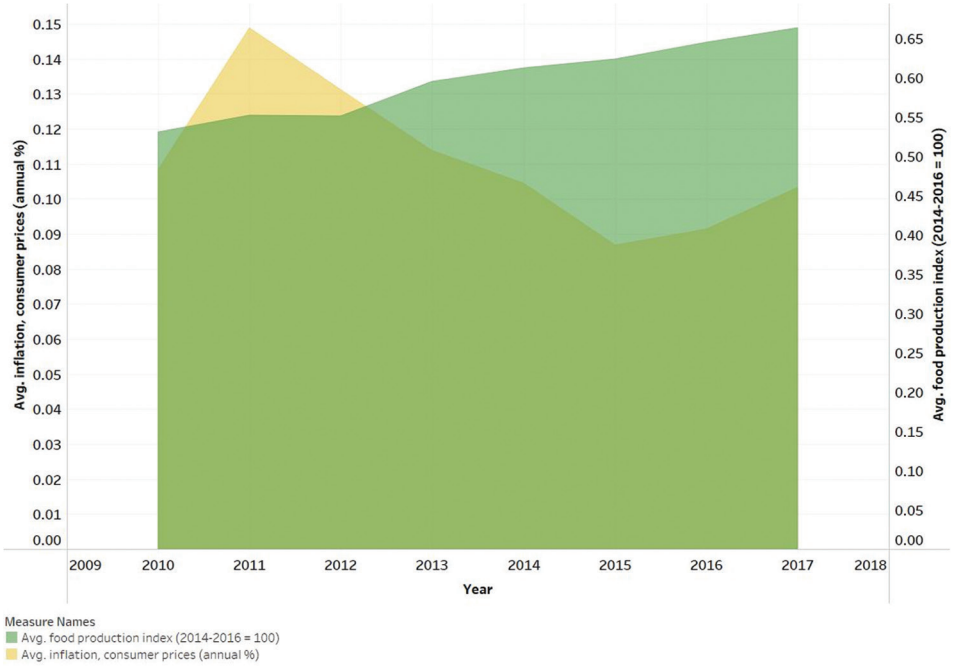

Figure 7. Area chart of inflation, consumer price (annual %), and the food production index

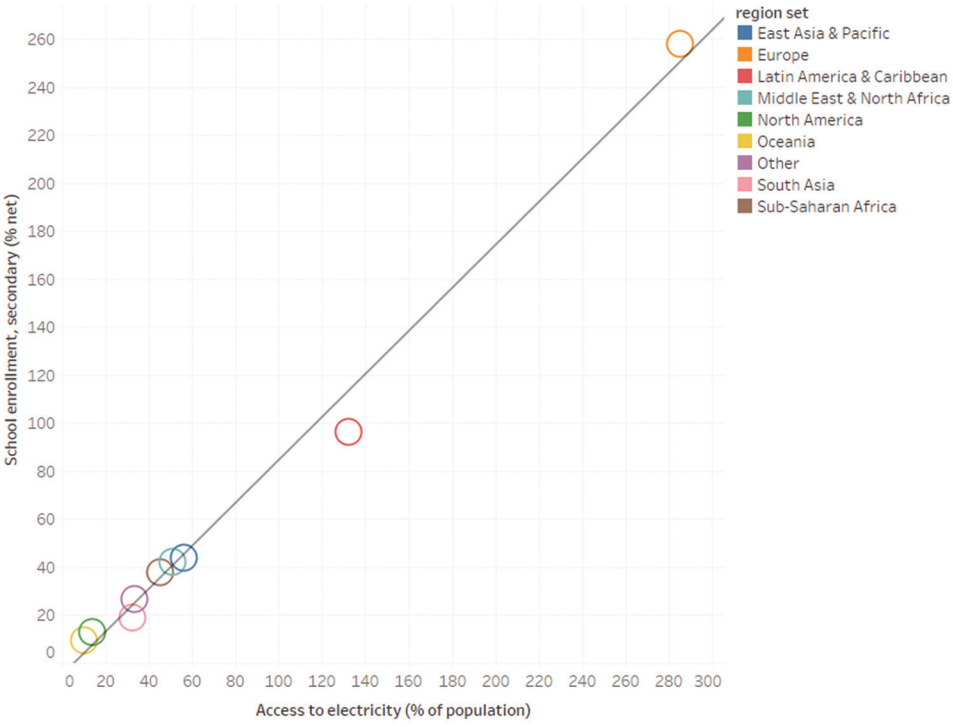

Figure 8. Scatter plot of access to electricity (% of population) and average secondary school enrollment (% net)

suggests that improving infrastructure and utilities could be a significant lever in enhancing educational development goals.

Figure 9 is a dual line chart that shows the trends of methane emissions (kt of CO2 equivalent) and immunization rates for measles (% of children aged 12 –

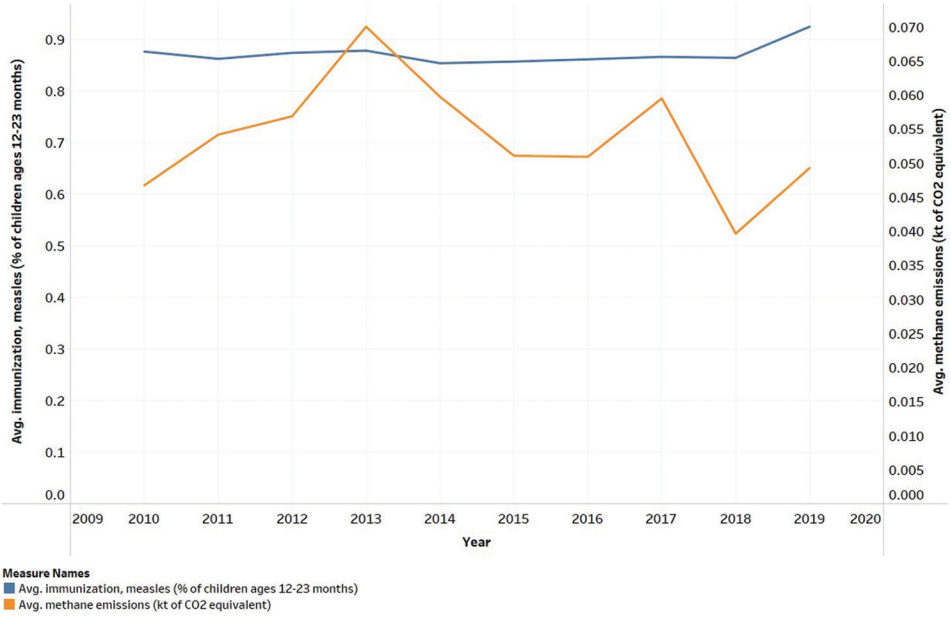

Figure 9. Dual-line chart of methane emissions (kt of CO_2 equivalent) and measles immunization rates (% of children aged 12 – 23 months)

23 months). Despite relatively high fluctuations in methane emissions over the years, measles immunization rates have remained consistently high, suggesting that countries on average, may be proactively maintaining high immunization coverage, mindful of environmental sustainability. This consistent prioritization of immunization programs implies a robust preventive healthcare effort to protect the younger population from the adverse impacts of environmental pollution. Promising, as this may appear, there is still much more effort needed from all regions in the sphere of climate change and policy formulation.

Figure 10 displays the trends of average PM2.5 air pollution and annual GDP growth (%). PM2.5 represents particles in the air that are less than 2.5 micrometers in diameter that can penetrate into the lungs and bloodstream, posing the greatest risk to health. This is referred to as 'fine particle pollution' and has been known to cause serious lung and heart diseases. The Environmental Protection Agency (EPA) has currently established the level of primary annual PM2.5 standard at 9 micrograms per cubic meter to strengthen the national air quality standards (EPA, 2024). The figure illustrates how changes in air pollution levels correlate with economic (GDP) growth over the years. This is in line with the fact that economic growth is typically associated with three kinds of pollution – CO_2 emissions, GHG emissions overall, and PM2.5 particulate matter emissions (Federal Reserve Bank, 2017). Therefore, there is a critical need worldwide for sustainable growth strategies that will boost the economy without harming the environment.

Figure 11 displays a scatterplot of GDP growth with annual freshwater withdrawals for different regions. It includes a trend line that models the relationship between these two variables. The trend shows a positive relationship between the variables. However, there is a wide dispersion of data points with no significant association across the regions ($p > 0.05$). The lack of a clear correlation suggests that other intermittent factors may affect the relationship. This indicates the complexity of economic growth and implies that a more comprehensive model, possibly incorporating additional economic and environmental variables, is needed to better understand the causes of GDP growth.

Figure 12 shows the association between methane emissions and food production index. The data suggests that higher methane emissions correlate with increased food production. This is in line with the fact that agricultural production accounts for approximately 10 – 12% of the emissions. The finding suggests that while increased agricultural activity may lead to higher methane emissions, countries must focus on long-term environmental sustainability to reduce the overall adverse effects of climate change.

Figure 13 illustrates the relationship between annual freshwater withdrawals as a percentage of internal water resources (at the top) and secondary school enrollment rates (at the bottom) across different regions. While most regions show moderate-to-high secondary school enrollment rates, their water withdrawals vary significantly,

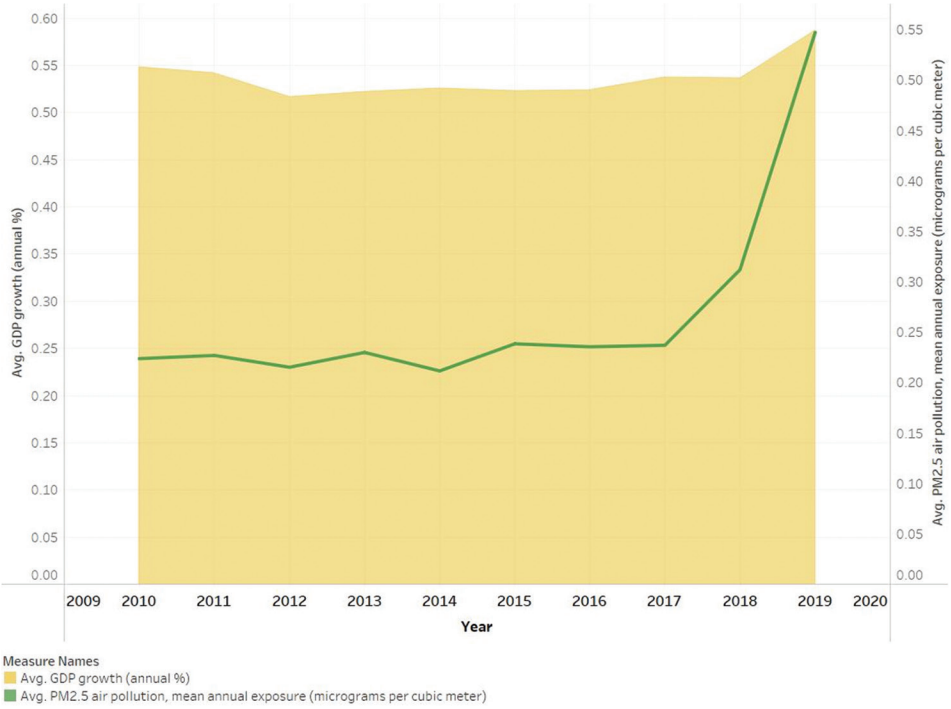

Figure 10. Area line chart of PM2.5 air pollution levels (mean annual exposure in micrograms per cubic meter) and annual GDP growth (annual %)
Abbreviation: GDP: Gross domestic product.

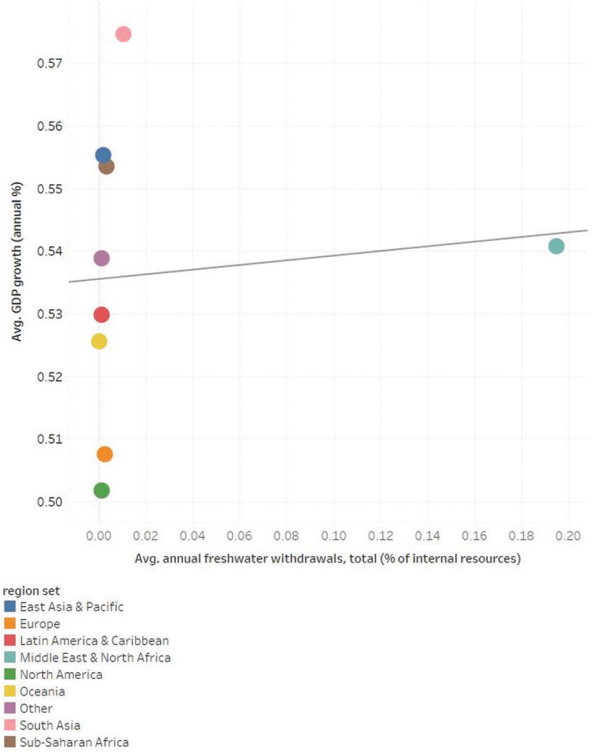

Figure 11. Scatterplot of annual freshwater withdrawals and GDP growth (annual %)
Abbreviation: GDP: Gross domestic product.

indicating varying pressures on water resources that do not consistently influence school enrollment. The data implies that socioeconomic factors beyond water availability play a significant role in education, calling for comprehensive policies addressing infrastructure, access, and socioeconomic challenges.

Figure 14 shows a dual-line chart showing the trends of unemployment rates and PM2.5 air pollution levels over the years. The chart indicates that periods of higher PM2.5 air pollution do not consistently correlate with higher unemployment rates; in some years, as pollution decreases, unemployment remains stable or even increases, suggesting other factors influencing unemployment beyond air quality. The lack of a clear correlation between PM2.5 levels and unemployment rates imply that while environmental policies are crucial for health and environmental quality, they may not directly impact economic conditions such as unemployment. This suggests that policymakers should consider a broad range of economic strategies in addition to environmental improvements.

Figure 15 contains an area chart displaying the trends in food production index and population. The food production index can be seen on the left y-axis while the population can be seen on the right y-axis, with the area fills showing their magnitudes. Although the population continues to rise, the food production index reaches a peak

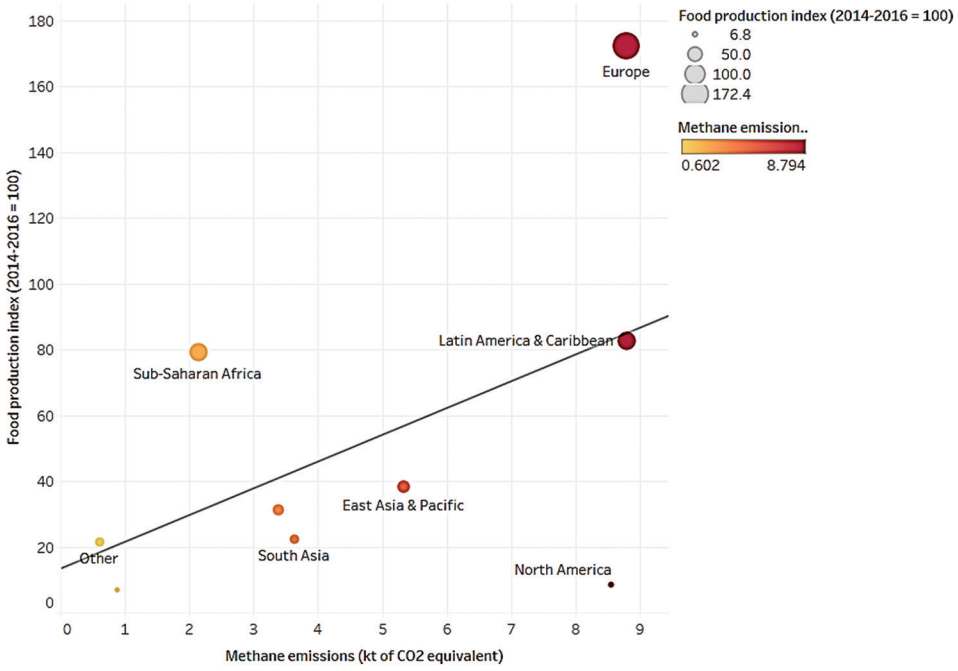

Figure 12. Scatterplot of methane emissions (kt of CO_2 equivalent) and the food production index

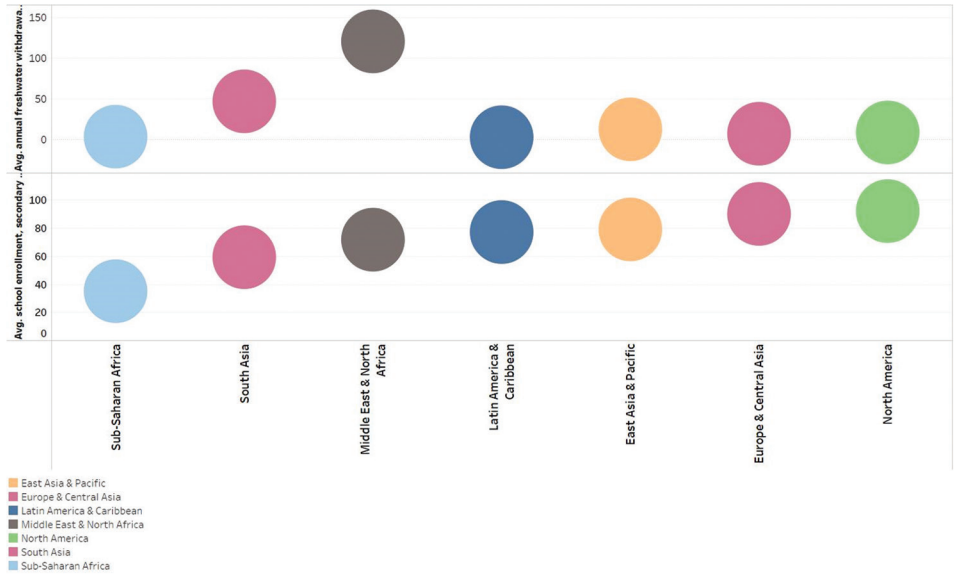

Figure 13. Comparative bubble chart of annual freshwater withdrawals (% of total revenue) and school enrollment (secondary) by region

in 2013 and then stabilized. This demonstrates diversity in food production efficiency in relation to population size. The data suggests challenges in maintaining or increasing food production efficiency with rising population growth, emphasizing the need for enhanced agricultural technologies or practices to sustain food security as the population continues to grow.

Figure 16 displays a scatterplot with a trend line that suggests a positive correlation between CO_2 emissions per capita and unemployment rates over the years. The association is significant (p <0.05). Higher CO_2 emissions are associated with higher unemployment rates, contradicting the hypothesis that increased emissions might reduce unemployment due to economic shifts. This trend suggests

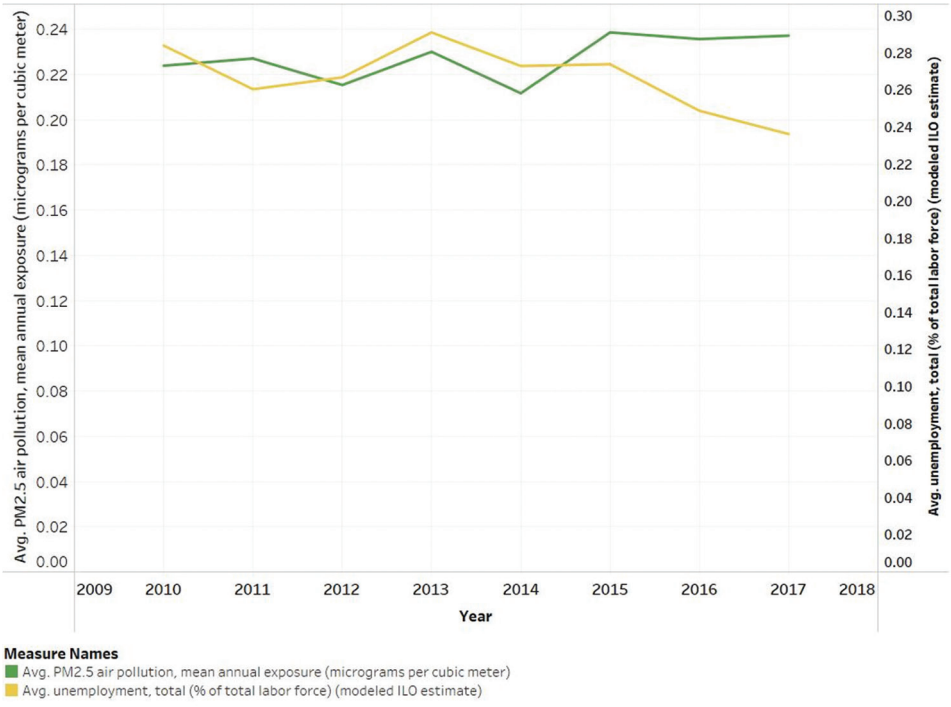

Figure 14. Dual-line chart of PM2.5 air pollution levels and total unemployment rates (% of total labor force)
Abbreviation: ILO: International Labour Organization.

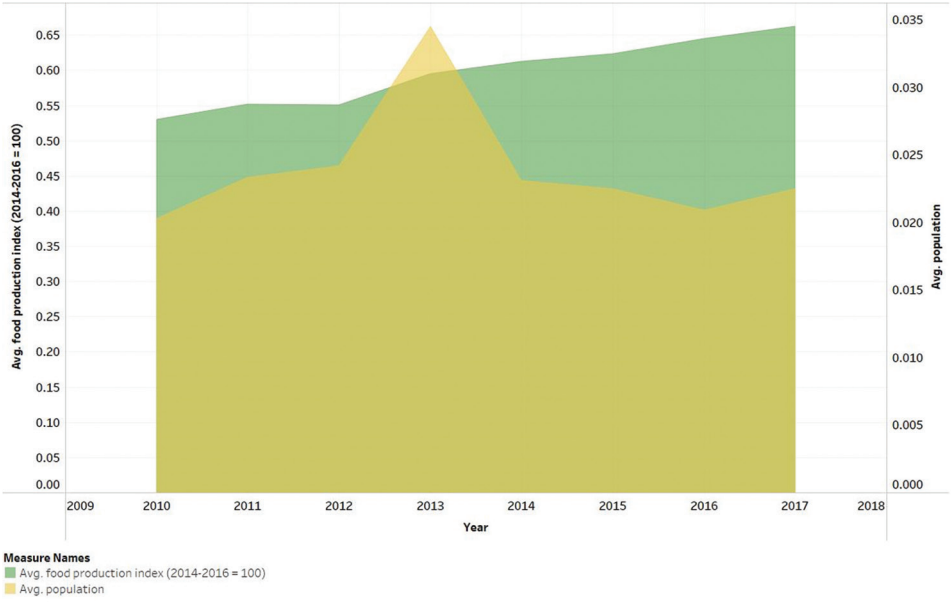

Figure 15. Area chart of population growth and food production index

potential economic challenges in regions with high CO_2 emissions, highlighting a need for policies that address both environmental and job creation strategies.

Figure 17 displays a dashboard showing the association between access to electricity and secondary school enrollment rates. The top chart in the dashboard shows the trend analysis for the years while the bottom chart shows a breakdown by region. The top chart shows that secondary school enrollment is positively associated with access to electricity. As access to electricity goes up, so does school enrollment. In the regional breakdown, some regions such

as East Asia & Pacific, Europe, and North America have high levels of access to electricity and school enrollment while others such as Sub-Saharan Africa show lower levels of electricity access and school enrollment. Therefore, the data suggests that improving access to electricity could significantly boost educational outcomes, particularly secondary school enrollment, highlighting electricity access as a key factor in educational development.

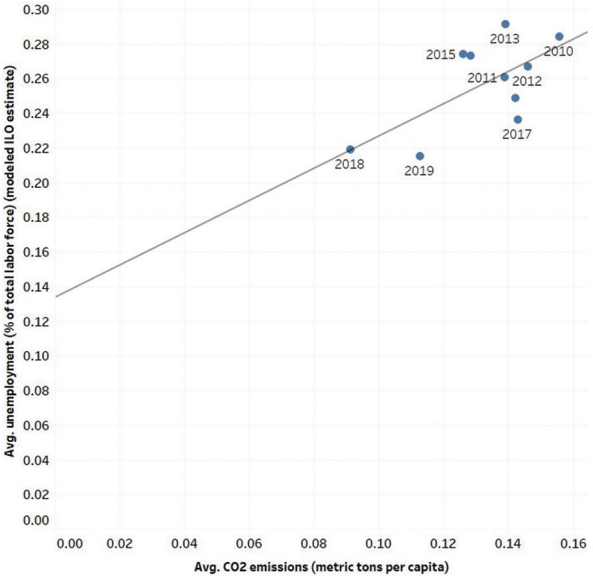

Figure 16. Scatterplot of CO_2 emissions (metric tons per capita) and unemployment rates (% of total labor force)

Figure 18 displays a dual-line chart graph showing the adjusted environmental impact and GDP growth (annual %). The adjusted environmental impact is a derived measure on the environmental impact per person (environmental impact score divided by the population). The chart reveals a dramatic increase in adjusted environmental impact around 2016 – 2017 to match a peak in GDP growth, followed by a sharp decline in both indicators following 2017. This suggests a potential correlation where periods of economic expansion may intensify environmental impacts, which is followed by a rapid decline possibly indicating a tipping point where environmental costs impact economic performance. This calls for strategies to balance economic growth with sustainable environmental practices.

Figure 19 displays the relationships between PM2.5 air pollution and under-five mortality rates, as well as between CO_2 emissions and measles immunization coverage, across different regions. The size of each bubble represents the total population of the region. Regions with higher pollution levels, both PM2.5 and CO_2 emissions (such as South Asia

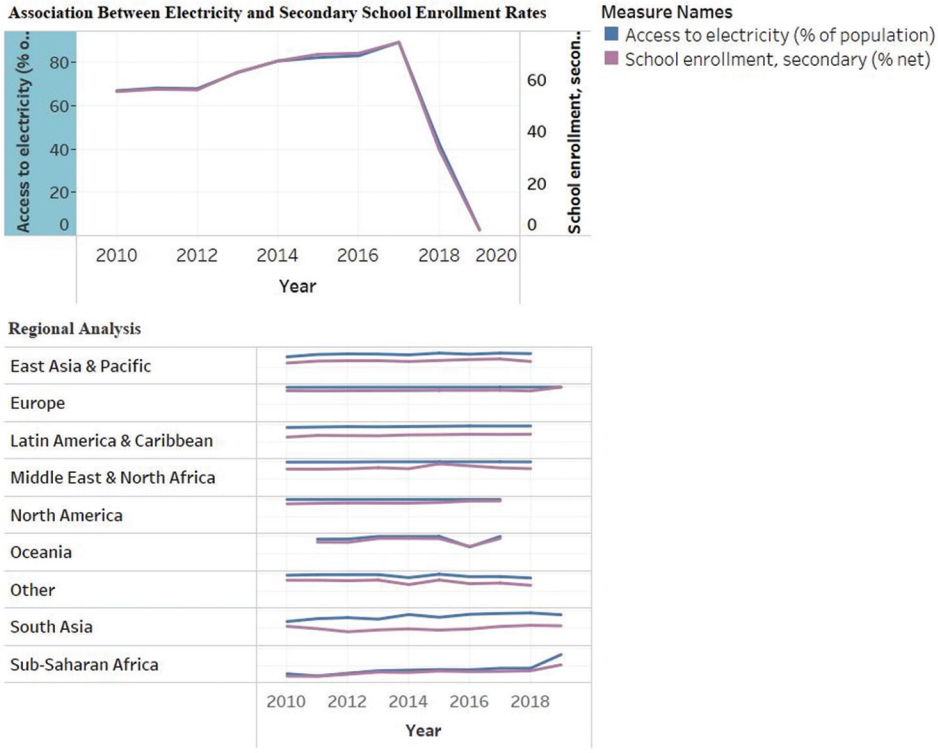

Figure 17. Dashboard of access to electricity and secondary school enrollment

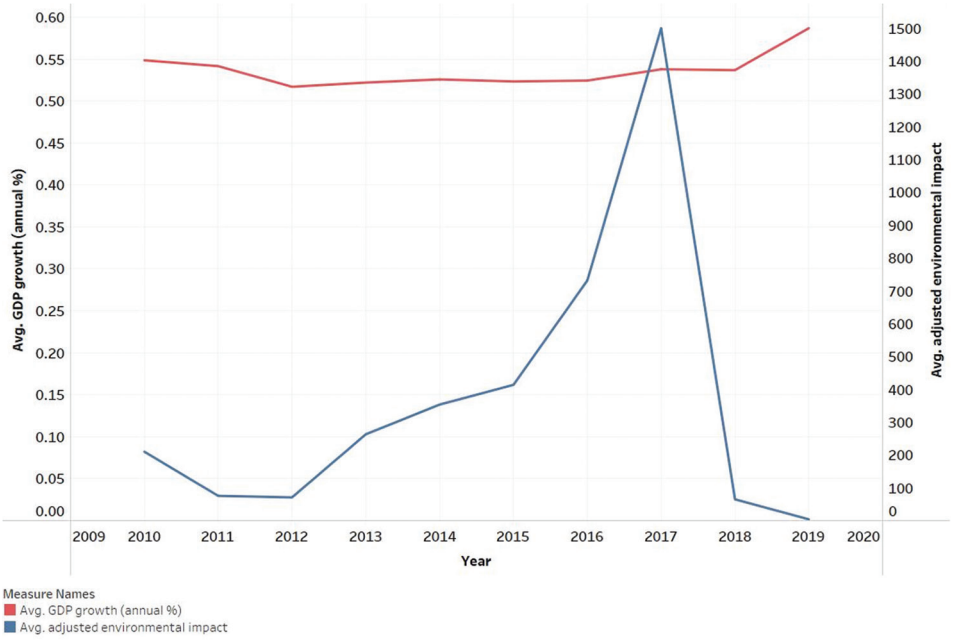

Figure 18. Dual-line chart of adjusted environmental impact and GDP growth
Abbreviation: GDP: Gross domestic product.

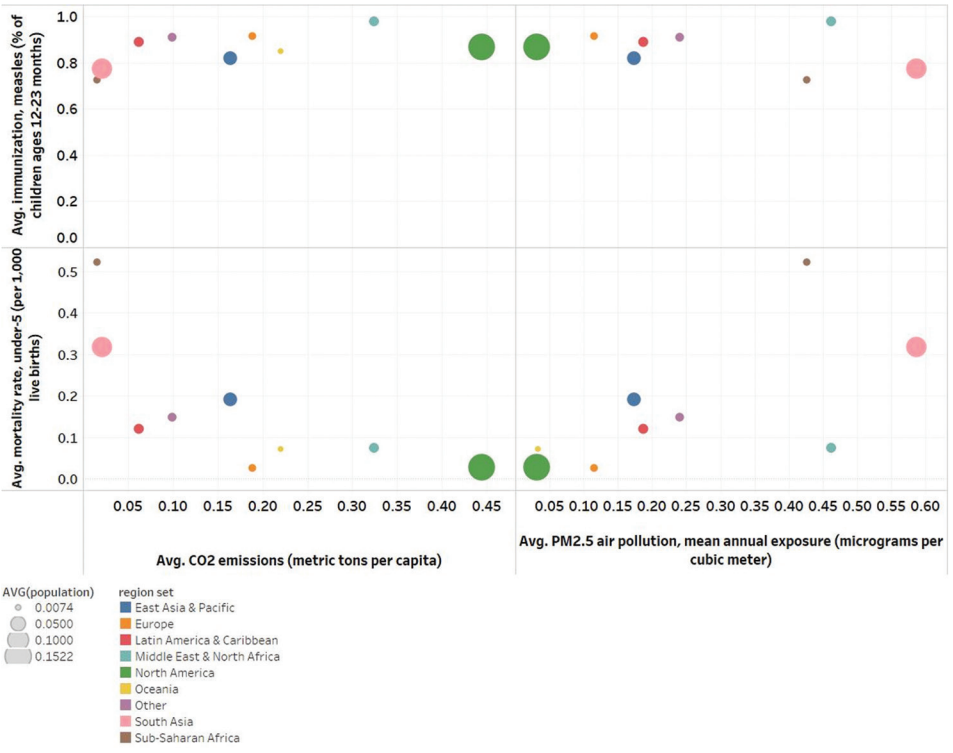

Figure 19. Scatterplot of CO_2 emissions, PM2.5 air pollution, mortality rate, and measles immunization across regions

and Sub-Saharan Africa) tend to show higher under-five mortality rates and lower measles immunization coverage. North America has low pollution levels and high measles immunizations. This reflects the negative impact that

pollution has on these health outcomes. The data suggests a significant public health challenge linked to air pollution, emphasizing the need for enhanced environmental and health policies to improve health outcomes, especially areas that have high pollution.

Table 3 displays the regression analysis summary with outputs such as R-square, F-statistics, and coefficients, for evaluating the relationship between CO_2 emissions (metric tons per capita) and inflation, and consumer price (annual %). There is a negative relationship between CO_2 emissions and inflation indicated by the negative coefficient of -0.184 for inflation, and a significant p-value ($p < 0.001$). This implies that a decrease in CO_2 emissions is associated with an increase in inflation. This association could be sensitive to economic conditions such that when the economy is slow, there will be reduced industrial activity and less CO_2 emissions.

5. Discussion

Table 4 offers a summary of the overall propositions, questions, analytic types, variables, chart type, and conclusion.

Our visualization study has mixed results. For example, CO_2 emissions declined in South Asia and Sub-Saharan Africa. It is likely that CO_2 emissions are associated with GDP growth. Generally speaking, this implies that developed countries are responsible for the overall higher emissions as a result of industrialization. Paradoxically, higher CO_2 emission is associated with higher school enrollment, an indirect effect of higher economic growth. CO_2 emission is also associated with higher unemployment rates, signaling that health issues are likely causing absenteeism and staying away from jobs. As inflation goes up, CO_2 emissions fall, perhaps due to efficient, green industrialization. Finally, CO_2 emission is associated with higher air pollution and higher under-five mortality rates. Simultaneously, immunization rates appear to decline. Another significant finding is higher air pollution is associated with higher child mortality, particularly in South Asia and Sub-Saharan regions. In North America, both air pollution and child mortality rates are lower. GDP growth is associated with increased air pollution. On the other hand, there is no evidence of a consistent correlation between air pollution and the unemployment rate. Similarly, no association is observed between methane emissions and the unemployment rate. However, increased measles immunization is associated with higher methane emissions, independent of the methane emissions being associated with food production, implying that agriculture plays a critical role. Freshwater withdrawal and food production show a steady increase. Efficient management of both will result in efficient use of water and agriculture. Furthermore, freshwater withdrawal is associated with an increase in GDP growth emphasizing the importance of managing water more effectively. Freshwater withdrawal and school enrollment tend to increase, independently of each other. There appears to be no significant association between access to electricity and GDP growth while school enrollment appears to increase with electricity. Generally, emissions and pollution have an adverse impact on quality of life indicators, affirming the urgent need to mitigate climate change.

Table 3. Regression table for CO_2 emissions and inflation

Statistic	Coefficient	p-value
Intercept	5.555	<0.001
Inflation, consumer price	−0.184	<0.001
F-statistics of the model	28.157	<0.001
R-value of the model	0.188	
R-square	0.0355	

Note: Dependent variable is CO_2 emissions.

6. Scope and limitations

This study is not without limitations. The study was scoped to include a limited set of variables (indicators in the World Bank's World Development Indicators database). The variables were chosen based on the current literature. By no means, every possible climate change or quality of life variable was identified or analyzed in this study. Due to missing values, the study period was limited as well. Nevertheless, the data does paint a dire picture of the effects of climate change. Therefore, the visualization relied on available data, which might not fully capture all aspects of climate change and its impact on the quality of life for people in various parts of the world. There could have been more sources for data that could be used, not just limited to the World Bank indicators. There was much missing data for many variables, such as threatened species data, which is only available for one year. The accuracy of data from developing countries might not have been as reliable due to insufficient data collection methods and fewer resources dedicated to data governance and quality. Being panel data, there was no scope for predictive analytics. The study is limited only to findings of association. Further, this study depends primarily on visualization and visual analytics resulting in mostly descriptive analysis, addressing the potential association between independent and dependent variables. Additional applications of statistical modeling and machine learning may shed light on more nuanced associations.

Table 4. Summary of propositions, questions, analytic types, variables, chart type, and conclusions

Serial #	Proposition	Question	Analytic type	Variable (s)	Chart	Conclusion
1	Higher CO_2 emissions are associated with slower GDP growth.	How do CO_2 emissions impact GDP growth rates?	Predictive	• Dependent: GDP growth • Independent: CO_2 emissions • Control: Population	Line plot	No significant association between increased CO_2 emissions and GDP growth.
2	Increased air pollution negatively impacts children's health.	How does PM2.5 exposure affect under-5 mortality rates?	Descriptive	• Dependent: Under-5 mortality rate • Independent: PM2.5 air pollution	Stacked bar chart	Higher exposure to PM2.5 is associated with increased under-5 mortality rates.
3	Water resource depletion affects food production.	How do annual freshwater withdrawals influence food production?	Predictive	• Dependent: Food production index • Independent: Annual freshwater withdrawals	Bar and line chart	No visible negative association is seen between water withdrawal and food production.
4	There is an association between access to electricity and GDP	How does access to electricity relate to GDP growth?	Predictive	• Dependent: GDP growth • Independent: Access to electricity	Bar and line chart	No visible association between electricity and GDP.
5	There is an association between methane emission and unemployment rate	Does methane emission influence unemployment rates?	Descriptive	• Dependent: Unemployment rates • Independent: Methane emissions	Bar and line chart	Methane emissions are not associated with unemployment rates.
6	High CO_2 emissions drive higher school enrollment.	How does CO_2 emissions affect secondary school enrollment?	Predictive	• Dependent: Secondary school enrollment • Independent: CO_2 emissions	Dual-axis line chart	Increased CO_2 emissions are associated with higher educational attainment (indirect effect of economic growth).
7	Inflation negatively impacts food production.	How does inflation affect the food production index?	Predictive	• Dependent: Food production index • Independent: Inflation	Area chart	Lower inflation is associated with reduced economic activity, affecting food production levels.
8	School enrollment rates correlate with electricity access.	How does access to electricity impact the school enrollment rate?	Descriptive	• Dependent: School enrollment rate • Independent: Access to electricity	Scatter plot	Higher access to electricity results in higher enrollment rates.
9	Methane emissions correlate with child immunization rates.	Doe methane emissions impact immunization coverage?	Predictive	• Dependent: Immunization against measles • Independent: Methane emissions • Control: Population	Dual-line chart	Economically stronger countries with high methane emissions are likely to have higher immunization rates.
10	As air pollution increases, GDP goes up.	How does PM2.5 air pollution affect GDP growth?	Predictive	• Dependent: GDP growth • Independent: PM2.5 air pollution	Area and line chart	Air pollution is associated with GDP growth.
11	More freshwater withdrawals are associated with higher GDP growth.	Does water usage correlate with GDP growth?	Descriptive	• Dependent: GDP growth • Independent: Annual freshwater withdrawals	Scatter Plot	Increased water use might indicate higher industrial activity and GDP growth.
12	Methane emissions are linked to decreased food production.	How do methane emissions impact food production indices?	Predictive	• Dependent: Food production index • Independent: Methane emissions	Scatter plot	Methane emissions are associated with food production.

(Cont'd...)

Table 4. ***(Continued)***

Serial #	Proposition	Question	Analytic type	Variable (s)	Chart	Conclusion
13	Higher water withdrawal is associated with higher school enrollment.	How does the amount of water withdrawn impact school enrollment rates?	Predictive	• Dependent: Secondary school enrollment • Independent: Freshwater withdrawals	Bubble chart	Higher freshwater withdrawal is associated with increased school enrollment (each is independently increasing or due to economic growth).
14	Higher air pollution increases unemployment rates.	How does the air pollution rate correlate with unemployment levels?	Predictive	• Dependent: Unemployment • Independent: PM 2.5 air pollution	Dual-axis line chart	No consistent association is detected.
15	Population growth challenges food production stability.	How does population size affect the food production index?	Descriptive	• Dependent: Food production index • Independent: Total population	Area chart	Larger populations may strain food production systems.
16	Increased CO_2 emissions correlate with higher unemployment rates due to economic shifts.	How do CO_2 emissions relate to unemployment rates?	Predictive	• Dependent: Unemployment • Independent: CO_2 emissions	Scatter plot	High CO_2 emissions might indicate industries in decline, affecting employment.
17	Improved access to electricity boosts school enrollment.	Does access to electricity influence school enrollment rates?	Descriptive	• Dependent: Secondary school enrollment • Independent: Access to electricity	Dual-line chart	Better electricity access is associated with increased school enrollment.
18	Aggregate climate change factors (environmental impact) on national GDP growth.	How do combined climate change factors like adjusted environmental impact influence overall GDP growth?	Descriptive	• Dependent: GDP growth • Independent: Adjusted environmental impact • Control: Total population	Dual-axis chart	Aggregating climate impact factors into a composite score will provide an overarching view of their influence on GDP growth across nations.
19	Pollution has an overall impact on regional health outcomes	How do specific pollutants like PM2.5 and CO_2 emissions affect health outcomes in different regions?	Descriptive (drill-down)	• Dependent: Under-5 mortality rate, immunization against measles, total population • Independent: PM2.5 air pollution, CO_2 emissions	Interactive stacked bar chart	Developing nations have higher under-5 mortality and lower immunization rates with higher CO_2 emissions and more severe air pollution.
20	Increasing CO_2 emissions leads to higher inflation rates	Does an increase in inflation rates predict an increase in CO_2 emissions?	Predictive	• Dependent: CO_2 emissions • Independent: Inflation (consumer prices) • Control: Population	Regression	A rise in inflation is linked to the decrease in CO_2 emissions (economic growth).

Abbreviation: GDP: Gross domestic product.

7. Conclusion and future research

The current study reveals and offers significant conclusions. With regard to water withdrawals and education, effective water management alone may not directly impact educational outcomes, emphasizing the need for comprehensive socioeconomic strategies. In terms of methane emissions and employment, the data suggests that other economic factors significantly influence employment, indicating a need for region-specific solutions. For the relationship between air pollution and mortality rates, higher air pollution is associated with higher child mortality rates, particularly in South Asia and Sub-Saharan Africa. Examining the association between methane emissions and immunization rates, stable immunization rates persist regardless of fluctuating methane emissions, suggesting that public health programs successfully shield child health initiatives from environmental pressures. Future research may include longitudinal studies to examine the long-term impacts of climate change on global health trends and economic conditions. For example, conducting cross-cultural comparisons to assess how different cultures

adapt to similar environmental challenges; and, examining the technological interventions, namely, how technology can assist with building resilience against climate-related disruptions. Primarily, this exploratory empirical study affirms that the mortality rate indeed rises with increasing emissions and pollution, and this is a cause for serious concern.

8. Implications and recommendations

The strong correlation between high air pollution and child mortality rates points to a public health crisis in many regions, particularly Sub-Saharan Africa and South Asia. Addressing air quality will require integrating health and environmental policies. The lack of correlation between water withdrawals and secondary school enrollment shows that water management alone cannot resolve broader socioeconomic challenges that affect education. Governments may integrate policies to simultaneously address air pollution and child health, prioritizing regions with high mortality rates. Policy makers might likely support regions reliant on limited sectors through policies that promote diversification, especially toward cleaner technologies and industries. Workers in different sectors ought to be retrained and supported through the transition to a low-carbon economy. The need for cost-benefit analysis, risk communication, and educating the public regarding climate change and its impact of quality of life is imperative in current times. Additional empirical and case studies will accelerate the understanding of the association between climate change and quality of life.

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Conflict of interest

The authors declare they have no competing interests.

Author contributions

Conceptualization: Wullianallur Raghupathi
Formal analysis: Dongli Zhang, Viju Raghupathi
Investigation: Dongli Zhang, Viju Raghupathi
Methodology: All authors
Writing – original draft: Wullianallur Raghupathi
Writing – review & editing: All authors

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

Data are available from the corresponding author upon reasonable request.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

How do college students who are parents feel anxiety, stress, and depression during their examination preparation?

Evangelos Demeroutis[1], Dimitris D. Vlastos[1,2] and Paraskevi Theofilou[2]*

[1]Department of Psychology, Scientific College of Greece, Athens, Greece

[2]Laboratory of Experimental and Applied Psychology, Scientific College of Greece, Athens, Greece

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Abstract

Anxiety, stress, and depression are elements of everyday life for some people. Situations and choices such as attending higher education institutions make these states even more difficult. Parallel employment and increased family obligations are thought to burden the mental states of students. This study purposed to highlight the increased levels of anxiety, stress, or depression experienced by college students who are also parents. It also explored the sources of these adverse mental states and probed how students with children tackled them. It was assumed that students who were parents would be more burdened by these mental states than other students. The administered questionnaire was based on the Depression, Anxiety, and Stress Scale-21 (DASS-21) with added questions regarding the sources of anxiety, stress, or depression and the ways participants dealt with them. However, the original hypothesis was rejected because the data obtained from the study sample of 94 participants revealed that students without children experienced more anxiety than students who were parents. No difference was found in the stress and depression levels reported by the two groups. Participants also highlighted how educational institutions can burden the mental state of students, for instance, through the number of assigned tasks and the examination period. Participants reported that they turned to their family members and friends or stayed at home to reduce anxiety, stress, and depression. Therefore, studies should be conducted to discover the probable reasons for higher levels of anxiety, stress, or depression sensed by college students who are not parents and how students who are parents mitigate these states.

Keywords: Anxiety; Stress; Depression; Student; Parent; Emotional relaxation; Higher education

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***Corresponding author:**
Paraskevi Theofilou
(ptheofilou@scg.edu.gr)

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1. Introduction

Present-day work environments require candidates for most jobs to be appropriately educated and trained. People who did not follow the path of higher education after their secondary education as well as those who have decided to change their work domains after some years or simply want to enrich their knowledge can attend public or private universities to obtain a higher education. However, some such individuals

have naturally structured their lives with children, as confirmed by a survey conducted in the USA, in which 22% of undergraduate students who participated were also parents (Cruse *et al.*, 2019) confronted with the challenges of balancing studies and family life. Student life is a source of stress that particularly affects the family, financial, and educational life of students (Bulo & Sanchez, 2014) and causes half of the student community to self-identify as depressed at some point in their educational journey (Furr *et al.*, 2001). Factors that can cause stress can emanate from educational facilities or personal environments (Yikealo *et al.*, 2018), and relate to attempts by students to avoid academic, socioeconomic, and personal failure (Pariat *et al.*, 2014). In addition, a study conducted in Romania evidenced that working students exhibited higher levels of stress and recorded lower academic performances than students who did not work (Săvescu *et al.*, 2017). Dr. Loukia Dimitriou *et al.* (2020) confirmed the negative effects of work stress on the studies and academic performance of working students in Greece and Cyprus. They related such effects to the free time accorded to students and their awareness of relaxation techniques. Finally, Norwegian scholars Hans Bonesrønning and Leiv Opstad (2012) found a positive correlation between study time and academic performance, reinforcing the hypothesis that the less study time students get, the more anxious they become about exam success.

This study aimed to detect and investigate the impact exerted by the existence of minor children on the examination preparation of their parents who are also students. Anxiety, stress, and depression adversely affect the daily functioning of people in increasing numbers. Therefore, mental health professionals as well as societies at large purpose to prevent and treat these conditions. Varied proven ways exist of tackling these mental states and these means should be integrated into societies to enhance the mental states of human beings.

1.1. Anxiety–Stress–Depression

The emotion of anxiety is thought to cause apprehension and tension, which instigate somatic changes such as increased blood pressure (APA, 2018). Anxiety is widespread in everyday human life and has been frequently depicted in the literature by authors such as Tolstoy (1882/2019), Yalom (1980/2020), and Freud (1930/2011). Of course, it must also be noted that anxiety represents a survival mechanism linked to areas in the brain such as the amygdala that process particular situations (Kandel, 1983). In the domain of mental states, anxiety denotes the sensing of fear without any stimuli (Merrel, 2008). Anxiety disorders constitute 20% of the mental disorders in the general population (Antony, 2010) and are most commonly diagnosed in children and adolescents (Beesdo *et al.*, 2009).

Conversely, stress signifies a reaction to external stimuli (Ρέππα, 2018) and causes biological reactions in several organs and organ structures areas such as the brain or the endocrine system (APA, 2018). Cortisol is the main hormone involved in stress; it travels throughout the body and affects the bodily tissues in numerous ways (Herman *et al.*, 2016). Chronic stress creates an unnatural biochemical environment in human bodies, affecting the programmed life cycle of cells, probably causing cancer, and triggering self-immune diseases among other effects (Tournier *et al.*, 2000). Post-traumatic stress disorder has been found to affect the general population and is linked to depression, anxiety, and substance abuse (APA, 2013; Pfefferbaum, 1997; Roussos *et al.*, 2005).

The mental state of depression manifests as prolonged sadness that affects a person's focus and mental endurance, evokes thoughts of guilt, and causes a general lack of interest (Ουλής, 2010). The Diagnostic and Statistical Manual of Mental Disorders (DSM-V) includes Major Depression Disorder (MDD) and records the following symptoms among other indicators: insomnia or oversleeping, significant weight loss, depression, tiredness, feelings of guilt, lack of focus, and absence of pleasure (Truschel, 2022). According to the World Health Organization (WHO), 3.8% of the global population suffers from depression, and women suffer from this state more than men ("Depressive disorder," 2023). Notably, grieving is not deemed a disorder even though it does incorporate moments of depression. In contrast, MDD entails a constant state of depression (Freud, 1917a). Aaron Beck (1987) presented a model titled the Beck Depression Triad, which describes how people with depression think about themselves, others, and the future.

Anxiety is linked to early maladaptive schemas (Αγγελή, 2015), and most extant studies suggest that cognitive behavioral therapy (CBT) and prescribed drugs help to alleviate this emotion (Stein & Sareen, 2015; Bandelow *et al.*, 2017). Stress disorders are believed to derive from exposure to traumatic events, and trauma-focused CBT, eye movement desensitization and reprocessing, and mindfulness practices (Mindfulness-Based Stress Reduction, MBSR) are among the many ways of dealing with stress disorders. Depression is linked to genetics, neurobiological, cognitive, and social factors (Goldstein & Devries, 2017), and is often managed through prescribed drugs such as selective serotonin reuptake inhibitors (SSRIs), CBT, and mindfulness practices (Harrington, 2005; Sipe & Eisendrath, 2012).

2. Methods

2.1. Research design

Quantitative cross-sectional research was conducted to determine the anxiety, stress, or depression effects exerted during examination periods on college students parenting minor children in comparison to students who did not have children. Therefore, two levels of variables were considered: the independent variable was having children, and the dependent variable was anxiety, stress, or depression levels sensed by students during examination periods.

2.2. Participants and sample

Convenience sampling was utilized for this study, which surveyed a total of 94 participants: 71 women (75.6%) and 23 men (24.4%). Of the total sample, 62 participants did not have children (65.9%) and 32 (34.1%) were parents. The average age of the participants was 34 years. The study was conducted with students enrolled in higher education institutions, aged above 18 years, and proficient in Greek. People who were not students and were not in the stipulated age range were excluded from the study.

2.3. Materials and tools

The administered questionnaire comprised a sociodemographic section, the questionnaire appended in Annexure A, and a few queries about the ways in which the participants perceived their mental state. The Depression, Anxiety, and Stress Scale-21 (DASS-21) (Datanalysis, 2021) weighted in Greek by Lyrakos *et al.* (2011) was used to collect the required information. P. F. Lovibond and S. H. Lovibond constructed this instrument in 1993 as a set of three self-reporting scales designed to measure negative emotional states such as depression, anxiety, and stress (Data analysis, 2021). The DASS-21 questionnaire is available for public use without special licensing. The internal consistency reliability of all the propositions of the scale is Cronbach's a = 0.965 (Data analysis, 2021). The scale also exhibits good content and construct validity. A sociodemographic questionnaire was also administered to apprehend the differences and trends pertaining to discrete groups of people. Other data were collected for analysis and discussion: for instance, participants were queried about sources of stress at educational institutions and how they contributed to self-perceived stress, anxiety, and depression in students. In addition, students were asked about the techniques that helped them handle the perceived anxiety, stress, and depression and their responses served as springboards for further discussion that could help devise proposals for students in need. Thus, new research on the subject may be initiated from the findings of this study.

2.4. Research process

The free MS Forms online platform was utilized to collect the data. The questionnaire was available through the college email to students attending the Scientific College of Greece (SCG) and to other college students via miscellaneous research-oriented internet forums. A consent form containing due information and seeking assent for participation in the study was sent to potential participants before the aforementioned data collection tools were administered. Participants were first asked to read the provided information and consent to their participation in the study. Then, they were granted access to the questionnaires. Subsequently, they received a debriefing form after they had completed the survey. The confidentiality and anonymity of all participants were ensured by inserting a five-digit alphanumeric code at the beginning of the form to recall their data if required. Notably, the participants were not deceived in any manner. The study was approved by the Research, Ethics, and Conduct Committee of the SCG under number TER2021-129.

2.5. Data analyses

Initially, the distribution of anxiety, stress, and depression scores was checked using the Shapiro–Wilk test. The results were not normal ($p < 0.001$); thus, nonparametric tests were employed. All samples were independent and the asymmetry of the values was considered positive. Subsequently, a Mann–Whitney U test was performed to compare the levels of anxiety, stress, and depression between students with and without children. Another Mann–Whitney U test was performed to discover further associations and compare levels of anxiety, stress, and depression between women and men and between employed and non-employed participants. In addition, Kruskal–Wallis tests were performed to detect whether statistically significant differences existed between the levels of anxiety, stress, and depression by age group, marital status, sources of stress from educational institutions, and relaxation activities.

3. Results

In terms of their ages, 27.7% of the participants were aged 18–25 years, 20.2% were 26–33 years old, 31.9% were grouped as 34–41 years, 8.5% were 42–49-year-olds, 8.5% spanned 50–57 years, and 3.2% were aged 58–65 years (Figure 1). In terms of employment, 31.9% of participants were unemployed and 68.1% were employed. In terms of their marital status, 63.8% of the participants were married, cohabiting, or partnered, 30.9% were single, 3.2% were divorced, and 2.1% were widowed.

The results of the first Mann–Whitney U test (Table 1) demonstrated a statistically significant difference between the two groups (students with and without children) only in anxiety levels (U = 642, p = 0.005). The median of the group of students with children was calculated at 1.00 (normal anxiety levels based on DASS) and was 3.00 for students without children (normal anxiety levels based on DASS). The interquartile range (IQR) of the group of students with children was 3.00 and this value was 4.75 for the group of students without children (Kent State University, 2023). Furthermore, the mean value for the group of students with children was reported at 1.69 and this statistic was 3.61 for the group of students without children. These values ranged within normal anxiety levels.

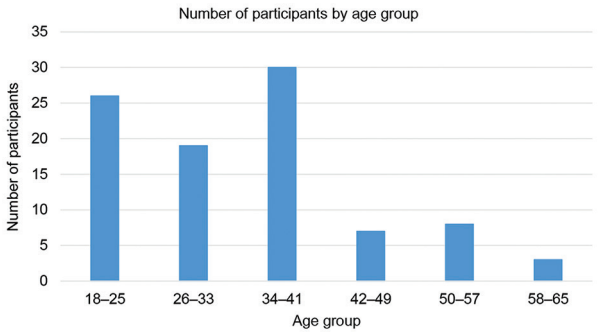

Figure 1. Participants by age group

Table 1. Mann–Whitney U test results of anxiety, stress, or depression and their descriptors between students who are parents and students with no children regarding (NAI: Students with children, OXI: Students without children)

D/A/S	Test	Statistic	*p*
Depression score	Mann–Whitney U	834	0.197
Stress score	Mann–Whitney U	818	0.164
Anxiety score	Mann–Whitney U	642	0.005
Descriptives			
Descriptive	**Kids**	**Anxiety score**	**Stress score**	**Depression score**
N	No	62	62	62
	Yes	32	32	32
Missing	No	0	0	0
	Yes	0	0	0
Mean	No	3.61	6.15	2.79
	Yes	1.69	4.50	1.72
Median	No	3.00	5.00	2.00
	Yes	1.00	4.00	1.00
Standard deviation	No	3.52	4.38	3.03
	Yes	2.21	2.69	1.78
IQR	No	4.75	4.50	4.00
	Yes	3.00	3.00	2.00
Minimum	No	0	0	0
	Yes	0	0	0
Maximum	No	13	16	13
	Yes	8	11	7

The second Mann–Whitney U test found no statistically significant differences in anxiety levels (p = 0.395), stress (p = 0.721), and depression (p = 0.493) between women and men (Table 2).The third Mann–Whitney U test evidenced no statistically significant differences between employed and unemployed participants in their levels of anxiety (p = 0.073), stress (p = 0.053), and depression (p = 0.053). Noteworthily, however, the employed participants registered higher values in all three scores (Table 2). The Kruskal–Wallis tests revealed no statistically significant difference between age groups (anxiety: p = 0.150, depression: p = 0.574, stress: p = 0.159), marital status (anxiety: p = 0.097, depression: p = 0.630, stress: p = 0.291), sources of stress emanating from educational institutions (anxiety: p = 0.070, depression: p = 0.067, stress: p = 0.228) and relaxation activities (anxiety: p = 0.626, depression: p = 0.674, stress: p = 0.224) (Table 3).

Regarding anxiety levels (Figure 2), normal values were presented by 70.2% of the participants, while 18.1% registered moderate values, and 11.7% recorded elevated values. Specifically, students who did not have children and presented normal anxiety values constituted 41.5% and students who were parents comprised 28.7%of the participants.

Notably, students who did not have children and recorded moderate levels of anxiety comprised 13.8%of the total number of participants, while students who were parents constituted 4.2% of the total sample. Furthermore, normal anxiety values were registered by 33% of female participants without children and 21.3% of women students with children. Finally, 23.4% of the participants who presented normal anxiety values were childless women aged between 18 and 33 years, while 13.8% of the

Table 2. Mann–Whitney U test results on anxiety, stress, or depression for groups according to gender and work status

Group	D/A/S	Test	Statistic	*p*
Gender	Anxiety score	Mann–Whitney U	776	0.721
	Stress score	Mann–Whitney U	739	0.493
	Depression score	Mann–Whitney U	722	0.395
Work	Anxiety score	Mann–Whitney U	725	0.053
	Stress score	Mann–Whitney U	723	0.053
	Depression score	Mann–Whitney U	743	0.073

participants who recorded normal anxiety values were women and men aged 34 to 41 years who were also parents.

Apropos stress levels (Figure 3), 78.7% of the participants presented normal values, 16% registered moderate values, and 5.3% recorded elevated values. Specifically, students who did not have children and presented normal stress values encompassed 48.9% of the participants, while students who were parents and recorded normal values comprised 29.8% of all respondents. Notably, students who did not have children and presented moderate stress values constituted 5.3%, of all participants, and 11.7% of all participating students without children registered high values. Normal stress values were presented by 40.4% of the participants who were women without children and 19.1% of the women with children. Finally, 37.2% of the participants who presented normal stress values were women aged between 18 and 41 years without children, while 14.8% of the participants who recorded normal values were women and men aged 34 to 41 years who were also parents.

In terms of depression levels (Figure 4), 81.9% of the participants exhibited normal values, 15.9% presented moderate values, and 2.1% recorded elevated values. Specifically, students without children who presented normal depression values comprised 50% of all participants, while students who were parents and recorded normal values constituted 31.9% of the study sample. Importantly, participants who presented moderate depression values and did not have children comprised 13.9% of the total sample, and 2.1% of the respondents who did not have children presented high depression values. Moreover, 42.6% of the participants who were women without children registered normal depression values along with 20.2% of the women students with children. Finally, 28.7% of the participants who presented normal depression values were women aged between 18 and 33 years and without children, and 15.9% were women and men who were parents and were aged 34 – 41 years.

In response to the query about what they perceived as sources of anxiety, stress, or depression at their educational

Table 3. Results of Kruskal–Wallis tests on anxiety, stress, or depression for groups according to age, marital status, sources of anxiety, stress, or depressionat educational institutions, and relaxation activities

Kruskal–Wallis	χ^2	df	p	ε^2
Age				
Anxiety score	8.11	5	0.150	0.0872
Stress score	7.94	5	0.159	0.0854
Depression score	3.83	5	0.574	0.0412
Marital status				
Anxiety score	10.74	6	0.097	0.1155
Stress score	7.33	6	0.291	0.0788
Depression score	4.35	6	0.630	0.0468
Sources of anxiety/stress/depression				
Anxiety score	13.11	7	0.070	0.141
Stress score	9.36	7	0.228	0.101
Depression score	13.22	7	0.067	0.142
Relaxation activities				
Anxiety score	6.19	8	0.626	0.0666
Stress score	10.63	8	0.224	0.1143
Depression score	5.76	8	0.674	0.0620

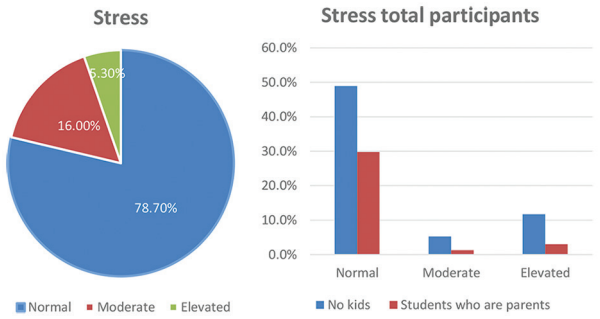

Figure 3. Stress scores

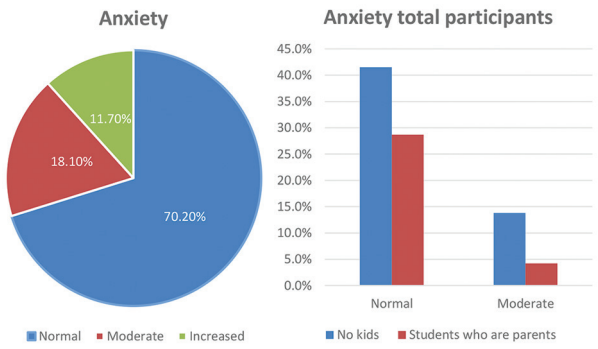

Figure 2. Anxiety scores

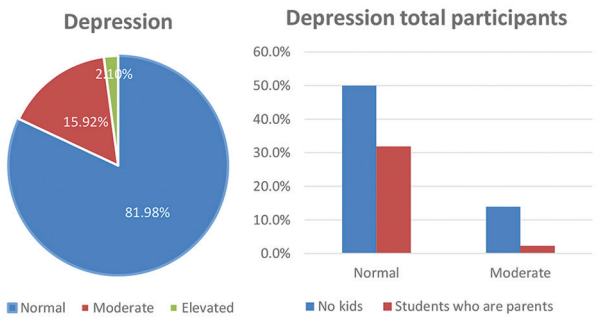

Figure 4. Depression scores

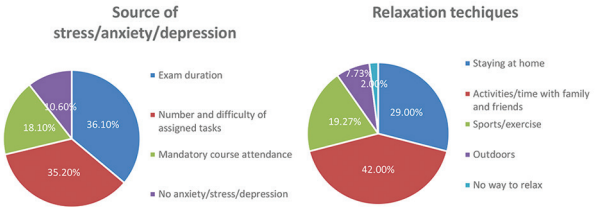

Figure 5. Student perceptions of the sources of stress, anxiety, or depression at their educational institutions and the relaxation techniques they employed.

institution, 36.1% of the participants answered the duration of the examinations, 35.2% the number and difficulty of assigned tasks, and 18.1% the mandatory course attendance (Figure 5). Only 10.6% of the participants answered that they did not feel anxiety, stress, or depression. Of this small cohort, 87.05% were students without children. When asked about their relaxation activities, 31.9% of the participants favored staying at home, 46.2% performed activities and spent time with their family and friends, 21.2% actively engaged in sports and exercises, and 8.5% participated in other outdoor activities. Only 2.2% of the participants did not register any means of relaxation.

4. Discussion

The present study aimed to evidence that students who have children experience increased levels of anxiety, stress, or depression during examination periods compared to students who do not have children. However, the study results demonstrated that students who do not have children recorded statistically significantly higher anxiety values than students who have children ($p = 0.005$). However, this study found no statistically significant differences between the two groups in their stress ($p = 0.164$) and depression ($p = 0.197$) levels. Therefore, the original hypothesis of the study was rejected. Thus, it is concluded that students who do not have children exhibit higher anxiety values than students who are parents. No statistically significant differences were found between these two groups by any other measure employed for this study. Therefore, no conclusion can derived about why students without children sense more stress than students who are parents.

The relatively small number of participants is deemed a major limitation of the present study because a total of 94 students answered the questionnaires, of whom 32 had children and 62 did not. Overall, 34.78% of the sample comprised parents, a number greater than was reported (22%) in the previously mentioned study conducted in the United States by Cruse *et al.* (2019). However, the present study did not specify the level of education whereas the findings of the aforementioned study conducted in the USA concerned undergraduate students. Săvescu *et al.* (2017) reported that working students experience increased levels of stress. The present study confirmed that working students exhibited higher anxiety, stress, or depression values than unemployed students, but not at statistically significant levels. As previously mentioned, Furr *et al.* (2001) evidenced with a sample of 1,455 students (N = 1,455) that 50% of students were identified as depressed at some point in their studies. However, only 18.1% of the participants in the present study displayed moderate and elevated depression levels. The introduction section of this paper referenced a study conducted by Dimitriou *et al.* (2020) that highlighted the correlation between anxiety and the application of relaxation techniques. However, only 2.2% of the participants in the present study reported that they could not relax, and most participants employed practices that helped them unwind. Yikealo *et al.* (2018) reported that educational institutions could themselves present sources of stress for students, and the present study attempted to identify these factors, which are presented in Figure 5. Finally, a 2012 survey revealed that reduced study times result in increased anxiety (Bonesrønning & Opstad, 2012). However, the present study did not address this aspect.

Moreover, the data for this study were collected through self-report tests, which present limitations mainly because it is difficult for people to remain unbiased when reporting their personal experiences (Devaux & Sassi, 2016). These limitations primarily concern the honesty of participant responses, the lack of introspection by respondents, their interpretations of questions, the response scales, their biases, and the sample type (Salters, 2023). For example, many people are likely to tender socially acceptable or preferable answers (Devaux & Sassi, 2016). Many scholars suggest that self-report questionnaires should be combined with behavioral observations and biometric data collection to avoid these limitations (Althubaiti, 2016).

This study highlighted elevated anxiety levels experienced by students who do not have children. Therefore, future research endeavors could attempt to discover the reasons for this finding, essentially targeting the sources of such anxiety but also determining the ways in which students who are parents reduce their anxiety levels. In addition, the educational community would benefit from investigations of the effects of educational institutions on the anxiety, stress, or depression levels of students and how measures can be devised to combat such sources and their effects.

5. Conclusion

This study concluded that students who do not have children experience higher anxiety than those who do. No

other significant difference was found regarding the stress or depression values between those two groups.

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Conflict of interest

Paraskevi Theofilou is an Editorial Board Member of this journal and Guest Editor of this special issue, but was not in any way involved in the editorial and peer-review process conducted for this paper, directly or indirectly. Separately, other authors declared that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author contributions

Conceptualization: All authors
Formal analysis: All authors
Investigation: All authors
Methodology: All authors
Writing – original draft: All authors
Writing – review & editing: All authors

Ethics approval and consent to participate

Ethical approval was obtained by the committee of the SCG – Scientific College of Greece under number TER2021-129.

Consent for publication

Not applicable.

Availability of data

Data supporting these findings are available within the article or on request.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Association of teleworking with employee psychosocial characteristics and well-being: A descriptive study

Angelos Mylonas[1], Dimitris D. Vlastos[1,2], and Paraskevi Theofilou[2]*

[1]Department of Psychology, SCG - Scientific College of Greece, Athens, Greece

[2]Laboratory of Experimental and Applied Psychology, SCG – Scientific College of Greece, Athens, Greece

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Abstract

In recent years, teleworking (also referred to as telecommuting) has been the focus of academic research, due to its wide implementation during the COVID-19 pandemic and its significant implications, including psychosocial effects, job satisfaction, and social interactions among employees. Thus, this study employed a quantitative approach to examine these concepts and determine to what extent they have been changed by the implementation of teleworking in companies. Based on the findings, the most important aspect of teleworking was the need for social interactions. These three concepts also showed a statistically significant, but not a strong correlation. First, the women in the sample had higher psychosocial effects and a greater need for social interactions, compared to the men, whereas the younger participants had less psychosocial effects. Second, the participants aged 51 – 60 years had lower averages for job satisfaction, while the participants aged 41 – 50 years had lower averages for social interactions. Third, those who worked in companies consisting of 51 – 200 employees had significantly higher psychosocial effects, but significantly lower job satisfaction, compared to the rest of the sample. Finally, demographic and work characteristics played important roles in the assessment of the impact of teleworking on psychosocial effects, job satisfaction, and social interactions.

Keywords: Job satisfaction; Social interactions; Psychosocial effects; Teleworking

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***Corresponding author:**
Paraskevi Theofilou
(ptheofilou@scg.edu.gr)

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1. Introduction

In recent years, the COVID-19 pandemic and its restrictive measures have brought about the need to implement teleworking on a large scale. Teleworking (also referred to as telecommuting) involves performing work duties from a location other than a traditional office environment. This approach, often performed from home, mainly leverages digital technology for communication and collaboration. In this regard, the development of information and communication technologies has made remote work both possible and effective (Baard *et al.*, 2014).

Previous researchers have focused on the use of these technologies and their impact on productivity and communication patterns within teams (Allen *et al*., 2015; Neeley, 2015). This is because some data has shown that teleworking can increase productivity. For this reason, the need to promote this model or a hybrid model has increased. In a hybrid model, employees work some days of the week from home via teleworking and some days in their office. This particular model has been widely implemented since the pandemic.

Teleworking is often associated with greater flexibility in working hours and environments, potentially improving work-life balance (Grant *et al*., 2013).Previous studies have also explored how this flexibility affects employee satisfaction, stress levels, and overall well-being (Kossek *et al*., 2011, Choi, 2020), which can have positive or negative effects. In this regard, it has been reported that teleworking employees tend to work longer hours to complete tasks that they would normally complete more quickly in the office (Golden & Gajendran, 2019). Meanwhile, there is significant interest in understanding how teleworking can reduce carbon footprints through reduced use of commuting and office space (Gajendran & Harrison, 2007).

Researchers have also examined the broader organizational changes required to support effective teleworking (DeFilippis *et al*., 2020). For instance, some studies have suggested that remote work can lead to higher productivity, whereas others have revealed the potential challenges in maintaining engagement and motivation without a physical presence (Bloom *et al*., 2015; Golden & Veiga, 2005; Ozimek, 2020). Teleworking also raises questions about access to technology and opportunities, especially for underprivileged demographics. Moreover, related research has explored how teleworking can either mitigate or exacerbate existing inequities in the workplace (Erickson *et al*., 2020; Raghuram *et al*., 2002).

Although previous research has primarily focused on productivity and job satisfaction (as outcomes of teleworking), there is a lack of understanding in regard to the emotional and social effects of teleworking on employees. Thus, the main objective of the present study is to determine how teleworking is associated with the psychosocial effects of employees by examining how it affects their general well-being. The secondary objectives are as follows. First, it focuses on the social interactions, the sense of belonging, and personal satisfaction of employees during teleworking hours. Specifically, it determines how relationships between colleagues, intrafamily relationships, and the quality of work are related by considering important factors such as the balance of family and professional life. Second, it examines the sense of social cohesion and the potential isolation that can arise from teleworking. In this regard, it determines which methods of communication employees choose and how they affect the relationships between them. Third, it investigates in what way ergonomics and the appropriate/inappropriate workplace directly affect the lives of employees. Through these objectives and hypotheses, we aim to provide a more comprehensive understanding of teleworking and suggest practical directions for improving the working conditions and well-being of such workers.

Finally, the research questions are as follows. First, how do employees rate their social interactions, sense of belonging, and collaboration during teleworking hours? Second, what are the psychological and physical relations to the well-being of teleworking employees?

2. Methods

2.1. Research design

Quantitative research is systematic approach that primarily focuses on the numerical determination of data and applies statistical, mathematical, or computational techniques to understand what is observed. The collected data is based on quantifiable evidence, rather than subjective perceptions, which helps maintain the consistency and credibility of the survey and allows for replication (Mertens, 2014). In addition, due to its structured and controlled methodology, the results can often be generalized to larger populations. This is facilitated through the use of random sampling techniques, which reduces possible bias and increases the representativeness of the results (Bryman, 2012). Meanwhile, using statistical methods to analyze the data provides the ability to identify and predict trends and relationships, which is especially useful in fields that aim to establish correlations or determine causality (Creswell, 2014). Finally, quantitative research can simultaneously analyze the data from numerous subjects, making it an effective method when dealing with large datasets. Meanwhile, modern data analysis software enhances this efficiency by enabling the rapid processing and interpretation of the data (Creswell & Creswell, 2017). Therefore, in this quantitative research, the questionnaire used for data collection was structured to examine the psychosocial effects, job satisfaction, and social interactions of teleworking employees, after which the averages of their corresponding questions and statements were evaluated.

2.2. Sample

Participant selection and sample adequacy are important for ensuring the representativeness and breadth of the results. Thus, this study selected 103 participants from various companies and industries, such as technology,

healthcare, and finance, in order to fully understand the impact of teleworking on employees' well-being. Meanwhile, we focused on various age groups, the work experience of the employees, and gender, with the latter ensuring that the different perspectives of men and women are considered. The diversity of this sample allowed us to detect the different challenges or benefits that employees face, depending on their industry, as well as how teleworking affects different career stages.

To properly investigate the impact of teleworking, the survey included the participants working traditionally, remotely, and in a hybrid format. By considering all these factors, it ensured that the findings are applicable to a wide range of work settings. In order to obtain the consent of the company and the consent of the employees, we contacted (via telephone and email) the management and human resource departments of the companies in this study.

2.3. Ethics

To observe the code of ethics, the participants were informed about the nature of the research, its objectives, and their rights, after which we obtained their written consent. They were also provided with information about how the data was collected, used, and stored with strict confidentiality. Additionally, codes and numbers were used (instead of names) to protect their anonymity. Meanwhile, access to the data was limited to qualified personnel, ensuring the confidentiality of the information. The participants were also informed of their right to withdraw at any time without penalty. This research was submitted for review to the research ethics committee to ensure compliance with ethical rules and regulations. Finally, special attention was placed on the questions and procedures concerning psychosocial issues. This ensured that the participants were not under pressure to reveal any personal information that could affect their sensitivity to these issues.

2.4. Psychometric tools

The selection and use of materials and tools is an important aspect of research design, ensuring the proper execution of the study and the reliability of the results. Hence, the materials and tools in this study are as follows:

2.4.1. To construct the questionnaires

- The questionnaires were created through Microsoft forms that covered job satisfaction, social interactions, and other related variables.
- The questionnaires consisted of closed-type/Likert scale questions.
- The questionnaires were designed with clear and objective questions that allowed the comparative analysis of the data.
- The questionnaires were developed by considering relevant variables such as job satisfaction, social interactions, emotional well-being, and the impact of teleworking.
- The questions and objectives were clarified in order to collect accurate data.
- The following questionnaires were used: the Job Satisfaction Questionnaire and the Organizational Climate Description Questionnaire.
- The Psychosocial Safety Questionnaire was also used to measure the psychosocial factors that influence well-being such as support from colleagues and supervisors.
- Various tools were used to measure mental and physical well-being such as the Subjective Well-Being Questionnaire.

2.4.2. For statistical processing

- A specialized JAMOVI software tool was used that allowed the statistical analysis of the data.
- Microsoft Excel was used to create easy-to-read analyses.

2.4.3. To analyze the data

- Since the sample consisted of more than 100 people, parametric tests were performed to draw latent variable conclusions, as suggested by Field (2013).
- At-test and an analysis of variance (ANOVA) were used to assess the differences between the groups and draw conclusions.
- Descriptive statistics were provided via minimum (MIN), maximum (MAX), mean (M), and standard deviation (SD), while the correlations between the key variables were obtained via the JAMOVI software tool.
- Cronbach's alpha test results were obtained.

2.4.4. Regarding the consent to participate

- Consent forms were created for the participants, thus protecting their rights and privacy
- Additional forms were created to provide information about the study and encourage participation
- We ensured that the responses remained anonymous by using anonymous data connections
- Finally, collaboration was conducted with specialized personnel, such as psychologists or researchers, to assist in the execution of the study and the evaluation of the results.

3. Results

First, the demographic characteristics of the sample were analyzed. In terms of gender, 38.8% were men and 61.2%

were women. As for their marital status, 52.4% were single, 17.5% were married, 5.8% were divorced, and 24.3% were in a relationship. Regarding children in the family, 76.7% stated that they did not have children, while10% had one child, 10% had two children, and 4% had three or more children. Based on the educational level of the sample, 21.4% were high school graduates, 27.2% were college graduates, and 51.5% had postgraduate degrees. Regarding their fields of work, the largest segment (49.5%) selected "another industry," while17.4%workedin the financial and insurance sector, 12% worked in telecommunications, information technologies, and other information services, 10% worked in marketing, and 10% worked in pharmaceutical and parapharmaceutical products. As for the number of employees, 10% worked in companies with 0 – 10 employees, 10% worked in companies with 11 – 50 employees, 41% worked in companies with 51 – 200 employees, 17.5% worked in companies with 201 – 500 employees, and 22.3% worked in companies with more than 200 employees. Regarding the positions of the participants, 63% were employees, 21.5% were middle managers, and 15.5% were senior-top executives. In relation to work experience, 5.8% had 0 – 3 years of experience, 5.8% had 3 – 5 years of experience, 45.6% had 5 – 10 years of experience, and 42.7% had more than 10 years of experience. As for the employment contract, 76.7% had an open-ended contract, while 23.3% had a fixed-term contract. Finally, in regard to working remotely, 50.5% worked 2 days a week, 23.3% worked 3 days a week, 11.7% worked 4 days a week, 9.7% worked 5 days a week, and 5% did not work remotely.

Second, the sample was asked about their views on teleworking. The largest segment (51%) stated that "I do not feel a clear impact on my professional development, due to teleworking," while 24.5% stated that "Teleworking positively contributes to my professional development, providing opportunities for learning and development." Then, the sample was asked if they had noticed any changes in their performance and job satisfaction since they began teleworking. In this regard, 50% answered "No, I have not noticed any significant changes in my performance or satisfaction." Next, the sample was asked to describe the social support they received from colleagues while teleworking. The largest segment (49%) responded that "I receive some social support from colleagues, but not always or not to a high degree" and 26.5% responded that "I experience limited social support from my colleagues during teleworking." Regarding satisfaction in particular, the sample was asked "How would you characterize your overall satisfaction with work combined with your personal activities while teleworking?" The largest segment (80%) answered "satisfied."

Finally, the sample was asked about several items related to employee well-being. First, they were asked about their perceptions of work-life balance during teleworking. The largest segment (80%) answered that "I have a good balance, but there is always room for improvement." They were also asked if the overall well-being of workers has changed because of the work, after which the largest segment (65%) answered that it "Depends on the circumstances." This indicates that there is no consensus among the employees. Finally, the sample was asked about how they perceived social cohesion in relation to the workplace. In this case, the majority (61%) responded that "Social cohesion in the workplace is satisfactory, but could be improved with more social activities."

Table 1 presents the MIN, MAX, M, and SD of the main variables in this study. Based on the findings, the Social Interactions dimension showed the highest average (3.54), whereas the Psychosocial Impact variable showed the lowest average (3.15).

As shown in Table 2, which shows the reliability of the three main variables in this study, they have acceptable Cronbach's alpha values. This indicates that the data has good internal consistency and reliability.

According to Table 3, the correlations between all three variables are statistically significant at the $p < 0.01$ level:

- The correlation between Psychosocial Effects and Job Satisfaction is $r(103) = 0.373$, $p < 0.01$.
- The correlation between Psychosocial Effects and Social Interactions is $r(103) = 0.469$, $p < 0.01$.
- The correlation between Job Satisfaction and Social Interactions is $r(103) = 0.471$, $p < 0.01$.

3.1. Statistically significant differences

In this study, a t-test and an ANOVA were used to examine the statistically significant differences, since it was assumed

Table 1. Means of the key variables

Variables	Min	Max	M	SD
Psychosocial impact	2.17	4.07	3.1558	0.387
Job satisfaction	2.50	4.25	3.2980	0.539
Social interactions	1.40	4.00	3.5480	0.604

Abbreviation: SD: Standard deviation.

Table 2. Data reliability

Variables	Items	Alpha
Psychosocial impact	4	0.623
Job satisfaction	27	0.892
Social interactions	5	0.812

that we have normal distributions in the main variables and do not need to conduct non-parametric tests. The first check concerned statistical differentiation by gender. In two out of the three cases, statistically significant differences were found. Specifically, the women had higher psychosocial effects and a greater need for social interactions, compared to the men. This indicates that gender is an important factor when estimating the main variables. The results are presented in Table 4.

The second check concerned the statistical differentiation in terms of age. In all cases, statistically significant differences were found. Specifically, the participants aged 51 – 60 years had lower averages for job satisfaction and participants aged 41 – 50 years had lower averages for social interactions. This indicates that age is an important predictor of the effects of teleworking. The results are presented in Table 5.

The third check concerned the statistical differentiation in terms of marital status. In one of the three cases, a statistically significant difference was found. Specifically, the divorced segment in the sample had significantly higher job satisfaction, compared to the rest of the sample. This indicates that marital status is an important factor when assessing the effect of teleworking on job satisfaction. The results are presented in Table 6.

The fourth check concerned the statistical differentiation in terms of the number of children within the family. In two out of the three cases, statistically significant differences were found. Specifically, those with two children had significantly higher job satisfaction, whereas those with one child had significantly lower social interactions, compared to the rest of the sample. The results are presented in Table 7.

The fifth check concerned the statistical differentiation in terms of educational level. In one of the three cases, a statistically significant difference was found. Specifically,

Table 3. Correlations of the variables

	Psychosocial impact	Job satisfaction	Social interactions
Psychosocial impact	1.000	0.373**	0.469**
Job satisfaction		1.000	0.471**
Social interactions			1.000

Note: **p<0.01.

Table 4. Significant gender differences

	Gender	N	M	SD	p-value
Psychosocial impact	Male	40	3.0000	0.48371	<0.001
	Female	59	3.5000	0.48021	
Job satisfaction	Male	40	3.4900	0.57459	0.218
	Female	60	3.5867	0.62476	
Social interactions	Male	40	3.0704	0.19595	0.029
	Female	61	3.1979	0.45681	

Abbreviation: SD: Standard deviation.

Table 5. Significant age differences

	N	M	SD	p-value
Psychosocial impact	18 – 30	8	2.7188	0.001
	31 – 40	53	3.0943	
	41 – 50	22	3.7386	
	51 – 60	10	3.9000	
	61+	6	3.2500	
	Total	99	3.2980	
Job satisfaction	18 – 30	9	3.4667	0.002
	31 – 40	53	3.5245	
	41 – 50	22	3.8364	
	51 – 60	10	2.9600	
	61+	6	3.8000	
	Total	100	3.5480	
Social interactions	18 – 30	11	3.0808	0.005
	31 – 40	53	3.0692	
	41 – 50	22	3.3990	
	51 – 60	10	3.2815	
	61+	6	2.9568	
	Total	102	3.1558	

Abbreviation: SD: Standard deviation.

Table 6. Significant differences in marital status

	N	M	SD	p-value
Psychosocial impact				
Single	54	3.3935	0.55287	0.56
Married	14	3.3929	0.32097	
Divorced	6	3.2500	0.00000	
In a relationship	25	3.0500	0.60381	
Job satisfaction				
Single	54	3.7148	0.31944	0.001
Married	15	3.0533	1.04599	
Divorced	6	3.8000	0.00000	
In a relationship	25	3.4240	0.62801	
Social interactions				
Single	54	3.2291	0.37163	0.192
Married	17	3.0839	0.40930	
Divorced	6	2.9568	0.01512	
In a relationship	25	3.0941	0.42907	

Abbreviation: SD: Standard deviation.

university and college graduates had a significantly lower assessment of the psychosocial effects of the pandemic, compared to the rest of the sample. This indicates that educational background is a significant differentiating factor when assessing the psychosocial effects of teleworking. The results are presented in Table 8.

The sixth check concerned the statistical differentiation in terms of company size. In two out of the three cases, statistically significant differences were found. Specifically, those who worked in companies with 51 – 200 employees had significantly higher psychosocial effects and significantly lower job satisfaction, compared with the rest of the sample. The results are presented in Table 9.

The seventh check concerned the statistical differentiation in terms of job position. In two out of the three cases, statistically significant differences were found. Specifically, the employees of the sample (i.e., the lower level in the hierarchy) had the highest social interactions, while the middle managers had the lowest job satisfaction. The results are presented in Table 10.

The eighth check concerned the statistical differentiation in terms of work experience, in which a statistically significant difference was found in only one case. Specifically, those with more than 10 years of experience had a significantly higher assessment of the psychosocial effects of the pandemic. The results are presented in Table 11.

The final check concerned the statistical differentiation in terms of the employment contract of the sample. In two out of the three cases, statistically significant differences were found. In particular, the employees with an open-ended employment contract had the highest assessment of psychosocial effects and lower job satisfaction, compared with the fixed-term employees. The results are presented in Table 12.

Table 7. Significant differences in the number of children

	N	M	SD	*p*-value
Psychosocial impact				
0	75	3.2600	0.58042	0.206
1	10	3.5500	0.42164	
2	10	3.4500	0.25820	
3+	4	3.0000	0.00000	
Job satisfaction				
0	76	3.6105	0.46176	0.001
1	10	3.8400	0.08433	
2	10	2.8400	1.23935	
3+	4	3.4000	0.00000	
Social interactions				
0	78	3.1804	0.38086	0.001
1	10	3.4296	0.37819	
2	10	2.8111	0.18841	
3+	4	2.8519	0.00000	

Abbreviation: SD: Standard deviation.

Table 8. Significant differences in educational background

	N	M	SD	*p*-value
Psychosocial impact				
High school graduate	22	3.3409	0.60032	0.003
University/College graduate	28	3.0179	0.37223	
Master's degree	49	3.4388	0.53893	
Job satisfaction				
High school graduate	22	3.4182	0.97767	0.318
University/College graduate	28	3.4929	0.32424	
Master's degree	50	3.6360	0.50255	
Social interactions				
High school graduate	22	3.1465	0.41234	0.511
University/College graduate	28	3.0899	0.20146	
Master's degree	52	3.1952	0.44853	

Abbreviation: SD: Standard deviation.

Table 9. Significant differences in company size

	N	M	SD.	*p*-value
Psychosocial impact				
0 – 10	10	3.3000	0.38730	0.037
11 – 50	10	3.3500	0.33747	
51 – 200	42	3.4583	0.61959	
201 – 500	18	3.0000	0.42008	
500+	19	3.1974	0.49707	
Job satisfaction				
0 – 10	10	2.3600	0.82624	0.001
11 – 50	10	3.6600	0.23190	
51 – 200	42	3.8000	0.21640	
201 – 500	18	3.8000	0.00000	
500+	20	3.3300	0.67207	
Social interactions				
0 – 10	10	3.0370	0.38252	0.627
11 – 50	10	3.1185	0.22951	
51 – 200	42	3.2222	0.47062	
201 – 500	18	3.1481	0.17325	
500+	22	3.1061	0.39956	

Abbreviation: SD: Standard deviation.

Table 10. Significant differences in job position

	N	M	SD	*p*-value
Psychosocial impact				
Senior-top executive	61	3.3074	0.55037	0.248
Middle manager	22	3.1591	0.43333	
Employee	16	3.4531	0.60703	
Job satisfaction				
Senior-top executive	62	3.7677	0.21787	0.001
Middle manager	22	2.9818	0.97767	
Employee	16	3.4750	0.44944	
Social interactions				
Senior-top executive	64	3.1319	0.33504	0.001
Middle manager	22	2.9899	0.31659	
Employee	16	3.4792	0.49255	

Abbreviation: SD: Standard deviation.

Table 11. Significant differences in work experience

	N	M	SD	*p*-value
Psychosocial impact				
0 – 3	6	2.5000	0.00000	0.001
3 – 5	6	2.5000	0.00000	
5 – 10	43	3.2733	0.42543	
>10	44	3.5398	0.49692	
Job satisfaction				
0 – 3	6	3.8000	0.00000	0.679
3 – 5	6	3.4000	0.00000	
5 – 10	44	3.5636	0.50167	
>10	44	3.5182	0.75860	
Social interactions				
0 – 3	6	3.1111	0.00000	0.138
3 – 5	6	2.9259	0.00000	
5 – 10	46	3.1039	0.35218	
>10	44	3.2475	0.45049	

Abbreviation: SD: Standard deviation.

4. Discussion

This study was carried out to identify the impact of teleworking on employees, which was widely established after the COVID-19 pandemic. Since teleworking is a multi-faceted and multi-dimensional phenomenon that affects humans in different ways, we mainly focused on three variables: psychosocial effects, job satisfaction, and social interactions. As suggested by Field, (2013), parametric tests were performed to draw latent variable inferences, since the sample consisted of more than 100 people.

Table 12. Significant differences in the employment contract

What employment contract do you have?	N	M	SD	*p*-value
Psychosocial impact				
Open-ended	75	3.3933	0.53299	0.001
Fixed-term	24	3.0000	0.44843	
Job satisfaction				
Open-ended	76	3.4500	0.66222	0.001
Fixed-term	24	3.8583	0.09286	
Social interactions				
Open-ended	78	3.1667	0.43715	0.401
Fixed-term	24	3.1204	0.12795	

Abbreviation: SD: Standard deviation.

Based on the findings, the majority of the sample did not feel that teleworking had a catalytic effect on them. Meanwhile, none of these variables dramatically changed during the research period. Specifically, the sample was generally satisfied with teleworking and that they had a good work-life balance (Morganson *et al.*, 2010).However, all the questions showed that there is room for continuous improvement.

These variables were also significantly and positively related. For example, teleworking had negative psychosocial effects, which resulted in a decrease in social interactions among the employees and a decrease in job satisfaction, and vice versa (Morris & Venkatesh, 2010). In fact, the results showed that the need for social interactions was the most important aspect of teleworking. Moreover, all the demographic characteristics (gender, age, marital status, and educational level) had a significant effect on the estimation of the main variables, as an impact of teleworking. Meanwhile, all the variables regarding employment (company size, job position, work experience, and employment contract) showed that the impact of teleworking was estimated differently by these sub-groups. This indicates that in order to improve this impact, more focus should be placed on these demographic groups and sub-groups as well as the specific characteristics of their respective companies and industries.

5. Conclusion

The results of this study showed that the most important aspect of teleworking is the need for social interactions. The three variables (i.e., psychosocial effects, job satisfaction, and social interactions) also showed a statistically significant, but not a strong correlation. First, the women in the sample had higher psychosocial effects and a greater need for social interactions, compared to the men, whereas

the younger participants had less psychosocial effects. Second, the participants aged 51 – 60 years had lower averages for job satisfaction, while the participants aged 41 – 50 years had lower averages for social interactions. Third, those who worked in companies with 51 – 200 employees had significantly higher psychosocial effects and significantly lower job satisfaction, compared to the rest of the sample. Finally, demographic and work characteristics played an important role in the assessment of the impact of teleworking on the psychosocial effects, job satisfaction, and social interactions of the employees.

However, there is one limitation of this study that should be noted. Specifically, this study only focused on a relatively small sample of employees and variables. Thus, additional variables and tests (e.g., ad hoc tests) should be conducted to elucidate the differences in the categories as well as generalize the results. Future research should also include remedial interventions to increase employees' job satisfaction and provide more social interactions during their teleworking hours.

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Conflict of interest

Paraskevi Theofilou is the Editorial Board Member of this journal and Guest Editor of this special issue, but was not in any way involved in the editorial and peer-review process conducted for this paper, directly or indirectly. Separately, other authors declared that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author contributions

Conceptualization: All authors
Formal analysis: All authors
Investigation: All authors
Methodology: All authors
Writing–original draft: All authors
Writing–review & editing: All authors

Ethics approval and consent to participate

Ethical approval was obtained by the committee of the SCG - Scientific College of Greece (TER2024-306).

Consent for publication

Not applicable.

Availability of data

Data supporting these findings are available within the article or on request.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Hospitalizations, deaths, and health costs for diabetes mellitus and obesity in Acre, Brazil: A retrospective time-series study (2000 – 2021)

Jorgimar Peres Ferreira[1,2], Mauro José de Deus Morais[1,2]*, Francisco Naildo Cardoso Leitão[1,2], Thaiany Pedrozo Campos Antunes[3], Douglas Silva de Oliveira[1,2], Luiz Carlos de Abreu[3], and Romeu Paulo Martins Silva[4]

[1]Center for Health Sciences and Sports, Federal University of Acre, Rio Branco, Acre, Brazil

[2]Multidisciplinary Laboratory of Studies and Scientific Writing in Health Sciences - LaMEECCS, Center for Health Sciences and Sports, Federal University of Acre, Rio Branco, Acre, Brazil

[3]Laboratory of Scientific Writing, School of Sciences of Santa Casa de Misericórdia (EMESCAM), Vitória/Espírito Santo, Brazil

[4]Special Academic Biotechnology Unit, Federal University of Goiás, Catalão, Goiás, Brazil

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Mihajlo Jakovljevic M.D. Ph.D. MAE

***Corresponding author:**
Mauro José de deus Morais
(mauro.morais@ufac.br)

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Abstract

Introduction: Obesity and type 2 diabetes mellitus (T2DM) are among the most significant public health challenges worldwide, with profound effects on morbidity, mortality rates, and healthcare costs. **Objective:** The aim of this study is to evaluate the trends in deaths, hospitalizations, and hospital costs associated with T2DM and obesity in Acre, Brazil, from 2000 to 2021. **Method:** This retrospective time-series study utilized official microdata from the Mortality Information System, the Hospital Information System (SIH/SUS), and the Information System for Notifiable Diseases, all registered with the Ministry of Health through the SUS Department of Informatics. Data were extracted for T2DM cases between 2000 and 2021, and for obesity cases from 2013 to 2021, focusing on age, sex, and race/skin color, as well as death rates, hospitalizations, hospital costs, and municipality-level variations. **Results:** Our findings reveal a significant increase in T2DM-related deaths over the study period, accompanied by rising hospital costs. A higher prevalence of T2DM-related mortality was observed among older age groups, with a roughly equal distribution between men and women. For obesity, hospitalizations were more frequent after the age of 30, particularly among women. In addition, a strong correlation was found between deaths from T2DM and hospitalizations due to obesity, suggesting that many T2DM-related deaths occurred among individuals also hospitalized for obesity, a condition that often involves multiple comorbidities.

Keywords: Deaths; Hospitalization; Diabetes; Obesity

1. Introduction

Obesity and type 2 diabetes mellitus (T2DM) are among the most significant global public health challenges, with considerable impacts on morbidity, mortality, and healthcare costs (Whiting *et al.*, 2011; Wild *et al.*, 2004). These diseases are classified as

non-communicable chronic diseases (NCDs) due to their multifactorial origins and long latency periods. They are often interrelated and share common risk factors, such as physical inactivity, poor diets, and unhealthy lifestyles (Hu, 2011). Ng *et al.* (2013) highlight that the global rise in obesity, driven by a combination of economic, social, and cultural factors has contributed to the increasing prevalence of T2DM across all age groups. The close relationship between these two conditions creates a dual burden for healthcare systems, particularly in developing countries, where effective prevention and treatment remain limited (Malik *et al.*, 2013).

The need to understand the trends in mortality and hospitalization rates related to T2DM and obesity is pressing, as these conditions are known to lead to a range of health complications, including cardiovascular, renal, and neurological diseases (Grant *et al.*, 2012). In Brazil, the economic burden of these comorbidities has become a critical concern. According to data from the Unified Health System (SUS), the rising number of hospitalizations due to complications due to T2DM and obesity-related complications results in escalating hospital costs, straining public health resources that are already facing budgetary and structural challenges (Ministry of Health, 2020). Therefore, examining trends in mortality, hospitalizations, and associated costs can provide valuable insights for the development of more effective public health policies.

The decision to focus on Brazil is further supported by the increasing prevalence of obesity and T2DM in the country, which currently affects more than 25% of the adult population (IBGE, 2022). These statistics reflect significant lifestyle changes among the Brazilian population over recent decades, driven by rapid urbanization and the increased consumption of ultra-processed foods (Monteiro *et al.*, 2004). Given the complexity and socioeconomic impacts of these conditions, understanding the growth patterns of these diseases and the factors influencing the sustainability of the healthcare system, particularly in preventive and primary care settings, is crucial (Conde *et al.*, 2022).

Based on these considerations, the primary objective of this study is to assess the trends in deaths, hospitalizations, and hospital costs associated with T2DM and obesity in Acre, Brazil, from 2000 to 2021.

2. Method

2.1. Study design

This study is classified as an ecological, retrospective time-series analysis using official microdata from the Mortality Information System (SIM), the Hospital Information System (SIH/SUS), and the Notifiable Diseases Information System (SINAN), all of which are registered with the Ministry of Health and accessible through the SUS Department of Informatics (DATASUS). Data were extracted for cases reported between 2000 and 2021 for T2DM and from 2013 to 2021 for obesity, capturing 100% of the official database for individuals aged 18 and over. The variables analyzed include age, sex, and race/skin color (Court of Justice of the Federal District and Territories, 2023). These data were linked to deaths, hospitalizations, hospital costs, and municipal-level information in the state of Acre, Brazil.

2.2. Data analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 20.0. Descriptive statistics were performed for all variables. Results are presented as mean ± standard deviation or median (interquartile range), along with minimum and maximum values where appropriate. Spearman and non-parametric Pearson correlations were used to compare initial and final values within each group. Statistical significance was set at $p \leq 0.05$ and $p \leq 0.01$ for both analyses.

For this study, which focuses on NCDs, T2DM and obesity were the main variables of interest. The analysis of obesity-related hospitalizations was limited to the period from 2013 to 2021 due to the availability of data from DATASUS starting in 2013. Thus, when correlating both variables, the same time period (2013 – 2021) was used.

2.3. Ethical aspects

This study did not require submission to an institutional Research Ethics Committee, as it utilized secondary data from publicly available databases, specifically the SIM and the SIH/SUS of the DATASUS.

3. Results

Table 1 presents the highest hospitalization costs due to T2DM in the municipalities of Rio Branco, followed by Cruzeiro do Sul and Sena Madureira, which had the highest expenditures on hospitalizations from 2000 to 2021. Regarding age groups, the 60 – 69 age group had the highest number of hospitalizations and, consequently, the highest costs, followed by the 50 – 59 age group. The 70 – 79 age group also showed significant hospitalization costs related to T2DM, though slightly lower than those of the 50 – 59 age group.

Table 2 shows the deaths from T2DM recorded between 2000 and 2021, categorized by age group, race/skin color, and sex. The highest number of deaths was observed in the 70 – 79 age group, followed by those aged 80 and above. In terms of race/skin color, a higher percentage of deaths were recorded for individuals with missing race/skin color information, followed by those identified as mixed race,

Table 1. Descriptive statistics for diabetes-related hospital costs by the municipality, hospitalizations by the municipality, and hospital costs by age group (2000 – 2021)

Municipality	Cost by municipality		Hospitalization by municipality		Cost by age group		
	Sum	Mean	Sum	Mean	Age group	Sum	Mean
Acrelândia	12,625	573.87	91	4.14	<1 y	48,133.17	2,187.87
Assis.Brasil	9,097	413.51	59	2.68	1 – 4 y	39,019.04	1,773.59
Brasiléia	180,911	8,223.22	403	18.32	5 – 9 y	42,653.00	1,938.77
Bujari	0	0.00	47	2.14	10 – 14 y	81,855.22	3,720.69
Capixaba	0	0.00	72	3.27	15 – 19 y	113,254.95	5,147.95
Cruzeiro.do.Sul	700,905[a]	31,859.33[a]	1,106[a]	50.27	20 – 29 y	216,099.43	9,822.70
Epitaciolândia	0	0.00	283	12.86	30 – 39 y	415,092.97	18,867.86
Feijó	9,433	428.77	99	4.50	40 – 49 y	559,399.98	25,427.27
Jordão	0	0.00	3	0.14	50 – 59 y	1,057,117.06[a]	48,050.78
Mâncio.Lima	40,025	1,819.33	200	9.09	60 – 69 y	1,105,697.40[a]	50,258.97
Manoel.Urbano	3,922	178.29	33	1.50	70 – 79 y	1,007,709.26[a]	45,804.97
Marechal.Thaumaturgo	1,677	76.21	60	2.73	>80 y	494,399.56	22,472.71
Plácido.de.Castro	44,327	2,014.85	182	8.27			
Porto.Acre	0	0.00	95	4.32			
Porto.Walter	815	37.05	36	1.64			
Rio.Branco	3,742,669[a]	170,121.32	4,668[a]	212.18			
Rodrigues.Alves	10,519	478.15	110	5.00			
Santa.Rosa.do.Purus	2,245	102.04	6	0.27			
Sena.Madureira	242,026[a]	11,001.16	760[a]	34.55			
Senador.Guiomard	43,646	1,983.92	227	10.32			
Tarauacá	44,521	2,023.69	234	10.64			
Xapuri	86,959	3,952.70	285	12.95			

Notes: [a]refers to the trend of hospitalizations and hospital costs due to diabetes from 2000 to 2021. When categorized by age group and municipalities, an increase was observed starting from the 40 – 49 age group, intensifying in the 70 – 79 age group when compared to other age groups. The municipality leading the trend was Rio Branco, followed by Cruzeiro do Sul and Sena Madureira. The data provided by the SUS Department of Bioinformatics system refers to the amount (Brazilian real) associated with the Hospitalization Authorization (AIH) approved during the period. This amount does not necessarily reflect the amount transferred to the establishment, as units may receive budgetary resources or face withholdings and payments. In addition, incentive payments and other budgetary resources not presented here may apply. Therefore, this value should be considered as the approved production value.
Abbreviation: y: Years.

who also exhibited significant numbers compared to other groups. In the sex category, the difference between males and females was minimal, with both sexes showing very similar figures.

Figure 1 illustrates the trend in deaths from T2DM from 2000 to 2021, categorized by age group. It is evident that the groups from 1 to 4 years up to 10 – 14 years remained stable with no significant changes. From the 15 – 19 age group onward, there was a slight increase, followed by a more pronounced rise in the 40 – 49 age group, reaching a sharp increase in the 70 – 79 age group compared to the other groups. A decrease in deaths was also observed in the 80 and older age group.

Figure 2 shows the trend in deaths from T2DM by sex, confirming that there were no significant differences between males and females. This observation suggests that death rates for both sexes remained closely aligned over the years.

Table 3 correlates T2DM-related deaths with age group, sex, and race/skin color variables. It shows that deaths in the 10 to 14 age group were predominantly among females, indicating a higher prevalence of T2DM-related deaths in women within this group. In addition, a correlation was found between deaths in the 20 – 29 and 80 and above age groups with the Indigenous race/skin color category, both occurring predominantly in females. Deaths in the

Table 2. Descriptive statistics of deaths from diabetes by age group, sex, and race/color from 2013 to 2021

Death by group	Minimum	Maximum	Sum	Average
<1 y	0	1	4	0.18
1 – 4 y	0	0	0	0.00
5 – 9 y	0	0	0	0.00
10 – 14 y	0	1	1	0.05
15 – 19 y	0	1	5	0.23
20 – 29 y	0	3	9	0.41
30 – 39 y	0	3	18	0.82
40 – 49 y	0	5	33	1.50
50 – 59 y	0	11	90	4.09
60 – 69 y	2	12	130	5.91
70 – 79 y	0	12	162[a]	7.36
>80 y	1	11	133[a]	6.05
Male	5	25	295	13.41
Female	5	26	290	13.18
White	0	3	9	0.41
Black	0	2	3	0.14
Brown	0	22	181[a]	8.23
Yellow/Asian	0	10	18	0.82
Aboriginal	0	1	1	0.05
Not informed	0	27	210[a]	9.55

Note: [a]highlights the largest cases found in the study: the 70 – 79 age group, individuals of mixed-race (parda), and those aged 80 and above, followed by cases in which race/color was unreported. This lack of identification occurred when providing data for hospitalizations between 2013 and 2021.
Abbreviation: y: Years.

30 – 39 age group showed correlations with Black, Mixed, and White race/skin color categories.

Figure 3 illustrates the trend in deaths from T2DM over the study period. It shows that 2015 had the highest number of deaths among the years observed.

Table 4 presents data on obesity-related hospitalizations from 2013 to 2021, categorized by age group, sex, and race. In terms of age group, individuals aged 40 to 49 had the highest hospitalization rates, followed by those aged 30 to 39. Regarding sex, females accounted for a higher prevalence of obesity-related hospitalization, with a total of 226 cases during the observed period. Concerning race, individuals identified as mixed race had the highest prevalence of obesity, with a total of 247 cases.

Table 5 shows the total hospital costs related to obesity, categorized by age group and sex. The data reveal a correlation between total hospital costs and the age groups of 30 – 39 and 40 – 49 years. Obesity hospitalization costs

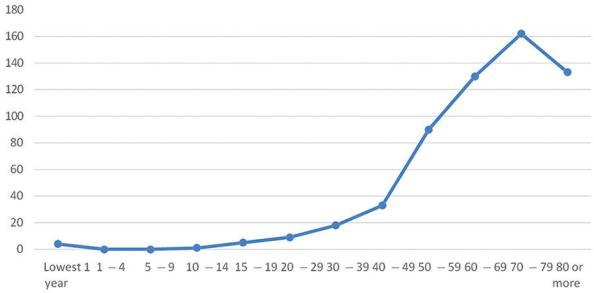

Figure 1. Death from diabetes by age group (2000 – 2021). The Y-axis represents the number of deaths, and the X-axis represents age groups.

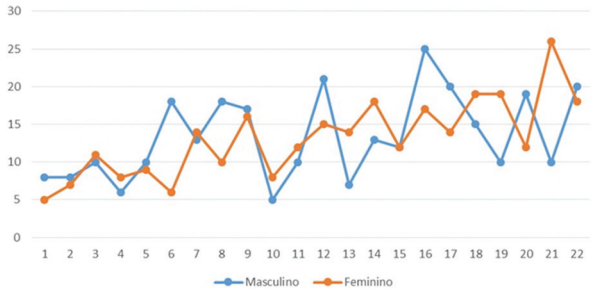

Figure 2. Death from diabetes by sex (2000 – 2021). The Y-axis represents variation in peaks of deaths due to diabetes, and the X-axis represents the evolution over the time series between the male and female sexes.

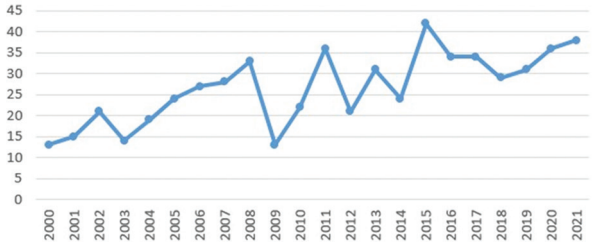

Figure 3. Death from diabetes in Acre, Brazil (2000 – 2021)
Source: The authors. The Y-axis represents the number of diabetes-related deaths, and the X-axis represents the years of observation.

in the 30 – 39 and 40 – 49 age groups were significantly correlated with total hospitalization costs in the 40 – 49 age group. For females, the total hospital costs were correlated with obesity hospitalization costs in both the 30 – 39 and 40 – 49 age groups. The temporal scope for the analysis of obesity hospitalizations is limited to 2013 – 2021, as data from the DATASUS system are only available from this period onward.

Table 6 presents the correlation between obesity hospitalizations and T2DM deaths from 2013 to 2021, categorized by age group, sex, and race/skin color. According to Pearson's correlation, T2DM deaths in the 30 to 39 age group were correlated with obesity

Table 3. Correlation of deaths from diabetes with age group, sex, and race

Death by age group	Male	Female	White	Black	Brown	Asian	Aboriginal	Not informed
<1 y	0.234	−0.335	−0.254	0.149	−0.153	0.069	−0.103	−0.038
1 – 4 y	-	-	-	-	-	-	-	-
5 – 9 y	-	-	-	-	-	-	-	-
10 – 14 y	0.139	0.049*	0.301	0.380	0.133	0.325	0.417	0.134
15 – 19 y	0.440	0.234	0.094	0.223	0.279	0.127	0.300	0.438
20 – 29 y	0.353	0.126	0.442	0.148	0.106	0.112	0.019*	0.081
30 – 39 y	0.114	0.086	0.000**	0.007**	0.025*	0.167	0.052	0.302
40 – 49 y	0.060	0.074	0.297	0.299	0.065	0.340	0.085	0.012*
50 – 59 y	0.000**	0.019*	0.228	0.317	0.055	0.172	0.197	0.015*
60 – 69 y	0.000**	0.005**	0.138	0.051	0.015*	0.059	0.244	0.012*
70 – 79 y	0.001**	0.003**	0.221	0.116	0.005**	0.131	0.157	0.060
>80 y	0.250	0.014*	0.278	0.458	0.203	0.387	0.047*	0.106

Notes: Spearman correlation test performed by the authors. *Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level.
Abbreviation: y: Years.

Table 4. Descriptive statistics of obesity-related hospitalizations by age group, sex, and race from 2013 to 2021

Hospitalization by group	Sum	Mean	Standard deviation	Variance
15 – 19 years old and obese	6	0.67	1.118	1.250
20 – 29 years old and obese	46	5.11	3.621	13.111
30 – 39 years old and obese	84	9.33	6.727	45.250
40 – 49 years old and obese	96	10.67	8.382	70.250
50 – 59 years old and obese	29	3.22	2.279	5.194
60 – 69 years old and obese	6	0.67	0.866	0.750
70 – 79 years old and obese	0	0.00	0.000	0.000
>80 years old and obese	1	0.11	0.333	0.111
Male and obese	42	4.67	5.477	30.000
Female and obese	226	25.11	16.458	270.861
White and obese	5	0.56	0.882	0.778
Black and obese	0	0.00	0.000	0.000
Brown and obese	247	27.44	21.007	441.278
Asian and obese	4	0.44	0.882	0.778
Aboriginal and obese	0	0.00	0.000	0.000
Not informed and obese	12	1.33	1.658	2.750

hospitalizations among individuals of Yellow race/skin color. In addition, a correlation was observed between male T2DM deaths and male obesity hospitalizations, suggesting that individuals who died from T2DM were likely hospitalized due to obesity. A similar correlation was found between the Yellow race/skin color in both T2DM deaths and obesity hospitalizations. Individuals of Black race/skin color also showed correlations with the Yellow race/skin color in obesity hospitalizations.

Notably, individuals with missing race/skin color information (underreporting) showed correlations with both male and female individuals, as well as with individuals of Mixed and Yellow race/skin color in obesity hospitalizations.

4. Discussion

Among the key findings of our study, as shown in Table 6, is the significant correlation between deaths from T2DM and hospitalizations due to obesity. This finding suggests that many deaths attributed to T2DM may be indirectly linked to obesity, even if obesity is not directly listed as the cause of death. Another notable finding is the highest prevalence of T2DM-related deaths in the 70 – 79 age group. In addition, the distribution of deaths between men and women was similar. We also observed that hospital costs related to both T2DM- and obesity-related hospitalizations were significantly high during the study period.

Hospital costs were particularly elevated in the age groups of 50 – 59, 60 – 69, and 70 – 79, based on average costs from 2000 to 2021. The increasing prevalence of obesity in the Brazilian population poses severe implications for both public health and the economy (Beaglehole & Horton, 2010). Previous studies have estimated that, in 2018, the total costs of hypertension, T2DM, and obesity to the SUS amounted to approximately 3.45 billion Brazilian Real, with 30% allocated to T2DM treatment and 11% to obesity (Costa *et al*., 2017). Therefore, the prevalence of NCDs associated with obesity presents a significant burden on the public health system in

Table 5. Spearman correlations between total hospital cost and obesity-related hospital service costs by age group and sex from 2013 to 2021

Obesity hospitalization costs	Total hospital costs								
	15 – 19 y	20 – 29 y	30 – 39 y	40 – 49 y	50 – 59 y	60 – 69 y	>80 y	Male	Female
15 – 19 y	0.000**	0.538	0.332	0.218	0.332	1.000	0.058	0.147	0.218
20 – 29 y	0.538	0.000	0.099	0.125	0.798	0.539	0.127	0.013*	0.187
30 – 39 y	0.332	0.050		0.002	0.265	0.673	0.127	0.036*	0.00**
40 – 49 y	0.130	0.154	0.042*	0.00**	0.058	0.388	0.127	0.004	0.025
50 – 59 y	0.332	0.831	0.265	0.187	0.00**	0.143	0.272	0.356	0.112
60 – 69 y	1.000	0.507	0.673	0.604	0.143	0.00**	0.433	0.779	0.360
>80 y	0.058	0.127	0.127	0.127	0.272	0.433	0.00**	0.127	0.127
Male	0.147	0.007**	0.036*	0.002**	0.356	0.779	0.127	0.00**	0.050*
Female	0.218	0.125	0.00**	0.004**	0.112	0.360	0.127	0.050*	0.00**

Notes: Non-parametric Spearman correlation performed by the authors. *The correlation is significant at the 0.05 level. **The correlation is significant at the 0.01 level.
Abbreviation: y: Years.

Table 6. Pearson correlation between obesity-related hospitalizations and deaths from diabetes (2013 – 2021)

Diabetes deaths	Obesity hospitalization					
	Male	Female	White	Brown	Asian	Not informed
<1 y	0.825	0.633	0.456	0.624	0.456	0.457
15 – 19 y	0.825	0.193	0.345	0.228	0.456	0.457
20 – 29 y	0.703	0.715	0.677	0.779	0.259	0.593
30 – 39 y	0.735	0.568	0.162	0.499	0.00**	0.800
40 – 49 y	0.962	0.560	0.169	0.569	0.419	0.875
50 – 59 y	0.693	0.509	0.530	0.572	0.584	0.951
60 – 69 y	0.258	0.881	0.110	0.835	0.510	0.168
70 – 79 y	0.615	0.383	0.796	0.401	0.897	0.603
>80 y	0.525	0.340	0.150	0.364	0.773	0.342
Male	0.025*	0.098	0.576	0.079	0.782	0.283
Female	0.641	0.922	0.993	0.908	0.071	0.953
White	0.389	0.438	0.083	0.337	0.00**	0.457
Black	0.448	0.572	0.204	0.451	0.00**	0.582
Asian	0.352	0.482	0.102	0.363	0.001**	0.493
Not informed	0.046*	0.037*	0.230	0.028*	0.041**	0.104

Notes: *The correlation is significant at the 0.05 level. **The correlation is significant at the 0.01 level.
Abbreviation: y: Years.

Brazil. Both public and private sector initiatives are needed to reduce the risk factors for these diseases.

It is also important to note that, since the establishment of SUS, rural areas and regions with lower socioeconomic development, such as the North and Northeast, have faced difficulties in the system's implementation. These challenges are largely due to the limited organizational infrastructure and a lack of human and financial resources in municipalities with smaller populations (Costa *et al.*, 2017).

Regarding T2DM-related deaths by age group, the significant increase in the number of deaths among individuals aged 50 and older (Figure 1) corroborates findings from another study on the prevalence of obesity and NCDs in Brazilian capitals. This study showed a sharp increase in the prevalence of T2DM, hypertension and dyslipidemia from the age of 40, peaking between the ages of 70 and 80 (Ministry of Health, 2017). Aging is often associated with an increase in body fat, as reduced growth hormone secretion leads to a decline in basal metabolic rate and lean mass, while the amount of body fat increases. This process can significantly raise body mass index (BMI) over time. Furthermore, previous research has linked weight gain and variations in adulthood to an increased risk of mortality and the development of NCDs, including certain types of cancer and cardiovascular disease (Vergnaud *et al.*, 2008).

Table 4 shows data on the relationship between hospitalizations due to obesity and the variable of sex during the studied period. We observed a higher prevalence of obesity in the female population compared to the male population, with 226 cases of female hospitalizations and 42 cases of male hospitalizations. Data from the Ministry of Health in 2017 revealed an increase in obesity in the adult population, with women showing a more pronounced rise. As validated in this research, the obesity rate was higher in women, at 65.5%, compared to 29.7% in men (Andrade *et al.*, 2012). These findings align with studies indicating that women tend to have greater fat disposition related to biotype, short gestation period between births, physiological processes of aging, and menopause (Pinheiro *et al.*, 2004; Pinho *et al.*, 2013).

When analyzing the correlation between hospitalizations for obesity and deaths from T2DM, we can consider obesity a significant risk factor for individuals with T2DM. Several correlations in this study are supported by other research, confirming that obesity is closely associated with one of the most prevalent diseases in modern society – T2DM. For example, when BMI (kg/m^2) exceeds 35, the risk of developing T2DM increases by 93 times in women and 42 times in men. The health risks associated with obesity increase progressively and disproportionately with weight gain, in what is known as the "J" curve. Furthermore, obesity exacerbates mortality risks (Pinho *et al*., 2013). In the same study (Pinho *et al*., 2013), it was found that approximately 75% of non-insulin-dependent diabetic patients are overweight. A 10% increase in body weight results in a 2 mg/dL increase in fasting blood glucose. Moreover, studies have shown that a waist circumference greater than 100 cm can increase the risk of developing T2DM by 3.5 times, even after controlling for BMI (Franchischi *et al*., 2000).

In the development of T2DM, the adipose tissue increases the demand for insulin, and in obese patients, it can create insulin resistance, leading to elevated blood sugar levels and subsequent hyperinsulinemia. However, the sensitivity of adipose tissue to insulin may remain high, suggesting that lipogenesis may still be favored. In some cases, this resistance may be attributed to a decrease in insulin receptor concentrations or a failure in the cellular transport mechanisms (Franchischi *et al*., 2000). This mechanism may help explain the absence of data on obesity-related deaths, as deaths might be reported under different risk factors. It is also worth mentioning that, according to DATASUS, the cause of hospitalization is the primary diagnosis listed, directly transcribed from the medical record by the registration service units. Since obesity can be the underlying cause of multiple diseases, the primary diagnosis reported in the medical record may focus on life-threatening conditions rather than obesity itself (Cascão *et al*., 2016).

In general, this study has shown that the incidence of type 2 diabetes and obesity has been higher in the female population compared to the male population.

This result is expected, as women are generally more proactive in managing their health and maintaining better control over their blood pressure levels than men. Women are more likely to visit health services and adhere to treatment regimens, while men, for cultural reasons, tend to avoid seeking medical assistance and taking care of their health (Dantas *et al*., 2017).

The lack of information on race/skin color may be attributed to difficulties faced by the interviewers in collecting data, a lack of clarity regarding the importance of this variable, or challenges faced by the participants in self-identifying their color or race, often due to pre-judice or a lack of awareness. This situation may be particularly relevant in the case of self-reported classifications of "non-white," which can carry negative social connotations, particularly for Black individuals (Araújo, 2016).

Moreover, research indicates that the prevalence of hypertension among Black women is up to 130% higher compared to White women. This disparity is linked to several factors, including genetic pre-disposition, poorer living conditions, limited access to healthcare, and higher levels of stress (Malta *et al*., 2017).

Given the increasing prevalence of T2DM and its chronic complications throughout the state, it is important for public authorities to invest in improving access to reliable information about the determinants and consequences of overweight. This effort includes developing comprehensive public policies aimed at fostering healthy choices in diet and physical activity across all social classes.

Regions with the highest rates of overweight and obesity, such as Rio Branco, Cruzeiro do Sul, and Sena Madureira, should be targeted for specific interventions focused on preventing T2DM and promoting healthy lifestyle habits. In addition, younger age groups should be prioritized, as they are at the highest risk for developing T2DM related to overweight and obesity.

5. Conclusion

Our findings reveal a significant increase in deaths due to T2DM over the study period, accompanied by rising hospital costs. The data also show a higher prevalence of T2DM in older age groups, with a relatively balanced distribution between men and women. Regarding obesity, hospitalizations were more frequent in individuals aged 30 and older, particularly among women. Furthermore, a notable correlation was found between T2DM-related deaths and hospitalizations due to obesity, suggesting that many T2DM-related deaths occurred in individuals also hospitalized for obesity, a condition that is associated with various comorbidities. In summary, we recommend further studies on this topic to inform the development of more effective and targeted public health policies to address these interconnected health issues.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Mauro José de Deus Morais, Francisco Naildo Cardoso Leitão
Formal analysis: Romeu Paulo Martins Silva
Investigation: Jorgimar Peres Ferreira, Douglas Silva de Oliveira
Methodology: Luiz Carlos de Abreu
Writing – original draft: Thaiany Pedrozo Campos Antunes
Writing – review & editing: Mauro José de Deus Morais, Romeu Paulo Martins Silva

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The data used for this study are available at www.datasus/tabnet under the Epidemiology and Morbidity section, hospital morbidity of SUS, and general by place of hospitalization.

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ACCSCIENCE PUBLISHING

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ORIGINAL RESEARCH ARTICLE

Sustainability of primary healthcare services through community participation: Assessing the role of ward development committees in northwestern Nigeria

Kabiru Abubakar Gulma*

School of Global Health and Bioethics, Euclid University, Banjul, The Gambia

Abstract

This study assessed 191 ward development committees (WDCs) and 200 primary healthcare center (PHC) catchment communities in Kebbi State, northwestern Nigeria, to determine the status and functionality of WDCs and their level of engagement with PHCs. The existence of other community structures relevant to primary health care was also explored. The study employed a cross-sectional design involving questionnaire survey with members of WDCs, health facility workers, and community members, in addition to reviewing records and documentation at PHCs and in the communities. The study found a pervasive existence and functioning of WDCs in all wards in Kebbi State. Almost all WDCs hold regular monthly meetings, with meeting notes available for the majority. While most of the WDCs had independent means of generating funds, the majority of them did not have functional bank accounts. We found that most WDCs performed key roles and activities, including supervision of health facilities, social mobilization, monitoring performance indicators, and using data for decision-making. We also found that the majority of the communities had other community-level structures, such as traditional birth attendants, volunteer community health workers, and the existence of a community emergency transport system to transfer pregnant women to PHCs during emergencies. WDCs and other community-based structures can potentially improve primary healthcare services in Kebbi State. However, efforts to optimize their performance are needed, including strengthening WDCs' capacity for financial management and encouraging a more widespread existence of other community-based health-related initiatives. Primary healthcare services in Kebbi State can be improved by optimizing the performance of WDCs and other community-based structures, leading to better health outcomes for the population.

Keywords: Ward development committees; Community support; Primary health care; Kebbi State; Nigeria

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***Corresponding author:**
Kabiru Abubakar Gulma
(gulma@euclidfaculty.net)

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1. Introduction

Primary health care is the cornerstone of any healthcare system, providing the initial point of contact between individuals and the broader healthcare infrastructure (Heritage

& Dooris, 2009). It encompasses a comprehensive range of services vital for preventing, diagnosing, treating, and managing diseases and illnesses (Ata, 1978). However, providing effective primary health care in countries like Nigeria, situated in Sub-Saharan Africa, is the beset with multifaceted challenges. These include resource limitations, inadequate financial allocations, and a persisting shortage of skilled healthcare personnel (Durey *et al*., 2016; Gholipour *et al*., 2023; Goodman *et al*., 2011).

A promising avenue for strengthening primary healthcare services has emerged amid these formidable challenges: Community involvement and participation (Cyril *et al*., 2015; Reeve *et al*., 2015). This approach recognizes the potential of harnessing local resources, knowledge, and community-driven solutions to augment healthcare delivery. At the heart of this community-centered endeavor are ward development committees (WDCs), representing governance structures and accountability mechanisms rooted in the ward-level context. These committees have evolved into integral components of primary healthcare management within Nigeria (Baghirov *et al*., 2019; Gholipour *et al*., 2018; Haldane *et al*., 2019).

The World Health Organization (WHO) defines community participation as "a process by which people are enabled to become actively and genuinely involved in defining the issues of concern to them, in making decisions about factors that affect their lives, in formulating and implementing policies, in planning, developing and delivering services, and in taking action to achieve change." Community participation in primary health care has been enshrined in the Alma-Ata Declaration in 1978, where it is clearly indicated that effective primary health care "requires and promotes maximum community and individual self-reliance and participation in the planning, organization, operation, and control of primary health care" (Ata, 1978).

Local community committees are common and have been widely studied in terms of their operations or impact on health services at peripheral health facilities, such as primary health centers, health posts, or dispensaries, in a number of African and other developing countries, including Nigeria, Uganda, Niger, Kenya, Benin Mexico, Peru, and Nepal among others (Gholipour *et al*., 2023; Goodman *et al*., 2011). Several other studies have shown the potential value of collaboration between communities and health professionals in health facilities for promoting primary health care (George *et al*., 2015; Mntambo, 2017).

The National Primary Health Care Under One Roof, a key policy directive by the National Primary Health Care Development Agency (NPHCDA) in Nigeria, mandated the establishment of at least one functional primary healthcare center (PHC) in each of the 8,812 wards across the country (Abosede & Sholeye, 2014; Abosede *et al*., 2012). WDCs were instituted to bolster these PHCs and enhance community engagement in healthcare governance, backed by the National Health Promotion Policy (Federal Ministry of Health, 2005). The kick-off of the WDC initiative in Kebbi State started in earnest in 2017 and is still becoming stronger today. These committees represent a concerted effort drawn from the PHC's catchment population, tasked with providing oversight on accountability and supporting healthcare activities (George *et al*., 2015). Previously, the lion's share of PHC responsibilities rested with government healthcare workers, resulting in elevated infant and maternal mortality rates, dilapidated healthcare infrastructure, and inadequate pharmaceuticals and consumables (Abosede & Sholeye, 2014; Federal Ministry of Health, 2005).

Recognizing these systemic challenges, the state took decisive steps to integrate WDCs into the fabric of local healthcare governance, emphasizing local ownership and accountability. Collaborative partnerships between entities such as the United States Agency for International Development programs, WHO, and the United Nations International Children's Emergency Fund provided crucial technical support and capacity-building initiatives aimed at reinforcing the role of WDCs in PHC affairs (McCoy *et al*., 2012). Yet, despite the existence of WDCs and other community support structures, the primary healthcare sector in Kebbi State continues to grapple with challenges, prompting the imperative to explore how these community-based structures can be optimized to ameliorate primary healthcare services (Karuga *et al*., 2022; Njelita *et al*., 2023).

The significance of WDCs in primary health care lies in their ability to bridge the gap between communities and healthcare facilities, fostering collaboration and accountability in healthcare delivery. These committees serve as a grassroots mechanism for engaging communities in health governance, promoting local ownership, and ensuring that primary healthcare services align with community needs and priorities. By facilitating regular interactions between health facility staff and community representatives, WDCs play a pivotal role in identifying healthcare challenges, mobilizing resources, and driving initiatives such as social mobilization and emergency response systems.

This study extends the existing body of knowledge by evaluating the functionality and depth of participation of WDCs, highlighting their roles in Kebbi State, Nigeria. The findings emphasize how WDCs contribute to operationalizing PHC services by enhancing community involvement in decision-making, supervision, and financial

management. Moreover, WDCs provide a structured framework for communities to hold healthcare providers accountable, thereby improving transparency and trust in the healthcare system. Understanding the value of WDCs offers actionable insights for policymakers and stakeholders to strengthen these committees, ultimately improving health outcomes through sustainable, community-driven healthcare systems.

1.1. Theoretical framework

This study is grounded in the framework of community participation in health governance, as articulated in the Alma-Ata Declaration of 1978, which emphasizes self-reliance and community involvement as cornerstones of effective primary health care. As defined by the WHO, community participation involves enabling individuals and communities to actively engage in decision-making, planning, and implementing health services that affect their lives.

WDCs operationalize these principles through structured roles and responsibilities that align with governance, accountability, and resource mobilization frameworks. Specifically, the study adopts a focus on key dimensions of WDC functionality:

1. Governance and accountability: Reflecting their role as a bridge between communities and health systems, WDCs monitor PHC performance and ensure transparency
2. Community engagement: As participatory agents, WDCs mobilize resources and support health initiatives, fostering grassroots ownership
3. Data-driven decision-making: Grounded in evidence-based practices, WDCs utilize PHC performance indicators to prioritize health interventions.

Although many studies have provided some information on community participation in primary health care in some ways, mainly through community health committees covering their roles, effectiveness, and challenges elsewhere, there is generally a lack of information on the functionality and depth of participation of such committees in Nigeria with little evidence of their evaluation in line with the mandate set by the NPHCDA. This study aims to provide evidence-based information by assessing the functionality of the WDCs and determining the depth of their engagement with and actions in health facilities in Kebbi State, Nigeria.

2. Research method

2.1. Study design

A cross-sectional study design was employed to assess the involvement and influence of WDCs and community structures on primary health care in Kebbi State from January 2020 to September 2021.

2.2. Study population

The study was conducted in Kebbi State, Nigeria, which has a total of 225 wards. Each ward has a designated "one functional PHC per ward," and these were the target PHCs for this study. Therefore, WDCs, their corresponding PHCs, and the catchment populations of these focal PHCs were included in the study.

2.3. Data collection

Four data collectors were involved in the study. There was an orientation meeting with the data collectors who were trained in using the data collection tool. The tool was pre-tested to ensure data is immediately received in Google Sheets for subsequent analysis.

Quantitative data were collected using Google Forms administered to WDC members, PHC staff, and community members. Approximately three respondents per ward completed the questionnaire.

2.4. Questions in the data collection tool

The study questionnaire included the following variables, adapted from the indicators used to assess the functionality of WDCs.

- Establishment and functioning of WDCs
- Frequency and documentation of WDC meetings
- WDC involvement in PHC supervision and decision-making
- Utilization of PHC service data by WDCs
- Financial management capacity of WDCs
- Community-led initiatives, including Drug Revolving Fund (DRF) schemes
- Availability and functionality of PHC services
- The presence of traditional birth attendants (TBAs) and emergency transport systems (ETSs)
- Involvement of volunteer service providers and mobilizers
- The existence of community accountability committees
- Community ownership and accountability mechanisms for PHC services

2.5. Validity and reliability of the data collection tool

The validity of the data collection tool was ensured through a careful design process, aligning the questionnaire with established indicators for assessing the functionality of WDCs and their impact on primary health care. Content validity was achieved by covering all relevant aspects of WDC activities, while face validity was confirmed through expert review and pre-testing with data collectors. Construct validity was strengthened by combining quantitative and qualitative data collection methods to comprehensively assess the WDCs' roles.

Reliability was ensured through several measures, including internal consistency checks during pre-testing and standardization of the data collection process through training. The use of structured questionnaires and stratified random sampling further enhanced the consistency and representativeness of the data. These steps collectively ensured that the tool reliably captured the involvement and influence of WDCs on primary healthcare services in Kebbi State.

2.6. Data analysis

Quantitative data were analyzed using descriptive statistics, and qualitative data were thematically analyzed to identify key themes and patterns.

2.7. Ethics approval and consent to participate

The Institutional Review Board of Euclid University granted ethical approval to conduct the study, adhering to the Declaration of Helsinki. In addition, all participants gave their informed consent to participate in the study.

3. Results and analysis

A total of 191 out of 225 WDCs in Kebbi State and 200 PHC catchment populations were assessed.

3.1. Key structure and function factors

This study evaluated WDCs based on structural and functional dimensions critical to their effectiveness in supporting primary health care. The structural factors assessed included:

- Establishment and routine engagement: All 191 WDCs were successfully established, demonstrating 100% adherence to the mandate of creating functional community health governance structures. Almost all WDCs (97%) conducted regular monthly meetings, with the same percentage documenting these meetings in official minutes, signifying a structured and consistent approach to community engagement. In addition, 87% shared these minutes with stakeholders, ensuring transparency and wider participation in decision-making processes.
- Governance and oversight: A significant 94% of WDCs actively monitored the performance indicators of PHCs. This involvement indicates a strong focus on governance and accountability, as committees ensured that key metrics, such as operational hours and service costs, were tracked and addressed.
- Financial management: Although 91% of WDCs reported having independent means of generating funds, only 16% maintained functional bank accounts. This gap highlights an area requiring improvement in financial management and accountability mechanisms. These findings emphasize the need for capacity-building initiatives to equip WDC members with the necessary skills for effective resource management.

The functional factors evaluated included:

- Social mobilization: WDCs played a pivotal role in mobilizing communities for public health interventions. For example, 96% of the committees coordinated social mobilization campaigns, such as immunization drives and maternal health programs. These efforts illustrate their active engagement in improving health outcomes within their communities.
- Resource mobilization and drug availability: Through community-led initiatives, 33% of the WDCs established their own DRF schemes in wards lacking functional government-supported DRF schemes. This initiative increased the availability of essential drugs, particularly in underserved areas. However, challenges such as the lack of formal financial systems and limited training in financial oversight hindered the full potential of these efforts.
- Transparency and accountability: WDCs also influenced PHC-level transparency. For instance, 61% of PHCs displayed operational hours, while 65% of them listed available services, reflecting improved communication and client-focused practices. These advancements were driven by the supervisory activities of WDCs and their emphasis on fostering accountability.

3.2. Subgroup comparisons

WDCs were divided into subgroups based on key structural indicators to explore the influence of structural factors on functionality. Comparative analysis was conducted as follows:

1. Meeting frequency and functional performance
   Committees that conducted monthly meetings (97%) demonstrated higher community engagement, with 85% successfully organizing social mobilization campaigns, compared to 63% for those meeting less frequently. The Chi-squared test revealed a statistically significant association between meeting frequency and community engagement ($p < 0.05$).
2. Financial management and resource mobilization
   WDCs with functional bank accounts (16%) showed higher success rates in implementing DRF schemes (45%) compared to those without bank accounts (28%). This suggests a positive link between financial infrastructure and resource mobilization.
3. Supervision and PHC accountability
   Committees actively monitoring performance indicators (94%) were more likely to influence PHCs

to display operational hours and service costs (72%) compared to those less engaged in supervision (48%).

Table 1 below shows the subgroup comparison of the structural indicators and key functional outcomes.

The non-participating sites differed from the participating ones in key structural and operational aspects, including lower rates of WDC establishment, less frequent community engagement activities, and limited financial management capacity, which may have hindered their involvement in the study.

3.3. Mechanisms of WDC contributions to health improvements

The mechanisms through which WDCs contribute to health improvements are closely tied to the foundational structures and functions that define their operations. Section 3.1 outlines critical aspects of WDC functionality, including governance, financial management, and community engagement. These factors serve as the basis for identifying and addressing challenges in implementing specific health improvement mechanisms.

3.4. Social mobilization

Social mobilization campaigns, driven by 96% of WDCs, represent a significant achievement in leveraging community engagement to improve health outcomes. This effort stems from the structured monthly meetings (97%) and consistent documentation practices highlighted in Section 3.1. These meetings provided platforms for planning and coordinating campaigns. However, implementing social mobilization faced challenges such as cultural resistance in certain communities and insufficient volunteer participation. Addressing these barriers is crucial to expanding the reach and effectiveness of WDC-led mobilization efforts.

3.5. Resource mobilization and financial management

The establishment of community-led DRF schemes by 33% of WDCs directly results from their capacity to independently generate funds (91%), as described in Section 3.1. Despite these successes, the lack of functional bank accounts (only 16% of WDCs maintained one) and limited financial literacy among committee members posed significant challenges. These financial constraints hindered the sustainability and scaling of DRF schemes. Capacity-building in financial management, as suggested in the Section 3.1 section, is a priority to overcome these challenges.

3.6. Transparency and accountability

The ability of WDC to influence transparency at PHCs, such as ensuring the public display of operational hours (61%) and available services (65%), reflects their active role in governance and oversight, with 94% monitoring PHC performance indicators. These achievements underscore the committees' potential to foster accountability. However, initial resistance from health providers, who often viewed WDC supervision as interference, highlighted the challenges of integrating external oversight into facility management. Strengthening the collaboration between WDCs and health providers through dialogue and training is essential to addressing this issue.

3.7. *ETSs*

ETSs established in 67% of communities were largely facilitated by WDC-led resource mobilization. These systems fill critical gaps in healthcare access for emergencies, particularly for maternal and child health. However, irregular contributions for maintenance and fuel shortages frequently disrupted operations. Strengthening financial mechanisms and community ownership, linked to the financial management structures outlined in Section 3.1, is key to ensuring the sustainability of these systems.

3.8. Evidence-based decision-making

A significant proportion of WDCs (94%) used PHC performance indicators for decision-making, reflecting their technical capacity and structured governance practices. This evidence-based approach has been pivotal in prioritizing health interventions. However, challenges such as limited access to reliable data and inadequate technical training for WDC members constrained their

Table 1. Subgroup comparison

Structural indicator	Subgroup	Key functional outcome	Percentage	*p*-value
Meeting frequency	Monthly meetings	Successful social mobilization	85	<0.05
	Less frequent meetings	Successful social mobilization	63	
Financial management	Committees with bank accounts	Successful DRF scheme implementation	45	<0.05
	Committees without accounts	Successful DRF scheme implementation	28	
PHC supervision	Active supervisors	Display of operational hours	72	<0.05
	Less active supervisors	Display of operational hours	48	

Abbreviations: DRF: Drug Revolving Fund; PHC: Primary healthcare center.

ability to maximize this function. Building data literacy among WDC members, as recommended in Section 3.1, can enhance their decision-making capabilities.

3.9. WDCs and community-driven healthcare initiatives

3.9.1. ETSs

WDCs identified the lack of reliable transport as a significant barrier to accessing healthcare services, particularly during emergencies. To address this, they organized a community-driven approach where households contributed funds for vehicle maintenance and fuel. Local leaders supported these efforts in some communities by donating motorcycles or vans. As a result, 67% of communities reported having operational ETSs, with 80% of pregnant women facing complications being transported to PHCs within the first hour of notification. However, the system faced challenges, including fuel shortages and irregular contributions, which disrupted operations in 23% of these communities.

3.9.2. Community-Led DRF

WDCs, in collaboration with PHC staff, initiated DRF schemes to address the challenge of drug availability. Through this initiative, community members contributed nominal amounts to purchase essential drugs, which were then sold at cost-recovery prices, with the proceeds reinvested to replenish stock. This approach proved effective, as 33% of WDCs established DRF schemes in wards where no government-supported DRF existed, resulting in a 50% increase in the availability of key drugs. However, the initiative faced challenges, particularly in tracking funds due to a lack of bank accounts and limited financial management training among WDC members.

3.9.3. Social mobilization for immunization campaigns

WDCs engaged community influencers and volunteers to promote immunization days, enhancing their efforts with door-to-door visits and announcements during religious gatherings. This strategy proved effective, with communities actively engaged in WDC-led social mobilization reporting a 40% increase in child immunization rates compared to baseline levels. However, cultural resistance in certain areas initially resulted in low turnout, necessitating sustained engagement to overcome these barriers and improve participation.

4. Discussion

This study, conducted in Kebbi State, illuminates the status of WDCs, their functionality, and their level of involvement with catchment health facilities, signifying the depth of impact they can have in shaping the primary healthcare landscape. The findings have important implications for implementation science and healthcare frameworks, contributing to the ongoing discourse on effective healthcare delivery and community participation.

4.1. Universal establishment of WDCs

A standout observation from this study is the universal establishment of WDCs in all wards of Kebbi State. The establishment of WDCs in every ward aligns with the principles of equitable access to health care, emphasizing that no community should be left behind, a fundamental aspect of contemporary healthcare frameworks. This finding signifies a commendable adherence to the requirement by the NPHCDA to have WDCs established to support community efforts in primary health care at the local level. This further presents an opportunity to foster a holistic collaboration between health facilities and communities to drive core principles of primary health care, including access and equity. In line with this finding, McCoy, Hall, and Ridge (2012) noted that, like WDCs, health facility committee's roles and functionality, as well as factors influencing them, are invariably influenced by contextual factors, the obvious of which is the influence of the larger health system including the regulatory and policy provisions which shape the approach towards community participation and the roles, mandates, and authority of health facility committees (McCoy *et al.*, 2012). In the case of Kebbi State and Nigeria as a whole, the National Health Promotion policy has certainly provided the framework for the establishment of WDCs across all wards. This policy framework has evidently facilitated the establishment of these committees, allowing them to serve as enablers for wider social accountability functions.

4.2. WDCs in Kebbi State: Cornerstones of community-driven health care

Our findings provide invaluable insights into the essential role played by WDCs in shaping the primary healthcare landscape. These WDCs serve as dynamic nuclei within their respective wards, fostering the integration of healthcare systems and driving sustainable change at the community level.

The universal establishment of WDCs was remarkable, and the study revealed that all wards in Kebbi State have successfully established functioning WDCs. This universal presence signifies a commitment to community engagement and grassroots participation in health care. Establishing WDCs in every ward aligns with the principles of equitable access to health care, emphasizing that no community should be left behind—a fundamental aspect of contemporary healthcare frameworks.

Structured meetings and comprehensive documentation also reveal the rigorous nature of WDC activities. A staggering 97% of WDCs conduct monthly meetings, marking their dedication to regular and structured engagement. These meetings transcend mere gatherings; they serve as platforms for collaboration, knowledge exchange, and collective decision-making—a hallmark of participatory implementation frameworks.

Furthermore, 87% of WDCs diligently document the minutes of these meetings. This meticulous record-keeping demonstrates their commitment to transparency and accountability. The practice of documenting meeting minutes not only complies with health care reporting standards but also embodies the spirit of evidence-based decision-making, a cornerstone of effective healthcare implementation.

4.3. Financial sustainability and accountability

WDCs also exhibit resourcefulness in funding their activities, with 91% possessing means of generating funds. This financial acumen highlights their commitment to self-sustainability, a principle cherished in modern healthcare systems. However, only 16% of WDCs maintain bank accounts, suggesting an opportunity for capacity-building in financial management. Establishing robust financial systems aligns with the principles of financial sustainability outlined in healthcare frameworks.

4.4. WDCs and accountability mechanisms

A noteworthy finding of the study is the profound impact of WDCs on accountability mechanisms within the healthcare system. Their involvement has led to the establishment of community-led DRF schemes, with 33% of these schemes initiated in Kebbi State, where no functional government-driven DRF existed. Establishing community-led DRF schemes resonates with the principles of resource mobilization, a pivotal component of healthcare financing frameworks.

WDCs have also played a transformative role in promoting transparency. For instance, 97% of these committees actively participate in PHC monthly meetings for decision-making. The result is a remarkable transformation in PHC facilities, with 61% publicly displaying their operational hours. This practice is a testament to the influence of WDCs on governance and accountability mechanisms, a principle deeply rooted in healthcare governance frameworks.

4.5. Community structures for enhanced healthcare access

Beyond the sphere of WDCs, the study unveils the significance of additional community structures in bolstering healthcare access. TBAs emerge as vital contributors, with 90% of assessed communities having TBAs. These community-based healthcare providers fill critical gaps, ensuring maternal and child healthcare services are accessible, even in remote areas. This community-driven approach resonates with the ideals of community participation embedded in many healthcare frameworks.

Furthermore, 67% of communities have established ETSs, a lifeline during healthcare crises. Consequently, maternal and child health outcomes are improved, aligning with the overarching goals of healthcare delivery frameworks.

4.6. Community participation in the wider context

The study delves deeper into community participation, extending beyond the purview of WDCs. Notably, 60% of communities boast volunteer service providers, while 25% have volunteer mobilizers for public enlightenment and campaigns. These volunteers play instrumental roles in augmenting healthcare service delivery. Their involvement echoes the principles of community engagement and participation that are inherent in healthcare systems strengthening frameworks.

The study's findings underscore the symbiotic relationship between community-based structures like WDCs, healthcare accountability mechanisms, community engagement, and enhanced accessibility, all within the context of implementation frameworks of science and health care. These outcomes emphasize the importance of leveraging local resources, fostering community participation, and promoting transparency as key strategies for implementing effective health care and ultimately improving health outcomes.

4.7. Community-driven health care

We found evidence of structured meetings and comprehensive documentation, such as meeting notes, among most WDCs. This suggests that WDCs deliberated on community issues related to primary care services offered by catchment health facilities. These meetings articulate community concerns and priorities, presenting opportunities to build consensus on viewpoints regarding the relationship between health facilities and communities. The study found that up to 97% of WDCs conduct monthly meetings, offering platforms for collaboration, knowledge exchange, and collective decision-making, a hallmark of participatory implementation frameworks. Furthermore, 87% of WDCs diligently document the minutes of these meetings. This meticulous record-keeping demonstrates their commitment to transparency and accountability. Documenting meeting minutes complies with health care

reporting standards and embodies the spirit of evidence-based decision-making, a cornerstone of effective healthcare implementation. In a similar study exploring the nature and roles of health facility committees in Kenya, Goodman *et al.* (2011) discovered that about 80% of the committees met at least once in a quarter, and in all cases, meeting notes were available (Goodman *et al.*, 2011). This study showed a similar finding to the current study.

4.8. WDCs: Guardians of primary health care

Our study also found that almost all WDCs (98%) engaged in routine health facility supervision as part of their activities. Most WDCs (94%) monitored health facility performance indicators during such supervisory visits. These findings suggest that WDCs undertake some deliberate efforts to ensure they are fully aware of what the health facilities are doing and use data for evidence-based decision-making on behalf of the communities they represent. Although it was not part of our study objective to determine the technical capabilities of WDC members, our findings suggest that many members wholly or partly possessed some technical skills necessary for data-driven decision-making. Monitoring performance indicators also requires a certain level of technical capacity from the supervising team. These findings are consistent with the established mandates of WDCs (Abosede *et al.*, 2012).

In a qualitative synthesis on participation in primary health care through community-level health committees in Sub-Saharan Africa, Karuga *et al.* (2022) found similar results regarding the role of community-level health committees in supervising and monitoring health facilities, as well as holding health workers accountable (Karuga *et al.*, 2022; Siachisa *et al.*, 2021). An important quality outcome of these roles performed by WDCs is the improvement of healthcare services at the health facilities, which, in turn, leads to improved community outcomes. However, a study by Njelita *et al.* (2023) assessing the awareness and roles of community members in health facilities found that most community members do not know about the roles and responsibilities of WDCs. This finding is significant because the roles performed by WDCs must match the level of awareness among community members; it underscores the narrative that not only do WDCs need to have good performance records, but the community members also need to be informed and mobilized to actively participate in attaining the health goals of their communities.

The roles of WDCs do not only stop at engaging health facilities but also mobilizing communities to seek care in health facilities. McCoy *et al.* (2012) noted that wider community mobilization is imperative for improved functioning of health facilities. Our findings show that 72% of the WDCs use health facility data obtained from supervisory visits and performance indicators for decision-making, which presents a valuable opportunity for evidence-based actions and priority setting. However, the extent to which these decisions can contribute to effective healthcare services at the health facilities and for the communities served depends on various factors and contexts. It is well known that the effectiveness of WDCs in influencing health services depends on multiple interacting factors at the levels of the committees, communities, health facilities (including personnel), and the wider health system (McCoy *et al.*, 2012). In addition, decisions made by these committees are likely to result in significant changes and outcomes only if they are supported by authorities at the local or state government levels (Njelita *et al.*, 2023).

In the present study, most of the committees (91%) stated they had independent means of generating funds for their routine activities. However, only a few (16%) disclosed that they maintained bank accounts in the committee's name. This finding aligns with findings from previous studies (Ogbuabor & Onwujekwe, 2018), which identified financial management as a key challenge for many such committees, highlighting an area for improvement. Siachisa *et al.* (2023) found financial resources and irregularities as constraints to the effective functioning of WDCs in Zambia (Siachisa *et al.*, 2021). In contrast, the current study found that the majority of the WDCs reported having sources of funds. Ezinwa (2017), in a study on the roles and challenges of WDCs, found that a key challenge faced by WDCs in Ogun State, Nigeria, was financial constraint (Ezinwa, 2017). As stated earlier, WDCs are highly context-specific and influenced by social, political, and economic factors, and all WDCs should be viewed as such (McCoy *et al.*, 2012).

Notably, our study highlights the roles played and efforts championed by the WDCs in Kebbi State. For instance, the efforts of the WDCs and their engagement with various stakeholders led to the establishment and operation of community-led DRF schemes, with about 33% of these schemes established in Kebbi State where no functional government-driven DRF scheme existed; in addition, through the routine engagement with PHCs via supervision and monitoring, about 61% of PHCs started displaying their operational hours publicly as a way of providing information to clients.

Beyond the sphere of WDCs, the study unveils the significance of additional community structures in bolstering healthcare access. We found that 90% of communities covered by WDCs had TBAs. These community-based healthcare providers filled critical gaps,

ensuring maternal and child healthcare services were accessible, even in remote areas. The study also found that 60% of communities had volunteer service providers, while 25% had volunteer mobilizers for public enlightenment and campaigns. These volunteers play instrumental roles in augmenting healthcare service delivery. Furthermore, 67% of communities have established ETS, a lifeline during healthcare crises. Ingrained in community healthcare frameworks, these systems facilitate the timely transfer of pregnant women to PHCs during emergencies. Consequently, maternal and child health outcomes improve, aligning with the overarching goals of healthcare delivery frameworks.

WDCs involvement echoes the principles of community engagement and participation inherent in healthcare systems strengthening frameworks.

The study's findings underscore the symbiotic relationship between WDCs and PHCs and also show some other community-based structures, like the volunteer corps and TBAs, which work within communities to improve access to health services. These revelations emphasize leveraging local resources, fostering community participation, and promoting transparency as key strategies for effective healthcare implementation and ultimately improving health outcomes.

4.9. Evidence-based success of WDCs

The universal establishment of WDCs in all wards highlights their pivotal role in community-driven health care. These committees actively engage in supervisory activities, with 98% routinely monitoring health facility performance indicators. Notably, 94% of WDCs used this data to inform evidence-based decision-making, resulting in practical improvements such as increased community confidence in healthcare services.

Social mobilization efforts led by WDCs achieved measurable outcomes. In communities where WDCs organized immunization campaigns, child immunization rates increased by 40% compared to baseline levels. Similarly, the ETS established in 67% of wards facilitated timely access to care, with 80% of emergencies addressed within the first hour of notification. One community leader remarked, "Our transport system has saved many lives by ensuring patients reach the PHC on time."

Financial contributions were another area of success. Despite only 16% of WDCs maintaining bank accounts, 91% reported independent means of generating funds. This enabled the establishment of community-led DRF schemes in 33% of wards where no government DRF existed, thereby improving the availability of essential drugs by 50%.

4.10. Challenges and barriers to WDC operations

The findings highlight the interplay between structural and functional factors in determining the effectiveness of WDCs. Committees with strong structural foundations, such as regular meetings and sound financial systems, demonstrated greater success in functional areas like community mobilization and resource management. Subgroup comparisons revealed significant disparities, suggesting that weaker committees require targeted capacity-building interventions. For instance, improving financial literacy and promoting the maintenance of bank accounts could enhance resource mobilization, while standardizing meeting schedules may foster better community engagement. These observations align with previous studies emphasizing the critical role of structural integrity in the functionality of health committees (McCoy *et al*., 2012; Njelita *et al*., 2023).

Despite these structural insights, the operational landscape of WDCs is fraught with several challenges that undermine their effectiveness. Resistance from health providers emerged as a key barrier, with some healthcare workers perceiving WDC oversight as intrusive, particularly during supervisory visits. For example, one PHC staff member reflected, "It felt like they were policing us instead of supporting us. Over time, we realized they were trying to improve services." In addition, gaps in community engagement were evident, with 15% of communities lacking awareness of WDC roles, limiting their ability to mobilize resources effectively. A community member explained, "We didn't know WDCs were supposed to help us with transport during emergencies." Financial sustainability also remains a pressing challenge. Although 91% of WDCs reported having the means to generate funds, only 16% had functional bank accounts, leading to informal financial handling and accountability gaps. Addressing these barriers requires comprehensive solutions such as financial management training and access to microfinance institutions, which could bolster financial sustainability and accountability. Together, these structural and operational challenges underscore the need for a multifaceted approach to enhance WDC functionality and impact.

4.11. Limitations of the study

While this study provides valuable insights into the role of WDCs and community structures in enhancing primary health care in Kebbi State, several limitations must be acknowledged, highlighting areas for future research and improvement. Much of the data, such as meeting attendance and financial contributions, were self-reported by WDC members, thereby potentially introducing biases

in reporting successes. For example, claims of increased drug availability were not independently verified against PHC inventories. In addition, the study's cross-sectional design offers a snapshot of the current situation but cannot track the long-term sustainability of WDC initiatives. Furthermore, uneven representation poses another limitation, as some remote wards with fewer resources may not have been adequately represented, potentially skewing findings toward more successful WDCs. Despite these limitations, the study underscores the contributions of WDCs and community structures to primary health care in Kebbi State and serves as a foundation for future research aimed at enhancing community-driven healthcare interventions and improving outcomes in resource-limited settings.

5. Conclusion

The study has brought to light the status and functionality of WDCs and the level of their engagement with primary health facilities in Kebbi State, Nigeria. The study also revealed key outcomes from the interaction between WDCs and PHCs, aimed at improving access to primary healthcare services in local communities. The existence of other community-level structures such as volunteer corps, TBAs, and ETS underscores the critical roles played by communities in contributing to primary healthcare delivery and the effective functioning of primary healthcare services. The findings suggest that most WDCs in Kebbi State are actively engaged in PHC activities, with almost all conducting regular meetings and using PHC service data for decision-making. The involvement of WDCs in PHC operations has led to accountability mechanisms, including establishing community-led DRF schemes and public displays of PHC services. The study also found that TBAs and ETS are crucial community structures for PHC services. Overall, the study suggests that the involvement of WDCs and community structures can significantly improve PHC services in resource-limited settings.

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Conflict of interest

The author declares that there are no competing interests.

Author contributions

This is a single-authored article.

Ethics approval and consent to participate

Ethical approval was granted by the Health Research Review Committee of the Kebbi State Health Ministry to conduct the study (registration number: 105:16/2020), and the study has adhered to the principle outlined in the Declaration of Helsinki. In addition, all participants gave their informed consent to participate in the study.

Consent for publication

Verbal consent was obtained from the participants to share their data.

Availability of data

Data are available from the corresponding author upon reasonable request.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

The impact of PTSD on memory and cognition

Sasha Kamal*

Researcher, International Neurological Trauma Research Center, Islamabad, Pakistan

Abstract

An earthquake devastated northern Pakistan on October 08, 2005, significantly affecting the mental health of the victims. Although post-traumatic stress disorder (PTSD) rates were noted to change, no official study has quantified its prevalence following this disaster. This study examines the relationship between PTSD symptoms and memory functions in child and adolescent earthquake survivors, focusing on those attending schools in the affected areas. Participants first completed a self-assessment PTSD questionnaire, followed a week later by the Rivermead Behavioral Memory Test. Subsequently, the Children and War Foundation's "Writing for Recovery" manual (April 2008 version) were implemented. The PTSD questionnaire and memory test were then re-administered to evaluate intervention outcomes. Results revealed that all three groups, control (A) and earthquake survivors (B and C), improved memory test scores after the intervention. However, control group A consistently outperformed groups B and C. PTSD symptoms in groups B and C decreased after applying the intervention, while no change was observed in the control group A. These findings highlight significant correlations between trauma and the severity of PTSD in adolescents. Adolescents exposed to trauma (groups B and C) demonstrated poorer memory functions compared to peers without PTSD (group A). Furthermore, the "Writing for Recovery" intervention effectively reduced PTSD symptoms and improved memory performance in earthquake survivors. This study underscores the critical impact of PTSD on neurological cognition and memory in young populations following natural disasters and demonstrates the potential benefits of targeted psychological interventions for trauma recovery.

Keywords: Neuroscience; Memory; Psychology; Neurology; Cognition; Post-traumatic stress disorder; Natural disasters

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***Corresponding author:**
Sasha Kamal
(sashakamal@hotmail.com)

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1. Introduction

Post-traumatic stress disorder (PTSD) is a widely occurring trauma condition triggered by a frightening or distressing experience that resulted in serious physical damage or endangered life (Nolen-Hoeksema & Morrow, 1991). PTSD can also affect family members of sufferers (Breslau, 2002). It can occur in individuals of any age, including children and adolescents (North *et al.*, 2004). PTSD can emerge after traumas such as earthquakes, car accidents, war, hurricanes, and physical attacks. Planned dialogs or the PTSD symptom self-report questionnaire are employed for PTSD analyses (Breslau, 2002; Pietrzak & Southwick, 2011).

A devastating earthquake measuring 7.7 on the Richter scale struck the northern areas of Pakistan at 08:50:38 on October 08, 2005 (Mancuso *et al*., 2008). The scale of the earthquake was so massive that it distorted mountains, transformed river paths, and eradicated all villages in the affected areas. Approximately 3.3 million people were rendered homeless after the earthquake. According to UN reports, more than 8 million individuals were directly influenced by the earthquake, which caused damage worth 300 billion Pakistan Rupees. Government records indicate that more than 73,000 individuals died and more than 135,000 people were injured but some sources claim that fatalities and injuries were actually much higher (Mancuso *et al*., 2008).

It was acknowledged that PTSD rates changed after the devastation, but no official published study exists on the occurrence of PTSD in its aftermath. Professor Mufti in Balkot conducted an unpublished study, which claims that 51% of patients receiving care from mental health professionals appeared to fit the established criteria for the diagnosis of PTSD. Previous studies on PTSD victims have asserted that this condition can result in unremitting psychopathology if it is ignored, and cause functional and memory-related disorders. (Henson *et al*., 1999; Kupfer *et al*., 2002; Lanius *et al*., 2001; Seddigh *et al*., 2005; Schweizer & Malm, 2003).

This study utilized the Writing for Recovery Manual designed specifically to help adolescents process traumatic experiences. The efficacy of structured writing is well-documented in the context of recovering from disaster and conflict.

An ordeal such as the Pakistan earthquake can instigate ongoing transformations in brain chemistry (Yehuda & McFarlane, 1995). Neuropsychological, neuropsychiatric, and neurological indications lead to despair, bad temper, and weak cognitive abilities due to the effects of such disasters on different enzymes in the nervous system. Severe anxiety assists ongoing modifications in cholinergic gene expression (Gray, 1999). Initially, bodily reactions to challenges instigate allostasis, which launches a multifaceted adaptive passageway. This reaction is subsequently disrupted by the sympathetic nervous system and the hypothalamic pituitary adrenal axis (Goenjian *et al*., 2003). Catecholamines are unconfined from the nerves and adrenal medulla throughout the initiation phase. They guide the emission of corticotropin (or corticotropes) in the pituitary (Gray, 1999). Inactivation returns this procedure to the baseline point of cortisol and catecholamine secretion. Unproductive inactivation forces the system to accumulate stress hormones, resulting in allostatic load and instigating pathophysiologic effects that generate PTSD (Jatzko *et al*., 2006; Adamec *et al*., 2007).

Psychological studies based on memory and PTSD suggest that sufferers experience disturbing memories, have bad dreams about the triggering event, and are immensely emotionally affected by their ordeal (Chung, 2001; Leeson *et al*., 2008; Liberzon & Martis, 2006; Mellman *et al*., 2001) They also exhibit attention problems (e.g., the inability to focus), hyperarousal, hypervigilance, evasion, startled reactions, and feel worse when they have disturbing memories or encounter triggers (Brewin, 1998; Shin *et al*., 2004). Existing studies on the neural correlates of memory impairment arising from disturbing experiences such as earthquakes have proposed that the damage could be caused by the neuroanatomical modification of certain limbic brain areas (e.g., amygdala) and the limbic cortex. Some studies have suggested that individuals who suffer from PTSD display problems in the prefrontal cortex (Shin *et al*., 2004). Several studies have recognized instantaneous memory mutilations apropos optical tasks in individuals who suffer from PTSD. A less significant hippocampal quantity has also been noted in PTSD sufferers. The limbic system is responsible for several essential neurological occupations, of which the monitoring of emotions is paramount. This structural group comprises the hippocampus, fornix cingulate cortex, amygdala, septum, and mammillary bodies (Bonne *et al*., 2008; Shin *et al*., 2004). These regions begin to reduce in size due to the forceful downpour of the corticotropic chemicals that enter areas of the brain that monitor emotions (the amygdala, hypothalamus, pituitary, and thalamus) (Bonne *et al*., 2008; Shin *et al*., 2004). Hence, certain studies suggest that PTSD sufferers have a smaller hippocampus. Some new studies have also indicated that such neurological changes may be heritable (Bonne *et al*., 2008).

The autonomic system is affected by sympathetic and parasympathetic activation; the behavioral system is affected by advantageous or disadvantageous behavior or approach; and the endocrine system is affected by hormones and chemicals. PTSD sufferers experience a forced overflow of chemicals triggered by returning images and emotions related to the disturbing event (Smith *et al*., 2006; Basoglu *et al*., 2000). Individual input pathways are thus compelled to blend into one collective input pathway, supplying both thalami with matching data (Smith *et al*., 2006).

The present analysis included correlation coefficients and regression equations to evaluate the relationships between PTSD symptoms and memory functions. Relevant scatterplots and regression equations are presented to substantiate the observed correlations. The analysis includes correlation coefficients and regression equations to evaluate relationships between PTSD symptoms and memory function. Relevant scatterplots and regression equations are presented to substantiate observed correlations,

highlighting the impact of PTSD on cognitive abilities and the challenges individuals face in maintaining associations and interactions with people despite their traumatic experiences.

The extant research endeavors have not attempted to control for possible links between PTSD and memory in adolescent earthquake victims in Pakistan. A gap exists in the literature because no published predominance study concerning PTSD and memory in adolescents has been published after the Pakistan earthquake. Therefore, this project planned to determine the presence of PTSD in relation to memory in child victims of the Pakistan earthquake of October 08, 2005. To this end, it focused on adolescents attending schools in the areas of Pakistan affected by the repercussions of the earthquake. This study also proposed to test the impact, strengths, and weaknesses of the Children and War Foundation's "Writing for Recovery" manual to alleviate PTSD in adolescents.

Hypothesis: It was posited that earthquake victims (participant groups B and C) would exhibit higher levels of PTSD and reduced memory performance compared to non-victims (group A). The Writing for Recovery intervention was expected to reduce PTSD symptoms and improve memory in the affected groups.

2. Methods

2.1. Participants

All participants of the study were earthquake victims recruited through the Earthquake Reconstruction and Rehabilitation Authority (ERRA), whose operations entail preparing, managing, observing, and controlling rebuilding and treatment activities in earthquake-effected areas in Pakistan.

Before the study was initiated, 47 earthquake victims aged between five and 76 years were casually interviewed. This task was undertaken to establish a general idea about the incidence of PTSD in the earthquake survivor environment. The interviewed individuals were included in the ERRA efforts. Subsequently, 25 other individuals also aged between 5 and 76 years were interviewed in the capital city of Pakistan. These respondents formed the control group and were approached and interviewed at random.

Three groups of participants were formed during the study. Each group comprised 15 adolescents (ten boys and five girls) aged between 13 and 15 years. Group A (33.3 %) encompassed adolescents who were not earthquake victims and was designated the reference group that would initially reveal whether the memory functions of earthquake victims were at all affected. Groups B and C (66.6%) both contained earthquake survivors, and both groups were identical. However, two groups of respondents were utilized rather than one to account for any variations in the results.

All participants belonged to the same nationality (Pakistani) and hailed from low socioeconomic environments with limited income. Elimination criteria were restricted to mental disabilities or any form of memory loss after the earthquake. Initially, each group was supposed to include 25 adolescents. However, the study required participants to be able to read and write and 15 participants were ultimately recruited per group because it was impossible to enlist 25 literate adolescents for both cohorts. In addition, the study required participants to be present for a week, and the requisite number of participants were unavailable for that duration. Moreover, the male–female participant ratio was originally envisaged as equal. However, males were much more willing to participate in the study and females seemed more hesitant due to the conservative nature and culture of the inhabitants of Pakistan. Therefore, the ultimate participant distribution was 66.6% male and 33.3% female.

2.2. Materials

Psychologists over the centuries have employed many different memory tests. The applications range from model tests of instant and deferred learning, recollection, and identification to complex hypotheses through investigational stimuli to appraise data development abilities.

Standard tests center on universal learning and memory abilities, and investigational assessments have probed the functions of stress-associated cues and their effects on memory. Studies conducted using standard tests of verbal or visual memory have indicated that patients who suffer from PTSD present memory conditions ranging from undamaged to placidly damaged memory functions. However, more complex memory tests involving stimuli focusing on specific personal experiences have reported modifications in cognitive data processing. The present study required a memory test that combined everyday verbal and visual memory with certain customizable stimuli attending to the Pakistan earthquake. Therefore, the Rivermead Behavioral Memory Test was used for this study. This assessment of daily memory functions is internationally recognized, extremely insightful, and short. It comprises 12 components (name recognition, image recognition, etc.) that evaluate several of the daily memory problems acknowledged in patients with memory difficulties. Most importantly, the test can be used to monitor change (Wilson, 2006). Thus, the Rivermead

Behavioral Memory Test was translated into Urdu, and certain components of the test were altered to work better with the circumstances of the Pakistan earthquake victims.

Mental health specialists have utilized an assortment of scientific and investigational neuropsychological tests to examine PTSD in patients. This study employed a questionnaire addressing PTSD symptoms that is endorsed by the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2000). The fourth edition of this instrument is also known as the DSM-IV, and this questionnaire was adapted for the present study for two reasons. First, it is the format used by mental health providers to conclude whether or not an individual suffers from PTSD. Second, it also accords adolescents a relaxed means of self-assessment (American Psychiatric Association, 2000). The questionnaire is basic; thus, adolescent respondents would not encounter difficulties in registering their answers. Moreover, the questionnaire was easily translated into Urdu.

Many thousands of adolescents were affected when the Pakistan earthquake occurred. Thousands became orphans, and thousands were detached from their families for some time. Their homes and schools were ruined and as a third-world country, Pakistan did not have the necessary resources to implement proper interventions for such adolescents (Mancuso *et al.*, 2008). Hence, the Writing for Recovery Manual (version April 2008) was applied because it was apt to the nature of this study.

In April 2005, numerous specialists in written and verbal expression after PTSD came together in Bergen, Norway to develop a writing manual for adolescents who experienced wars or disasters (such as the Pakistan earthquake). The manual is reliable and is regarded as the best in the field because these specialists had previously successfully adapted cognitive behavioral therapy techniques. Furthermore, this manual was selected because it deals with written memory and the present study focused on memory and PTSD. Moreover, the manual was easy manual to administer and its basic format and language made it easy to translate into Urdu.

2.3. Measures

Before the study began, 47 earthquake victims aged between five and 76 years were casually interviewed to attain a general idea of PTSD conditions in the earthquake survivor environment. The casual interviews were also conducted to develop a context and acquire an impression of the conditions of earthquake victims. The control group of 25 individuals who were not earthquake victims was then interviewed. This measure was adopted to compare and contrast the lives, feelings, thoughts, and emotions of earthquake victims and the general population of Pakistan.

The same principal measures were utilized for all three groups. First, the participants filled out the self-assessment PTSD questionnaire. This stem was intentionally informally implemented to allow honest self-assessment by participants.

Second, the Rivermead Behavioral Memory Test was administered a week after completing the questionnaire. This specific test was used for many reasons including the fact that it allowed repetitive evaluations through daily illustrations, and the researcher could thus examine the consistency, development, or decline in memory during the study period. This test was also chosen for the present study because it enabled the researcher to chart a clear link between memory and PTSD.

Third, the Writing for Recovery Manual (version April 2008) was applied. This instrument was selected because scholars worldwide consider it a leading and updated intervention method. This study required an intervention that would help the participants instead of upsetting them and would simultaneously help the researcher assess the level of PTSD in the participating adolescents.

Fourth, the Rivermead Behavioral Memory Test was readministered to compare the results of the memory test before and after the manual was applied. This retest was also intended to determine whether the manual affected memory cognition.

Finally, the PTSD self-assessment questionnaire was also readministered to ascertain the types of effects exerted by the manual on PTSD in the participating adolescents. These steps remained the same for all three groups. For example, even group A filled out the PTSD questionnaire, even though the participants designated to this group were not earthquake victims. This action was taken to ensure uniformity throughout the study and to discover whether group A's PTSD results before and after the intervention were comparable to the outcomes obtained for groups B and C.

However, group A was tested in Islamabad while groups B and C were tested at the same location in Mansehra because group A represented the control group and comprised adolescents who were not earthquake victims.

Each writing manual session lasted 15 min, the Rivermead Behavioral Memory Test took approximately 25 min to complete, and filling in the PTSD questionnaire did not take more than 20 min. A maximum time limit of 25 min was imposed on every activity undertaken during the study because adolescent earthquake victims usually display reduced attention, concentration, and patience.

2.4. Procedure

The ERRA was provided with consent forms and other necessary details in advance in Islamabad a few weeks before the study commenced in Mansehra. Additional information was obtained from ERRA on discrete reconstruction sectors such as housing, education, health care, environmental, livelihood, transportation, power generation, social protection, telecommunication, and disaster risk reduction. Subsequently, the Mansehra office of ERRA organized two different groups (B, and C) of adolescents aged 13-15 for this particular study. Each group comprised 15 adolescents and each encompassed ten boys and five girls.

The 1st day at the Mansehra location was spent getting to know the adolescents, who were briefed about the nature of the study and were informed that anything they wrote during the study would remain confidential. This assurance was provided to help them feel comfortable about participating in the study. Notably, the two groups B and C were segregated for the duration of the study to avoid any disruption to the study and avoid variations in the results. The separation of the groups was also important because two groups were instituted instead of one only to account for any variations in the results.

The study was conducted solely in Urdu. Each group was handled separately throughout the experiment, at different times every day. A quiet room with 20 tables and chairs served as the setting for the study so that the participants could focus on their work without being able to see the responses tendered by other participants. Two members of the ERRA team were also always present throughout the study to ensure that the participants felt comfortable, help if they needed assistance, or answer any questions. Each participant was given two pencils and one eraser. The PTSD self-assessment test was given to both groups on the 2nd day.

Thereafter, the respondents were given a break of 1 week from the study. This interruption was intentional: the writing manual sessions can be emotionally draining for some participants, and the researcher did not wish to overwhelm the adolescents. The Rivermead Behavioral Memory Test was administered after the 7-day break. This test took 20 – 30 min to complete. Each participant was assigned a number and respondents were asked to always use the same number and not write their names on their different tests. The pages were also precoded to make up for any human errors committed by the participating adolescents in inscribing their numbers on their pages. This encoding ensured confidentiality and each participant inscribed the same number on every form to facilitate the calculation of the results.

The writing manual was applied on the 4th day and over the next 3 days; the adolescents were requested to write about their deepest reflections, notions, and ideas for 15 min. Once they were done, they were instructed to staple their pages together (if more than one) and deposit their pages in a box at the back of the room. At the end of every session, the participants were reminded that their thoughts were private and they did not need to talk to their colleagues about what they had written. Each session was followed by biscuits and juice in the open courtyard.

The Rivermead Behavioral Memory Test was reapplied to both groups 1 day after the writing manual sessions were completed. The next day, the PTSD self-assessment test was also read ministered to both groups.

The same procedure was applied in the same manner to group A in Islamabad. Notably, however, group A was tested after groups B and C, and the environment/setting differed for the control group A from the setting previously described for groups B and C.

An individual scoring system was designed for each activity because the study was executed on a small scale and results were required for comparative purposes. The PTSD questionnaire comprised 24 yes/no. Therefore, one point was awarded for each "yes" answer. Given the questionnaire characteristics, the higher the score, the stronger the respondent's PTSD symptoms. The subsets of the Rivermead Memory Test were scored separately and the results depended on how accurately an individual performed on each part of the test. The subsets included remembering an appointment, recollecting a short route (immediately and after a delay), recalling a belonging, remembering to deliver a message, recalling images, orientations, and stories (immediately and after a delay), remembering names, and recognizing faces. The Rivermead test scoring was converted to 100 maximum points to maintain reliability; thus, each subtest was accorded a maximum of 8.33 achievable points.

3. Results

A total of 45 participants aged between 13 and 15 years participated in the present study. However, males and females were not equally represented (66.6% of the participants were male, and 33.3% were female).

Tables 1-3 list the results obtained for each group (A, B, and C) on the PTSD questionnaire before (PTSD I) and after (PTSD II) the writing manual was applied.

Tables 4-6 present the results of the Rivermead Behavioral Memory Test for each group (A, B, and C) before (Memory I) and after (Memory II) the writing manual was applied.

Table 1. Group A (control) participants

Participant ID	PTSD I (pre-intervention)	PTSD II (post-intervention)
1	5	5
2	6	6
3	3	3
4	2	2
5	1	0
6	5	5
7	7	7
8	4	4
9	8	8
10	6	6
11	9	9
12	5	5
13	7	7
14	8	8
15	2	2
Total	78	71

Notes: Score indicates PTSD symptom severity. The score ranges from 0 to 24, with higher scores indicating greater symptom severity.
Abbreviation: PTSD: Posttraumatic stress disorder.

Table 2. Group B (earthquake survivors) participants

Participant ID	PTSD I (pre-intervention)	PTSD II (post-intervention)
1	22	18
2	22	14
3	13	12
4	19	19
5	21	15
6	15	14
7	11	2
8	20	18
9	24	4
10	16	19
11	9	4
12	5	6
13	10	7
14	20	11
15	13	1
Total	240	164

Notes: Score indicates PTSD symptom severity. The score ranges from 0 to 24, with higher scores indicating greater symptom severity.
Abbreviation: PTSD: Posttraumatic stress disorder.

Table 3. Group C (earthquake survivors) participants

Participant ID	PTSD I (pre-intervention)	PTSD II (post-intervention)
1	20	16
2	22	20
3	22	12
4	17	15
5	15	10
6	20	19
7	7	8
8	24	18
9	18	2
10	14	3
11	10	3
12	7	4
13	14	8
14	16	19
15	18	2
Total	244	159

Notes: Score indicates PTSD symptom severity. The score ranges from 0 to 24, with higher scores indicating greater symptom severity.
Abbreviation: PTSD: Post-traumatic stress disorder.

Table 4. Rivermead behavioral memory test in group A (control)

Participant ID	Memory I (pre-intervention)	Memory II (post-intervention)
1	67	73
2	43	96
3	30	32
4	12	25
5	76	78
6	50	82
7	82	81
8	85	90
9	52	62
10	41	54
11	92	95
12	45	60
13	39	50
14	56	80
15	81	92
Total	851	1050

Notes: Score indicates memory performance. The score ranges from 0 to 100, with higher scores indicating better memory performance.
Abbreviation: PTSD: Post-traumatic stress disorder.

The results suggest that all three groups performed better in the memory test after the writing manual was applied. Figure 1 shows the percentage changes between the results obtained by the three groups on the rivermead

Table 5. Rivermead Behavioral Memory Test on group B (earthquake survivors)

Participant ID	Memory I (pre-intervention)	Memory II (post-intervention)
1	15	20
2	64	80
3	45	42
4	18	27
5	21	43
6	38	56
7	52	67
8	33	78
9	21	45
10	31	59
11	42	63
12	18	45
13	10	32
14	26	58
15	32	49
Total	472	746

Notes: Score indicates memory performance. The score ranges from 0 to 100, with higher scores indicating better memory performance.
Abbreviation: PTSD: Post-traumatic stress disorder.

Table 6. Rivermead behavioral memory test in group C (earthquake survivors)

Participant ID	Memory I (pre-intervention)	Memory II (post-intervention)
1	80	83
2	22	48
3	42	31
4	17	40
5	22	64
6	46	67
7	31	64
8	47	59
9	54	58
10	12	47
11	19	93
12	7	42
13	34	31
14	31	65
15	70	45
Total	453	837

Notes: Score indicates memory performance. The score ranges from 0 to 100, with higher scores indicating better memory performance.
Abbreviation: PTSD: Post-traumatic stress disorder.

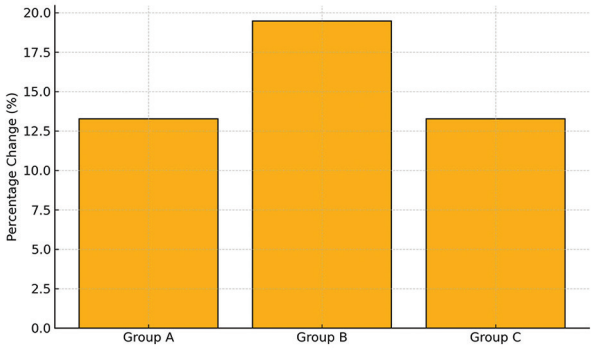

Figure 1. Percentage changes in rivermead behavioral memory test results in different groups.
Note: Group A is control, groups B and C are earthquake survivors.

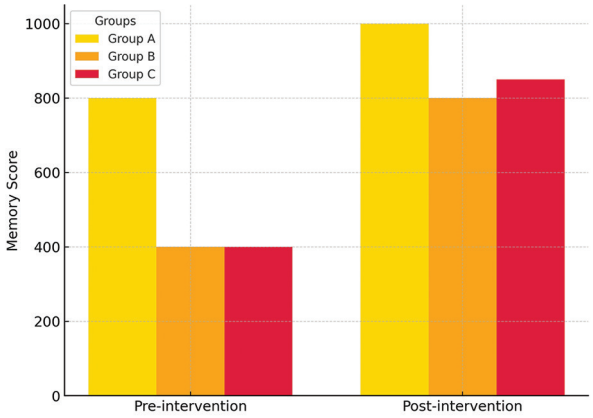

Figure 2. Percentage change between memory I and memory II in different groups.
Note: Group A is control, groups B and C are earthquake survivors.

behavioral memory test administered before and after the application of the writing manual: group A increased its score by 13.27%, and the tallies for groups B and C augmented by 19.47% and 13.27%, respectively (Figure 2).

It is also evident that the results obtained by groups B and C evinced greater improvement than the scores attained by control group A.

3.1. Correlations between the PTSD test and the writing for recovery manual

The test scores of all three groups of adolescents evinced lower PTSD symptoms after the application of the Writing for Recovery Manual (Figures 3 and 4). The results obtained by group A on the first and second PTSD tests varied minutely; however, the scores computed for groups B and C evidenced substantive improvement. Group A's results changed only by 1.9%; conversely, the symptoms reported by groups B and C diminished by 21.16% and 23.61%, respectively.

4. Discussion

The results presented in Table 7 elucidate that all three groups (A, B, and C) performed better at the memory test after the manual was applied. The results of control group A did not register any significant variations between the first and second PTSD tests. However, both groups of earthquake victims (B and C) reported fewer PTSD symptoms. Overall, the memory test results obtained by control group A were superior to the tallies attained by both groups of adolescent earthquake victims, B and C. The results of this study endorse the findings reported by preceding studies: groups B and C comprising adolescent earthquake victims evinced PTSD rates of 66.66% and 67.77%, respectively. These rates align with the approximately 70% occurrence rate found in children who experienced the Armenian earthquake in 1988 (Goenjian *et al.*, 2003; Armenian *et al.*, 2000). This study's complex design allowed the prospect of inspecting adolescent responses to the traumatic earthquake event. The age range of this study's participants was fixed between 13 and 15; therefore, it was difficult to determine whether age played a role in the PTSD findings. However, 47 earthquake victims from all age ranges were casually interviewed before the study was initiated. It was noted that the younger the victim, the more the symptoms of PTSD were present. The results of these individuals were compared to those of 25 individuals who were not earthquake victims. Younger individuals who did not suffer the effects of the earthquake displayed a more stable psychological state than earthquake victims (Green, 1991). This study's male–female ratio was unequal because 66.6% of the participants were male and 33.3% were female. However, the results obtained in the memory tests by female respondents in all three groups were consistently higher than the scores of male participants. Perhaps, this outcome can be explained by the conservative Pakistani culture, in which girls in rural areas are generally encouraged to stay at home while boys are considered providers. Therefore, the trend that girls try twice as hard has developed because girls feel they must prove themselves equal to their male counterparts.

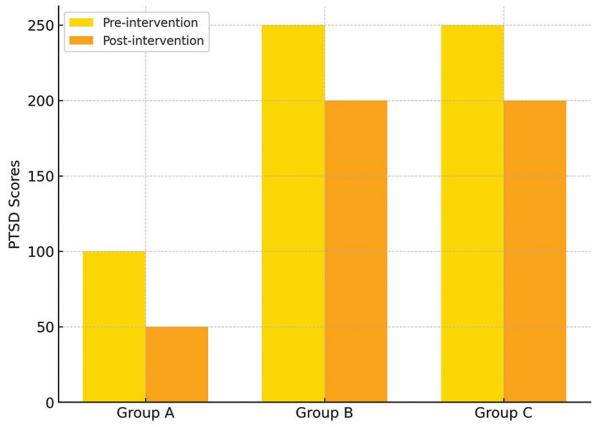

Figure 3. PTSD score changes in pre-intervention and post-intervention groups.
Note: Group A is control, groups B and C are earthquake survivors.

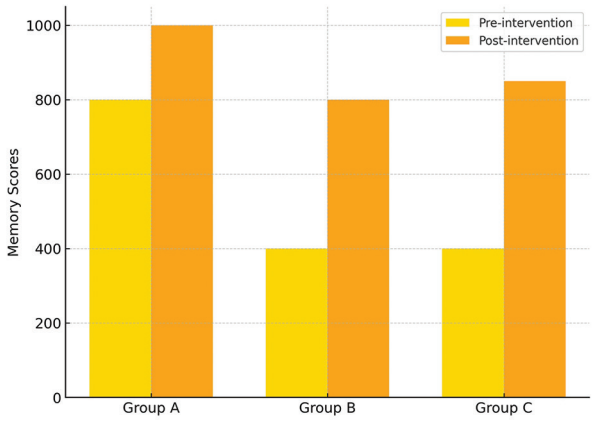

Figure 4. Memory test results in pre-intervention and post-intervention groups.
Note: Group A is control, groups B and C are earthquake survivors.

Notably, all adolescents in the study except for the members of the control group A were directly exposed to the earthquake. Of the participants designated to groups B and C, 80% claimed that they had repeated distressing memories and/or dreams. However, this proportion lowered to 70% after the Writing for Recovery Manual and Memory II were applied.

During the writing manual exercises, 60% of the participants designated to groups B and C claimed to

Table 7. Consolidated results

Group	PTSD pre-intervention (PTSD I)	PTSD post-intervention (PTSD II)	Memory Test pre-intervention (Memory I)	Memory Test post-intervention (Memory II)
Control Group A	78	71	851	1050
Earthquake survivors Group B	240	164	472	746
Earthquake survivors Group C	244	159	453	837

avoid thoughts, feelings, and conversations about the earthquake. This finding affirms the results reported by previous studies that PTSD sufferers practice avoidance. Of the participants in groups B and C, 90% of the girls reported recurring anxiety compared to only 70% of the boys. Perhaps, this outcome could be attributed to the expressive nature of girls and their openness to candidly inscribing their feelings and thoughts. These results could also stem from the fact that women represent the population segment most susceptible to the psychosomatic effects in the aftermath of earthquakes (Breslau *et al*., 1997). The answers tendered by groups B and C during the writing manual exercises are much more emotional than the responses by the adolescent participants in group A. It is evident as expected that the participants designated to groups B and C suffered some form of trauma that group A respondents did not experience.

The results illuminate that the writing manual exerted a positive impact on the adolescent earthquake victims. The participants in control group A also benefited from the intervention; however, the members of groups B and C benefited more. Clearly, an intervention is required for Pakistani adolescents who experienced the adverse effects of the earthquake. The writing manual was extremely helpful as an intervention because it helped the adolescent participants express their feelings without upsetting them. Thus, they felt lighter and better.

The neural networks involved in PTSD entail intricate exchanges between the amygdala, hypothalamus, pituitary, and thalamus. PTSD-induced chemical reactions in the hypothalamic-pituitary-adrenal axis result in dysregulation of stress hormones, particularly cortisol, which can impair memory and cognition by altering synaptic plasticity and hippocampal functioning. The present analysis included correlation coefficients and regression equations to evaluate the relationships between PTSD symptoms and memory function. Relevant scatterplots and regression equations are presented to substantiate the observed correlations.

Many participants appeared to transform their emotional pain into physical discomfort during the writing manual sessions. They complained about headaches, backaches, or other physical ailments. Perhaps, this transfiguration occurred because Pakistanis are not accustomed to oral or written therapy and do not know how to express emotional pain. Furthermore, PTSD may be connected to heightened severity of pain in multiple ways. Amplified stress, worry, or apprehension can increase pain sensitivity (Bryant *et al*., 1999). The capacity of PTSD sufferers to handle pain may also be hindered by their personal awareness of pain. Moreover, adolescents who have suffered such a catastrophe become too preoccupied with tackling their negative memories and feelings about the event and ignore the means of decreasing their pain (Bryant *et al*., 1999; Saxe & Mino, 2004).

However, several limitations of the study must be acknowledged. First, a single researcher conducted the entire study, including its initial conception and design, establishing its methodology, accomplishing all relevant tasks, performing the analyses, ascertaining and discussing the results, and deriving the conclusions. Second, the study data obtained from the PTSD questionnaire and writing manual exercises were based on self-assessment and self-reflection. Thus, the facts, symptoms, and other information collected from the adolescent participants of this study could diverge from reality. Third, some words or meanings may be lost in translation because the study was conducted in Urdu. Fourth, certain results could not be calculated due to the characteristics of the writing manual exercises: it is impossible to compute the thoughts and feelings expressed by individuals during the writing tasks. Such expressive written exercises cannot be compared and contrasted against each other. Finally, control group A was not tested in the same setting as groups B and C. Hence, the comparative results may not be as reliable due to environmental factors.

Overall, the scores revealed an improvement between PTSD I and PTSD II: the overall scores of PTSD II decreased, indicating an alleviation of PTSD symptoms after the manual was applied.

5. Conclusion

PTSD is generally underdiagnosed in Pakistan. Moreover, no suitable and verified intervention system exists in Pakistan that can be massively administered in the aftermath of a disaster. The effects of the Pakistan earthquake elucidate the substantively inferior quality of Pakistan's mental health system compared to the structures established in developed countries. Perhaps, this deficiency exists because Pakistan must focus primarily on issues such as housing, food, employment, and electricity; thus, mental health difficulties are not considered necessary for survival. Mental health professionals in Pakistan should prepare for all types of future disasters. In the context of the Pakistan earthquake, mental health professionals must administer interventions to help adolescents with PTSD. This study has evidenced an intervention that is advantageous and improves both PTSD and memory. Studies conducted on the Bam earthquake have also indicated that Western therapies and interventions can be successful (Emami *et al*., 2005). Perhaps, such an intervention has not been adopted in Pakistan on a large scale because Pakistani culture is unfamiliar with oral or written therapy. In general, Pakistanis believe that their feelings should be repressed

and not expressed. The articulation of one's innermost thoughts and feelings is considered a Western notion.

The present study on children who were victims of the devastating earthquake in Pakistan in 2008 focused on adolescents attending schools in the affected areas. It aimed to determine the presence of PTSD in the participating adolescents and attempted to ascertain the relationships between PTSD and memory. It also intended to test the impact, strengths, and weaknesses of the Children and War Foundation's Writing for Recovery Manual-based intervention for adolescents with PTSD. The study results illuminated that all three groups A, B, and C performed better at the memory test after the manual was applied. The results of the first and second PTSD tests administered to control group A evinced negligible variations. However, both groups B and C, which comprised adolescents who were earthquake victims, reported fewer symptoms of PTSD after the intervention. The overall memory test scores of control group A were superior to the results recorded for both groups B and C.

Perhaps follow-up studies can yield a formal recovery system for people suffering from PTSD in Pakistan. The institution of such a structure could also help mental health professionals in Pakistan prepare for wide-ranging types of disasters in the future.

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None.

Conflict of interest

The author declares that she has no competing interests.

Author contributions

This is a single-authored article.

Ethics approval and consent to participate

This study was conducted in strict adherence to the principles outlined in the Declaration of Helsinki. All procedures involving human participants were reviewed and approved by the Ethics Committee. Written informed consent was obtained from all participants or their legal guardians before their inclusion in the study. Participation was voluntary, and confidentiality of personal data was rigorously maintained throughout the research process.

Consent for publication

Not applicable.

Availability of data

The data supporting the findings of this study are available from the corresponding author on reasonable request.

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Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Vaccine hesitancy and its association with demographics, mental health, and disability: Findings from the VH-3 study in the United States, India, and China

Arinjita Bhattacharyya[1], Shikshita Singh[2†], Swarna Sakshi[3†], Anand Seth[4†], and Shesh N. Rai[4*]

[1]Merck & Co, Inc., Rahway, New Jersey, United States of America

[2]Department of Osteopathic Medicine, Rocky Vista University College of Osteopathic Medicine, Ivins, Utah, United States of America

[3]Alabama College of Osteopathic Medicine, Dothan, Alabama, United States of America

[4]Biostatistics and Informatics Shared Resource, University of Cincinnati Cancer Center, Cincinnati, Ohio, United States of America, Cancer Data Science Center, University of Cincinnati College of Medicine, Cincinnati, Ohio, United States of America, Department of Biostatistics, Health Informatics and Data Science, University of Cincinnati College of Medicine, Cincinnati, Ohio, United States of America

These authors contributed equally to this work.

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***Corresponding author:**
Shesh N. Rai
(raise@ucmail.uc.edu)

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Abstract

The novel coronavirus (SARS-CoV-2), which causes COVID-19, has claimed millions of lives since December 2019. The rapid development of vaccine candidates and treatments has led to increased confusion and mistrust regarding the development, emergency authorization, and approval processes. To better understand vaccine hesitancy, we analyzed two publicly available datasets: One from the Inter-University Consortium for Political and Social Research Covid-19 database and the other from the United States (US) Census Bureau's Household Pulse Survey Phase 3.2. In India, 90.2% of 1,761 participants indicated acceptance of a COVID-19 vaccine. A binary logistic regression model, using vaccine hesitancy as a dichotomous variable, showed that rural populations had an odds ratio (OR) of 3.45 ($p < 0.05$) for vaccine hesitancy. In addition, income played a significant role, with individuals earning 7501 – 15,000 Indian Rupees (INR)/month, or US$ 91 – 183, having an OR of 1.41 compared to other income groups. In the US, 67.3% of 1,768 participants expressed willingness to accept the vaccine. White participants had an OR > 1 compared to other racial groups, while low-income groups earning US$ 2000 – 4999/month had an OR of 1.03. In China, 90.0% of 1,727 participants indicated they would accept a vaccine, with high-income groups showing the least resistance (OR = 0.96) compared to other groups. Among the three countries studied, the US exhibited the highest rate of vaccine hesitancy. This ongoing issue warrants attention from the World Health Organization.

Keywords: Vaccine hesitancy; COVID-19; Pandemic; SARS-Cov-2; Mental health; Multinomial logistic regression

1. Introduction

Vaccine hesitancy has posed challenges for healthcare providers and public health officials for years. In light of the COVID-19 pandemic, vaccine hesitancy has become even more relevant and has emerged as a global issue. The SAGE Working Group on Vaccine Hesitancy (WG) defines vaccine hesitancy as a "delay in acceptance or refusal of vaccination despite the availability of vaccination services" (MacDonald *et al.*, 2015). Several conceptual models exist for categorizing vaccine hesitancy; one widely used model is the "3Cs" model, which the WG incorporated into their definition of vaccine hesitancy. The "3Cs" model consists of three factors: (i) confidence, (ii) complacency, and (iii) convenience. Confidence represents the trust of the vaccine recipient in the effectiveness and safety of the vaccine and the delivery system. Complacency occurs when the perceived risk of the disease is low in view of the recipient; other factors can also contribute to complacency, such as the initial success of the vaccine program. Convenience relates to the availability and accessibility of the desired vaccine (MacDonald *et al.*, 2015). Application of the 5Cs framework was used to study vaccine hesitancy among pregnant women. The 5Cs model includes constraints, complacency, calculation, confidence, and collective responsibilities (Casubhoy *et al.*, 2024). The 3Cs and 5Cs models focus on psychological factors, but cultural and structural influences on vaccination behavior need to be investigated.

Vaccine hesitancy is not unique to the COVID-19 vaccine. As of August 13, 2024, 70.6% of the global population has received at least one dose of the COVID-19 vaccine, but only 32.7% of individuals in low-income countries had received at least a first vaccine by April 13, 2024 (Yamanis, 2024; "Deployment of COVID-19 vaccines," 2024). Despite high childhood vaccination rates in developed countries, recent outbreaks of vaccine-preventable diseases, such as measles and mumps, have demonstrated the existence of clusters of unvaccinated populations. A national survey of childhood vaccines and influenza vaccines in the United States (US) found that one in 15 (6.7%) parents were hesitant about childhood vaccines, while the prevalence for influenza vaccine hesitancy was more than one in four (25.0%) parents. In addition, the same survey found that about one in four parents believed the influenza vaccine to be effective. One in eight (12.5%) parents was also concerned with the side effects of influenza and routine childhood vaccines. Prevailing hesitancy toward vaccines in the US begs the question: What are the specific factors that contribute to vaccine hesitancy? A theoretical framework guiding the current research is to account for variation in vaccine acceptance across different diseases. These barriers are psychological and physical. In other words, how recipients perceive the usefulness of taking a vaccine, the associated risk of the vaccine, and a host of other factors.

Health beliefs influence vaccine hesitancy. Several theories are propounded to explain health behaviors, e.g., the health belief model (HBM), protection motivation theory, and theory of planned behavior, among others. Till today, HBM has remained a dominant theory of health beliefs with its five primary components: Primary sustainability, primary severity, perceived benefits, perceived barriers, and cues to action. In the mid-1980s, a sixth component of self-efficacy was added, which reflects a person's confidence in his/her ability to successfully perform a behavior (Abraham & Sheeran, 2015). Recently, Limbu *et al.* (2022) have provided a systematic review of HBM to COVID-19 vaccine hesitancy, covering 30,242 participants. These authors identified other HBM modifying factors to be associated with COVID-19 vaccine hesitancy, namely, gender, education, age, geographical location, occupation, income, employment, marital status, race, ethnicity, knowledge of COVID-19 prior diagnosis, history of flu vaccine, religion, nationality, and political affiliation.

Schmid *et al.* (2017) attempted to classify the barriers to influenza vaccine uptake into its micro- and macro-levels. The micro-level barriers are generally psychological and physical. These barriers can be related to the theories of health decision-making and behavior. The authors identified 258 micro-level barriers. These barriers were subsequently grouped into the following categories: utility, risk perception, social benefit, subjective norm, perceived behavioral control, attitude, past behavior, experience, knowledge, and unhealthy lifestyles. Specifically, our focus is on respondents' attitude, sociodemographic factors, and their risk perception. In addition, we will break down the COVID-19 vaccine hesitancy rates among the different regions of the US.

The contributing factors for COVID-19 vaccine hesitancy can vary. Social media organization (Wilson & Wiysonge, 2020), vaccine characteristics (Wong *et al.*, 2021), political affiliations (Albrecht, 2022), education level (Zychlinsky Scharff *et al.*, 2022), employment, risk of infection (Gatto *et al.*, 2021), distrust of the COVID-19 vaccine (Nair *et al.*, 2021), and general vaccine avoidance (Shen & Dubey, 2019). Past studies looking into COVID-19 vaccine hesitancy have used a large-n cross-country regression framework, survey with choice-based conjoint analysis, and regression analyses to analyze data in previous studies.

According to Sallam (2021) (based on data up to December 25, 2020), the highest COVID-19 vaccine

acceptance rates among adults were reported in Ecuador (97.0%), Malaysia (94.3%), Indonesia (93.3%), and China (91.3%). In contrast, the lowest COVID-19 vaccine acceptance rates were observed in Kuwait (23.6%), Jordan (28.4%), Italy (53.7%), Russia (54.9%), Poland (56.3%), the US (56.9%), and France (58.9%). Lin *et al.* (2020) reported similar findings for China, with vaccine acceptance rates ranging from 88.6 to 91.3%, and found 79.8% acceptance in South Korea. Other highly receptive countries included Brazil (85.4%), South Africa (81.6%), Denmark (80.0%), and the UK (79.0%).

Sallam *et al.* (2022) updated their previous vaccine acceptance rates based on the regional classification of the Joint Nations Program on HIV/AIDS (UNAIDS) (Tables S1 and S2; survey date varied from May 2020 to June 2021). Within the South Asian region, vaccine acceptance data from lower-middle-income countries (LMIC) were available: Bangladesh (61%), Afghanistan (63%), Pakistan (72%), India (79%), and Nepal (97%). Southeast Asian countries with LMIC were Lao People's Democratic Republic (62%), Philippines (63%), Indonesia (65%), Timor-Leste (66%), Myanmar (86%), and Vietnam (97%). The figures in parentheses indicate the vaccine acceptance rate.

We also examined the vaccine acceptance rates in the Association of Southeast Asian Nations countries. These countries are: (i) Brunei, (ii) Cambodia, (iii) Indonesia (65%), (iv) Lao PDR (62%), (v) Malaysia, (vi) Myanmar (86%), (vii) the Philippines (63%), (viii) Singapore, (ix) Thailand, and (x) Vietnam (97%). Note that Brunei and Singapore are high-income countries, while Malaysia and Thailand are both upper-middle-income countries. No vaccine acceptance data were available for Cambodia (Sallam *et al.*, 2022).

We analyzed vaccine acceptance data from the original five BRICS countries: Brazil (83%), Russia (30%), India (79%), China (82%), and South Africa (76%), as well as the newly added BRICS countries in 2024: Egypt (25%), Iran (62%), and the United Arab Emirates (60%). Based on World Bank data, India is the only BRICS country classified as a LMIC. A recent study by Lazarus *et al.* (2023), which surveyed 23,000 respondents across 23 countries from June 29 to July 10, 2022, found that willingness to accept vaccination was 79.1%, representing an increase of 5.2% from June 2021. However, vaccine acceptance decreased in eight of the surveyed countries. In addition, Yanto *et al.* (2022) found a vaccination acceptance rate of 71% in Southeast Asian countries during the 2020 – 2021 period (Table S1).

A recent systematic review on the impact on mental health (MH) during COVID-19 reported that there have been relatively high rates of anxiety symptoms (6.3% – 50.9%), depression (14.6% – 48.3%), post-traumatic stress disorder (7.0% – 53.8%), psychological distress (34.4% – 38.0%), and stress (8.1% – 81.9%) among the population of China, Spain, Italy, Iran, the US, Turkey, Nepal, and Denmark (Xiong *et al.*, 2020). Other studies also found high rates of negative MH outcomes in the Italian general population within 3 weeks of lockdown (Rossi *et al.*, 2020). Studies have also shown a positive association between the probability of contracting COVID-19 and anxiety within the younger age group, while older individuals were better in this perspective and did not show concerns regarding MH (Smith *et al.,* 2021). Experts have pointed out the need for attention to COVID-19-related impacts on MH, stress, anxiety, and human psychology. Providing psychological first aid is an essential care component for populations that have been victims of emergencies and disasters before, during, and after the event (Talevi *et al.*, 2020).

Another study conducted in China found that the high prevalence of MH problems was positively associated with frequent social media exposure during the COVID-19 outbreak, highlighting a need for further attention from health and government officials (Gao *et al.*, 2020). Anxiety levels increased from 18.1% before the pandemic to 25.3% within 4 months after its onset, while the prevalence of moderate to severe depression increased from 21.5% to 31.7%. In a 2023 study by Xiao *et al.* in China, the cognitive theory of stress was used to assess the effects of information quality and media richness on social media fatigue amid the disruptions caused by the COVID-19 pandemic. The authors concluded that high-quality information reduces the likelihood of social media fatigue, while richer media content may lead to increased fatigue among recipients. This social media fatigue could subsequently contribute to MH issues (Xiao *et al.*, 2023). In addition, a 2022 study by Jia *et al.* measured information overload among individuals in the US (n = 493) and China (n = 571). The authors concluded that Chinese participants had significantly lower levels of information overload compared to their US participants ($p < 0.001$) (Jia *et al.,* 2022).

Based on our literature review on vaccine hesitancy, we recognized the value of comparing the three largest countries by population, as direct vaccine hesitancy comparisons among these three nations had not been previously conducted. Our motivation also stemmed from the desire to include a representative country from each income category: the US as a high-income country, China as a middle-income country, and India as a low-income country.

Our objective was to estimate the COVID-19 vaccine hesitancy rate using the US Census Bureau's Household

Pulse Survey (HPS). The estimation was carried out using hesitancy responses as the dependent variable in the multinomial and binary logistic regression models. In the multinomial logistic regression (MLR) model, the response variable had three categories: "Hesitant," "Non-hesitant," and "Unsure," but the binomial logistic regression (BLR) model had only two categories for the response variable, namely, "Hesitant" and "Not hesitant." The purpose of this study was to gain insight by comparing multinomial and binomial logistic response probabilities. Further insight into the response probabilities can be obtained by using recently developed penalized methods. In these methods, regression parameters are pulled toward zero based on the contribution of independent variables. Additional details on the penalized methods are discussed under Model 4.

2. Data description

Here we analyzed two cohorts: (i) The Inter-University Consortium for Political and Social Research (ICPSR) COVID-19 database that focuses on the global vaccine hesitancy data; and (ii) HPS data that concentrates on surveys of identified households in the USA. A detailed overview of both datasets is addressed below:

2.1. ICPSR data

The first dataset is extracted from the ICPSR COVID-19 database (https://doi.org/10.3886/E130422V1) (Zhang *et al*., 2021). It is an open COVID-19 data repository where any researcher can deposit her/his dataset (s) following the guidelines. The datasets are from around the world and cover different aspects of COVID-19. It is maintained by the Institute of Social Research (ISR), University of Michigan. As of August 14, 2024, 104 datasets were deposited covering different aspects of COVID-19 from around the world. ICPSR is managed by ISR, University of Michigan, holds survey data from many organizations of the US government, and is a consortium of many universities. The data quality is excellent and available to researchers in the US and outside the US. The cross-sectional survey is conducted to assess the prevalence of vaccine hesitancy in the US, India, and China, due to their large sample sizes. For India, there were 1,761 participants who completed the survey as of November 2020, of which 90.2% indicated acceptance of a COVID-19 vaccine. In the US, 1,768 individuals participated in the survey from August to November 2020. Of the individuals who participated, 67.3% indicated that they would accept the vaccine. A total of 1,129 of them either had a parent or a child, of which 67.6% would accept the vaccine. In China, there were 1,727 participants, of which 1551 indicated that they would accept a vaccine. 90.1% of them who had either a parent or child were willing to accept a vaccine.

2.2. HPS data

The data for this study was collected from the HPS (Household Pulse Survey, n.d.), which spans the period from July 21, 2021, to October 11, 2021. The HPS is designed for rapid deployment, collecting data to measure how emerging issues impact US households from social and economic perspectives. This initiative is collaboration between the Census Bureau and the National Center for Health Statistics (NCHS) focused on the effects of COVID-19 in the US. Data collection started on April 23, 2020, and follows a 2-week on, 2-week off schedule for collection and dissemination. The data are of good quality and maintained by the US government agencies. This ongoing effort addresses various COVID-19-related issues, including long COVID, hospital data, and long-term care. We chose the HPS dataset because it has several variables that provide a measure of household experiences and the social and economic effects of the COVID-19 pandemic. The dataset's large sample size across the US is particularly valuable for studying COVID-19 vaccine hesitancy. By utilizing the HPS data and employing MLR analysis, we aim to characterize the key aspects contributing to COVID-19 vaccine hesitancy across different demographics and regions in the US.

The dataset contains 515,558 household samples from weeks 34 to 39, with a total of 202 characteristics. Of these, 382,908 represent individual households. For the analysis, we focused on those who had not received any vaccine, which comprised 43,859 samples (11.4%) and 202 variables. After removing missing values, the population was reduced to 5,758 samples and 202 factors. Households that responded to the "Question seen but category not selected" (−99) and "Missing/Did not report" (−88) were not considered in the final analysis, resulting in a dataset of 5,758 unique participant households. Based on the existing literature on vaccine hesitancy and an inspection of the datasets, we selected the following covariates to examine their relationship with vaccine hesitancy: Gender, region, health insurance, income, MH service status, marital status, MH medicine prescribed, race, indicators of anxiety, interest in work, feeling down, worried, education, seeing, hearing, mobility, and memory. In addition, we defined two more variables: One for geographical regions (Northeast, Mid-Atlantic, Southeast, Great Lakes, Midwest, Southwest, Northwest, West, and Mid-South) and another for political views (red, blue, or red/blue [mixed]) depending on the election results from the past decade.

3. Methods

Our investigation is motivated by the following research questions:

(i) What is the level of vaccine hesitancy among the three largest countries by population size: the US, India, and China?
(ii) What factors are associated with vaccine hesitancy in these countries?
(iii) How can cross-sectional and longitudinal data be utilized to study vaccine hesitancy?
(iv) Which subgroups require further research on vaccine hesitancy?

To address these questions, we analyze two datasets on vaccine hesitancy. The first dataset is extracted from the ICPSR COVID-19 database (https://doi.org/10.3886/E130422V1) and includes cross-sectional survey data assessing the prevalence of vaccine hesitancy in the US, India, and China. The second dataset is derived from the HPS data.

For the ICPSR dataset, we report proportions and summary statistics to give an overview of the vaccine hesitancy global picture. The HPS dataset was analyzed using multinomial and binary logistic regression. When the response or outcome can be categorized into two classes, such as "Hesitant" and "Not hesitant," and with several explanatory variables, then a BLR is commonly used. If there are more than two categories, then a natural extension of BLR is MLR. Individual Chi-square tests of independence between vaccine hesitancy and health categories and exploratory data analysis supplemented and helped in our understanding of the causal factors influencing vaccine hesitancy. Rstudio (*RStudio|Open Source & Professional Software for Data Science Teams-RStudio*, n.d.) and Microsoft Excel were utilized for the analysis. Figure 1 provides a flow diagram from the HPS dataset to develop a logistic model for the analysis.

3.1. Model 1

MLR is a statistical regression model used to predict categorical outcomes in the form of probability with more than two unordered categories. It is an extension of BLR. The theory behind MLR includes the following key components:

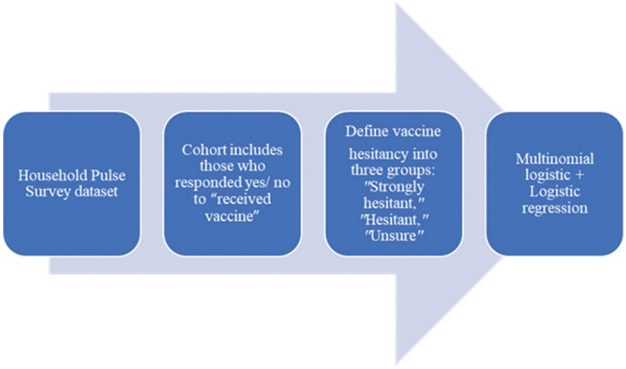

Figure 1. Flowchart for vaccine hesitancy data analysis

3.1.1. Logistic regression

The MLR builds on the principles of BLR. The BLR models the relationship between a set of predictor variables and a binary outcome variable. It uses the logistic function to estimate the probability of the outcome being in one category versus the other. In MLR, this concept is extended to multiple outcome categories.

3.1.2. Categorical outcome variable

In MLR, the outcome variable is categorical, with three or more unordered categories. Each category represents a distinct and mutually exclusive outcome. Examples could include predicting the choice of a political party (e.g., democrat, republican, and independent) or predicting the type of vehicle chosen (e.g., car, truck, SUV).

3.1.3. Logits and log odds

The probabilities of each category are modeled as the log odds (logit) of being in that category (Equations I and II). The log odds represent the natural logarithm of the ratio of the probability of being in a specific category to the probability of being in a reference category. The reference category is one of the categories used as the baseline for comparison.

3.1.4. Parameter estimation

The estimates of the parameters of an MLR model are obtained using maximum likelihood estimation. The goal is to find the set of parameter values that maximize the likelihood of observing the observed data.

3.1.5. Model equations

The MLR uses multiple sets of equations to describe the relationship between the predictor variables and the outcome categories. Each equation compares the log odds of membership in one category to the log odds of being in the reference category. The parameters (coefficients) estimated for each predictor represent the change in log odds associated with a one-unit change in the predictor variable.

3.1.6. Model assumptions

The MLR assumes that the relationship between the predictors and the outcome categories is linear on the logit scale. It also assumes that the error terms are independent and follow a multinomial distribution.

3.1.7. Model interpretation

The coefficients in MLR indicate the change in log odds of being in a specific category as the predictor variables

change. These coefficients can be exponentiated (converted to odds ratios [ORs]) to interpret the direction and magnitude of the relationship between the predictors and the outcome categories.

The independent variables can be either dichotomous (i.e., binary) or continuous (i.e., interval or ratio in scale). Here P (Hesitant)=p_1= probability of falling in class "Hesitant," P (Unsure) = p_2 = probability of falling in class "Unsure," P (Not hesitant) = p_3 = probability of falling in class "Not hesitant," $p_1+p_2+p_3 = 1$.

$$\log(p_1/p_3) = b_{10}+b_{11}X_1+\cdots+b_{1p}X_p \quad \text{(I)}$$

$$\log(p_2/p_3) = b_{20}+b_{21}X_1+\cdots+b_{2p}X_p \quad \text{(II)}$$

After obtaining the estimates of the coefficients (b_{10},b_{11},⋯,b_{1p},b_{20},⋯,b_{2p}), the ORs, which are obtained by exponentiating the log odds, are used to determine the significance of the independent variables when compared between the two groups. If OR > 1, and $p < 0.05$, then the participants are more likely to be in the "Hesitant" (Unsure) group than the "Not hesitant" group. The joint *p*-value is calculated by multiplying the individual *p*-values from the two models in the MLR.

3.2. Model 2

Binary logistic regression is a subset of MLR in which there are only two categories for the response variable (Equation III). Here, there are only two categories in the outcome variable: "Hesitant" and "Not hesitant."

$$\log\left(\frac{p_1}{1-p_1}\right) = b_0 + b_1X_1 + \ldots. + b_pX_p \quad \text{(III)}$$

3.3. Model 3

The dataset was divided into training and testing datasets, the MLR model was applied to the training dataset, and the responses were predicted for the test dataset. A confusion matrix was created to compute the accuracy, sensitivity, and specificity of the model (Machine Learning Mastery, 2020).

3.4. Model 4

3.4.1. Penalized methods

The penalized methods, especially the L1-penality method known as the least absolute shrinkage and selection operator (LASSO), are useful when traditional all-subset regression methods become computationally inefficient. The traditional regression methods will typically have all the estimates of regression coefficients as non-zero. Certain types of constraints on the parameters provide both theoretical and computational advantages. The LASSO or L1 constraint $(\text{Norm } [\beta])_1$ gives sharp corners, which results in sparsity and convexity, while $(\text{Norm } [\beta])_2$ (ridge regression) does not give sparsity. This difference is related to how squared error loss interacts with the constraint sets of LASSO and ridge regression. Sparsity is desirable in general, but it becomes particularly important when the number of parameters is larger than the sample size. Sparsity implies a lesser number of parameters in a model, focusing on the most important ones. The LASSO has the properties of both sparsity and convexity. In all-subset regression, whether forward or backward selection, coefficients that are not important or insignificant (based on a *p*-value or some other criteria) are set to zero. In machine language parlance, feature selection is akin to all-subset regression in a multiple or logistic regression model. Having the property of convexity allows easy optimization in terms of useful parameters and with less computational time. For further details, please refer to Hoerl and Kennard (1970); Bertsimas *et al.* (2016); and Hastie *et al.* (2017). In penalization methods, feature selection and efficient classifier construction are achieved simultaneously. Among the widespread penalized techniques are LASSO, elastic net, and ridge regression (Hastie *et al.*, 2015).

3.4.1.1. LASSO

It regularizes (constrains) the regression coefficients toward zero by penalizing the regression model with the sum of coefficients as a penalty term called L1-norm. This penalty forces the coefficient estimates, with a minimum contribution to the model, to zero.

The log-likelihood of BLR is shown below (Equation IV):

$$l(\beta) = \sum_{i=1}^{n}\left[y_i\log(\pi_i)+(1-y_i)\log(1-\pi_i)\right] = \sum_{i=1}^{n}[y_i\log(\frac{\pi_i}{1-\pi_i})+\log(1-\pi_i)] \quad \text{(IV)}$$

Where π_i = Pr (y_i = 1/x_i) is given by $\pi_i = 1+e^{-x_i\beta}$. Substituting π_i in the loglikelihood gives (Equation V):

$$= \sum_{i=1}^{n}[y_ix_i\beta - \log\left(1+e^{x_i\beta}\right)] \quad \text{(V)}$$

When using the LASSO penalty term λ, a regularizing parameter, the likelihood is represented by Equation VI:

$$l_\lambda^L(\beta) = \sum_{i=1}^{n}[y_ix_i\beta - \log(1+e^{x_i\beta})] - \lambda\sum_{j=1}^{p}|\beta_j| \quad \text{(VI)}$$

It uses the L1 penalty, which uniformly penalizes all the parameters, and due to the convexity of a function, the estimates of parameters are optimum with a minimum mean square error. The fit is independent of multiplicative scaling.

3.4.1.2. Ridge regression

Ridge assigns the L2 penalty, which is the squared magnitude of the overemphasized coefficients, with λ determining the weight assigned to the penalty. The larger the value of λ, the more likely the coefficients approach zero, but the L2 penalty does not help in finding the optimum estimates. Unlike LASSO, the Ridge model will not shrink these coefficients to precisely zero. The likelihood is represented by Equation VII:

$$l_{\lambda}^{R}(\beta) = \sum_{i=1}^{n}[y_i x_i \beta - \log(1 + e^{x_i \beta})] - \lambda \sum_{j=1}^{p} \beta_j^2 \quad \text{(VII)}$$

Here, β^2 is the L2 penalty. It uses the L2 penalty. The L2 penalty does not induce sparsity. With sparsity, one can perform variable selection and also provide a level of interpretability of parameters.

3.4.1.3. Elastic net

Elastic net is a convex combination of LASSO and Ridge, with the effectual reduction in the effect of coefficients with L2 norm and exactly setting some coefficients to zero with L1 norm. The likelihood is represented by Equation VIII:

$$\lambda \sum_{j=1}^{p} \beta_j^2 + (1-\lambda) \sum_{j=1}^{p} |\beta_j| \quad \text{(VIII)}$$

Here, λ is the penalty as a mixture of the previous two approaches. With the L1 norm, some regression coefficients can be set to zero, thereby decreasing the number of parameters, and hence, it is not surprising that it can outperform LASSO on data with positively correlated variables.

Theoretically beneficial and computationally advantageous penalized methods will be explored in future publications but are described here.

4. Results

4.1. Pre-processing

Pre-processing relates to the HPD dataset. The responses toward the intention of getting a vaccine were categorized into the following groups: (i) "Not hesitant" for those who definitely plan to get vaccinated. (ii) "Unsure" for those who are likely to get vaccinated but have some uncertainty. (iii) "Hesitant" for those who probably will not get vaccinated. (iv) "Strongly hesitant" for those who definitely will not get vaccinated. This study aims to gain an in-depth understanding of the factors contributing to vaccine hesitancy. The sample size is adequate to draw inferences related to a broader population.

For the application of MLR analysis, we combined the "Hesitant" and "Strongly hesitant" categories into a single group. The income categories were redefined as follows: "low-income group" for total household income <US$ 34,999, "middle-income group" for incomes between US$ 34,999 and 74,999, and "high-income group" for those earning more than US$ 75,000. The education categories were reclassified into: (i) "High school" (including less than high school and some high school), (ii) "High school graduate" (high school graduate or equivalent), (iii) "some college, no degree received," (iv) "Associate/bachelor's degree," and (v) "Graduate degree." The responses related to depression factors, such as frequency of anxiety, worry, interest, and feeling down for over 2 weeks, were regrouped into three categories: "Not at all," "Several days," and "Always," which includes responses for "More than half the days" and "Nearly every day." Other forms of impairment, such as hearing, seeing, remembering, and mobility, were also included and recategorized as "Impaired" (including some difficulty, a lot of difficulty, and cannot do at all) and "Not impaired" (no difficulty). In addition to the selected factors for investigation in the MLR model to understand their impact toward vaccine hesitancy, we also included the following variables: race (White, Black, and others); gender (male, female, and transgender); health insurance status (yes, no); whether respondents received MH services (yes, no); whether MH medicines (psychopharmacological drugs) were prescribed (yes, no); and region (Midwest, Northeast, South, and West). Analysis indicated that individuals in the Midwest and West regions seemed to be more vaccine-hesitant than those in the Northeast or South. Furthermore, these regions were divided by topography into eight regions: West, Northwest, Midwest, Southwest, Southeast, Mid-Atlantic, Northeast, and Great Lakes (Table 1). Additional subsets were identified among

Table 1. Regions of the United States

Region	States
Northeast	Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, Maine
Mid-Atlantic	Virginia, West Virginia, Pennsylvania, New York, New Jersey, Maryland, Delaware
Southeast	Georgia, Florida, South Carolina, North Carolina, Mississippi, Alabama, Tennessee, Kentucky
Great Lakes	Minnesota, Wisconsin, Illinois, Indiana, Ohio, Michigan
Midwest	Iowa, Nebraska, Kansas, Missouri
Southwest	Arizona, New Mexico, Texas, Oklahoma, Louisiana, Arkansas
Northwest	Alaska, Idaho, Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado
West	Washington, Oregon, California, Nevada, Hawaii
Mid-South	Louisiana, Mississippi, Alabama, Arkansas, Tennessee, Kentucky

these states, which were divided into red, red/blue or swing states, or blue states, depending on the results of presidential elections over the past decade. All missing values were omitted, resulting in a final dataset of 5,758 respondents.

Table 2 describes the summary statistics of baseline characteristics among the three hesitancy groups. The Chi-square test of significance and *p*-values are reported. Gender, MH services, income, race, marital status, education, and stress indicators such as anxiety, worry, interest, being down, region, visual impairment, mobility, and remembering were statistically significant ($p < 0.05$). Figure 1 shows the counts of the vaccine hesitancy status of the households in the US. The maximum proportion of the households was "Hesitant," followed by "Unsure" about taking a vaccine.

4.2. Primary results

Those who did not receive MH services exhibited higher percentages of vaccine hesitancy (strongly hesitant+ hesitant = 61%) than those who received MH services (strongly hesitant+ hesitant = 56%) (Figure 2A). Among the vaccine-hesitant groups, transgender individuals had the highest level of hesitancy, followed by males and females (Figure 2B). Individuals receiving MH (Figure 3B) services appeared to be less vaccine-hesitant than those who did not receive any MH services. The West and Midwest regions were mostly hesitant toward vaccines, followed by the northeast and south (Figure 4A). Graphically, it seemed that middle-and low-income groups were more likely to be unsure and hesitant than high-income groups, while White individuals were more hesitant, followed by other racial groups and Black individuals (Figure 5A and B). Those who reported "not at all" anxious and "not at all" losing interest were more likely to be vaccine-hesitant (Figure 8B). Those with some degree/being high school graduates were also more likely to be vaccine-hesitant (Figure 6A). In addition, females receiving MH services were more likely to be hesitant/unsure about vaccines (Figure 3B). The distribution of vaccine hesitancy status across the US is shown in Figure 7. Race is a major criterion in assessing the variability of responses toward vaccine hesitancy. In our study, we found that 93.4% of Whites were hesitant or unsure about vaccines, whereas 87.2% of Blacks fell into the same categories. Notably, when we separated the percentages of hesitant and unsure groups, we found that Blacks were more unsure about the vaccine than Whites. This discrepancy may vary from study to study; here, we are dealing with raw survey values rather than weighted values by population. Therefore, this may be one of the limitations and thus not representative of the broader population or align with conclusions from other studies.

The age is another important criterion; the maximum age is 90 and the minimum age is 20 in the data set. We calculated the age from the year of birth to the current year and saw that old individuals are the most hesitant, followed by the mid-age group and young groups. When we combine both unsure and hesitant groups, both mid and old-age groups are at 94.1% of vaccine hesitancy, while the young group is at 92.9%. These numbers are in the ballpark, so a clearer conclusion about the age and hesitancy cannot be made. There are other studies that support this conclusion.

4.2.1. Model 1: MLR

Considering previous literature and other vaccine hesitancy studies, we selected the above-mentioned factors that would contribute to understanding the outcome of interest (vaccine hesitancy). Model 1 considers the full model, including all the samples and the 17 chosen variables.

We considered the variables to be significant if $p < 0.05$ and with OR >1 compared to the reference group. Furthermore, we created a joint *p*-value called a combined *p*-value that gathers the information from both comparisons and is utilized for testing the overall result. The cut-off for this combined *p*-value is also 0.05.

In Model 1, the MLR analysis is carried out, in which we have considered the "Hesitant" and "Strongly hesitant" categories in one group. This is the full model. The computational algorithm converged, thereby providing the estimates of the coefficients. In Model 2, the BLR was applied to two groups. In Model 3, the dataset was split into training and testing datasets, and the prediction accuracies, sensitivities, and specificities were reported. In all the models, "Not hesitant" was considered as the reference category. Results from Model 1 MLR relating sociodemographic and health characteristics to the odds of belonging to three hesitancy classes ($n = 5758$). The OR estimate, 95% confidence interval (CI), and the *p*-values corresponding to the Wald test are reported. Reference categories are in parenthesis in Table 3.

Males were more likely to be hesitant or unsure about vaccines than females. Individuals belonging to the Northeast and Southern regions are more vaccine hesitant/unsure than those in the Midwest. Low- and middle-income groups of individuals were more likely to be hesitant or unsure about vaccines than high-income groups. Unmarried individuals were vaccine pro than married individuals. Asians are more likely to be in the "Not hesitant" groups than other races. Those who are not at all down or worried are more likely to be in the "Not hesitant" group than in the "Hesitant" group. High school students, those having some education, no degree or graduate degree, were more likely to be in the "Hesitant" or "Unsure" group than

Table 2. Summary statistics of vaccine hesitancy status, n (%): Baseline characteristics and demographics

Characteristics	Total	Vaccine hesitancy status, *n* (%)			*p*-value	Comparison test
		Unsure	Not hesitant	Hesitant		
n (%)	5758 (100)	1792 (31.1)	457 (7.9)	3509 (60.9)		
Gender					<0.001	
Male	2137 (37.1)	587 (27.4)	170 (7.9)	1380 (64.5)	<0.001	Male versus Female
Female	3601 (62.5)	1198 (33.2)	286 (7.94)	2117 (58.7)		
Transgender	20 (0.3)	7 (3.5)	1 (5.0)	12 (60)		
Region					0.0161	
West	1675 (29.1)	485 (28.9)	131 (7.82)	1059 (63.2)	0.0265	West versus South
South	2437 (42.3)	786 (32.2)	212 (8.6)	1439 (59.0)	0.526	South versus Northeast
Northeast	952 (16.5)	317 (33.2)	72 (7.5)	563 (59.1)	0.066	West versus Northeast
Midwest	694 (12.1)	204 (29.4)	42 (6.0)	448 (64.5)	0.0265	South versus Midwest
X					0.321	West versus Midwest
X					0.075	Northeast versus Midwest
Mental health services					<0.001	
Yes	568 (9.9)	224 (39.4)	44 (7.0)	300 (52.8)		
No	5214 (90.6)	1592 (30.5)	413 (8.0)	3209 (61.5)		
Mental health medicines prescribed					0.06	
Yes	953	326 (34.2)	76 (8.0)	551 (57.8)		
No	4805	1466 (30.5)	381 (8.0)	2958 (61.5)		
Income					<0.001	
High	3127 (54.3)	1429 (45.6)	104 (3.3)	1594 (50.9)	<0.001	High versus Middle
Middle	2092 (36.3)	971 (46.4)	146 (6.9)	975 (46.6)	<0.001	High versus Low
Low	2147 (37.3)	1000 (55.8)	207 (45.3)	940 (26.8)	0.004	Middle versus Low
Race					<0.001	
Black	919 (16.0)	401 (43.6)	117 (12.7)	401 (43.6)	<0.001	Black versus White
White	4290 (74.5)	1218 (28.3)	275 (6.4)	2797 (65.1)	<0.001	White versus Other
Other	549 (9.5)	173 (31.5)	65 (11.8)	311 (56.6)	<0.001	Black versus Other
Marital status					<0.001	
Married	2767 (48.1)	753 (27.2)	189 (6.0)	1825 (65.9)		
Not married	2991 (51.9)	1039 (34.7)	268 (8.9)	1684 (56.3)		
Education					<0.001	
High school	212 (3.7)	87 (41.0)	37 (17.4)	88 (41.5)		
High school grad	983 (17.1)	309 (31.4)	103 (10.4)	571 (58.0)		
Some college, no degree	1711 (29.7)	558 (32.6)	139 (8.1)	1014 (59.2)		
Associate/bachelor's degree	2095 (36.4)	641 (30.5)	124 (5.9)	1330 (63.4)		
Graduate degree	757 (13.1)	197 (26.0)	54 (7.1)	506 (66.8)		
Region 2					<0.001	
West	1023 (17.8)	325 (31.7)	84 (8.2)	614 (60.0)		
Southwest	1750 (30.4)	493 (28.1)	141 (8.0)	1116 (63.7)		
Southeast	907 (15.8)	301 (33.1)	82 (9.0)	524 (57.7)		
Northeast	427 (7.4)	118 (27.6)	26 (6.0)	283 (66.2)		
Mid-Atlantic	957 (16.6)	351 (36.6)	82 (8.5)	524 (54.7)		
Great lakes	694 (12.1)	204 (29.3)	42 (6.0)	448 (64.5)		

(Cont'd...)

Table 2. ***(Continued)***

Characteristics	Total	Vaccine hesitancy status, *n* (%)			*p*-value	Comparison test
		Unsure	Not hesitant	Hesitant		
Political view					0.1841	
Red	1142 (20.0)	342 (29.9)	96 (8.4)	704 (61.6)	0.2382	Red versus Blue
Blue	2955 (51.0)	962 (32.5)	225 (7.6)	1768 (59.8)	0.080	
Swing (Red/blue)	1661 (29.0)	488 (29.3)	136 (8.1)	1037 (62.4)	0.914	Red versus Swing
Anxious					<0.001	
Always	1615 (28.0)	577 (35.7)	157 (9.7)	881 (54.5)		
More or less	1525 (26.5)	584 (38.2)	153 (10.0)	788 (51.6)		
Not at all	2618 (45.5)	631 (24.1)	147 (5.6)	1840 (70.2)		
Worry					<0.001	
Always	1376 (23.9)	495 (35.9)	144 (0.0)	737 (53.5)		
More or less	1526 (26.5)	581 (38.0)	156 (10.2)	789 (51.7)		
Not at all	2856 (49.6)	716 (25.0)	157 (5.4)	1983 (69.4)		
Interest					<0.001	
Always	1218 (21.2)	431 (35.3)	128 (10.5)	659 (54.1)		
More or less	1402 (24.3)	536 (38.2)	140 (9.9)	726 (51.7)		
Not at all	3138 (54.5)	825 (26.2)	189 (6.0)	2124 (67.6)		
Down					<0.001	
Always	1177 (20.4)	411 (34.9)	133 (11.3)	633 (53.8)		
More or less	1514 (26.3)	557 (36.8)	146 (9.6)	811 (53.6)		
Not at all	3067 (53.3)	824 (26.9)	178 (5.8)	2065 (67.3)		
Seeing					<0.001	
Impaired	1734 (30.1)	611 (35.2)	154 (8.9)	969 (55.9)		
Not impaired	4024 (69.9)	1181 (29.3)	303 (7.5)	2540 (63.1)		
Hearing					0.555	
Impaired	661 (11.5)	203 (30.7)	46 (7.0)	412 (62.3)		
Not impaired	5097 (88.5)	1589 (31.2)	411 (8.1)	3097 (60.8)		
Mobility					<0.001	
Impaired	1266 (22.0)	452 (35.7)	129 (10.1)	685 (54.1)		
Not impaired	4492 (78.0)	1340 (29.8)	328 (7.3)	2824 (62.8)		
Remembering					<0.001	
Impaired	3080 (53.5)	1738 (56.4)	195 (6.3)	1147 (37.2)		
Not impaired	5678 (98.6)	3054 (53.7)	262 (4.6)	2362 (41.5)		

Notes: $P<0.05$ indicates the overall differences among groups and for specific comparisons where indicated in the table. X indicating four regions are considered. P-values were generated for all six combinations.

in the "Not hesitant" group. Those with impaired mobility and impaired hearing belonged to the "Not hesitant" group. Respondents from Western states were more leaning toward vaccine hesitancy than from other states. Respondents from swing states were more toward vaccine hesitancy or being unsure than non-hesitancy.

4.2.2. Model 2: BLR

In model 2, we segregated the unsure group from "Hesitant" and "Non-hesitant" groups, thus having two outcomes for which a BLR model is best suited. Results from Model 2 BLR relating sociodemographic and health characteristics to the odds of belonging to three hesitancy classes (n = 5758). The OR estimate, 95% CI, and the p-values corresponding to the Wald test are reported in Table 4. Reference categories are in parentheses.

Model 2 had similar results with those belonging to the male group from the West region, those who belonged to Black, other, or White race groups, low- and middle-income groups, having high school, high school

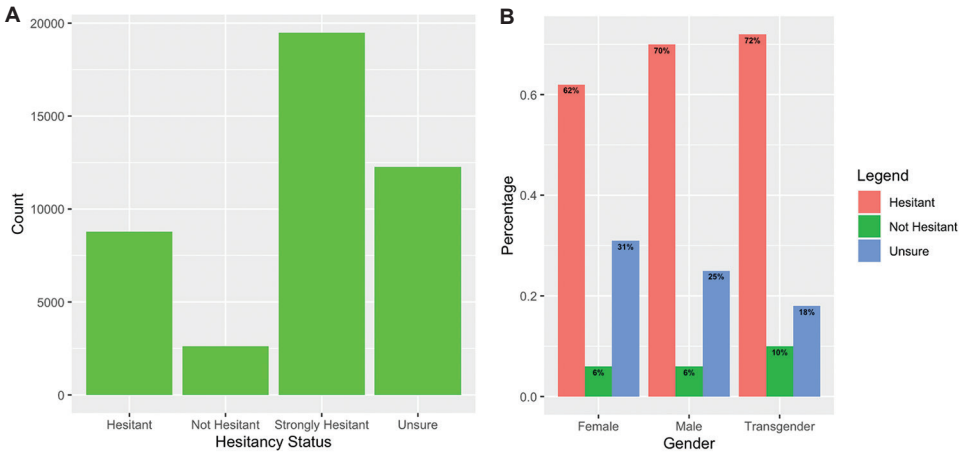

Figure 2. Participants expressing level of hesitancy by count and gender

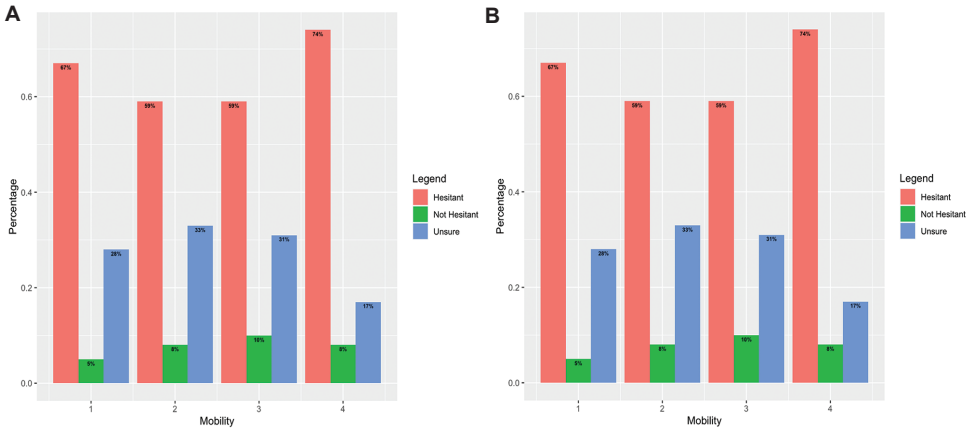

Figure 3. Participants expressing level of hesitancy by mobility and by mental health and gender

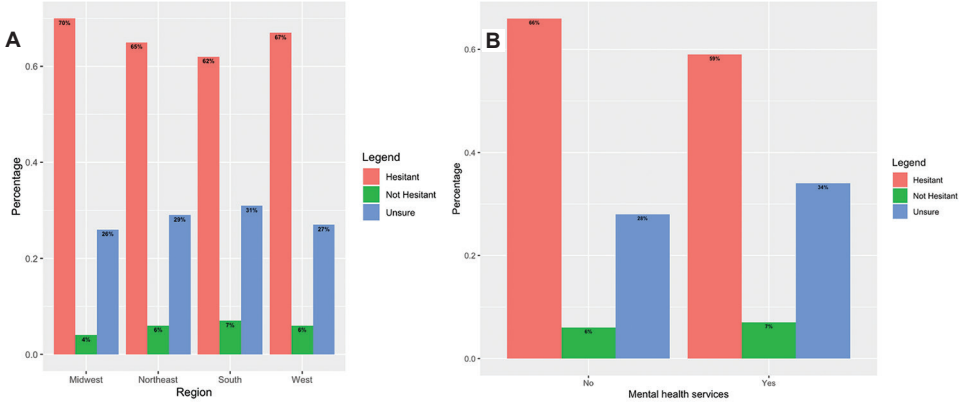

Figure 4. Participants expressing level of hesitancy by region and whether mental health services received

grad, some college, no degree, belonging to red states were more likely to belong to the vaccine-hesitant group than the "Not hesitant" group. Individuals of the Western region, having impaired mobility, were more likely to belong to the "Not hesitant" group than the "Hesitant" group.

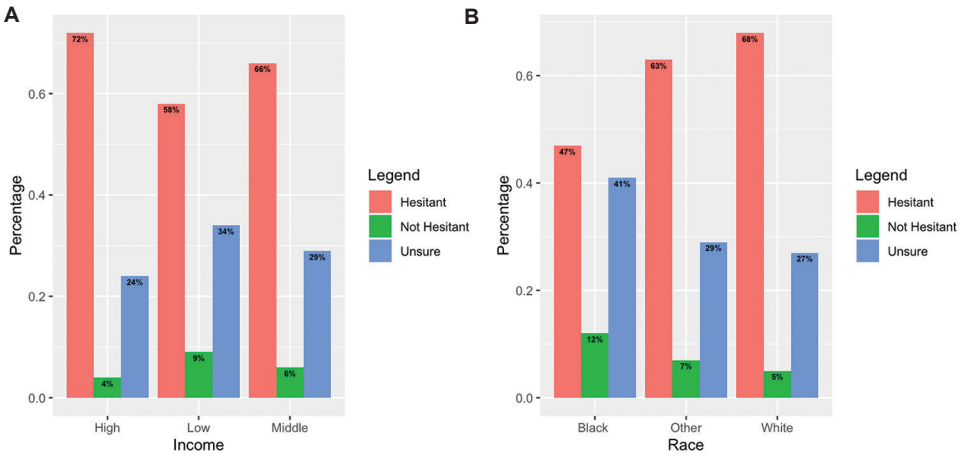

Figure 5. Participants expressing level of hesitancy by income status

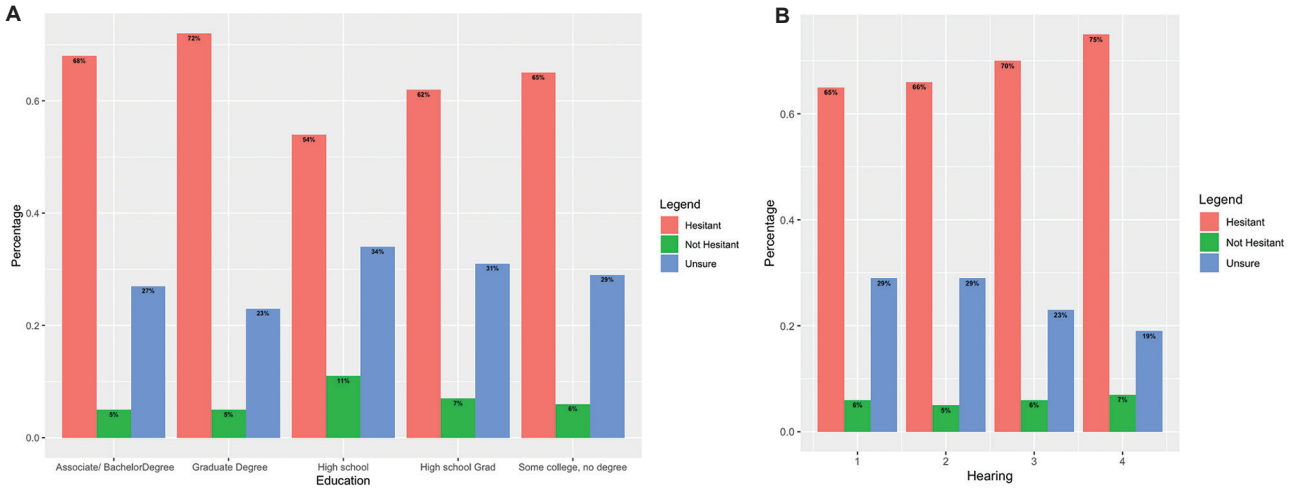

Figure 6. Participants expressing a level of hesitancy by education and by hearing

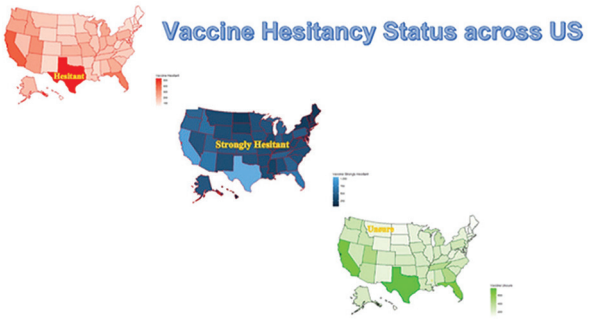

Figure 7. Vaccine hesitancy status across the Unites States
Notes: Provisional data from the National Vital Statistics System are incomplete, especially for December due to reporting lags. Deaths that occurred in the US territories and foreign countries are excluded. Deaths where COVID-19 was a contributing factor but not the underlying cause is not included.

4.2.3. Model 3: Training and test data

In this model, the data were partitioned having *n*1% of data as the training set and *n*2% = 1−*n*1% as the test set. The accuracy, sensitivity, specificity, and model performance are given in Table 5. With 85% of data reserved for the training set and the rest for the test set, the model has the highest accuracy of 63.5% in the training set and 70.12% in the test set. The same variables were significant as that of the full model of the MLR. The prediction of vaccine hesitancy using the MLR model is explained here. The model predicted the vaccine hesitancy status with the predictors used in the MLR model. With 85% data partition, the accuracy for prediction in the test set was 63.5%. The sensitivities of the prediction with 85% data partition are 71% in the "Hesitant" group, and specificities are 94% and 76% in the

Table 3. Multinomial logistic regression results

Category	Hesitant versus not hesitant					Unsure versus not hesitant					Overall
	OR	SE	2.5% CI	97.5% CI	*p*-value	OR	SE	2.5% CI	97.5% CI	*p*-value	*p*-value_all
(Intercept)	0.11	−5.73	0.05	0.23	0	0.6	−2.12	0.37	0.96	0.03	0
Gender (Female)											
Male	1.23	1.91	0.99	1.53	0.06	0.95	−0.78	0.84	1.08	0.44	0.0264
Transgender	0.33	−1.02	0.04	2.72	0.31	0.83	−0.38	0.31	2.2	0.7	0.217
Region (Midwest)											
Northeast	1.38	0.96	0.72	2.63	0.33	1.26	1.29	0.89	1.78	0.2	0.066
South	1.67	1.68	0.92	3.02	0.09	1.42	2.18	1.04	1.95	0.03	0.0027
West	0.97	−0.06	0.34	2.75	0.95	0.75	−1.02	0.43	1.3	0.31	0.2945
Mental health service (No)											
Yes	1.01	0.05	0.7	1.46	0.96	1.14	1.18	0.92	1.4	0.24	0.2304
Mental health prescription (No)											
Yes	0.85	−1.04	0.63	1.15	0.3	0.94	−0.64	0.79	1.13	0.53	0.159
Income (High)											
Low	2.06	4.7	1.52	2.78	0	1.22	2.3	1.03	1.44	0.02	0
Middle	1.83	4.23	1.38	2.43	0	1.09	1.13	0.94	1.28	0.26	0
Race (Asian)											
Black	0.67	−1.63	0.41	1.09	0.1	1.15	0.76	0.8	1.65	0.45	0.045
Other	0.38	−3.37	0.21	0.67	0	0.61	−2.43	0.4	0.91	0.01	0
White	0.29	−5.43	0.19	0.45	0	0.61	−2.86	0.44	0.86	0	0
Anxiety (Always)											
More or less	1.43	1.98	1	2.03	0.05	1.17	1.45	0.95	1.45	0.15	0.0075
Not at all	0.94	−0.27	0.6	1.48	0.78	0.71	−2.53	0.54	0.92	0.01	0.0078
Worry (Always)											
More or less	0.96	−0.24	0.66	1.37	0.81	1	0	0.8	1.25	1	0.81
Not at all	0.65	−1.8	0.41	1.04	0.07	0.81	−1.45	0.62	1.08	0.15	0.0105
Marital status (Married)											
Not married	0.99	−0.06	0.8	1.24	0.95	1.16	2.19	1.02	1.32	0.03	0.0285
Interest (Always)											
More or less	1.16	0.8	0.81	1.65	0.42	1.1	0.86	0.88	1.37	0.39	0.1638
Not at all	1	−0.01	0.66	1.51	0.99	0.88	−0.96	0.69	1.14	0.34	0.3366
Down (Always)											
More or less	0.81	−1.11	0.56	1.17	0.27	1.11	0.88	0.88	1.4	0.38	0.1026
Not at all	0.72	−1.4	0.46	1.14	0.16	1.22	1.39	0.92	1.61	0.16	0.0256
Education (Associate/Bachelor)											
Graduate degree	1.29	1.43	0.91	1.82	0.15	0.84	−1.75	0.69	1.02	0.08	0.012
High school	3.06	4.86	1.95	4.81	0	1.64	2.98	1.19	2.28	0	0
High school grad	1.59	3.08	1.18	2.13	0	1.01	0.09	0.84	1.2	0.93	0
Some college, no degree	1.29	1.88	0.99	1.68	0.06	1.05	0.61	0.9	1.21	0.54	0.0324
Seeing (impaired)											
Not impaired	1.07	0.52	0.84	1.35	0.6	0.94	−0.92	0.81	1.08	0.36	0.216
Hearing (impaired)											
Not impaired	1.63	2.73	1.15	2.32	0.01	1.24	2.13	1.02	1.51	0.03	0.0003

(Cont'd...)

Table 3. *(Continued)*

Category	Hesitant versus not hesitant					Unsure versus not hesitant					Overall
	OR	SE	2.5% CI	97.5% CI	*p*-value	OR	SE	2.5% CI	97.5% CI	*p*-value	*p*-value_all
Mobility (impaired)											
Not impaired	0.78	−1.9	0.61	1.01	0.06	0.89	−1.47	0.76	1.04	0.14	0.0084
Remembering (impaired)											
Not impaired	0.96	−0.36	0.75	1.22	0.72	0.96	−0.55	0.83	1.11	0.58	0.4176
State (Great Lakes)											
Mid-Atlantic	1.14	0.37	0.58	2.23	0.71	1.06	0.31	0.74	1.52	0.75	0.5325
Northeast	0.86	−0.39	0.41	1.81	0.7	0.75	−1.41	0.51	1.12	0.16	0.112
Southeast	0.99	−0.03	0.51	1.92	0.98	0.86	−0.82	0.6	1.23	0.41	0.4018
Southwest	1.28	0.51	0.5	3.28	0.61	1.19	0.67	0.72	1.95	0.5	0.305
West	1.79	1.13	0.66	4.86	0.26	1.64	1.81	0.96	2.81	0.07	0.0182
Political views (blue)											
Red/blue (swing states)	1.35	1.76	0.97	1.88	0.08	1.05	0.45	0.86	1.27	0.65	0.052
Red	0.84	−0.22	0.19	3.79	0.82	0.67	−0.99	0.31	1.48	0.32	0.2624

Notes: $P<0.05$ indicate the differences between Hesitant versus not Hesitant, and also between Unsure and Not Hesitant groups. In addition, $P<0.05$ also refers to the overall comparisons among the three groups in the last column of the table.
Abbreviations: CI: Confidence interval; OR: Odds ratio; SE: Standard error.

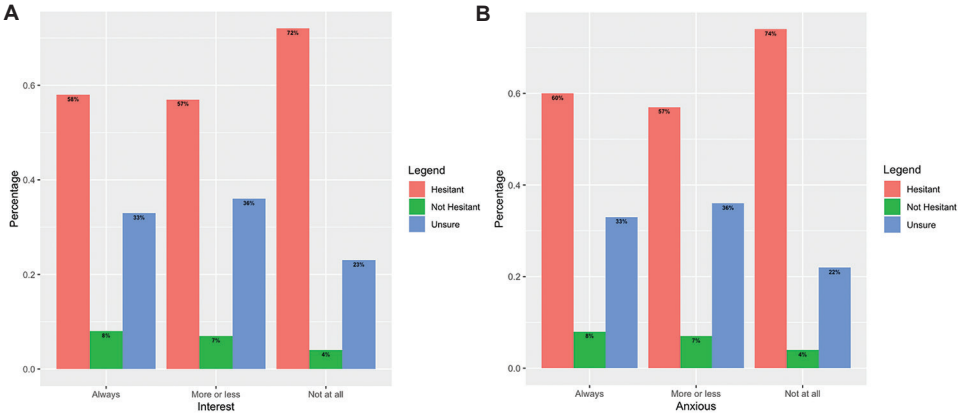

Figure 8. Participants expressing a level of hesitancy by interest status and by anxiety status

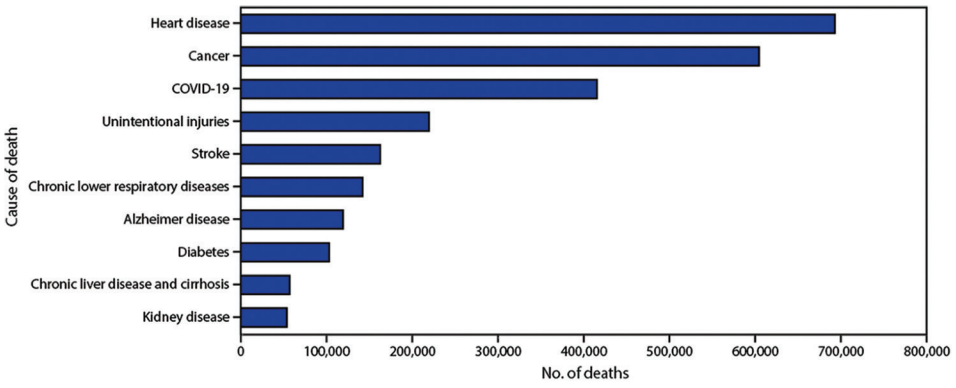

Figure 9. Number of deaths and cause of death across the United States. Adapted from Ahmad *et al.* (2022)

Table 4. Logistic regression results

Category	OR	2.5% CI	97.5% CI	*p*-value
(Intercept)	15.3	7.406	32.48	<0.00
Gender (Female)				
Male	0.79	0.64	0.98	0.03
Transgender	2.77	0.53	50.95	0.33
Region (Midwest)				
Northeast	0.50	0.07	2.029	0.39
South	0.44	0.06	1.66	0.29
West	0.62	0.39	0.98	0.04
Mental health service (No)				
Yes	1.04	0.73	1.51	0.80
Mental health prescription (No)				
Yes	1.14	0.85	1.54	0.36
Income (High)				
Low	0.52	0.38	0.69	<0.00
Middle	0.55	0.42	0.73	<0.00
Race (Asian)				
Black	1.62	1.01	2.54	0.03
Other	2.17	1.26	3.74	0.00
White	2.83	1.83	4.26	<0.00
Anxiety (Always)				
More or less	0.75	0.53	1.05	0.097
Not at all	0.94	0.60	1.47	0.81
Worry (Not at all)				
More or less	1.04	0.73	1.48	0.81
Not at all	1.41	0.90	2.23	0.13
Marital status (Married)				
Not married	1.06	0.85	1.31	0.58
Interest (always)				
More or less	0.90	0.64	1.27	0.56
Not at all	0.95	0.64	1.42	0.82
Down (always)				
More or less	1.28	0.90	1.82	0.16
Not at all	1.50	0.97	2.32	0.06
Education (associate/bachelo's)				
Graduate degree	0.72	0.52	1.03	0.06
High school	0.40	0.26	0.62	<0.00
High school Grad	0.63	0.47	0.84	0.00
Some college, no degree	0.79	0.61	1.02	0.07
Seeing (impaired)				
Not impaired	0.91	0.72	1.15	0.45
Hearing (impaired)				
Not impaired	0.66	0.46	0.92	0.01

(Cont'd...)

Table 4. ***(Continued)***

Category	OR	2.5% CI	97.5% CI	*p*-value
Mobility (impaired)				
Not impaired	1.21	0.95	1.54	0.11
Remembering (impaired)				
Not impaired	1.02	0.81	1.29	0.80
State (Great LAKES)				
Mid-Atlantic	1.41	0.35	9.60	0.66
Northeast	1.63	0.39	11.33	0.54
Southeast	1.48	0.37	10.04	0.62
Southwest	1.24	0.75	2.06	0.38
West	0.75	0.00	0.00	0.08
Political view (blue)				
Swing	1.06	0.54	1.04	0.93
Red	15.32	0.29	6.77	<0.00

Note: $P<0.05$ refers to statistically significant odds of being Hesitant versus Not Hesitant.
Abbreviations: CI: Confidence interval; OR: Odds ratio; SE: Standard error.

Table 5. Performance of prediction models by train-test partitions

Partition (%)		65			70			80			85	
Training set accuracy		62.5			63.46			63.19			63.5	
Test set accuracy		68.36			68.35			68.85			70.12	
Categories	**NH**	**H**	**Un**	**NH**	**H**	**Un**	**NH**	**H**	**Un**	**NH**	**H**	**Un**
Training set sensitivity	0.25	0.64	0.46	0.00	0.64	0.44	0.16	0.64	0.43	0.16	0.64	0.45
Testing set sensitivity	0.50	0.69	0.41	0.50	0.69	0.39	0.50	0.70	0.40	0.50	0.71	0.41
Training set specificity	0.92	0.60	0.71	0.92	0.59	0.71	0.92	0.60	0.71	0.92	0.61	0.71
Testing set specificity	0.94	0.55	0.75	0.94	0.52	0.75	0.94	0.52	0.75	0.94	0.55	0.76

Abbreviations: H: Hesitant; NH: Not hesitant; Un: Unsure.

"Not hesitant" and "Unsure" groups with the test data. This shows that this model is efficient in predicting the vaccine hesitancy status. Further improvements in the prediction results could be made with k-fold cross-validations.

5. Discussion

A 2021 study by Robinson *et al.* (2021) concluded that intentions to receive COVID-19 vaccines have been declining across 13 countries. Using an MLR model, we found that gender, geographical region, income, marital status, race, worry, education level, hearing ability, and sight were influential variables in determining vaccine hesitancy (Figures 3B, 4A, 5B, 6B, and 8A). Our analysis showed that being male, White, living in the south/northeast or in a rural area, having low to middle income, and being single were more likely to be associated with vaccine hesitancy. Meanwhile, females and Asians were less likely to be associated with vaccine hesitancy. Marzo *et al.* (2022) found age, residential area, education levels, and employment status to be associated with vaccine hesitancy. On the other hand, based on a meta-analysis of 1,166,275 Southeast Asia respondents by Yanto *et al.* (2022), none of the ten covariates (age, sex, education, previous COVID-19 infections, smoking, marriage status, health insurance, living together, chronic diseases, and healthcare workers) were significantly associated with vaccine acceptance. Other factors cited for low vaccine acceptance include concerns about side effects, safety, effectiveness, perceptions that vaccines are unnecessary, inadequate information, short duration of immunity, and a general anti-vaccine stance (Lin *et al.*, 2020). Our study also analyzed vaccine hesitancy in the two major countries, India and China. Results showed that similar to the US, the rural population in India was more likely to be vaccine-hesitant (OR = 3.46). Jennings *et al.* (2023) found the relationship between trust in government and vaccine hesitancy to be robust across 113 countries. The authors found most variables had weaker and often non-

significant effects in India. The personality trait appears to play a bigger role in vaccine hesitancy in India (Jennings *et al.*, 2023). A meta-analysis of 60 articles published on the Indian population by Dey *et al.* (2023) identified three major factors for vaccine hesitancy: Side effects 93.7%), concern regarding efficacy (30%), and safety (30%). In addition, low-income groups in India and China were also more hesitant to take the vaccine. The Northern region in China demonstrated to be vaccine-hesitant in our sample. By comparing vaccine hesitancy data from the US to India and China, we see that there are some common factors that contribute to vaccine hesitancy. In all three countries, low income and a rural geographic area are associated with increased vaccine hesitancy.

A 2021 questionnaire by Khubchandani *et al.* (2021) found that those living in rural areas, having lower incomes, and having lower levels of education were more likely to be vaccine-hesitant. These results are in concordance with our findings. Khubchandani *et al.* (2021) reported that approximately 22% of respondents were hesitant to receive the vaccine, while our data shows that 61% of the respondents of the HPS survey were hesitant to receive the vaccine. Most of the respondents to the HPS survey data used were able-bodied, white, female, having high income, and living in the West or South.

Pourrazavi *et al.* (2023) conducted a systematic review of 91 studies to investigate cognitive determinants of vaccine hesitancy across several countries. Of these 91 studies, 14 were of US participants, two studies from India, and eight studies from China. Concerns about efficacy, safety, and side effects of the COVID-19 vaccine were common across studies and across three countries. In addition, lack of trust in government was also a common theme across countries. Other US participants' responses can be categorized as: anti-vaccine attitude, not worried about getting the COVID-19 vaccine, make me feel sick, other individuals may need more than I, vaccine-causing relapse of Multiple Sclerosis, and concern about the ingredients in the vaccine. In India, it was the lack of enough information and the question of whether they are eligible for vaccination, while on the other hand, in China, conspiring beliefs, complacency, and psychological distress were the responses in addition to what is indicated above.

An umbrella review, which is a systematic review of reviews, using the SAGE working group model, is quite revealing. However, one significant limitation is that many studies included in the umbrella review were conducted before the launch of a COVID-19 vaccine (Kafadar *et al.*, 2022). These authors identified 79 factors based on 31 studies out of a total of 3,392 studies identified. Four categories of vaccine hesitancy were identified: (i) contextual, (ii) individual and group, (iii) vaccine-specific, and (iv) disease-specific. Contextual factors were sex, age, ethnicity, education, and income. Individual and group factors were: (i) information sources; (ii) trust; and (iii) personal experiences. Vaccine-specific determinants were: (i) vaccine safety and effectiveness; (ii) perceived vaccine barriers; (iii) concern over the rapid development; and (iv) inadequate knowledge status of COVID-19 vaccines. Finally, disease-specific factors included knowledge and perceptions of COVID-19 vaccines. Other factors included planning a family or currently pregnant or breastfeeding, consistent anti-vaccine status, previous negative experiences, religious restrictions, racial discrimination, or believing in conspiracy (Kafadar *et al.*, 2022). A 2024 umbrella review of 78 meta-analyses published between 2021 and 2023 put a hesitancy rate of 32% (95% CI: 25 – 39%) in the general population (Rohbeni *et al.*, 2024). In their study, the lowest hesitancy rate of 13% was among healthcare workers to 48% among pregnant and breast-feeding women (Rabbani *et al.*, 2024), followed by speed of vaccine development and safety concerns (19.4%), followed by trust and confidence (13.2%) (Nwachukwu *et al.*, 2024).

Trogen & Pirofski (2021) posit that overcoming vaccine hesitancy will require a proactive approach. In addition to identifying sociodemographic characteristics relating to being vaccine-hesitant, as we have done in this study, the reason behind vaccine hesitancy must be investigated further and also addressed. Assessing vaccine hesitancy is complex. It is possible that factors at play in larger countries may be different from those in smaller countries. Out of the 98 countries for which vaccine hesitancy data were available, 27/98 (28%) had a vaccine acceptance rate of <50%. It is of interest to note that out of twenty-two South Asian and Southeast Asian countries, only Hong Kong had less than a 50% acceptance rate. Based on the results from our study, public health officials and policymakers can target educational and policy interventions to the more hesitant groups to alleviate the reasons behind the vaccine hesitancy and encourage vaccine uptake.

Several other variable selection methods, such as LASSO and Elastic-net were utilized, which did not produce any potential increase in the accuracy of the model. In the k-fold cross-validation, data are put in k bins. One bin is used as test data, and k-1 bins are used as training data. The process is continued repeatedly until all k-bins are used one-by-one as test data.

5.1. Strengths

The unique contribution of this study is the utilization of two robust datasets to study vaccine hesitancy: One cross-sectional dataset from the University of Michigan, US,

and the other from the US Census Bureau. Our analysis identified some new vaccine hesitancy subgroups across different regions of the world for low-, middle-, and high-income countries (Table S1). For the US, India, and China, we have tabulated the reasons for vaccine hesitancy in detail (Table S2) for future investigators. Our results indicate that rural participants are approximately three and a half times more hesitant compared to urban participants. This subgroup should be analyzed in future studies to replicate the effect.

5.2. Limitations

We acknowledge the limitations of our research. First, we used raw survey data from the HPS survey without applying population weights, which may have led to potential biases and may not be the true representation of the population. Therefore, the results should be interpreted with caution when guiding policies and making further inferences. Second, we could have further explored penalized methods such as LASSO, elastic-net, and shrinkage prior methods to gain a better understanding of the prediction and estimation algorithms. This will be investigated in future studies. Third, k-fold cross validations could have been used in the prediction process to further assess and improve the results. Finally, our data were collected in 2021, a period during which techniques were continually evolving. COVID-19 was associated with approximately 460,000 deaths in the US during January – December 2021, as per the CDC website (https://www.cdc.gov/mmwr/volumes/71/wr/mm7117e1.htm). COVID-19, listed as the underlying cause of 415,399 deaths in 2021, ranked as the third leading underlying cause of death after heart disease (693,021 deaths) and cancer (604,553 deaths) (Figure 9) (Ahmad *et al*., 2022). In addition, based on the Advisory Committee on Immunization Practice recommendation from February 28, 2024, all individuals aged 65 or greater should receive one additional dose of any updated COVID-19 vaccine (Nwachukwu *et al*., 2024). It is also important to note that our data lacks information on rural populations. Future studies should focus on individuals with mental disorders, anxiety disorders, substance-related disorders, schizophrenia, and other comorbidities (Kafadar *et al*., 2022).

6. Conclusion

The ICPSR data analysis provides an overview of vaccine hesitancy on an international level and offers guidance for health policymakers and governments regarding the number of unvaccinated individuals in the world. This information is crucial for informing the necessary preparations to address the significant challenge of COVID-19.

The cross-sectional survey through the ICPSR database provided insights into vaccine hesitancy on a global scale, comparing acceptance rates across different cultures and examining how regional demographics may affect hesitancy. Each country-related data can be analyzed to determine the hesitancy rates and determine the lowest range of acceptance rates, thereby gaining a better understanding of the reasons behind the low acceptance. However, it is important to note that selection bias may occur in cross-sectional surveys, as study participants could be different from eligible participants who are not included. The HPS data provides a large US national sample, incorporating multiple variables that enhance insight. By utilizing these two datasets, researchers can conduct in-depth analyses of major factors, such as demographics, region, and MH status, all of which are associated with vaccination hesitancy. These findings can inform more effective management strategies to tackle future pandemics across the globe.

Based on the results of this study, vaccine campaign health planners should closely consider the availability of MH services in the community, as well as the stress factors influencing vaccine acceptance, including individuals' anxiety levels, concerns about vaccination, and interest in receiving the vaccine (Figures 4B and 8B). In addition, visual, mobility, and memory impairments are also significant contributors to vaccine acceptance. Our findings suggest that factors such as education, marital status, income, and race must also be addressed in vaccination campaign planning. We recommend a survey questionnaire to be administered at the beginning of a vaccine campaign, including all these critical factors, which have been shown to significantly impact vaccine acceptance. In addition, questions relevant to the community and at the time of the campaign should also be incorporated to have a successful vaccine campaign. We also suggest that planners should develop a country-specific questionnaire. Vaccine hesitancy is an ongoing issue and should be addressed at the World Health Organization level. The World Health Organization should form a central committee and regional committees based on the regions mentioned in the paper. These committees should only focus on the factors related to the acceptance of vaccines, especially COVID-19 since the mandate of SAGE is much broader.

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Conflict of interest

The authors declare that they have no competing interests.

Authors contributions

Conceptualization: Shesh N. Rai, Shikshita Singh, Swarna Sakshi

Data Curation: Arinjita Bhattacharya, Shikshita Singh, Swarna Sakshi, Anand Seth

Formal Analysis: Arinjita Bhattacharya, Shikshita Singh, Swarna Sakshi, Anand Seth

Investigation: Anand Seth, Shikshita Singh, Swarna Sakshi, Arinjita Bhattacharya

Methodology: Shesh N. Rai, Anand Seth, Arinjita Bhattacharya

Writing – original draft: Swarna Sakshi, Shikshita Singh, Anand Seth, Arinjita Bhattacharya

Writing – review & editing: Anand Seth, Arinjita Bhattacharya, Shesh N. Rai, Swarna Sakshi

Ethics approval and consent to participate

Ethics approval was not required since no participant was subjected to observations and/or intervention.

Consent for publication

Not applicable.

Availability of data

The first dataset is extracted from the ICPSR COVID-19 database (https://doi.org/10.3886/E130422V1). The second dataset is available from https://www.census.gov/data/experimental-data-products/household-pulse-survey.html.

Further disclosure

The work has been published as a pre-print and is available here https://www.medrxiv.org/content/10.1101/2022.04.13.22273843v1.full.pdf.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Sentiment and concern evaluation using online health community reviews

Chen Wang and Huiying Qi*

Department of Health Informatics and Management, School of Health Humanities, Peking University, Beijing, China

Abstract

In the online health community (OHC), each patient review of doctors includes an evaluation and an emotional attitude toward the doctor. Subsequent patients usually browse the comments of other patients about doctors when choosing a doctor and subsequently make decisions based on these reviews. Through sentiment analysis, a user's emotional orientation can be judged from the review, enabling an understanding of patients' emotional tendencies and main concerns regarding doctors during medical treatment. This also provides a reference for OHC doctors to improve service quality. This study used a method based on a sentiment dictionary to analyze the sentiment value of reviews and selected three different types of diseases (diabetes, leukemia, and depression) as examples from user reviews of the "Good Doctor Online" community. SnowNLP, a Python library for Chinese natural language processing, was used to realize the sentiment analysis of the reviews. The program correctly identified the sentiment of most reviews. Although the sentiments of OHC reviews are mostly positive, there are also a few extremely negative reviews. Most positive patient reviews about doctors are related to their good attitude and patience with patients and their condition.

Keywords: Online health community; Patient review data; Sentiments; Sentiment analysis; Sentiment dictionary-based

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***Corresponding author:**
Huiying Qi
(qhy@bjmu.edu.cn)

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1. Introduction

The profound integration of Internet technology with the health-care industry has led to the emergence of online health care, a quintessential example of the "Internet + Medical" service model, which is being increasingly adopted. Online health communities (OHCs) are composed of medical professionals, patients, and individuals seeking health-related information. These communities transcend temporal and geographical boundaries, optimize the consolidation of medical resources, and facilitate interactions between patients and health-care providers (Wu *et al.*, 2017). OHCs offer a valuable platform where individuals can search for health information, share experiences regarding disease treatments, and seek emotional support. Given that OHCs connect doctors and patients through digital networks, delays in information feedback from both parties are not uncommon. Timely evaluation and feedback from patients are crucial for doctors to enhance the quality of subsequent medical services.

Sentiment analysis is the process of examining textual data to ascertain the emotional tone as positive, negative, or neutral and to discern whether the sentiment expressed is in agreement or opposition. With the exponential growth of unstructured text data on the Internet, driven by the rapid advancement of web technologies, sentiment analysis has become integral to the automated assessment of online reviews. This technology enables us to comprehend the perspectives and sentiments of users when they share their thoughts online. For instance, Ahmed *et al.* (2020) developed a methodology for emotion clustering based on sentence context and introduced a weakly supervised neural network model that integrates manual and automated learning to construct a multilingual sentiment dictionary. This dictionary significantly enhances the precision of sentiment discrimination. Ji & Fangbi (2016) proposed a deep neural network model for sentiment analysis of massive open online course reviews, utilizing it to evaluate the emotional tenor of online course feedback. Liu *et al.* (2020) gathered posts on various topics, such as heart disease, hypertension, depression, and obsessive-compulsive disorder, from Baidu Post Bar. Through thematic modeling and sentiment analysis of these posts, they identified the thematic and emotional disparities in content posted online by individuals suffering from physical and mental health conditions. Ortigosa *et al.* (2014) presented a novel method for sentiment analysis on Facebook, achieving an accuracy of 83.27% in analyzing the emotions expressed in user-written content. Consequently, sentiment analysis has been extensively applied to the examination of a diverse array of comments across various contexts.

In the OHC, the comments and feedback of patients are evaluated accordingly. Sentiment analysis based on OHC reviews is a method to analyze the subjective reviews of users and obtain their emotional tendencies and attitudes. In an OHC, every review by the patients of doctors includes an evaluation and the emotional attitudes toward doctors. Subsequent patients usually browse the comments of other patients on doctors when choosing a doctor and subsequently make decisions by referring to these reviews. Through sentiment analysis, the emotional orientation of users can be identified from these reviews. Sentiment analysis on OHC user reviews is particularly important; however, there are only a few sentiment analysis studies on OHC user reviews.

In this study, the emotional value of reviews was analyzed using a method based on an emotional dictionary to better understand the emotional trends of patients and the main concerns regarding doctors during medical treatment, as well as to provide a reference for improving the service quality of OHC doctors.

2. Methods

2.1. Data source

Good Doctor Online is one of China's leading online medical platforms. As of May 2024, more than 240,000 doctors have registered on the platform. In this study, we selected three different types of diseases (diabetes, leukemia, and depression) as examples, analyzing the reviews by users in the Good Doctor Online community. These three diseases rank among the top three in the number of visits on the Good Doctor Online medical platform and are regarded as common diseases in chronic diseases, hematological diseases, and psychology, all of which have typical clinical significance and research representativeness. The Python language was used to design a multithreaded crawler tool to crawl all patients' reviews on doctors that are related to the treatment of the three diseases. A total of 85425 reviews of 7423 doctors were collected.

2.2. Data analysis

This study utilized the Python library SnowNLP (SnowNLP, 2017) of Chinese natural language processing to realize the emotional analysis of the reviews. The stop word list is supplemented by the Harbin Institute of Technology Stop Word List and Baidu Stop Word List to use a more comprehensive list to remove stop words. First, links, special symbols, and pictures were removed from the text. Then, the Jieba segmentation package was used to segment each sentence, fetch the emotion dictionary, identify the emotion classification of each word in the sentence, and calculate the emotion score. The resulting data included all the reviews associated with the corresponding doctor. The sentiment module in SnowNLP of the Python class library was used to analyze a single sentence, and the corresponding sentiment value of each review was obtained. The size of this value represents the probability that the review was positive. The resulting data included all the reviews associated with the corresponding doctor. Similarly, the sentiment module was used to analyze a single sentence, and we obtained the corresponding sentiment value of each review. The size of the value represents the probability that the review was positive.

For the emotional analysis of each review, the top five high-frequency words in all reviews corresponding to each doctor were extracted, and the word frequency statistics were calculated. If there were limited reviews, the keywords were extracted in a particular order.

3. Results

3.1. Sentiment analysis

The sentiment value output results range from 0 to 1. From the overall analysis of the emotional results, we selected

two critical points as the emotional orientation threshold. According to the program, when the sentiment value is greater than 0.8, the review is considered a positive review; when the sentiment value is less than or equal to 0.5, the review is considered a negative review; and when the sentiment value is between 0.5 and 0.8, the review is considered a neutral review. For instance, the review, "Excellent medical skills, striving for perfection. Warm attitude, kind words, patient guidance, careful diagnosis, formulation of a good plan, instructions for precautions, and finally, control of the disease always make us feel warm. Thank you very much, Director Bai!" had a sentiment value of 0.99, as calculated by SnowNLP; this review is regarded as a positive review. In contrast, another review states: "Doctor was impatient after talking with me for about 10 min. He did not ask me the cause of my illness at all. He directly said that I'd head to a rehabilitation institution to pay for my mental problems and did not care about my condition. I can hardly understand! Should the psychiatrist not know the condition in detail and then prescribe medicine? Finally, he threw the medical record book directly and signaled me to leave." This review had a sentiment value of 0.26 and was thus regarded as a negative review. Another review, "After asked me about my child's condition, he directly prescribed medicine and did not communicate with my child; it seemed that he was in a hurry," had a sentiment value of 0.61, which was classified as a neutral review.

To verify the accuracy of the emotional orientation threshold, we randomly selected 100 reviews for the selected diseases from the total number of reviews (leukemia: 11021; diabetes: 33274; and depression: 41130). For these 100 reviews, the results of program recognition were compared with those of manual recognition (Table A1). The matching rate between program recognition and manual recognition is 87%, which indicates that the program can correctly recognize sentiment for most reviews. For some reviews, a lower sentiment value is given by program recognition for reviews with positive implications, leading to a certain degree of mismatch with manual recognition. In addition, it is revealed that positive reviews account for a large proportion, suggesting that the program can make accurate judgments in identifying positive emotions.

Among the 85425 reviews, 80.3% were positive, 11.1% were neutral, and 8.6% were negative. To better understand the sentiment distribution law of different types of reviews, we divided the sentiment value range (0 – 1) into 10 equal parts and separately carried out segmented statistical percentages of the sentiment values of all reviews (Figure 1). In general, the larger the sentiment value, the more reviews are distributed within the corresponding interval, resulting in a higher proportion. As the sentiment value decreases, the number of reviews distributed in the corresponding interval

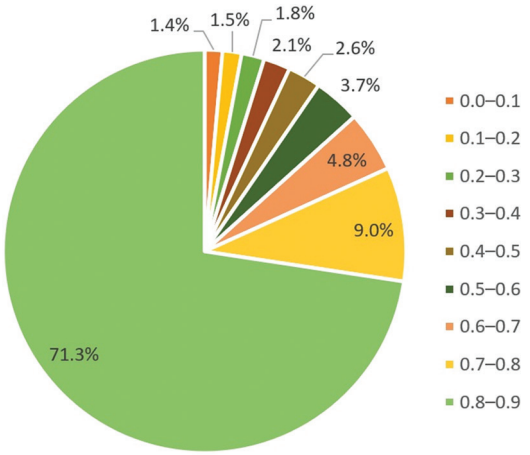

Figure 1. Distribution of sentiment value of reviews

decreases. However, in the "0 – 0.1" interval representing the most negative emotion, the number of reviews increased slightly compared to the intervals of "0.1 – 0.2," "0.2 – 0.3," and "0.3 – 0.4." We can infer from this phenomenon that while most reviews in OHCs are positive, there are also a significant number of extremely negative reviews.

Due to the difference in pathogenesis and prognosis of the selected diseases, patients adopt different approaches and seek medical treatment accordingly. To compare the similarities and differences of sentiments in the reviews by patients with diabetes, leukemia, and depression, we counted the number and percentage of reviews with different sentiments corresponding to the three diseases, respectively (Table 1). Overall, the positive reviews of the three diseases accounted for the highest proportion, whereas the negative reviews accounted for the lowest proportion, indicating that most patients were satisfied with the doctors' diagnosis and treatment. Among the three diseases, leukemia was associated with the highest proportion of positive reviews and the lowest proportion of negative reviews, while diabetes was associated with the lowest proportion of positive reviews and the highest proportion of negative reviews. This observation could be associated with the different prognoses of the two diseases. Diabetes is difficult to cure completely, and the current treatment approach primarily relies on drug-assisted therapy. Patients with diabetes tend to leave more negative reviews, which may be related to the poor efficacy of drug treatment. In contrast, the treatment period for acute leukemia is significantly shorter and yields more efficacious outcomes, making patients more inclined to give positive reviews.

3.2. Concern analysis

After using the Jieba library for word segmentation, word frequency statistics were carried out for all the reviews.

As the primary subjects of these reviews are doctors and patients, the terms "doctor" and "patient" had the highest frequency count. To identify other keywords in the reviews and analyze their relationship with the respective diseases, we removed the terms "doctor" and "patient" and recalculated the word frequency from the reviews (Table 2). Our findings in Table 2 indicate that patients are more concerned about the professional title of doctors, namely, whether doctors are chief physicians or professors. The terms "attitude" and "patience" were also frequently used in the reviews, and their frequency was comparable to other terms, including "medical" and "illness." Collectively, the word frequency results and the generally positive sentiments of the reviews suggest that doctors have a good attitude and patience toward the patients and their condition.

After stopping word segmentation, a third-party module, WordCloud was utilized to generate the word cloud of the terms used in the reviews (Figure 2). Figure 2A-D corresponds to the word cloud for all reviews, positive reviews, negative reviews, and neutral reviews, respectively. The term "patience" holds a dominant position across all review types, indicating that regardless of the patient's emotional orientation, the doctor's patience is a crucial factor influencing their perception of the doctor. Doctors who patiently listen to patients' histories, explain illnesses, and answer questions are often praised by patients in most of the positive reviews. Conversely, doctors who are insufficiently patient in answering questions or listening to patients tend to receive negative reviews from the patients. In addition, the term "attitude" also constitutes a significant proportion across all review types, highlighting the importance of the doctor's attitude during diagnosis and treatment in the minds of patients. If a doctor meticulously treats the patient, receives them with kindness, or speaks in a gentle tone, it creates a positive impression of the doctor's attitude, leading to positive evaluations in patient reviews. However, if a doctor speaks rudely or is absent during treatment, patients may perceive the doctor as having a poor attitude, resulting in negative reviews.

For the positive reviews, the term "skill" is relatively prominent, reflecting patients' focus on the doctor's medical abilities when making positive evaluations. Combined with the positive emotions in the reviews, patients generally commend doctors for their excellent medical skills, extensive experience, accurate diagnosis, and appropriate medication prescriptions. Furthermore, it can be inferred from the positive reviews that patients also consider their own "condition" and "improvement," the doctor's "patience" and "attitude," the doctor's "director" title, and expressions of "thanks" to the doctor (Figure 2B).

In the word cloud diagram for the negative reviews (Figure 2C), apart from focusing on the doctor's attitude and patience, the main concern of patients is the "reply." It can be speculated that untimely responses or poor-quality replies from doctors are significant factors contributing to negative patient reviews. The high frequency of the term "responsible" in negative reviews suggests that patients believe responsibility is an essential quality that doctors

Table 1. Comparative analysis of patient sentiments in reviews for different diseases

Review type	Diabetes (*n*=33274)		Leukemia (*n*=11021)		Depression (*n*=41130)	
	Quantity	Proportion (%)	Quantity	Proportion (%)	Quantity	Proportion (%)
Positive	26462	79.53	9058	82.19	33079	80.42
Negative	3075	9.24	837	7.59	3454	8.40
Neural	3737	11.23	1126	10.22	4597	11.18

Table 2. Frequency of words used in the reviews

1		2		3		4		5	
Word	Frequency	Word	Frequency	Word	Frequency	Word	Frequency	Word	Frequency
Director	11887	Patience	3811	Medical skill	1813	Patience	1182	Patience	1071
Patience	6321	Director	2474	Attitude	1471	Therapy	1052	Attitude	1044
Professor	3574	Therapy	2390	Patience	1465	Traditional medicine	1023	Traditional medicine	867
Attitude	3335	Traditional medicine	1935	Therapy	1115	Attitude	888	Therapy	680
Traditional medicine	2306	Attitude	1907	State	972	State	838	State	630

Note: The five categories (1 – 5) refer to the 25 high-frequency words that appear in the comments and their frequency of occurrence.

Figure 2. Word cloud for patient reviews: (A) All reviews; (B) positive reviews; (C) negative reviews; and (D) neutral reviews

should possess. The terms "check," "doctor," "consultation," and "convenient" also appear more frequently in the negative reviews, possibly due to unpleasant or inconvenient experiences that patients encounter during the registration process or while seeing a doctor. This suggests that patients are concerned not only with the basic diagnosis and treatment process but also with factors such as hospital environment and treatment procedures, which are less directly related to the doctors themselves.

Finally, for neutral reviews, terms like "responsible" and "satisfied" indicate that patients generally approve of the doctor's diagnosis and treatment process. Conversely, some terms, such as "patience," "attitude," "explain," "revisit," and "reply," suggest that patients may not be entirely satisfied with their communication with the doctors. Although patients are mostly satisfied with the doctors' diagnostic and treatment services, the frequent appearance of the term "hope" also implies that patients are attentive to areas for improvement in various aspects. Ultimately, the combination of both positive and negative emotions results in neutral evaluations.

4. Discussion

4.1. Related studies

Text analysis, a research hotspot in the field of natural language processing, has seen its methods and topics continuously evolve (Cui *et al.*, 2023; Fu *et al.*, 2023; Elbattah *et al.*, 2021; Nandwani & Verma, 2021). Many scholars have employed topic models, such as Latent Dirichlet Allocation (LDA), to mine discussion topics and latent themes among users in health communities. They have also optimized model structures or introduced algorithms, such as random forests, to enhance the precision and applicability of topic identification (Bi *et al.*, 2020; Chen *et al.*, 2024).

In addition, sentiment analysis and emotion recognition have also garnered significant attention. Numerous studies have identified positive or negative emotional tendencies of users during the process of seeking medical advice and medication by constructing sentiment dictionaries or training classification models, revealing emotional fluctuations and their impacts at different times and on different topics (Han *et al.*, 2018; Liu & Kong, 2021; Luo *et al.*, 2020; Necaise & Amon, 2024; Rustam *et al.*, 2021). To better extract and understand the users' potential needs and behavioral patterns from vast amounts of unstructured text with higher accuracy in semantic understanding and topic clustering, some studies have adopted methods that integrate deep learning with topic modeling (Shen *et al.*, 2021). Furthermore, research from the perspective of social support and emotional connection has revealed the driving role of negative emotions in users' information needs, as well as the importance of positive support for

maintaining community interaction and emotional health (Lu *et al*., 2017).

Meanwhile, recent studies have further indicated that social media plays an increasingly important role in sharing health experiences and expressing emotions. By analyzing user-generated content on platforms like Weibo from spatial and temporal dimensions using machine learning and topic modeling, key factors affecting user satisfaction can be identified. In addition, medical institutions can improve their services and response efficiency (Xiang *et al*., 2023). Several studies utilized composite models (e.g., combining logistic regression, clustering, and random forests) to improve the accuracy of sentiment polarity judgment, finding that negative reviews often trigger more interaction and information diffusion. Subdividing the functional and emotional elements in doctor-patient relationships is of great significance for understanding patients' real needs and optimizing the construction of OHCs (Chen *et al*., 2022; Pan *et al*., 2024; Sun *et al*., 2022; Zhang *et al*., 2014).

Deep learning-based methods have gained prominence in recent years for sentiment analysis. For example, the BERT pre-training language model has replaced Word2Vec and GloVe in embedding word vectors into other models to enhance sentiment classification performance (Fang *et al*., 2020). Another approach involves using a convolutional neural network (MF-CNN) model that leverages diverse feature information. By utilizing abstract features of word diversity and two methods for computing the network input matrix, this model optimizes the sentiment classification effect (Cai *et al*., 2019). In addition, a computational framework employing a deep learning-based language model has been developed for sentiment analysis using a delayed recurrent neural network (d-RNN) and its hierarchical variant (Hd-RNN). Experimental results demonstrate that Hd-RNN outperforms other technologies (Chaudhuri, 2022). Furthermore, an LSTM model, named PosATT-LSTM, has been introduced, which considers the importance of each contextual term and incorporates position-aware vectors for aspect-level sentiment classification (Zeng *et al*., 2019).

Overall, existing research indicates that the study of OHCs is crucial for gaining insights into user needs and improving platform service quality. Unlike existing research that focuses on overall sentiment trends, emotional distribution, or topic mining, the present study directly extracts the key elements from patient evaluations/reviews, making the research objectives and audience more focused on real patient experiences and needs. Traditional machine learning methods require a large number of labeled corpora; the more training data available, the higher the accuracy. However, labeling samples requires a significant amount of manpower. Deep learning methods require large-scale training data. In comparison, the sentiment dictionary-based analysis method is easier to operate and can improve accuracy by expanding the sentiment vocabulary according to the text. With higher emotional word coverage and accuracy, this method yields more precise emotional classification. Therefore, this study adopted the sentiment dictionary-based method.

4.2. Sentiments and concerns

The vast array of reviews and the multitude of information available in OHCs significantly influence individuals' search for health information, exchange of disease-related treatment experiences, and emotional support. Gaining insights into the sentiments and concerns expressed in the reviews can help users understand the trends within OHCs, making it a valuable area for exploration. Sentiment analysis methods based on sentiment dictionaries provide a reliable and powerful tool for analyzing the sentiment of OHC reviews. The quantification of complex, subjective text greatly facilitates the study of sentiment orientation and the primary concerns reflected in the reviews.

According to the program feedback results, positive reviews constituted the highest proportion at 80.3%, followed by neutral reviews at 11.1%, whereas negative reviews made up the lowest proportion at 8.6%. In general, the number of reviews decreases as the sentiment value calculated by the program decreases, revealing an extremely skewed distribution within the sentiment value range (0 – 1). Among the three typical diseases – diabetes, leukemia, and depression – diabetic patients gave relatively fewer positive reviews and more negative reviews, whereas leukemia patients gave more positive reviews and fewer negative reviews. This observation suggests that patients have varying emotional orientations toward different diseases, and these differences may be related to the prognosis and treatment of the diseases.

Regarding the different sentiments expressed in the reviews, patients primarily focus on the doctor's "attitude" and "patience," which can be presumed to be important criteria for their evaluation of doctors. In the positive reviews, patients place significant attention on doctors' medical skills, with most reviews expressing affirmation and gratitude for the doctors' expertise. In the negative reviews, patients highlighted several key issues, including the doctor's response, sense of responsibility, hospital environment, and the diagnosis and treatment process. A poor experience in any of these aspects may significantly affect patients' emotions, thereby leading to negative reviews. The main factor influencing neutral reviews is that patients have mixed experiences regarding the doctor's

attitude, response, follow-up visits, and other issues. Likewise, they might have both positive experiences and slightly negative feelings, leading to a neutral evaluation based on the actual situation.

Hence, analyzing the emotions and concerns expressed in OHC reviews can provide valuable insights into patients' perceptions and expectations of doctors.

4.2.1. Prevalence of positive sentiments

Most reviews in OHCs are positive, indicating that patients generally have favorable experiences with doctors. This suggests that the overall level of service provided by doctors is satisfactory. However, the existence of negative reviews, albeit fewer in number, highlights areas of improvement. Therefore, doctors should focus on maintaining and enhancing the positive aspects of their services while addressing the specific issues mentioned in the negative reviews.

4.2.2. Importance of doctor-patient interaction

Patients place significant emphasis on the attitude and patience of doctors, highlighting the importance of interpersonal skills in health care. Hence, training programs should be implemented to enhance the communication skills, empathy, and patience of doctors. This will not only improve patient satisfaction but also foster a more positive perception of the health-care experience.

4.2.3. Disease-specific concerns

Sentiment analysis revealed differences in emotions among patients with different diseases. For instance, diabetic patients express more negative sentiments, possibly due to the chronic nature of the disease and the ongoing treatment process. Doctors should adapt their communication and support strategies to address the unique challenges and concerns associated with each disease. For chronic conditions like diabetes, providing comprehensive education, support groups, and regular follow-ups can help manage patient expectations and improve satisfaction.

4.3. Recommendations for improvements

Based on the identified key factors influencing patient sentiments, several recommendations can be suggested for doctors and OHCs to improve patient sentiments and address patient concerns.

4.3.1. Communication and support

Doctors should prioritize clear and empathetic communication with patients. This includes taking the time to listen to patient concerns, thoroughly explaining medical conditions and treatment options, and providing emotional support when needed. OHCs can facilitate this by offering secure communication systems and virtual consultation tools.

The response speed and quality can also be improved, as patients often express dissatisfaction with delayed responses or inadequate replies from doctors. Hence, doctors should strive to respond more promptly to patient inquiries and ensure that responses are comprehensive and helpful. OHCs can support this by implementing efficient notification systems and providing guidelines for doctors on how to craft effective responses.

4.3.2. Focus on holistic care

Patients are not only concerned with the medical expertise of doctors but also with their overall experience, including the hospital environment and the diagnostic and treatment process. Health-care providers should work to create a comfortable and supportive environment for patients. OHCs can assist by providing resources to improve hospital facilities, treatment procedures, and patient rights, enabling patients to make better-informed decisions and set realistic expectations.

4.3.3. Leverage feedback for continuous improvement

OHCs offer extensive feedback that can be used for continuous improvement. Doctors should actively monitor and analyze patient reviews to identify areas for improvement. OHCs can facilitate this by providing tools for sentiment analysis and feedback aggregation, enabling doctors to make data-driven decisions.

4.4. Study limitations

This study had certain limitations, such as the small amount of data collected for sentiment analysis, which led to an emotion classification accuracy of only 87%. To improve emotion classification accuracy, more data should be collected and the sentiment dictionary should be updated in future studies. In addition, this study relied solely on sentiment dictionaries, which limited the ability to classify context, irony, or complex sentences. In future work, it is recommended to consider integrating machine learning techniques, such as BERT and LSTM, for more detailed sentiment classification. Another limitation that should be discussed is that the focus on three diseases may limit the generalizability of the findings. Expanding the study to include other prevalent diseases (e.g., cardiovascular diseases) could enhance its applicability. In addition, since dissatisfied patients in OHCs may be more inclined to post reviews, the proportion of negative reviews may be overestimated, and this bias may impact the accurate evaluation of the overall service quality of doctors.

5. Conclusion

Based on the analysis of reviews from OHCs, we observed that while sentiments vary slightly across reviews related to different diseases, most of the reviews are positive. In examining patient reviews, it is evident that patients are not only concerned with the doctor's medical skills but also place significant importance on the doctor's attitude and patience, highlighting the crucial role of providing a positive patient experience. Henceforth, we aim to expand our research to include multiple OHCs and integrate text mining with questionnaire surveys to conduct a more comprehensive sentiment analysis of OHC users.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Huiying Qi
Formal analysis: Huiying Qi
Investigation: Chen Wang
Methodology: Huiying Qi
Visualization: Chen Wang
Writing – original draft: Chen Wang
Writing – review & editing: Huiying Qi

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The data used in this study can be obtained or downloaded from www.haodf.com/.

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Appendix

Table A1. Comparison between program and manual recognition of patient reviews (*N*=100)

Disease	Number	Program	Manual	Match
Leukemia	1	Pos	Pos	Yes
	2	Pos	Pos	Yes
	3	Pos	Pos	Yes
	4	Pos	Pos	Yes
	5	Pos	Pos	Yes
	6	Pos	Pos	Yes
	7	Pos	Pos	Yes
	8	Pos	Pos	Yes
	9	Pos	Pos	Yes
	10	Pos	Pos	Yes
	11	Pos	Pos	Yes
	12	Neg	Neu	No
	13	Pos	Pos	Yes
Diabetes	1	Pos	Pos	Yes
	2	Pos	Pos	Yes
	3	Pos	Pos	Yes
	4	Neu	Pos	No
	5	Pos	Pos	Yes
	6	Pos	Pos	Yes
	7	Pos	Pos	Yes
	8	Neg	Neg	Yes
	9	Pos	Pos	Yes
	10	Pos	Pos	Yes
	11	Pos	Pos	Yes
	12	Pos	Pos	Yes
	13	Pos	Pos	Yes
	14	Neg	Neg	Yes
	15	Pos	Pos	Yes
	16	Pos	Pos	Yes
	17	Pos	Pos	Yes
	18	Neg	Pos	No
	19	Pos	Pos	Yes
	20	Pos	Pos	Yes
	21	Pos	Pos	Yes
	22	Pos	Pos	Yes
	23	Pos	Pos	Yes
	24	Pos	Pos	Yes
	25	Neu	Pos	No
	26	Pos	Pos	Yes
	27	Pos	Pos	Yes
	28	Neu	Pos	No
	29	Pos	Neu	No
	30	Pos	Pos	Yes
	31	Pos	Pos	Yes
	32	Pos	Pos	Yes
	33	Pos	Pos	Yes
	34	Neu	Pos	No
	35	Pos	Pos	Yes
	36	Pos	Pos	Yes
	37	Pos	Pos	Yes
	38	Pos	Pos	Yes
	39	Pos	Pos	Yes
Depression	1	Neg	Neg	Yes
	2	Pos	Pos	Yes
	3	Pos	Pos	Yes
	4	Pos	Pos	Yes
	5	Pos	Pos	Yes
	6	Pos	Pos	Yes
	7	Neu	Pos	No
	8	Pos	Pos	Yes
	9	Neu	Pos	No
	10	Pos	Pos	Yes
	11	Pos	Pos	Yes
	12	Neg	Neu	No
	13	Pos	Pos	Yes
	14	Pos	Pos	Yes
	15	Pos	Pos	Yes
	16	Pos	Pos	Yes
	17	Pos	Pos	Yes
	18	Pos	Pos	Yes
	19	Pos	Pos	Yes
	20	Pos	Pos	Yes
	21	Pos	Pos	Yes
	22	Pos	Pos	Yes
	23	Neu	Neu	Yes
	24	Pos	Pos	Yes
	25	Pos	Pos	Yes
	26	Neg	Pos	No
	27	Pos	Pos	Yes

(Cont'd...)

Table A1. *(Continued)*

Disease	Number	Program	Manual	Match
	28	Pos	Pos	Yes
	29	Pos	Pos	Yes
	30	Pos	Pos	Yes
	31	Neg	Neu	No
	32	Pos	Pos	Yes
	33	Pos	Pos	Yes
	34	Pos	Pos	Yes
	35	Pos	Pos	Yes
	36	Pos	Pos	Yes
	37	Pos	Pos	Yes
	38	Pos	Pos	Yes
	39	Pos	Pos	Yes
	40	Pos	Pos	Yes
	41	Pos	Pos	Yes
	42	Pos	Pos	Yes
	43	Pos	Pos	Yes
	44	Pos	Pos	Yes
	45	Neu	Pos	No
	46	Pos	Pos	Yes
	47	Pos	Pos	Yes
	48	Pos	Pos	Yes

(Cont'd...)

Table A1. *(Continued)*

Note: The matching rate is 87%.
Abbreviations: Pos: Positive; Neu: Neutral; Neg: Negative.

ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Survey findings in a health-promoting university campus in Northern Germany: Monitoring students' health awareness and needs

Vasiliki Kolovou[1]* and Delphine Dierckens[2]

[1]Department of Nursing and Health Care, Faculty V of Diaconic Studies, Health Care and Social Work, Hannover University of Applied Sciences and Arts, Hannover, Lower Saxony, Germany

[2]Applied Health And Lifestyle Sciences, Hogeschool West-Vlaanderen (Howest) University of Applied Sciences, Bruges, West Flanders, Belgium

Abstract

This study examines the implementation of a health-promoting project in a university faculty campus in northern Germany, involving students enrolled in nursing and health care, social work, and inclusive education programs, both in full-time and vocational tracks. The study explores students' current level of awareness regarding the main health-promoting activities through a baseline survey. The survey's primary objective was to inform and enhance the university's existing student health activities. This paper outlines the study design and presents the descriptive findings of the baseline survey data, focusing on students' awareness, involvement, and needs on campus. The survey represents a practice-oriented approach to actively monitor students' needs while raising awareness about health promotion within the university environment.

Keywords: Health promotion; University; Setting; Survey

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***Corresponding author:**
Vasiliki Kolovou
(vasiliki.kolovou@hs-hannover.de)

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1. Introduction

In July 2015, the new "Prevention Act" (Federal Law Gazette, 2015) came into effect in Germany, aiming to improve cooperation between social security institutions, federal states, and local authorities in prevention and health promotion across various age groups and life settings. This legislation aligns with the Ottawa Charter for Health Promotion, which states that prevention and health promotion should occur where people live, work, and learn (Ottawa-Charta, 1986). The "setting-based approach" advocates for developing preventive interventions that address the contexts in which people live, learn, and work, as well as the needs and their needs and capacities in different settings. Health is significantly influenced by environmental, economic, social, organizational, and cultural factors (Dooris *et al.*, 2014).

Universities represent a crucial setting for health promotion. In Germany, universities employ approximately 780,000 staff members and enroll about 2.86 million students (Destatis, 2024). Beyond their substantial presence, universities are significant because students are future professionals who can act as potential multipliers of health promotion in other settings. Furthermore, students are a vulnerable target group regarding

health, as young adults often engage in high health-risk behaviors such as excessive alcohol consumption, physical inactivity, and inadequate fruit and vegetable intake (Kwan *et al*., 2013).

The self-assessment method of general health, an established and internationally used method for measuring subjective health in population surveys, was employed to assess the general health status of German students. A recent study (Deindl *et al*., 2023), based on data provided by the National Educational Panel Study, surveyed students aged 16 – 25 years in their first study year, asking them to rate their health as very good, good, moderate, poor, or very poor. The findings showed that 51% of students reported very good health, while 41% stated that their health was good. These results contrast with those of a previous survey, where 81.8% of the students reported their health as either very good or good (Grützmacher *et al*., 2018).

Despite the majority of students reporting good to very good health, there is a notable prevalence of health-risk behaviors among this population. An earlier study (Keller *et al*., 2008) found that 31% of German students were current smokers, and 62% engaged in binge drinking. Furthermore, over 95% failed to meet the recommendation of eating five or more servings of fruits and vegetables daily, and 60% did not exercise sufficiently. These findings underscore the importance of investing in health-promoting initiatives at universities. Moreover, German students were also concerned about the broader impact of the epidemic on their future life-related decisions (Knolle *et al*., 2021).

Several German universities are actively involved in health promotion efforts. As part of the Prevention Act, the German statutory health insurance funds must support health promotion projects based on the setting-based approach in all living environments, such as municipalities, day-care facilities, in-patient nursing homes, and universities. As a result, various organizations such as the Federal State Association for Health and Academy for Social Medicine in Lower Saxony (Landesvereinigung für Gesundheit und Akademie für Sozialmedizin Niedersachsen e. V., 2023) have been established to support health-promoting universities. Notably, this organization founded the National Working Group for Health-Promoting Universities (AGH) in 1995 (Arbeitskreis Gesundheitsfördernde Hochschulen, 2023). The AGH is a nationwide network of university representatives and university-related organizations, aiming to foster health-promoting living, learning, and working conditions for all university groups and assist universities in setting up health-promoting structures. The AGH aligns its efforts with several key international guidelines, including the Ottawa Charter (1986), Agenda 21 (1992), the Jakarta Declaration (1997), the Edmonton Charter (2005), the Convention on the Rights of Persons with Disabilities (2008), the Charter (2015), the 17 Sustainable Development Goals (2015), and the Charter of Digital Fundamental Rights of the European Union (2018).

At present, over 150 German universities are affiliated with the AGH. In 2018, the Competence Center for Health-Promoting Universities (KGH: Kompetenzzentrum Gesundheidstfördernde Hochschulen) was established as a collaborative project between the Federal State Association for Health and Academy for Social Medicine in Lower Saxony and the statutory health insurance fund, Techniker Krankenkasse. The KGH focuses on raising awareness, improving skills, and contributing to high-quality development and knowledge retention in the field of health-promoting universities. It also aims to strengthen the cooperation between company health management and student health management.

In addition to the nationwide network for health-promoting universities, there is a growing need for regional networking and exchange. Hence, several regional networks have been established, including the "Netzwerk Gesunde Hochschulen (Network of Health-Promoting Universities [NORD])," which was founded in 2021. Coordinated by the Hannover University of Applied Sciences and Arts, this network is based in Campus Kleefeld. At present, 20 universities in northern Germany are members of the NORD network. The main goal is to share and develop innovations in health-promoting interventions in universities, transfer knowledge, and leverage the interdisciplinary nature of the network as a resource. Furthermore, the network supports embedding health promotion into personnel and organizational policies.

Following the Prevention Act (Federal Law Gazette, 2015), the project "Health-Promoting Faculty V - Campus Kleefeld" was launched in 2016 at Faculty V of the Hannover University of Applied Sciences and Arts, with the support of the health insurance fund, Techniker Krankenkasse. The project concluded on April 15, 2019 (Bonse-Rohmann *et al*., 2020). Notably, this project targeted not only the students but also the academic and administrative staff. The goal was multifaceted: reducing health risks and absenteeism; creating attractive study and working conditions; offering sustainable and innovative health-promoting interventions; increasing motivation and satisfaction of students, teachers, and staff; and ensuring consideration for all three status groups on campus.

To promote the health of all three status groups, a steering committee was established using a participatory

process, ensuring all target groups were represented in the steering committee.

To enhance health promotion on campus, six "health circles" were created, each focusing on specific health-related themes. For example, the "Active Breaks" circle implemented actions such as incorporating active breaks into courses, lessons, and meetings and training multiplicators – students or teachers who could sustain these activities over time. The "Cycle to Campus" circle promoted cycling to and from campus, while the "Loaning of Outdoor Play Material" circle encompassed a kiosk with outdoor play equipment, such as table tennis, badminton, balls, and frisbees. The "Fruit Day" circle involved distributing free fruits on campus once per semester. The "Dancing/High-intensive training/Running/Jogging" circle offered weekly sports activities on campus, such as dancing, high-intensive training, or running, and the "Meditation/Activation" circle provided meditation courses after lunch. Overall, these health circles prove to be an effective tool for analyzing, planning, implementing, and evaluating health-promotion interventions in the university setting.

An overview of the health-promoting interventions on Campus Kleefeld is presented in Table 1. The framework of the "health matrix" was used to classify each activity (Vlaams Instituut Gezond Leven, 2021). This framework emphasized the need for a balanced mix of different strategies related to education, environment, agreements, and rules as well as care and guidance to create a health-promoting policy in settings like universities.

The first strategy, education, aims to inform participants, strengthen competencies, and raise awareness about healthy lifestyles. The second strategy, environmental interventions, aims to modify the physical and social environment to protect health and encourage healthy behavior. The third strategy involves establishing agreements and rules to clarify expectations regarding healthy and unhealthy behaviors. Finally, the fourth strategy, care and guidance, focuses on early detection and referral to care for those in need.

These different strategies should be applied at multiple levels to guarantee a quality health policy. The first level targets individuals or priority groups, such as students in this context. The second level involves functionally or geographically defined groups, like classes. The third level encompasses the entire target group and its environment within the setting, such as the faculty. Finally, the final level addresses the physical and social environment outside the university setting.

Upon reviewing the interventions, it is evident that none focused on the strategy of care and guidance. A possible explanation is that central services at the Hannover University of Applied Sciences and Arts provide individual guidance and support for students, such as psychological-therapeutic counseling. However, there are no interventions centered on agreements and rules.

A large number of interventions aim to modify the environment, including the installation of water dispensers, the purchase of chairs and outdoor play materials, and the provision of space for social gardening. These interventions are structurally integrated into the campus and are therefore regarded positively in sustaining on-campus health promotion. There is also an equal focus on education as well as care and guidance: for instance, Alcohol eCHECKUP TO GO, a subscription-based program developed by the Counseling & Psychological Services of San Diego State University (Counseling & Psychological Services San Diego State University, 2023),

Table 1. Health matrix for Campus Kleefeld

Strategies	Student	Class	Faculty	Environment (Social and physical environment)
Education	Run/jog/walk meetings, high-intensity interval training courses	Active breaks	Voluntary courses for health promotion, Healthy Snack–Fruit Day, partnership with the European Lifestyle Medicine Organization	Partnership with the European Lifestyle Medicine Organization
Environmental interventions			Social gardening, provision of outdoor play material, provision of chairs for outdoor teaching, water dispensers	Project on bike repair station
Agreements and rules			The faculty committee agrees to support activities and promote healthy behaviors	
Care and guidance			Alcohol eCHECKUP TO GO	Alcohol eCHECKUP TO GO

offers a personalized online self-test that provides insights into drinking behavior and connects users with nearby guidance resources. In addition, a 2-day seminar is organized each semester, focusing on health topics, such as sexually transmitted diseases, mental health, and alcohol consumption. A partnership with the European Lifestyle Medicine Organization (ELMO) enables students to access health-related training courses at a reduced cost while also providing them with valuable health-related publications and resources. ELMO, as a non-profit, non-political, and non-religious scientific and medical organization, emphasizes evidence-based approaches to disease prevention and health promotion. Its focus on nutrition, physical activity, sleep, and psychology, supported by real-life cases, is particularly relevant to enhancing students' understanding of healthy decision-making. (European Lifestyle Medicine Organization, 2023).

Furthermore, weekly running meetings and high-intensity interval training sessions are conducted under teacher guidance, with virtual sessions during pandemic-affected semesters. Overall, most interventions focus on the faculty level, which helps reach a broader audience. This support is facilitated by a faculty committee committed to promoting healthy behaviors among all status groups on campus. However, during the survey, a lack of clear communication strategy was observed, resulting in many offers going unnoticed. Promotional methods primarily included posters placed at strategic locations on campus, which often got lost among other informational materials. To avoid overwhelming students and teachers with emails, invitations were typically sent only once. For faculty-promoted issues, direct communication during lectures was preferred, making health-related offers more accessible to students in the Nursing and Health Care department but less so for those in other departments, such as Social Work or Inclusive Education.

In the preceding section, an overview of health promotion in the university setting was provided, with a focus on the "Health-Promoting Faculty V - Campus Kleefeld." The next section will describe efforts to assess whether the above-outlined structure meets the current needs of students.

1.1. Research aim

In April 2019, the Health-Promoting Faculty V - Campus Kleefeld project ended with the final goal of embedding health promotion into the faculty's structure and policy. Four years later, with a new generation of students and significant global changes, this small-scale research aims to evaluate whether past interventions are appreciated by the current and if new health promotion needs have emerged. It is expected that the recent health crisis, the climate crisis, and other developments may have shifted these needs.

A study by Busse *et al.* (2021) examined the impacts of the COVID-19 pandemic on health risk behaviors among 5021 students at four German universities in 2020. Notably, there were changes in binge drinking and physical activity: 31% of students reported a decreased vigorous physical activity and 22% reported decreased moderate physical activity during the pandemic. Although 24% of the students engaged less in binge drinking, 5% reported more episodes of binge drinking, with a pre-pandemic binge drinking rate of 45.8%. Factors associated with changes in health-risk behaviors included female gender, younger age, lacked trusting relationships, and symptoms of depression (Busse *et al.*, 2021).

The pandemic also affected mental health. An online survey among German students (Holm-Hadulla *et al.*, 2021) found that 72.2% had a World Health Organization – five well-being score below 50, indicating poor well-being and potential depressive symptoms. In addition, 41.6% showed signs of major depressive syndrome, while 20% reported generalized anxiety or panic syndromes, due to social isolation during the pandemic. Similar results were found in another study (Schröpfer *et al.*, 2021) that reported significantly higher psychological stress in 44% of German students during the pandemic.

A recent health report by Techniker Krankenkasse (Meyer *et al.*, 2023) surveyed 1000 students aged 18 and above nationwide and found significant deterioration in students' general health compared to a baseline survey in 2015. In 2015, 84% of students rated their overall health as very good or good, whereas in 2023, only 61% did so. Conversely, the proportion of students describing their health as less good or poor increased from 3% in 2015 to 10% in 2023. Specifically, 68% reported stress-related exhaustion in the past 12 months, 59% experienced headaches, 55% had back pain, and 53% suffered from concentration difficulties. Furthermore, 43% reported sleep problems, 34% experienced depressed mood, and 29% felt lonely (Meyer *et al.*, 2023). In contrast, another study (Voltmer *et al.*, 2021) found no significant changes in mental health among German students between 2019 and 2020, based on data from one German university.

2. Methodology

This section outlines the strategy used to assess awareness and involvement among students in health-promoting activities on the Kleefeld campus of the Hannover University of Applied Sciences and Arts as well as evaluate the future needs of these students. Over the past few years, students faced numerous challenges, including the

COVID-19 pandemic, the transition to online learning, technical difficulties and challenges, increased workplace demands (particularly for those in the nursing sector working in emergency rooms), spiraling inflation, rising energy cost following the pandemic, and the onset of the Russia–Ukraine conflict.

The first objective was to assess awareness of previous health-promoting interventions on campus. Students were asked to provide their opinions on whether they were aware of these interventions, had participated in them, and considered them successful. This assessment utilized a Likert scale. In addition, students were asked to evaluate the comprehensiveness of the interventions and the effectiveness of the communication. The second objective was to assess students' needs and preferences, beginning with a general question about the importance of health promotion in universities. Students were also asked to identify the most important health-related topics, which included commonly recognized themes (e.g., physical health, mental health, drug abuse) and less common ones (e.g., social well-being, the use of media, sedentary behavior). This approach allowed for a broader understanding of health without requiring prior knowledge. An open-ended question was included to further explore students' needs, allowing students to suggest health-promoting interventions. A third focus was on identifying students interested in participating in future health-promoting interventions. The nature of the questions will be analyzed in more detail below. The survey questions, originally formulated and conducted in German, have been translated into English for this article.

2.1. Survey questions

The survey employed structured questions to assess students' awareness, involvement, and needs regarding campus health promotion, covering demographics, past participation, satisfaction, and future engagement. The key items are outlined below:

(i) Personal data (age, sex, education)
(ii) How important is the provision of health promotion services in a university environment to you? (1 = v*ery important* to 5 = *very unimportant*)
(iii) Indicate the importance of each health topic (1 = *very important* to 5 = *very unimportant*). Multiple answers are possible: exercise, stress management, substance use, mental health, social health, media use, sleeping, sedentary behavior, healthy eating, drinking enough water, and other
(iv) What on-campus activities have you participated in/What on-campus facilities have you used in the past? Multiple responses possible: social gardening, playground equipment rental, outdoor teaching, healthy apple snacks, water dispensers, eCHECKUP TO GO, alcohol prevention, health runs, high-intensity interval training (HIIT), partnership with ELMO (European Lifestyle Medicine Organization), and other health promotion actions in studies, and other
(v) How satisfied are you with the health promotion services offered on campus? (1 = *very satisfied* to 5 = *very dissatisfied*).
(vi) How complete is the health promotion offer on campus? How complete is the offer? (1 = v*ery complete* to 5 = *very incomplete*).
(vii) Do you have any other ideas for health promotion activities? Yes, specifically: No
(viii) How satisfied are you with the communication and dissemination of information about health promotion? (1 = *very satisfied* to 5 = *very dissatisfied*)
(ix) Does student health promotion need to be covered during class time? (1 = *completely agree* to 5 = *completely disagree*)
(x) Would you like to be involved in the design of health promotion on campus? Yes, no, or maybe. If no, why not?: I lack the necessary knowledge/expertise, I don't find it meaningful, the topics don't appeal to me, because of my studies I don't have time, because of my workload I don't have time, because of my family life I don't have time, and other. If maybe, what makes you doubt?

2.2. Data collection

A survey questionnaire was developed with Google Forms in the German language. The questionnaire was structured into several sections. Initially, basic demographic characteristics, such as age, sex, and study course, were collected. The second section inquired about the importance of health promotion on campus/at the university and which health-related topics are considered crucial for a health-promoting university (e.g., physical health, mental health, social well-being, sleep, and substance abuse). The third section provided an overview of past health-promoting interventions and environmental changes on campus. Students were asked if they were aware of these measures, had utilized them, and how successful they perceived them to be. In addition, they were asked about their satisfaction with the health promotion offerings and whether they had suggestions for improvement. Satisfaction with communication regarding health promotion and the inclusion of health promotion in courses was also assessed. In the final section, students were asked about their interest in participating in a working group to implement various health-promoting ideas on campus, evaluating their popularity and sustainability.

They were also presented with a range of six reasons for not participating in health-promoting activities on campus.

All students from Faculty V of the Hannover University of Applied Sciences and Arts were eligible to participate in the online survey. Faculty V – Social Welfare and Health Care – is one of the five faculties of Hannover University of Applied Sciences and Arts, located at the Hannover-Kleefeld site. It offers five bachelor courses and three master courses. Students were invited to complete the survey through different recruitment methods: during seminars in the Nursing and Health Care department, through email to all students, and through social media. The Faculty V of Hannover University of Applied Sciences and Arts approved conducting the survey.

To minimize bias, a non-random convenience sampling was combined with voluntary participation. Students were approached outside the campus catering facility and encouraged to scan a QR code to complete the survey. The survey was also promoted through a poster (Figure 1) and the faculty's Instagram account. The survey took place from May 2, 2023, to May 19, 2023. Participants provided consent and were informed that the data would be published in an academic journal. Collected personal data included gender, age range, and study course. The survey required approximately five minutes to complete, and participants received no compensation.

2.3. Data analysis

Descriptive statistics were used to analyze the data from the questionnaire. Faculty V had 1310 students during the semester that the survey was conducted, of which 209 filled in the questionnaire, resulting in a response rate of nearly 16%. The distribution of the respondents by gender, age, and study course can be found in Table 2.

3. Results

3.1. The importance of health promotion at university

When students were asked about the importance of health promotion services at university (Figure 2), 61.3% of respondents answered positively (25.4%: *very important*, 35.9%: *important*), 27.3% were neutral, and 11.5% considered health promotion at university as unimportant.

When evaluating the importance of different health topics, students ranked "mental health" (*very important* + *important*: n = 193) and "stress management" (*very important* + *important*: n = 191), the most important topics, closely followed by "drinking enough water" (*very important* + *important*: n = 190) and "healthy food" (*very important* + *important*: n = 184).

Figure 1. The poster designed by the authors to encourage students to fill out the online questionnaire through QR code

Table 2. Distribution of the characteristics of the respondents

Variable	n	%
Gender		
Female	148	70.8
Male	57	27.3
Prefer not to say/other	4	1.9
Age		
18 – 24	91	43.5
25 – 29	52	24.9
30 – 34	21	10
35 – 39	16	7.7
40 – 44	11	5.3
≥ 45	18	8.6
Study course		
Social work	87	41.7
Religious education and social work	35	16.7
Nursing (including extra-occupational courses)	65	31.1
Inclusive education (including extra-occupational courses)	22	10.5

No topics were distinctly rated as unimportant, although some received lower scores in the *very important* or *important* categories, including drug use, media usage, and active breaks (sedentary behavior).

3.2. Awareness of previous interventions

Students were asked about their participation in past campus health interventions. Figures 3-12 illustrate the students' awareness of these interventions and their perceived success. The most recognized intervention was

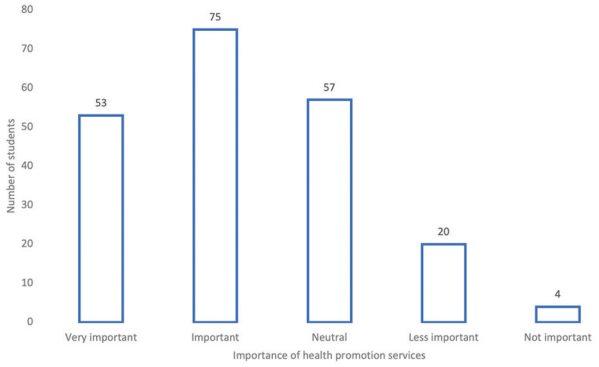

Figure 2. Importance of health promotion services in the university environment

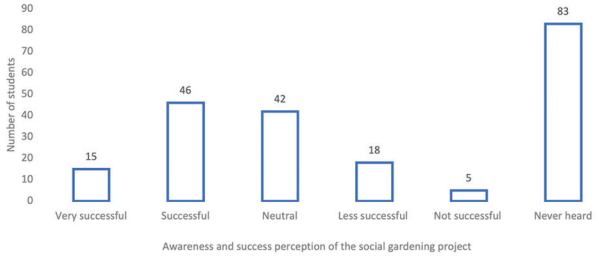

Figure 3. The awareness and success perception among students of the social gardening project

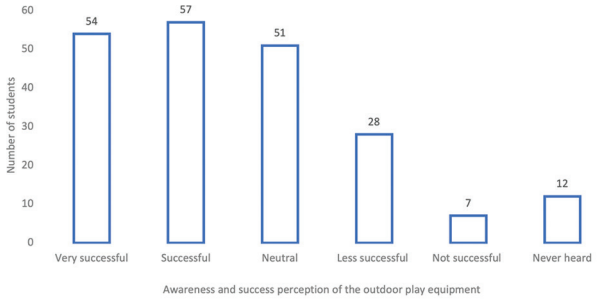

Figure 4. The awareness and success perception among students of the outdoor play equipment

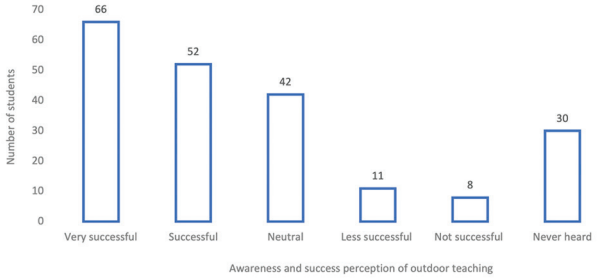

Figure 5. The awareness and success perception among students of outdoor teaching

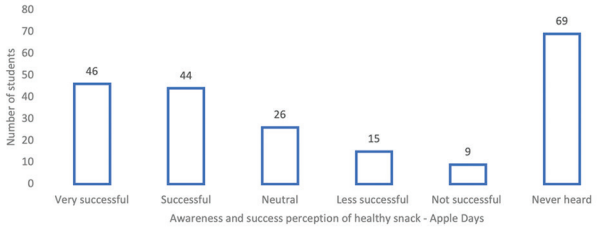

Figure 6. The awareness and success perception among students of the healthy snack (Apple Days)

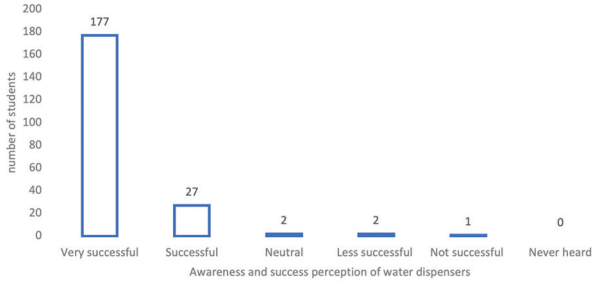

Figure 7. The awareness and success perception among students of the drinking water dispensers

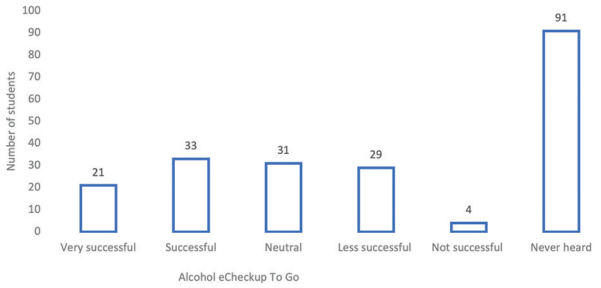

Figure 8. The awareness and success perception among students of the Alcohol eCHECKUP TO GO

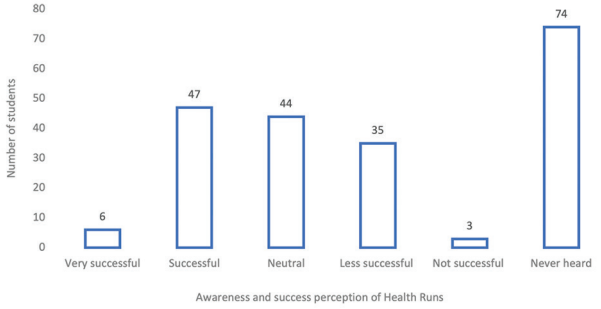

Figure 9. The awareness and success perception among students of the Health Runs

the installation of drinking water dispensers (84.7%). Other interventions that were well-known and utilized

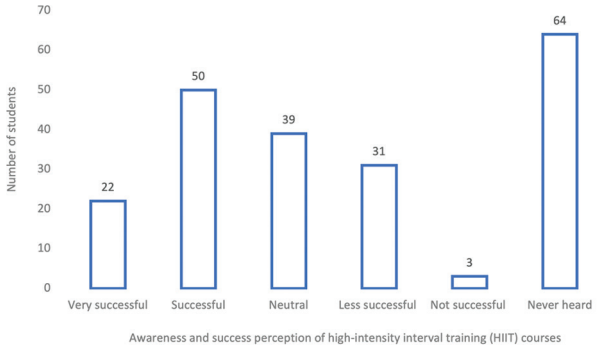

Figure 10. The awareness and success perception among students of the high-intensity interval training courses

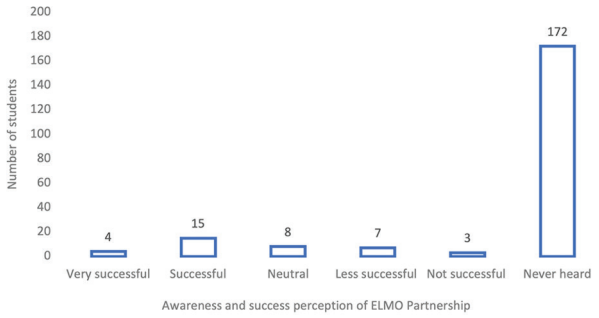

Figure 11. The awareness and success perception among students of the partnership with the European Lifestyle Medicine Organization

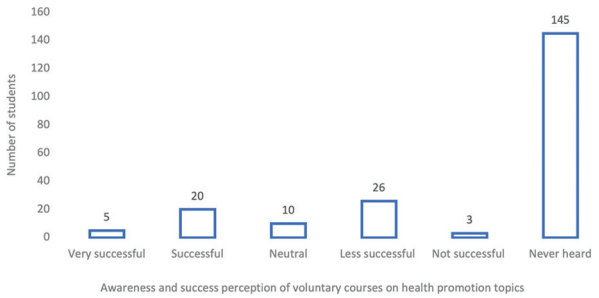

Figure 12. The awareness and success perception among students of the voluntary courses on health promotion topics

included the provision of chairs for outdoor teaching (31.6%), outdoor play materials like spike balls, frisbees and badminton (25.8%), and apple snacks (22%). Less familiar interventions included HIIT courses (10.5%), the Alcohol eCHECKUP TO GO (10%), and the social gardening project (7.2%). The least known interventions were the Start to Run/Health Run meetings (2.9%), the voluntary courses on health topics (2.4%), and the ELMO partnership (2.1%). Some students mentioned interventions not part of the Campus Kleefeld health project, while a significant number reported being unaware of any interventions.

Almost half of the respondents were neither satisfied nor dissatisfied with the campus offerings of health-promoting interventions. Overall, 38.7% expressed satisfaction, while 12.4% were dissatisfied with these interventions. The question regarding the completeness of campus offerings showed a similar distribution of responses.

3.3. Future needs and ideas

In addition to identifying important health topics, students were asked to suggest new interventions in the survey's open-ended question (Do you have any other ideas for health promotion activities? No/Yes, specifically). A total of 108 students provided some suggestions and ideas, which were analyzed and categorized into six themes: (i) healthy food and drinks; (ii) physical activities; (iii) mental health, stress management, and options to relax; (iv) adaptations in the direct physical environment; (v) social topics; and (vi) ideas concerning communication about the offers.

Suggestions related to healthy food and drinks represented 20% of the comments, primarily focusing on the student restaurant's current offerings. Students felt that the meals were not healthy enough and suggested more fresh snacks, such as fruits and vegetables. There was also a demand for more vegan and vegetarian options, as well as a kitchenette for preparing or reheating home-packed lunches. Notably, many students requested additional water dispensers on campus and in the student restaurant, including those with sparkling water.

Regarding physical activity, 30 suggestions were received and analyzed, accounting for slightly more than one-third of all suggestions. The most common requests included active breaks or walks during lessons and a broader range of sports options on campus, such as basketball hoops, volleyball courts, and outdoor gyms.

The open-ended answers showed a high demand (around 45%) for interventions focused on mental health, stress management, and relaxation. Students suggested yoga courses, mindfulness courses, breathing exercises, and dedicated relaxation spaces. Some expressed the need for reduced performance pressure and more guidance and support for mental health issues, including access to coaches or contact points. Workshops on this theme were also highly recommended.

A small number of students (8%) noted their need for environmental changes on campus, such as more outdoor seating and tables for relaxation and a cozy reading area in the library. The idea of a bike repair station on campus, currently under development in collaboration with students from another faculty, was well received. To gauge support for this idea, an additional question was included

in the survey: "Do you think it is useful for you to install a bicycle repair station on campus with an air pump and some basic gadgets for small repairs?" Three-quarters of respondents reacted positively to this idea (Figure 13). This question was included to encourage university management to initiate the bike repair station project.

On the topic of social well-being, students suggested organizing activities that foster social connections, such as gatherings during lunch breaks. Students who are also parents expressed the need for more support, including meetings for parents to connect and potentially assist each other with childcare, as well as a playroom on campus.

A recurring concern was the lack of communication about various interventions. Earlier survey questions revealed that some interventions were unknown to students, largely due to insufficient or invisible communication. A related suggestion was to incorporate more health topics during lectures. This was also reflected in the response to whether health promotion should be covered during class time, with 75.6% of respondents answering positively (Figure 14).

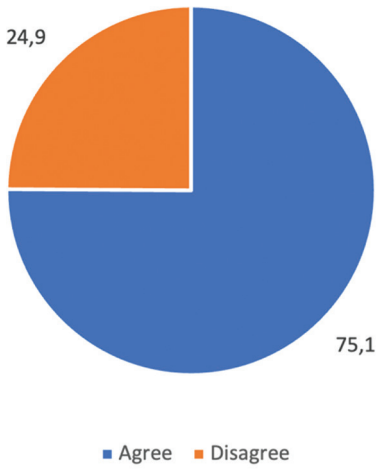

Figure 13. Agreement on the idea of installing a bike repair station on campus

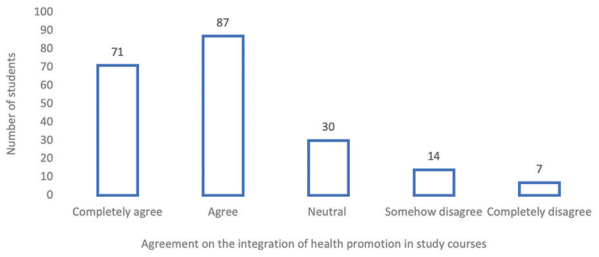

Figure 14. The agreement on the integration of health promotion in study courses

3.4. Willingness to participate in health promotion at university

The survey concluded by asking if students were interested in actively participating in health promotion activities on campus, from idea collection and intervention design to implementation.

The smallest group consisted of students interested in such actions (7.7%), who provided their contact details for further collaboration on health promotion at Campus Kleefeld.

In contrast, almost half the respondents (48.8%) expressed no interest. When asked why, the most common reason was a lack of time due to family life, studies, or work. The second most frequent reason was a perceived lack of knowledge or expertise. Some students noted that there were no concrete benefits associated with participation, such as credit points or reference letters.

A large group of students (43.5%) was hesitant about participating. The reason for their doubt was quite similar: uncertainty about the time commitment required for cooperation in a working group, given their scarce time. Another recurring reason was their impending graduation, meaning they would no longer be on campus in subsequent semesters.

4. Limitations

The survey methodology employed a baseline assessment and a practice-oriented approach. This approach was chosen for its speed, insightfulness, and dual purpose: to measure the current level of awareness among students and to inform them about the university's existing health-associated activities. The survey utilized a non-random convenience sampling method on campus over 17 days, complemented by an online survey distributed via student email. However, this method is susceptible to several potential biases.

One concern is survey fatigue, exacerbated by the frequent participation in many online surveys and the general lack of time, which many students mentioned in the results. Students in Faculty V often study part-time while balancing professional and family responsibilities. Another potential issue is self-selection bias, where individuals with particular characteristics or interests are more likely to participate, potentially skewing results. This could lead to biased findings if only students who identify with the topic's importance or have higher expectations due to greater knowledge or motivation participate, such as those from the Nursing and Health Care department.

To mitigate these issues, the survey was designed to be as concise as possible, minimizing the time needed for

completion. To address self-selection bias, an additional effort was made to approach students during lunchtime, allowing for interaction with students from diverse departments and study courses within the faculty. This approach also served as a prompt to consider healthy nutritional choices.

5. Discussion and recommendations

An evaluation of the survey results indicates that while students exhibit some awareness of previous interventions, this awareness appears to be limited. It remains unclear whether this limitation stems from inadequate communication efforts, ineffective messaging, or a lack of student engagement. To address this uncertainty, a more comprehensive and multi-channel communication strategy should be implemented, followed by a subsequent survey to assess potential improvements in student awareness.

Awareness is primarily focused on structurally anchored interventions, such as water dispensers and outdoor play materials, which is logical given their visibility. Nevertheless, several interventions were unknown to students, possibly due to insufficient communication or the cessation of working groups after the project phase. These working groups were not integrated into the faculty's operations, resulting in limited staff resources to sustain the project post-initiation. A similar observation was made by Dietz & Schäfer (2023), who state that "only a very small number of German higher education institutions have embedded health into all aspects of campus culture, across the administration, operations, and academic mandates" (Dietz & Schäfer, 2023).

Health promotion at universities is a relevant topic among students. This is evident not only from the small minority (11.5%) who explicitly stated that they find this topic unimportant but also from the numerous suggestions provided for additional interventions, indicating a vibrant interest in the subject. This demonstrates a genuine need for active health promotion in the university environment, particularly focusing on mental health and stress management.

A systematic literature review conducted in 2021 identified peer learning and peer mentoring as the strategies with the most significant results in addressing anxiety and stress (Pointon-Haas *et al.*, 2024). Another systematic review identified that interventions such as mindfulness, cognitive behavioral therapy (CBT), and interventions delivered through technology were effective compared to passive controls, with CBT potentially offering enduring effects over time (Worsley *et al.*, 2022). A review of randomized controlled trials on interventions for common mental health issues (Huang *et al.*, 2018) found that recreational interventions such as exercise, art, and peer support were particularly effective in treating depression and anxiety among students. While CBT and mindfulness-based interventions were also beneficial, recreational approaches (exercise, art, and peer support) demonstrated stronger effects in reducing symptoms of depression and generalized anxiety disorder (Huang *et al.*, 2018).

It is noteworthy that the evidence regarding the population under study remains somewhat unclear, as many studies included a broad spectrum of student types, such as undergraduates, graduate students, and professional students. This diversity introduces variability in age ranges and distinct challenges unique to each group, which may impact the relevance and comparability of the findings. In addition, many studies report results across a wide range of mental health issues, making it difficult to conclude about specific conditions. Furthermore, the literature reviews included studies with varying degrees of methodological rigor, potentially impacting the consistency and reliability of the findings.

Based on the present survey's findings, it appears that solutions and intervention programs tailored to the needs profile of students are the most suitable approach. Adopting participatory approaches that involve students in the design and implementation of interventions, rather than merely targeting them, could be the most efficient strategy. Such approaches could be carefully designed and integrated into research courses or project-based learning activities within the study program.

Evaluation methods like realistic evaluation, as developed by Pawson & Tilley (1997), can provide valuable insights for program participants. This approach emphasizes how program outcomes emerge from the participants' responses or "reasoning" based on the resources and opportunities offered by the program. Essentially, it is the interaction between the program's context and the participant's reasoning that drives the outcomes, making this approach highly adaptive and participant-centered. This approach could form the basis of a process starting from the baseline survey that explores what students know and aspire to, considering their needs and interactions with the campus (Pawson & Tilley, 1997).

To strengthen future health promotion efforts in university settings such as the one under study, a key focus could be on leveraging the enthusiasm of students who are not only interested in their health but also in contributing to the well-being of their peers. Engaging these students as ambassadors or peer supporters could enhance outreach and foster a culture of collective health responsibility within the student body.

A subset of students expressed a willingness to actively participate in such efforts. The interest shown by students

can serve as a foundation for developing bottom-up health promotion initiatives. However, it is crucial to ensure that these student-led initiatives are supported by experts in health promotion, providing the necessary knowledge and experience to ensure that interventions are rigorous, safe, and effective. In practice, this would require a well-accepted student-health-management concept that implements a holistic health promotion approach and allocates sufficient staff resources to sustain and integrate health promotion activities on campus (Preuss *et al*., 2022; Stock, 2024). University leadership plays a crucial role in prioritizing, initiating, and shaping the development of key topics within any institution. They are responsible for determining the significance of these issues for the university's growth and for allocating the necessary resources to support them. This decision-making process influences the institution's strategic direction and ability to evolve in key areas (Meier & Steinke, 2023).

This article highlights a practice-oriented approach aimed at engaging and raising awareness among students about health promotion in a university setting. The survey results demonstrated a strong demand for such initiatives, indicating that health promotion is a priority for students and should be framed as a central issue on campus.

There is no doubt that since the establishment of AGH in 1995, the significance, scope, and funding for health promotion have steadily grown in German universities (Arbeitskreis Gesundheitsfördernde Hochschulen, 2023). Despite this progress, health promotion remains a voluntary responsibility rather than a legal requirement for universities. Policymakers in Germany may consider adopting regulations that mandate universities to actively promote health resources, ensuring all students are informed of and have access to these services. A unified policy framework across German universities could help standardize health services, enhance consistency in student support, and bridge existing gaps between institutions. In addition, it would facilitate the structural integration of health-promoting measures into university policies, ensuring the implementation of harmonized, resource-oriented initiatives. This would help ensure that students in all fields of study, regardless of their department, have access to comprehensive health resources.

Notably, although funding for university-based networks and projects has increased through contributions from statutory health insurance funds, particularly under the Prevention Act, there has been little strategic investment in university health promotion resources. In addition, there is a lack of systematic exchange with international developments or projects related to health promotion in universities (Bonse-Rohmann, 2023). These factors could act as catalysts for implementing a unified policy framework across German universities.

6. Conclusion

Addressing the health of German students through university policies can have broader societal impacts. By investing in preventive health measures and support systems, policymakers can promote resilience and reduce long-term healthcare costs associated with untreated mental and physical health issues. Health initiatives in universities can also set a precedent for health-conscious habits that students carry forward into their professional lives, ultimately benefiting the wider population. As the pressures of academia grow, policies ensuring ongoing, adaptable support for student health will be essential in addressing the complex needs of Germany's student population.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Vasiliki Kolovou
Formal analysis: Delphine Dierckens
Investigation: All authors
Methodology: Vasiliki Kolovou
Writing – original draft: Delphine Dierckens
Writing – review & editing: Vasiliki Kolovou

Ethics approval and consent to participate

Conducting the survey was approved by the Faculty V of Hannover University of Applied Sciences and Arts. Participants provided their verbal consent to participate in the study voluntarily.

Consent for publication

Participants were informed about the study's purpose and the collected data would be published in academic papers.

Availability of data

The data used in this study are available upon request from the corresponding author.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

Impact of maternal and child health services on early post-partum modern contraceptive uptake in Pakistan: A quantitative analysis

Amna Noor Asim*, Muhammad Mohsin Latif Kiani, and Javed Ali

Department of Research and Survey, National Institute of Population Studies, Islamabad, Pakistan

Abstract

The initiation of post-partum contraception is crucial for the health of mothers and their children. The early acceptance and uptake of modern contraceptive methods among women can be significantly boosted by the provision of maternal and child healthcare (MCH) services. This study examined whether the utilization of MCH services increases women's early adoption of modern contraceptive methods. The data were taken from the Pakistan Demographic and Health Survey (2017 – 2018) for currently married women aged 15 – 49 years, and a multinomial logistic regression model was used to analyze the data. The results reveal that the richest women were twice as likely (relative risk ratio [RRR] = 2.14, $p < 0.001$) to use modern contraceptive methods and 4 times more likely (RRR = 4.16, $p < 0.001$) to use traditional contraceptive methods than the poorest women. Similarly, women with media exposure were more likely (RRR = 1.43, $p < 0.001$) to use modern contraceptive methods in comparison with their counterparts. Notably, women aged 30 – 34 years (RRR = 2.08, $p < 0.001$) were more likely to use modern contraceptives. Expanding MCH services, focused on addressing wealth disparities, media exposure, and education levels, is crucial. In addition, regional and age-specific barriers to contraceptive use should be tackled, particularly in underserved areas such as Balochistan and among younger reproductive age groups.

Keywords: Maternal; Post-partum; Uptake; Contraceptives; Services; Healthcare; Sustainable

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***Corresponding author:**
Amna Noor Asim
(nooramnaasim@gmail.com)

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1. Introduction

The initiation of post-partum contraception is crucial for the health of mothers and their children. To encourage and assist women in adopting early contraceptive use, maternal and child healthcare (MCH) services must be supported. MCH services have received considerable attention in the demographic and public health literature. Improvement in MCH services reflects a nation's overall socioeconomic progress. Thus, improved access to and utilization of high-quality reproductive health services are essential for decreasing maternal and child mortality and morbidity.

In September 2015, all UN Member States adopted the Sustainable Development Goals (SDGs) Agenda 2030. These 17 goals aimed to end poverty, promote gender equity, and create a peaceful and prosperous world. Goal 3, among these goals, focuses on the

"*Good Health and Well-being of Women and Children.*" The United Nations has established worldwide goals to lower the maternal mortality ratio (MMR) to 70/100,000 live births for Target 3.1. By adopting modern contraception methods for family planning and birth spacing, individuals can contribute to achieving Goal 3 of the SDGs Agenda 2030 (Stenberg *et al*., 2021).

MCH services are analyzed through the antenatal care that women receive, delivery in the healthcare facility, tetanus injections during pregnancy, and checkups after delivery (i.e., post-natal care). Meanwhile, child healthcare is analyzed through the provision of complete immunization. Frequent visits to healthcare facilities enable women to become familiar with and adopt early initiation of post-partum contraception (Dutamo, 2015). The contraceptive prevalence rate is the percentage of women who use any method for spacing or limiting the birth and for avoiding unintended pregnancies. These family planning methods are further divided into traditional and modern contraceptives. Modern methods include male and female sterilization, condoms, intrauterine contraceptive devices, pills, and injectables. Traditional methods include rhythm, withdrawal, etc.

High maternal and infant mortality rates are attributed to the inadequacy of many developing nations in providing universal coverage for the most crucial reproductive, maternal, and child health interventions (Hotchkiss *et al*., 2005; Owusu *et al*., 2021). Most women in developing countries do not initiate contraception, which causes unintended pregnancy (Bellizzi *et al.,* 2020). Recent research indicated that women who receive MCH services are more likely to use contraceptives early in life (Kumar *et al*., 2020; Kumar & Reshmi, 2022). A study also emphasized the significance of utilizing MCH services for the early adoption of contraception (Seiber *et al*., 2005).

Family planning programs that encourage the utilization of modern contraceptives can lower the MMR in two ways. The first and more obvious effect is a decrease in the number of pregnancies resulting from increased contraceptive use. However, the second effect involves reducing unsaved abortions. Reducing the number of pregnancies lowers the risk of maternal death for women and reduces the overall number of fatalities (Bansal *et al.*, 2022; Stover & Ross, 2010). Rising contraceptive use lowers the average risk of mortality associated with each pregnancy and delivery by preventing high-risk births. The utilization of contraceptives is one of the significant determinants of fertility decline, and it prevents unwanted pregnancies (Ahmed *et al.,* 2019). The utilization of post-partum contraception is crucial for improved MCH outcomes as it prevents unintended pregnancies during the 1st year after childbirth (Blazer & Prata, 2016). Moreover, women who do not use contraceptives may have a twofold increased risk of maternal death compared with users (Bansal *et al.*, 2022).

This research is particularly relevant in the context of SDG 3, which prioritizes the health and well-being of women and children. This progress may be attributed to international, national, and regional initiatives for the underprivileged and marginalized populations. In the past 10 years, the MMR has declined from 276 deaths to an average of 186 deaths/100,000 live births in Pakistan (Chistie *et al.,* 2021). Similarly, in children aged <5 years, the mortality rate (U5MR) declined from 87.1 deaths/1000 live births to 67.2 deaths/1000 live births in the past 10 years (Sharrow *et al*., 2022). However, the neonatal mortality rate (NMR) has declined from 50 deaths/1000 live births to 40.4 deaths/1000 live births in the past 5 years. Therefore, initial post-partum contraception plays a vital role in lowering the NMR.

An understanding of the dual functions of MCH services justifies this study. These services enhance the health of both mothers and children by offering essential medical treatment during and after pregnancy. Furthermore, they act as a crucial platform for early contraception instruction and encouragement, which helps reduce the risks associated with closely spaced pregnancies. The study aimed to close a knowledge gap by examining how MCH service consumption affects contraceptive behavior among married women aged 15 – 49 years, particularly given that Pakistan continues to face challenges in achieving universal reproductive healthcare coverage.

Although previous research offers significant insights, few studies have used nationally representative data to quantify the effect of MCH services on post-partum contraception in Pakistan. Most research tends to focus separately on MCH services or contraceptive use, leaving a gap in understanding their connection. This emphasizes the importance of research like this one to close this gap and offer proof for focused interventions.

The main objective of this study was to determine whether the utilization of MCH services affects the utilization of modern contraception within a year after childbirth. This study also aimed to analyze other sociodemographic factors (as control variables) associated with the utilization of MCH services among married women in Pakistan.

2. Methods

2.1. Data and variables

This study uses data from the fourth round of the Pakistan Demographic and Health Survey (PDHS) conducted

in 2017 – 2018. The PDHS Program is a 5-year initiative designed to help organizations gather and analyze data for population, health, and nutrition programs that are planned, tracked, and evaluated. The U.S. Agency for International Development provides funding for the Demographic and Health Surveys (DHS) program through ICF International, while other development partners also contribute to funding the PDHS 2017-18. The sample design used in the 2017 – 2018 PDHS was stratified in two stages. A two-stage selection procedure was used to select samples separately for each stratum.

The survey covered 13,118 ever-married reproductive women aged 15 – 49 years, of whom 12,363 eligible women were successfully interviewed. The outcome variable was the utilization of a modern contraceptive method within the 12 months after the delivery of the recent child. Therefore, the analysis is based on 5,990 women who gave birth in the 5 years preceding the survey.

The main independent variable was the utilization of MCH services, defined as the utilization of MCH services from the time of pregnancy through the post-partum time, including complete child immunization (Das *et al*., 2020). The MCH index was created by aggregating different indicators for maternal (antenatal care, facility-based delivery, post-natal care, and tetanus injection) and child (complete child immunization) healthcare indicators. The study also used several control variables such as a place of residence, region, wealth index, women's age at the time of the survey, educational status, media exposure, own mobile phone, use of the internet, and desire for another child (Seiber *et al*., 2005; Dixit *et al*., 2017; Kumar *et al*., 2020; Bansal *et al*., 2022). This study incorporates information communication and technology indicators to assess the effect of technology. The detailed definition and construction of the variables are given in Table 1.

2.2. Methodology

The bivariate and multivariate analyses were used to measure the association between the dependent and independent variables and examine their significance levels. Cross-tabulations were computed as part of the bivariate analysis to display the frequencies and percentages of key socioeconomic and demographic characteristics and MCH indicators in relation to the usage of modern contraceptive methods. Furthermore, in the multivariate analysis, a multinomial logistic regression model was employed to evaluate the effect of the utilization of MCH services on the early initiation of modern contraceptive methods.

3. Results

Table 2 shows the percentages of women who were using the MCH service index and other sociodemographic indicators with respect to the early initiation of contraceptive methods. Therefore, Table 2 shows that among women who did not use MCH services, 79% did not use any contraceptive method within 12 months following birth, 16% used a modern method, and the remaining 5% used a traditional method. In contrast, 60% of women in Pakistan who utilized the MCH service did not use any method, 29% were using modern methods, and 11% were using traditional contraceptive methods. Thus, women who utilize MCH services are more aware of using modern contraceptive methods. Compared with those without media exposure (18%), women who had media exposure

Table 1. Definition of the variables

Variable	Definition
Use of modern contraceptives (dependent variable)	The utilization of modern contraceptives was measured through the questions asked to currently married women aged 15 – 49 years using any contraceptive method. Modern contraceptive methods: Female sterilization, pill, intrauterine device, injectable, implants, condom, diaphragm, foam/jelly, and lactational amenorrhea method
Maternal and child healthcare index is composed of the given variables	
1. ANC	ANC was measured based on the respondent's visits during their pregnancies in the 5 years preceding the survey and received at least four antenatal care visits from any skilled personnel during pregnancy for the most recent birth
2. Facility-based deliveries	All births that took place in medical facilities 5 years preceding the survey for the most recent birth were taken into account when determining institutional delivery
3. Post-natal care	Post-natal care is received by the respondent within 41 days after giving birth
4. Tetanus injection	Respondent has received tetanus injections during pregnancy
5. Child immunization	Full immunization is defined as those children aged 12 – 23 months receiving one dose of bacillus Calmette – Guerin, three doses of diphtheria pertussis, and tetanus, an oral polio vaccine, and one dose of the measles vaccine.
Socioeconomic and demographic indicators	Age of women, education of women, employment status, place of residence, media exposure, own mobile phone, use of the internet, wealth index, region, and desire for more children, as ascertained at the time of the survey.

Notes: The definitions of the variables are taken from the Pakistan Demographic and Health Survey 2017 – 2018.
Abbreviation: ANC: Antenatal care.

Table 2. Percentages of the uptake of contraceptives with respect to maternal and child variables and sociodemographic variables

Variables	Non-users		Traditional users		Modern users		Total	
	%	No.	%	No.	%	No.	%	No.
Maternal and child health								
No	79	1688	6	122	16	340	100	2150
Yes	60	2318	11	425	29	1104	100	3847
Media exposure								
No	76	5171	6	436	18	1242	100	6849
Yes	63	5135	10	853	27	2219	100	8207
Wanted child								
Wanted then	68	4912	9	633	23	1636	100	7181
Wanted later	47	524	13	148	39	434	100	1106
Employment status								
No	69	8979	9	1112	22	2904	100	12995
Yes	64	1334	9	178	27	559	100	2071
Wealth index								
Poorest	82	2377	3	91	14	418	100	2886
Poorer	74	2384	6	201	20	655	100	3240
Middle	66	1948	9	276	25	742	100	2966
Richer	63	1820	11	314	26	744	100	2878
Richest	58	1786	13	408	29	904	100	3098
Age								
15 – 19	91	665	3	19	6	44	100	728
20 – 24	82	1827	5	110	13	283	100	2220
25 – 29	73	2308	7	219	20	619	100	3146
30 – 34	62	1765	11	307	27	781	100	2853
35 – 39	60	1630	11	291	30	817	100	2738
40 – 44	58	1059	11	205	31	557	100	1821
45 – 49	68	1061	9	139	23	362	100	1562
Education level								
No education	74	5675	6	490	19	1462	100	7627
Primary	65	1357	9	199	26	547	100	2103
Secondary	63	1960	11	337	27	835	100	3132
Higher	60	1323	12	264	28	619	100	2206
Region								
Punjab	63	2150	11	361	26	889	100	3400
Sindh	69	1897	6	176	24	666	100	2739
KP	67	1588	10	227	24	563	100	2378
Balochistan	83	1433	4	73	13	218	100	1724
Others (ICT, GB, and AJK)	67	3247	9	453	23	1127	100	4827
Residence								
Urban	63	4579	11	812	26	1863	100	7254
Rural	73	5736	6	478	20	1600	100	7814
Own mobile								
No	73	6199	7	612	20	1735	100	8546
Yes	63	4115	10	678	26	1728	100	6521
Use internet								
No	69	9102	8	1063	23	2954	100	13119
Yes	62	1212	12	227	26	509	100	1948

Note: The full terms of abbreviations for regions mentioned in this table are: AJK: Azad Jammu and Kashmir, GB: Gilgit Baltistan, ICT: Islamabad Capital Territory, and KP: Khyber Pakhtunkhwa.

(listening radio, watching TV, and reading newspapers) used modern contraceptives (27%). In the PDHS survey, women were asked regarding their desire for their last child/birth. The percentage of women using contraceptives was significantly lower among those who wanted their last child at that time, with 23% using contraceptives, compared with 39% of women who desired to have their last child at a later time.

A higher percentage of young women used modern contraceptive methods than older women. Working women and women with higher wealth quantiles used modern contraceptive methods (27% and 29%, respectively) than non-working women and women with lower wealth quantiles (22% and 14%, respectively). Women who owned a mobile phone or used the internet were more likely to use a modern contraceptive (26% each) than those who did not own a mobile phone (20%) or never used the internet (23%).

The outcome variable of the study was the utilization of modern contraceptive methods. Therefore, the dependent variables were categorized into three to distinguish between modern method users, traditional method users, and non-users. The three categories were as follows: 0 referred to not using any method, 1 indicated the use of a traditional method, and 2 represented the use of a modern method by women. A multinomial logistic regression model was applied, with the non-use of contraceptive methods as the reference category. In Table 3, column 1 represents the odds of using a traditional method, whereas column 2 shows the odds of using a modern contraceptive method compared with the reference category (non-use).

The results indicate that a one-unit increase in the utilization of MCH services results in 1.4 times higher odds

Table 3. Results of contraceptive methods by using the multinomial logistic technique

Use of contraceptives	RRR	SE	z	*p*>z	95% CI	
Non-users of contraceptive methods (reference category=0)						
Traditional contraceptive methods=1						
MCH	1.41	0.17	2.84	0.00	1.11	1.78
Wanted child later	1.71	0.22	4.11	0.00	1.32	2.20
Wealth index (Ref: poorest)						
Poorer	1.95	0.40	3.27	0.00	1.31	2.92
Middle	3.08	0.64	5.40	0.00	2.05	4.64
Richer	3.42	0.76	5.52	0.00	2.21	5.28
Richest	4.16	1.00	5.94	0.00	2.60	6.67
Media	1.24	0.14	1.93	0.05	1.00	1.55
Own mobile	0.87	0.10	−1.20	0.23	0.70	1.09
Use internet	0.96	0.15	−0.26	0.79	0.71	1.30
Telephone	0.61	0.10	−2.97	0.00	0.44	0.85
Residence	0.72	0.08	−3.04	0.00	0.58	0.89
Region (Ref: Punjab)						
Sindh	0.66	0.10	−2.64	0.01	0.48	0.90
Khyber Pakhtunkhwa	0.86	0.13	−0.96	0.34	0.64	1.17
Balochistan	0.48	0.10	−3.38	0.00	0.31	0.73
Others	1.00	0.12	0.04	0.97	0.79	1.28
Respondent age (Ref: 15 – 19)						
20 – 24	1.00	0.27	−0.01	0.99	0.58	1.71
25 – 29	1.30	0.35	0.98	0.33	0.77	2.19
30 – 34	1.79	0.48	2.17	0.03	1.06	3.04
35 – 39	1.88	0.53	2.25	0.02	1.08	3.26
40 – 44	1.65	0.61	1.35	0.18	0.80	3.40
45 – 49	1.23	0.81	0.31	0.76	0.33	4.50
Respondent education (Ref: none)						
Primary	1.16	0.18	0.97	0.33	0.86	1.58
Secondary	1.32	0.19	1.95	0.05	1.00	1.74
Higher	1.30	0.22	1.54	0.12	0.93	1.83
Employment status	1.23	0.19	1.35	0.18	0.91	1.67
Constant	0.03	0.01	−8.73	0.00	0.01	0.06
Modern contraceptive method=2						
MCH	1.51	0.12	5.18	0.00	1.29	1.76
Wanted child later	2.03	0.18	7.86	0.00	1.70	2.42
Wealth index (Ref: poorest)						
Poorer	1.42	0.16	3.03	0.00	1.13	1.77
Middle	1.71	0.21	4.34	0.00	1.34	2.17
Richer	1.73	0.24	4.02	0.00	1.32	2.26
Richest	2.14	0.32	5.03	0.00	1.59	2.88
Media	1.43	0.11	4.65	0.00	1.23	1.67
Own mobile	1.03	0.08	0.41	0.69	0.89	1.20
Use internet	0.82	0.09	−1.73	0.08	0.66	1.03
Telephone	0.66	0.08	−3.61	0.00	0.53	0.83
Residence	0.95	0.07	−0.74	0.46	0.81	1.10
Region (Ref: Punjab)						
Sindh	1.01	0.11	0.12	0.91	0.82	1.24
Khyber Pakhtunkhwa	1.34	0.14	2.81	0.01	1.09	1.65
Balochistan	0.57	0.08	−3.81	0.00	0.43	0.76
Others	0.95	0.09	−0.55	0.59	0.80	1.14
Respondent age (Ref: 15 – 19)						
20 – 24	1.21	0.23	0.97	0.33	0.83	1.75
25 – 29	1.59	0.30	2.47	0.01	1.10	2.29
30 – 34	2.08	0.39	3.86	0.00	1.43	3.02
35 – 39	1.87	0.37	3.14	0.00	1.27	2.76
40 – 44	2.63	0.63	4.01	0.00	1.64	4.22
45 – 49	1.38	0.58	0.77	0.44	0.61	3.14
Respondent education (Ref: none)						
Primary	1.21	0.13	1.81	0.07	0.98	1.49
Secondary	1.35	0.13	2.99	0.00	1.11	1.63
Higher	1.53	0.18	3.50	0.00	1.21	1.94
Employment status	1.28	0.13	2.35	0.02	1.04	1.57
Constant	0.04	0.01	−11.55	0.00	0.02	0.07

Abbreviations: RRR: Relative risk ratio; CI: Confidence interval, MCH: Maternal and child healthcare.

of using traditional methods than non-users (reference group), with all other variables constant. Similarly, a one-unit increase in the utilization of MCH services for modern contraceptives, relative to non-users and with other variables held constant, results in 1.51 times higher likelihood of preferring modern methods over not using any method at all.

Regarding fertility desire, for each one-unit increase in the desire for a child later relative to the desire for a child now, the odds for preferring traditional methods over not using any would increase by 1.7 times, whereas the odds of using modern contraceptive methods compared with not using any would increase by 2.03 times, keeping all other variables unchanged.

Compared with women in the poorest quintile, those with the highest wealth quintile are more likely to adopt modern contraceptive methods rather than not use any method relative to the poorest who are more likely to adopt modern methods than not use any, assuming that all other variables are held constant.

At the provincial level, modern contraceptives are less likely used by women in Sindh, Khyber Pakhtunkhwa, and Balochistan than by those in Punjab who prefer using modern contraceptive methods to not using any method.

Compared with young women, middle-aged women are more likely to adopt modern contraceptive methods than non-users. Women who had secondary or higher educational attainment are more likely to use modern contraceptives. Specifically, for each 1-unit increase in educational attainment up to secondary level and higher, there would be 0.3- and 0.44-unit increases in the adoption of modern contraceptive methods compared with never-users. Women with high educational attainment may have better abilities to express their fertility desires or may have received proper health education and services from providers (Dixit *et al*., 2017). Table 3 shows that working women are more likely to use contraceptive methods than non-working ones relative to non-users, holding other variables constant.

4. Discussion

Based on a sample of married women aged 15 – 49 years who gave birth in the 5 years preceding the survey, the study examined the effects of maternal healthcare consumption on modern contraceptive usage within the 12-month post-partum period in Pakistan. In Pakistan, the proportion of married women who use contraception is still far lower than that in neighboring nations. The adoption of modern contraceptive methods is positively and significantly affected by the utilization of MCH services.

This study found that women who utilize MCH services are more likely to avail of modern contraceptive methods, which shows a positive and highly significant association with the uptake of modern contraception methods (Alhassan *et al.,* 2020). Women who utilize healthcare services are more likely to interact with healthcare practitioners, increasing their exposure to information regarding family planning methods (Ahmed *et al.,* 2019; Alhassan *et al.,* 2020). This could be an explanation for the association. Following this exposure, they might be inspired and empowered to use various contraceptive forms. The results of the study also revealed that the utilization of modern contraceptives has a positive and significant relationship with the desire for another child. If a mother wanted a child later, then women would use modern contraception to meet their desire.

In Pakistan, women who used modern contraceptive methods were favorably correlated with maternal age, higher education levels, coming from wealthier quantiles, and working. The results show that older women (aged 35 – 39) in Pakistan are more likely to take modern contraceptives than younger women (aged 15 – 29), consistent with previous findings (Jejeebhoy *et al*., 2019; Kumar *et al*., 2020).

Women who gave birth in the 5 years preceding the survey were asked if they desired their most recent child at the time of delivery, later on, or not at all. Because an unanticipated pregnancy increases a woman's awareness, early initiation of modern contraceptive methods was found to significantly positively affect all three models among women who reported having an unplanned delivery.

A notable distinction in the early uptake of modern contraceptive methods was observed between women from the wealthiest and the poorest backgrounds. Women from the low-income group were unable to adopt sterilization, which was associated with government incentive programs, or pay for the expense of modern spacing techniques once they reached the required family size. The study found a strong correlation between the early commencement of modern contraceptive use after childbirth and exposure to electronic mass media, such as radio and television.

This study also found a notable difference in the utilization of modern contraceptive techniques between rural and urban areas, which likely indicates that women living in rural areas are still not receiving sufficient information and services about contraception. Women residing in Punjab used more modern methods than those in other regions of the country. The findings of the multinomial logistic model show that the utilization of MCH, age, place of residence, region, and wealth quintile were the most important factors in predicting whether or not Pakistani women will adopt contraception (Iqbal *et al.,* 2017; Woldemicael & Tenkorang, 2010). However, women who received appropriate maternity healthcare demonstrated a higher prevalence of utilizing modern contraceptives, indicating that the utilization of maternal healthcare is a significant predictor.

5. Conclusion and recommendations

Based on the results, the study recommended that the government should overcome the structural barriers through programs strengthening the coverage and quality of MCH. In addition, MCH services must be sensitized about the pivotal role that modern contraceptive use plays in MCH, particularly in low-resource settings. The low adoption of modern contraceptives in Pakistan could be due to the illiteracy of women, low uptake of MCH services, and more desire for children.

The results of the study indicate the need to step up outreach initiatives to support female education, expand female career prospects, and stop unwanted pregnancies. By doing so, women would make knowledgeable decisions

about their health and reproductive options. An increase in the utilization of modern contraceptives in Pakistan may result from the need for more assistance in improving the utilization of maternal healthcare. Thus, the main focus should be to guarantee that married women in the present day have access to maternal health services, irrespective of their financial status. The results also indicate that wealth, along with other factors such as education and rural living, is a major contributor to this discrepancy. To overcome these persistent discrepancies in healthcare utilization, resources must be allocated to rural communities that are poorer and have lower educational levels.

Expanding immunization services, particularly for vulnerable families, is also essential to achieve progress toward universal health coverage under the SDG 2030 Agenda. The country should effectively implement equity-oriented resource allocation strategies. Moreover, to raise awareness about the importance of modern contraceptive use, efforts should be directed toward home visits for health campaigns.

The study has certain limitations related to the data analyzed. It relies on cross-sectional data from the PDHS, which restricts the ability to establish causal relationships between the utilization of MCH services and contraceptive uptake. Moreover, the study does not account for the male perspective in decision-making regarding modern contraceptive methods, which is a critical factor in many cultural contexts. Finally, the categorization of contraceptive use could be refined by focusing on two distinct groups: users and non-users of modern contraceptive methods.

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The authors declare no conflict of interest.

Author contributions

Conceptualization: Amna Noor Asim
Formal analysis: Muhammad Mohsin Latif Kiani
Investigation: Javed Ali
Methodology: Amna Noor Asim, Muhammad Mohsin Latif Kiani
Writing – original draft: Amna Noor Asim.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The data used to draw analysis and all the supporting endorsements or any conclusive statements supported by any data can be accessed from the references and the data are available on the website of NIPS nips.org.pk/publicdata/micro-data-set-of-pakistan-demographic-and-health-survey-2017-18-in-stata-format.

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ORIGINAL RESEARCH ARTICLE

Exploring the association between gender inequality and healthcare: A visualization study

Wullianallur Raghupathi[1†*], Sarah Jinhui Wu[1†], and Viju Raghupathi[2]

[1]Department of Information, Technology, and Operations, Gabelli School of Business, Fordham University, New York, New York, United States of America

[2]Department of Management, Marketing and Entrepreneurship, Koppelman School of Business, Brooklyn College, New York, New York, United States of America

Abstract

This study investigates the multiplex association between gender inequality and healthcare. The aim of the study is to comprehend how inequalities in gender affect healthcare across different populations worldwide. Visualization was conducted to study the effect of various gender inequality variables on different healthcare indicators. The study emphasizes the critical need for eliminating gender inequalities to reduce disparities in healthcare. By analyzing publicly available data from the World Bank, we find that higher access to anti-retroviral drugs is associated with a lower incidence of human immunodeficiency virus (HIV) among both genders and higher life expectancy. Importantly, increased female engagement in politics and government is linked to higher life expectancy. In addition, higher female representation is associated with lower fertility rates (particularly in high-income countries) and a declining incidence of HIV over time. Higher parity among the genders in school enrollment increases overall life expectancy, with female expectancy exceeding that of males. Simultaneously, higher parity is associated with reduced fertility rates. A lower enrollment among females is also correlated to higher fertility rates. Finally, higher parity also reduces the mortality rate for several diseases. Economic growth, education, income, political and government representation, population, and unemployment influence gender inequities, leading to disparities in healthcare delivery.

Keywords: Fertility rate; Gender inequality; Incidence of human immunodeficiency virus; Health; Life expectancy; School enrollment; Self-employment; Unemployment

†*These authors contributed equally to this work.*

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***Corresponding author:**
Wullianallur Raghupathi
(raghupathi@fordham.edu)

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1. Introduction

According to the World Health Organization (WHO, 2021), gender has implications for healthcare across all aspects of a person's life. Previous studies have demonstrated the relationship between gender inequality and health, particularly in the recognition and mitigation of adverse health conditions, consequentially leading to efforts to mitigate these disparities (Anderson *et al.*, 2021; De Laat *et al.*, 2024; Kent *et al.*, 2012; King *et al.*, 2020; Musani, 2024). Women have the right to the best quality of overall health. This right is requisite to their individual lives and general contentment, and to being actively involved in all aspects of their lives (Heise *et al.*, 2019; Milner *et al.*, 2021; Van Wijk

et al., 1996). Good health represents an equilibrium across all aspects of contentment and is not merely the absence of adverse health conditions (Van Wijk *et al*., 1996). However, healthiness and contentment have been deprived for most women. A major obstacle is the inequality between the genders and within the genders across the various ethnicities, gentries, and locations. Gender inequalities in healthcare stem from the primary inequality between men and women that is prevalent in many cultures (Braveman & Gruskin, 2003; Dahlin & Harkonen, 2013; Franklin *et al*., 2021; Su *et al*., 2022). The Platform for Action rightfully emphasizes that the existence of economic servitude and poverty and economic subjugation of women, violence against women, historically hostile viewpoints toward the female gender, discrimination by race, employment and income levels, the limited control women may have over their sexual and reproductive rights, and the powerlessness and vulnerability in all walks of life negatively impact women's health. Major policy and other forums have affirmed that to achieve greater health during one's lifespan, equality in sharing of family obligations, progress, and tranquility are required (Grown *et al*., 2005; United Nations, 1995; Van Wijk *et al*., 1996). Researchers from diverse entities and fields have recently highlighted significant gender disparities in accessing healthcare services and in the provision and quality of care received (Coles *et al*., 2022; Doyal *et al*., 2003; Heyman *et al*., 2019; Percival *et al*., 2023).

Both healthcare providers and consumers have hardly recognized the impact of gender in shaping the delivery and quality of healthcare services. Gender encompasses both biological differences and the distinct roles in culture and society between traditionally defined men and women. In addition, it is crucial to acknowledge the assumptions and limitations imposed on their respective functional responsibilities (Cislaghi *et al*., 2020; Denton *et al*., 2004). The gender-sensitive healthcare system ought to consider the culturally and socially implemented gender differences in overall health, including curative, preventive, and reproductive healthcare, education, research, infrastructure issues, financing, and policymaking (Artazcoz & Benach, 2001; Backhans *et al*., 2009; Domado, 2024; Gupta *et al*., 2019). A healthcare delivery system that is perceptive to women is essential, as women generally cope with health issues that are vastly different from those of men. Further, even if they face the same issues as men, they are likely to be affected in different ways. The physiological traits, processes, and biorhythms of women vary substantially from those of men, particularly in the domains of reproductive and sexual health. Likewise, the aspirations and reality in the economic and social conditions of women differ considerably from those of men. Therefore, their overall demands and rights for healthcare delivery are also vastly different (Darmstadt *et al*., 2019; Doyal, 2012; George *et al*., 2019; Lancet, 2020; Sen *et al*., 2007). Furthermore, women have historically faced a stereotypical perception of being the primary care provider, as well as an excessive user of healthcare services in the family. In clinical practice, women are generally perceived to fall ill more frequently under the assumption that they face additional reproductive health problems and inexplicable emotional or physical health issues (Palència *et al*., 2014; Sen *et al*., 2018; Sörlin *et al*., 2011). Even with these presumed ubiquitous traits, major dissimilarities persist among women, differentiated by age, culture, job status, ethnicity, motherhood, race, sexual preference, and socio-economic strata, among others (Ekbrand & Hallerod, 2018; Greene & Patton, 2020; Heymann *et al*., 2019; Lancet, 2010). Historically, healthcare providers and key players have overlooked the fact that women are an eclectic group with clearly delineated aspirations and demands (Hay *et al*., 2019; Jones *et al*., 2018; Macintyre *et al*., 1996). Research has highlighted systemic inequalities and underscored the need for targeted interventions to address health inequities (Langer *et al*., 2015; Madell & Hayward, 2019).

Gender inequality in healthcare has been a critical issue with far-reaching consequences due to its impact on individuals, communities, and societies. Unfortunately, there is limited research on the relationship between gender programs and inequities in gender and women's health (Palència *et al*., 2014; Shannon *et al*., 2019; Sörlin *et al*., 2012; Vélez *et al*., 2020; Weber *et al*., 2019; Yoong *et al*., 2019). Therefore, understanding the impact of gender inequality can help inform decision-making and shaping policies aimed at alleviating discrimination in healthcare and ameliorating the delivery and caliber of the healthcare system, leading to better health outcomes for all individuals (Steinert *et al*., 2021; WHO, 2011; 2019a; 2019b; 2021). This exploratory study aims to analyze the association between gender inequality and healthcare in various countries. Our primary research question is: "Which major catalysts and indicators are associated with gender inequality and healthcare globally?"

It is generally accepted in epidemiology and the sociology of health that in developed countries, men have a shorter lifespan than women, but women experience greater malaise than men (Heidari & Bachelet, 2018; Lancet, 2020; Macintyre *et al*., 1996). Numerous arguments have been proposed and tested (e.g., differences in risks associated with biases and discrimination in healthcare). Several studies have revealed that the directions of gender inequities in health-related conditions were more complex

than traditionally understood (Macintyre *et al*., 1996; Raj, 2011; Read & Gorman, 2010; Roxo *et al*., 2021). The trends and immensity of gender-related disparities in health varied depending on the prevailing indications or observations, as well as the stage of the life cycle (Macintyre *et al*., 1996; Palència *et al*., 2014; Van Wijk *et al*., 1996). Gender inequality is persistent during the entire life cycle for affliction in psychological issues but less pronounced or contradictory for many physical indications (Macintyre *et al*., 1996). Research from recent decades increasingly supports the perspective that gender inequalities in healthcare are vested in the social aspects, while also acknowledging that males have their biological limitations (Madell & Hayward, 2019; Read & Gorman, 2010). Gender perceptions have mostly transformed, and several of these likely impact gender-related challenges in health and sickness. An affirming possibility is that gender inequalities in healthcare have changed over time (Artazcoz & Benach, 2001; Heise *et al*., 2019; Sen & Ostlin, 2007). For example, while there was previously a female excess, this disparity has lessened. Gender inequalities refer to the different treatment of men and women, resulting in the systematic empowerment of men, often with adverse effects on women's health. It is universally recognized that while the lifespan of women is longer than that of men in advanced countries, women often live with poor health conditions (Annandale & Hunt, 2000; Espelt *et al*., 2010; Palència *et al*., 2014). In other words, gender inequalities in healthcare stem from inequities in relative financial situations and power dynamics (Arber & Khlat, 2002), as well as the division of labor based on sex (Malmusi *et al*., 2012). As Sen & Ostlin (2007) articulated, enhancing gender equity in healthcare and articulating women's rights to healthcare are two key strategies to mitigate overall disparities and ensure fair and equitable healthcare delivery. Therefore, to reiterate, the topic of gender differences in healthcare warrants continuous and periodic studies.

The aim of this exploratory study is to investigate the multi-dimensional relationships between gender inequality (e.g., immunization, access to anti-retroviral drugs and school enrollment, self-employment, unemployment, and women in parliament) and health variables (e.g., fertility rate, incidence of human immunodeficiency virus [HIV], life expectancy, and mortality rate) (Dahlin & Harkonen, 2013; Denton *et al*., 2004; Ekbrand & Hallerod, 2018; King *et al*., 2020; Milner *et al*., 2021). Using visual analytics, the study seeks to understand the extensive and interactive dimensions of gender inequality and healthcare. By elucidating the aforementioned relationship, we can shape policies and strategies to bridge the gap in gender inequality and its effect on health. Based on the results and insights obtained, we offer some key implications and future direction.

2. Methods

2.1. Data and variables

Data were gathered from the World Bank's World Development Indicators (WDI) database for 173 countries between 2007 and 2019 (https://databank.worldbank.org/reports.aspx?source=2&country=ARE).

Due to delays in data upload by several countries, particularly developing countries, missing values are prevalent. Consequently, data from recent years are more difficult to access. Preprocessing of data was performed to remove rows of data with missing values. In addition, normalization of the data was conducted to ensure that values across indicators, data types, and scales could be analyzed collectively. Software platforms, including Excel for coding data, Python for preprocessing, R programming languages, and Tableau for statistical analysis and visualization, were used accordingly. Tables S1 and S2 display the independent variables (i.e., gender inequality) and dependent variables (i.e., health). The variables were chosen based on the categorization of the indicators in the World Bank's WDI database (Denton *et al*., 2004; Franklin *et al*., 2021; Milner *et al*., 2021; Roxo *et al*., 2021; Sörlin *et al*., 2011; Sörlin *et al*., 2012; Weber *et al*., 2019).

2.2. Visualization

We adopted the descriptive visualization analytical technique, supported by visual analytics (Börner *et al*., 2019; Keim, 2001; Keim *et al*., 2010; Raghupathi & Raghupathi, 2013; Raghupathi & Raghupathi, 2021; Wong & Thomas, 2004), to provide insight into the association among and between gender inequality and health indicators. This data-driven approach, known as descriptive analytics, facilitates the study of historical data as it is. Visual analytics is particularly relevant when the data render itself to association rather than causal studies, for which control groups and experimentation are required (Kohlhammer *et al*., 2011; Raghupathi & Raghupathi, 2020; Thomas and Cook, 2005). The dual model of integrating the platforms and tools with the modeling capability of visualization helps uncover previously unidentified associations, enabling data-driven decision-making (Cao *et al*., 2018; Singh & Singh, 2020). Visualization renders complex data into easily understandable charts that are self-explanatory, supporting the idea of "letting the data reveal itself." Taken together, the series of charts form a compelling narrative (Kohlhammer *et al*., 2011; Raghupathi & Raghupathi, 2021; Raghupathi *et al*., 2023; Zhang *et al*., 2024).

3. Results

3.1. Gender inequality and preventative health

We analyzed the role of gender in the association between different dimensions of preventative healthcare. First, we assessed the association between access to anti-retroviral drugs (as an aspect of preventative health) and the incidence of HIV (Figure 1).

Figure 1 displays the relationship between access to anti-retroviral drugs and incidence of HIV by region for males (Figure 1A) and females (Figure 1B). Over the years, access to anti-retroviral drugs has increased, leading to a gradual decrease in the incidence of HIV for both genders. Higher access to anti-retroviral drugs is generally associated with lower HIV incidence rates. In general, females have a higher rate of access to anti-retroviral drugs and a lower incidence of HIV compared to males. The significant association between increased drug access and lower HIV incidence in women is promising and provides a strong rationale for healthcare policies aimed at promoting gender equality.

Figure 2 displays the association between access to anti-retroviral drugs and life expectancy by region for males (Figure 2A) and females (Figure 2B). The size of the box indicates the accessibility to anti-retroviral drugs, and the color intensity represents the life expectancy. For both genders, Africa has the lowest life expectancy and the second lowest access to anti-retroviral drugs. As Africa is predominantly where HIV incidence reports are documented, this chart suggests a socioeconomic issue beyond gender – access to HIV drugs is lowest in the countries that need them most, impacting both genders. This is possibly due to poor awareness, limited education, and a low standard of living.

Figure 3 displays the association between measles immunization rate (as an indicator of preventative health) and life expectancy for males and females. The chart indicates that while the life expectancy of females has remained lower than that of males, the gap has reduced in recent years. Increased immunization rates have contributed to a longer life expectancy and may help reduce gender inequity in health.

3.2. Gender inequality, income, and HIV

The association between gender inequity, in terms of the economic dimension of a country's income level, and health outcomes, that is, HIV incidence and mortality rate, are presented in Figures 4 and 5, respectively.

Figure 4 displays the proportion of HIV incidence in different income levels (high, medium, and low) for males (Figure 4A) and females (Figure 4B). HIV incidence in females is lower overall for all income levels. However, the discrepancy is notably higher for the middle-income level,

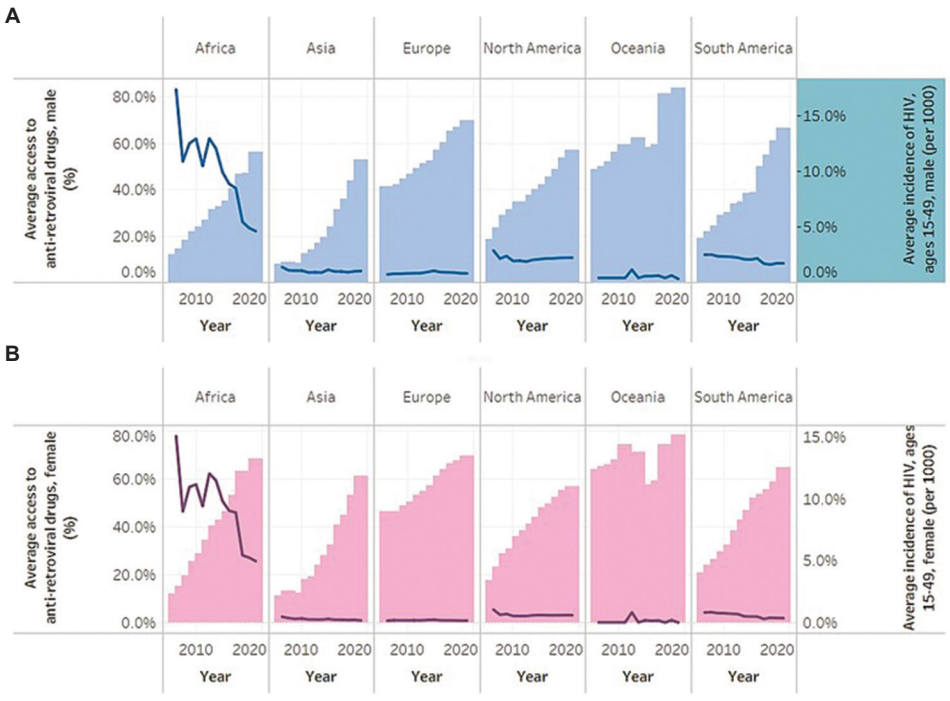

Figure 1. Association between access to anti-retroviral drugs and human immunodeficiency virus (HIV) incidence among males (A) and females (B) Shaded areas refer to access to anti-retroviral drugs; lines refer to the average incidence of HIV.

where higher income does not necessarily translate into increased investment in education and HIV prevention for women.

Figure 5 depicts the trend of mortality rates for males (blue line) and females (pink line) at different income levels. Female mortality rates are lower than males in middle-income and high-income countries, but not so in low-income countries. This suggests that in low-income countries, less attention and resources are allocated to women's health, leading to increased mortality rates among females.

3.3. Gender inequality, employment, and health outcomes

It is important to explore whether gender inequality in employment is associated with health outcomes, such as mortality, fertility rate, HIV incidence, and life expectancy, among others.

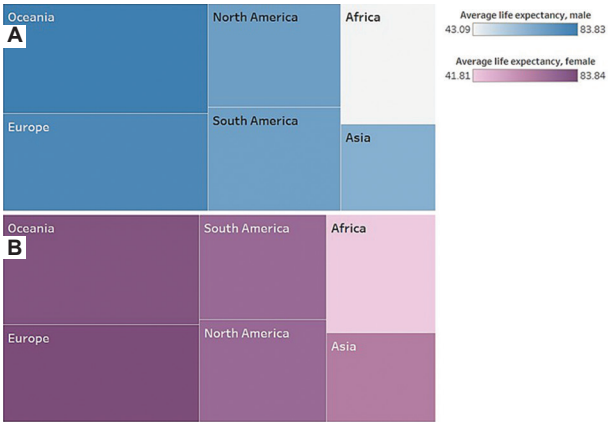

Figure 2. Association between the access to anti-retroviral drugs and life expectancy by region for males (A) and females (B)

Figure 6 displays the association between unemployment rate and mortality rate by region for both males (Figure 6A) and females (Figure 6B). The size of the bubble is proportional to the mortality rate, while the intensity of the color is proportional to the unemployment rate. Africa and Europe have high rates of unemployment and mortality for both genders. In contrast, the unemployment and mortality rates are generally higher for females than for males in Asia, Africa, North America, and South America. Higher unemployment is associated with higher mortality rates. Therefore, policymakers should consider the association between employment and healthcare in framing national policies aimed at gender equity.

Figure 7 presents the yearly trend of unemployment (pink bars) and fertility rates (purple line) for females. Average fertility rates have been declining globally since 2006, while the unemployment rate has fluctuated, peaking around 2010 – 2013. In general, the unemployment rate is proportional to the fertility rate, suggesting that as more women gain employment and the standard of living improves, they may choose to have fewer children.

Figure 8 displays the association between the unemployment rate and HIV incidence for males (Figure 8A) and females (Figure 8B) at different income levels. In middle-income and low-income countries, unemployment is higher for women than for men. However, HIV incidents are more frequent for men than women. In these countries, higher unemployment in men is correlated with a higher incidence of HIV compared to women.

Figure 9 explores the relationship between self-employed individuals and life expectancy for both genders. Both charts display a similar relationship, where self-

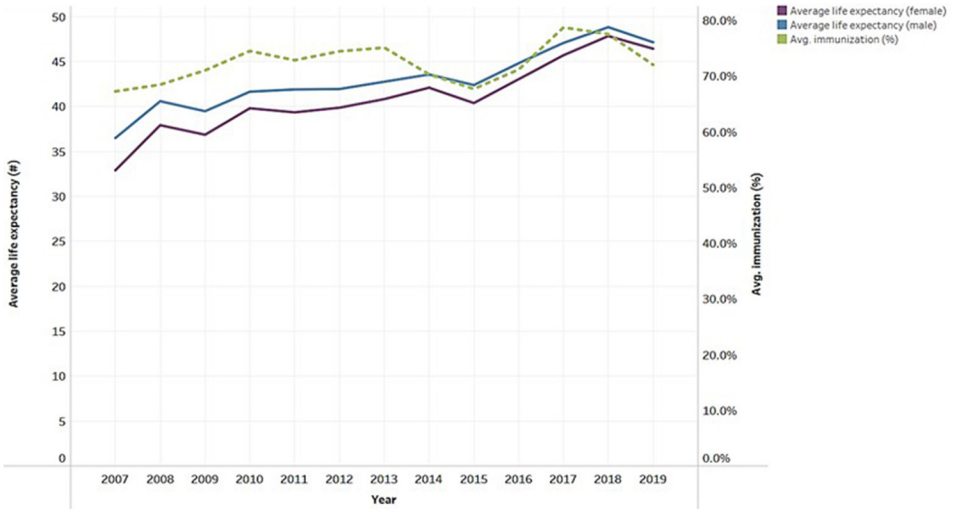

Figure 3. Association between average immunization (%) and life expectancy for male and female (#)

employed work (described as household work) decreased over the years, while life expectancy increased. There seems to be no difference between the percentage of males and females who are self-employed, not in its impact on life expectancy.

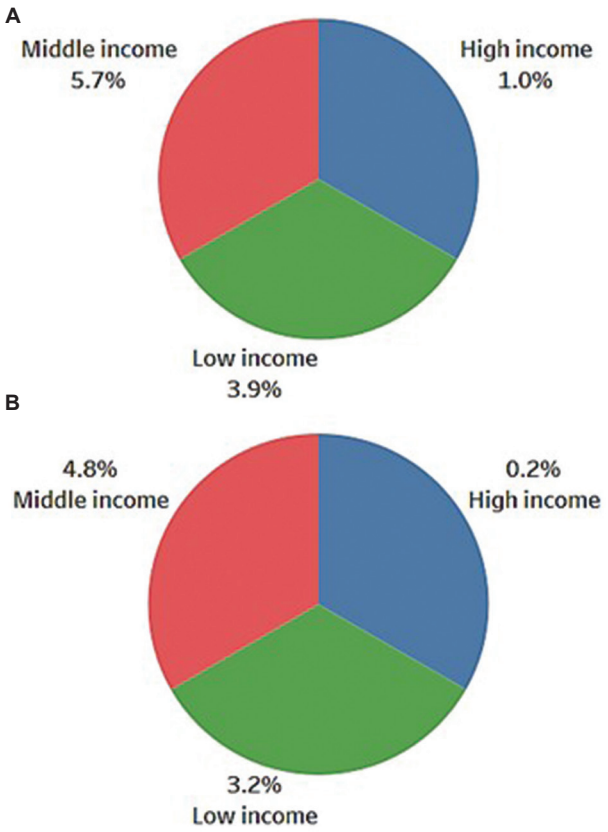

Figure 4. Human immunodeficiency virus incidence among males (A) and females (B) by income level

The study further explores women's employment (represented by women in the parliament) and its association with health outcomes. Figure 10 displays the percentage of seats held by women in parliament (lines) and the female life expectancy (bars) at the various income levels. Female representation in parliament has been increasing across all three income levels. The average life expectancy for females has also increased over time, with low-income countries exhibiting the slowest growth rate among the three groups. Low-income countries may lack the initiative to promote women to government and decision-making roles, which may be a contributing factor to the female life expectancy lagging behind that of higher-income countries.

Figure 11 displays the association between women in parliament and fertility rates by region. The size of the box indicates the percentage of women in parliament; the color intensity represents the fertility rate of women. Africa has the highest average fertility rate with a relatively lower representation of women in parliament. Europe has a slightly higher representation of women in parliament, but a very low fertility rate. In general, a higher representation of women in parliamentary jobs appears to correspond to lower fertility rates in women. This could be due to the challenges faced by working women due to the demands of the job, in terms of having or raising children. The findings provide insights for future employment policies to consider childcare resources as a motivating factor for working women.

Figure 12 illustrates the association between the percentage of government positions held by women and HIV incidence among females for the period of study. Over

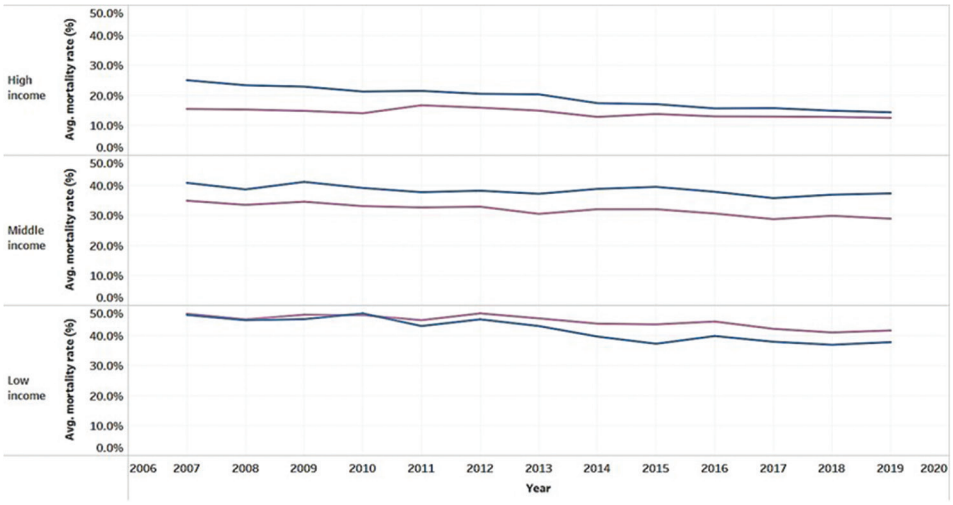

Figure 5. Mortality rates from cardiovascular disease, cancer, diabetes, and chronic respiratory disease of males (blue) and females (pink) by income level

time, as the proportion of political positions occupied by women increased, the incidence of HIV among females displayed a decreasing trend.

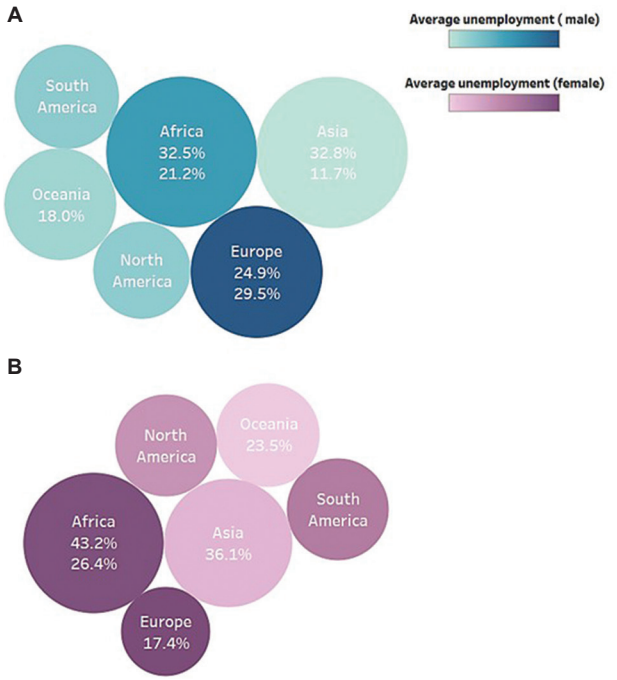

Figure 6. Association between unemployment and mortality (from cardiovascular disease, cancer, diabetes, and chronic respiratory disease) rates by gender and region for males (A) and females (B).

3.4. Gender inequality, education, and health quality

The study also explores the association between gender parity in education and health. Figure 13 displays the gender parity index in school enrollment and life expectancy for males and females. The gender parity index is the ratio of female-to-male enrollment in primary and secondary schools in a region. Life expectancy is significantly and positively correlated with the gender parity index for school enrollment. Female life expectancy exceeded male life expectancy as the parity increased, suggesting that increasing equity in school enrollment may have reduced overall gender inequality in society and improved women's health.

Figure 14 displays the association between the gender parity index in school enrollment (primary and secondary) and fertility rates by region. The size of the circle corresponds to the fertility rate, while the color intensity corresponds to the gender parity index in school enrollment. Africa has the lowest gender parity index in enrollment (indicating the lowest female enrollment rate), but the highest fertility rate for women. Countries with high gender parity in enrollment have a low fertility rate, implying that increased female enrollment in schools is correlated with lower fertility rates – an expected finding, as the standard of living improves with education.

Figure 15 displays the average mortality rates for males and females and the gender parity index for school enrollment by income level. For all income levels, the

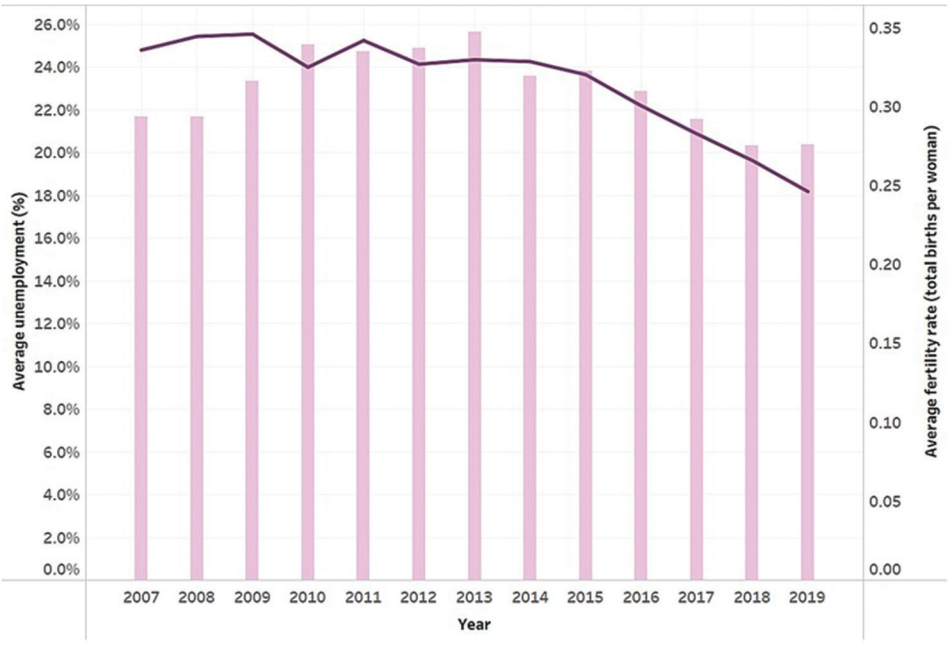

Figure 7. Association between female unemployment rate (pink bars) and fertility rate (purple line)

Figure 8. Association between unemployment rate and human immunodeficiency virus incidence for males (A) and females (B)

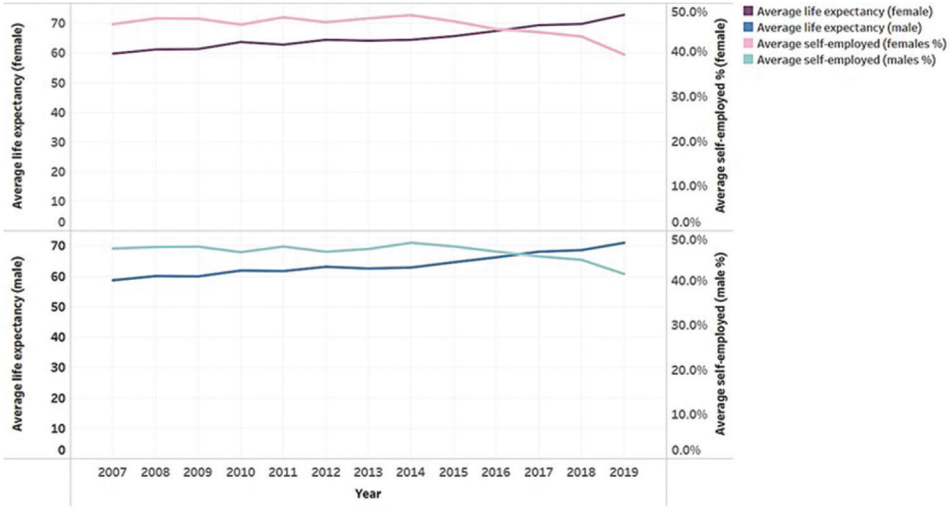

Figure 9. Association between self-employment and life expectancy by gender

average mortality for females is higher than that for males. In high-income regions where gender parity is the highest, the average mortality for males and females is relatively lower. There is a negative association between the gender parity index in school enrollment and the average mortality for males and females. Higher enrollment of women in schools often leads to lower mortality rates from cyclic vomiting syndrome (CVS), cancer, diabetes, or chronic respiratory disease (CRD), except for Africa and Asia, where this could be a result of cultural differences.

Table S3 summarizes the findings of Figures 1–15, highlighting their respective hypothesis, research

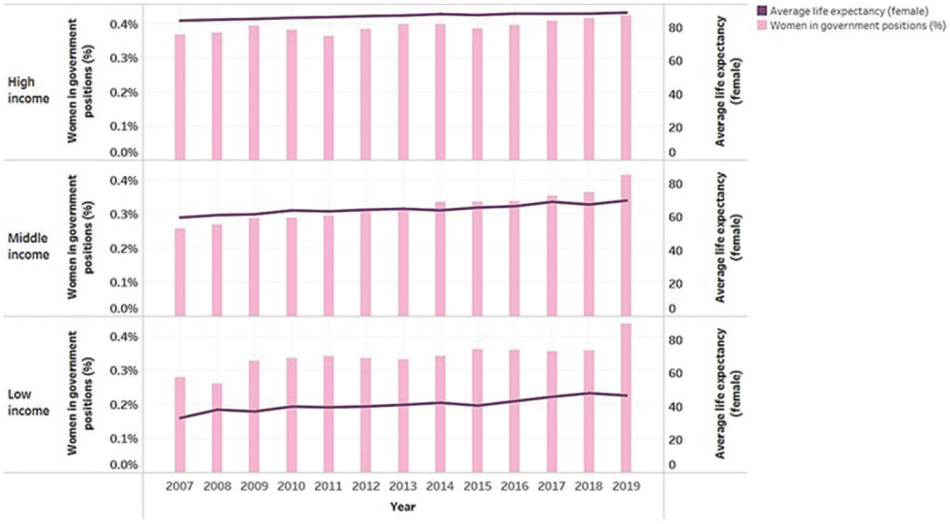

Figure 10. The proportion of women in parliament and female life expectancy by income level

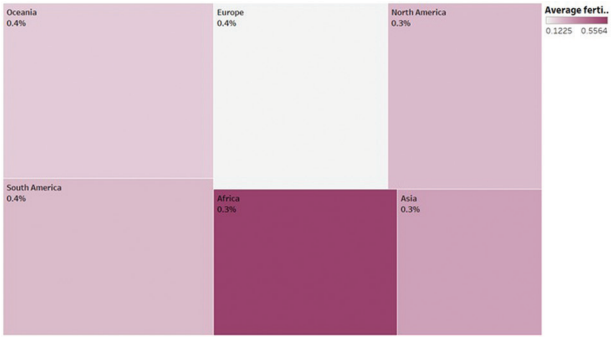

Figure 11. Association between women in parliament and fertility rates by region

questions, analytical type, variables, graph/chart type, and conclusion.

4. Discussion

Overall, our study revealed mixed results. Regarding gender equity and preventative healthcare, higher accessibility to anti-retroviral drugs is associated with a lower incidence of HIV among both genders, and the association is more pronounced in females than males.

Reduced accessibility to anti-retroviral drugs is also associated with lower life expectancy. While life expectancy for females is lower than that of males, immunization contributes to a higher overall life expectancy. Data analysis highlighted a socioeconomic challenge beyond gender. Countries like Africa have a low life expectancy and poor access to anti-retroviral drugs, highlighting that those most in need are the ones lacking access to HIV drugs. This can have a lasting impact on both genders. Therefore, addressing this socioeconomic challenge by improving awareness, education, and the standard of living is critical.

In addition, our findings indicate that greater and faster access to drugs and immunization can enhance life expectancy and reduce HIV incidences, highlighting the need for targeted policy interventions.

The lower HIV incidence in females than in males is not correlated to a higher income or economic growth, as it was observed that HIV incidence is higher in middle-income than in low-income countries. In middle-income countries, more income does not necessarily translate into investment in education or prevention of HIV for women.

Female mortality, however, is higher in low-income countries than in middle- or high-income countries. High-income countries are likely to have lower mortality from CVD, cancer, diabetes, or CRD for both genders. Low-income countries require more policy initiatives directed at improving women's health.

Higher unemployment is associated with high mortality rates for both genders, while more pronounced for females. In framing national policies, governments should consider the association between employment rate and quality of health care. When unemployment declines, fertility rates also decline. This suggests that, as the standard of living increases and more women gain employment, they may choose not to have children.

Higher unemployment is associated with higher HIV incidence for males, but not so for females. Importantly, as more women are engaged in employment in politics and government, life expectancy increases; over time, HIV incidences in females decline. However, higher representation is also associated with lower fertility rates,

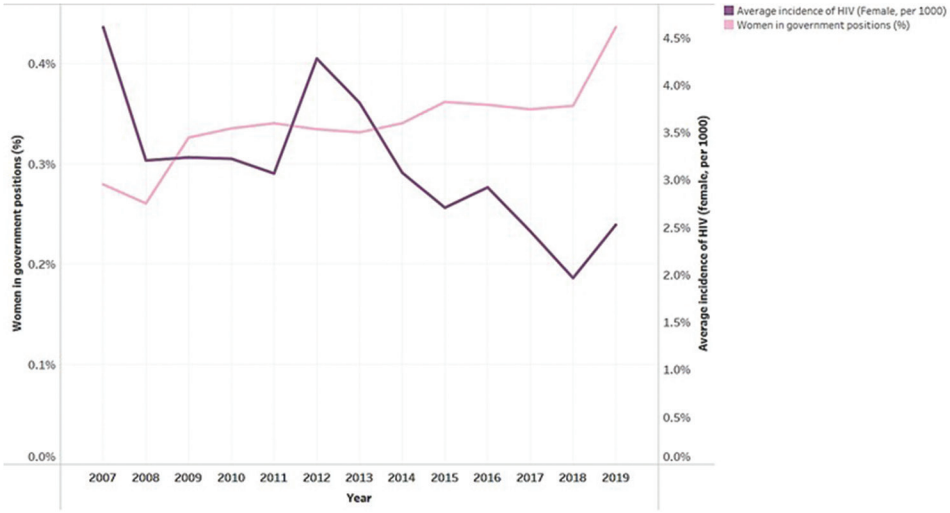

Figure 12. Association between seats held by women in parliament and human immunodeficiency virus incidences

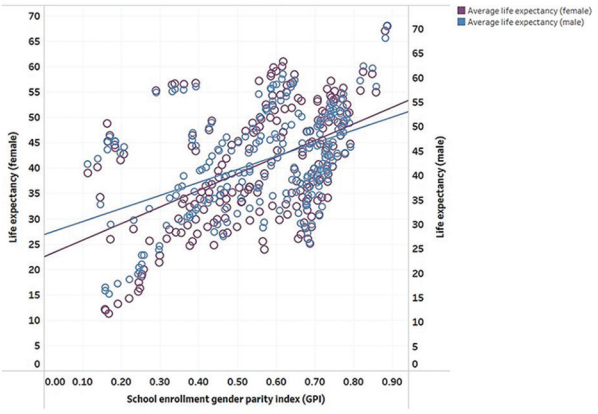

Figure 13. Association between gender parity index in school enrollment and life expectancy

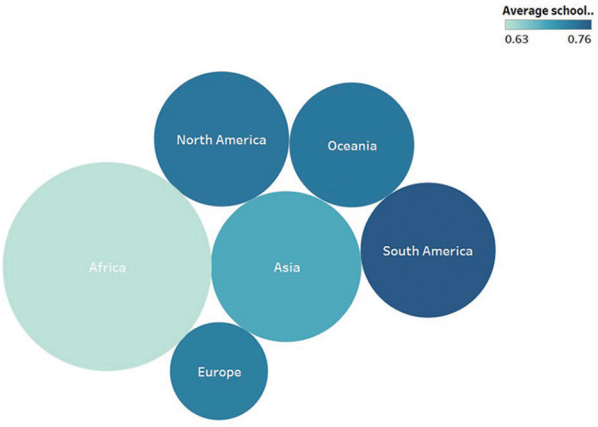

Figure 14. Association between school enrollment and fertility rates by region

particularly in high-income countries. The high demands of the jobs may pose considerable challenges to women in having or raising children.

Our findings also present interesting perspectives on gender parity. Higher parity among the genders in school enrollment increases overall life expectancy, with female life expectancy exceeding that of males. This suggests that equity in school enrollment may reduce overall gender inequity in society and improve women's health. Simultaneously, higher parity in enrollment is associated with reduced fertility rates. A lower enrollment among females is correlated with higher fertility rates. Finally, higher parity also reduces the mortality rate for several diseases.

Overall, education, employment, and income level play influential roles in shaping gender parity in the economy. Improving gender parity demonstrated promising results, in terms of immunizations, HIV incidences, and life expectancy, particularly for women.

Findings on fertility for women appear to adversely impact the gender parity index in some income levels. Essentially, in high-income countries, having more women in education is associated with lower fertility rates. The primary reason is the foregone earnings that come with giving up well-paying jobs for having or raising children. Health policymakers need to fully comprehend the mechanisms through which women's education is associated with fertility. They should also consider the changing social contexts, in which this association is situated – for example, in light of increasing work-life balance awareness, family-friendly work policies, acceptance of career women, flexible work environments,

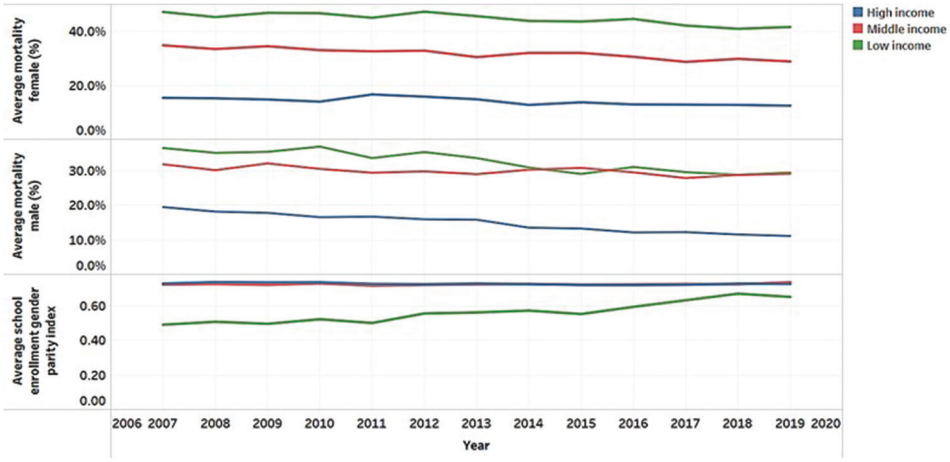

Figure 15. Association between school enrollment gender parity index and mortality rates for males and females at different income levels

and knowledge of birth control (Kim, 2023). However, the discrepancy in social contexts between high- and low-income countries requires careful consideration.

Overall, the net effect is that there is gender inequality in healthcare delivery, but there is a lot of potential for improvement. Economic growth, education, income, population, and parity in employment are some critical indicators that influence gender inequities, leading to disparities in healthcare. In addition, social, economic, and political factors influence a country's progress toward achieving gender parity. Considering the diverse factors and contexts influencing gender equity in healthcare, further exploration is warranted.

4.1. Scope and limitations

This study is subject to some limitations. First, due to the substantial number of missing values for one or more indicators/variables (i.e., common for data sources of this size), only some countries were included. In addition, it takes many years for countries, particularly developing countries, to upload the data. This delay in reporting resulted in more recent years not being included in the sample. Second, this is a cross-sectional study and not a time-series panel. In addition, to keep the study feasible and focused, it only includes indicators available under the gender and health categories. Future studies may include a larger set of indicators for a more comprehensive analysis. Besides that, the data source is secondary, relying on the expectation that countries have uploaded authentic and high-quality data to the WDI database. It is conceivable that the data are not comprehensive, as factors such as ethnicity, race, and culture-based indicators may be excluded. Data in the WDI database are also coded as male or female, with newer elements of gender possibly left out. Hence, caution is needed in interpreting data at a granular level to avoid population fallacy. There may also be some confounding indicators in the gender-health association that ought to be included. Finally, while visualization was applied in this research for a preliminary exploration of the associations between variables, it did not assess linearity (correlation) or causality.

4.2. Managerial implications and recommendations

Gender influences nearly all aspects of life, from economic opportunities to access to healthcare.

Gender inequalities in health outcomes are shaped by broader societal and gender disparities that affect healthcare access and the overall quality of care provided.

Public health officials can use the research findings to tailor policies that address inequitable health access and enhance the quality of care for all. For example, promoting vaccinations can help reduce the risk of adverse health outcomes for individuals regardless of gender. Governments may also incentivize female enrollment in schools, as increased gender parity has been linked to longer life expectancy for both men and women. In addition, officials can implement health programs that cater to gender-specific needs, particularly in low-income countries. Empowering women to take charge of their lives, including active participation in legislative and decision-making bodies, as well as ensuring equal opportunities for education and employment, can gradually lead to a higher quality of life and improved healthcare. Shifting the focus to primary and preventive health, along with strengthening public health initiatives, can further reduce these disparities.

5. Conclusion

This study attempts to understand the complex connection between gender inequality and health.

Through visualization and descriptive analysis, our study offers insight into the various indicators and areas where stakeholders should focus their resources to reduce gender disparities and their impact on healthcare. The overall objective is to improve public health for all, particularly in areas such as immunization, fertility rate, HIV, and other diseases, access to anti-retroviral drugs, mortality rate, and life expectancy, among more. Both gender inequality and health are central to individual and societal well-being and quality of life. The framing and analysis of these issues should consider the macro-level factors (e.g., culture, ethnicity, race, religious beliefs, and social dynamics) and the hierarchy within which the gender-health connection is shaped. This holistic approach requires the integration of diverse disciplines, innovative models, and comprehensive data sources. As health disparities continue to widen globally and gender inequalities persist, it is crucial to explore alternative perspectives in research and strategy regarding gender equity and healthcare delivery, as well as the prevailing inequities. When shaping action research and developing strategies, stakeholders, including governments, must recognize the paradox of gender equality – both as a catalyst for equal opportunity and, in some cases, a trigger for inequality. Addressing these macro-level disparities requires targeted interventions at the highest levels of government and society. Researchers play a critical role in empirically examining the phenomenon and publishing their findings. Similarly, policymakers can develop innovative policies and collaborate with governments and other stakeholders for effective implementation. The government plays an active role in advocating for actionable policies and implementing them. All stakeholders must effectively communicate the benefits and risks to the public at large. Gender equality and equitable access to healthcare are fundamental human rights, and education is key to advancing these goals.

The present study paves the way for future research endeavors. Future studies should explore the impact of climate change on gender inequality and healthcare, particularly whether climate change disproportionately affects women. Additional research through focus groups, case studies, field studies, and the analysis of other data categories (e.g., economic data and poverty) may provide deeper insights into the relationship. Beyond macro-level factors, future research could examine country governance systems, healthcare delivery models (e.g., national systems, insurance-based, hybrid systems, and single vs. multi-payer systems), and the role of digital technologies in enabling healthcare (e.g., e-health, m-health, and telemedicine). In addition, future research can build on the preliminary associations between variables highlighted in the current research and investigate other trends, such as linearity and/or causality.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

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Formal analysis: Viju Raghupathi
Investigation: All authors
Methodology: Wullianallur Raghupathi, Sarah Jinhui Wu
Writing–original draft: Wullianallur Raghupathi
Writing – review & editing: Sarah Jinhui Wu, Viju Raghupathi

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Data are available from the corresponding author on reasonable request.

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ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

ORIGINAL RESEARCH ARTICLE

COVID-19 pandemic health expenditures and family economic behaviors: China health and retirement longitudinal study (CHARLS)

Shawn Dinh[1†], Wupeng Yin[2†], Niliarys Sifre-Acosta[1], and Nan Hu[2,3*]

[1]Department of Dietetics and Nutrition, FIU Robert Stempel College of Public Health and Social Work, Miami, Florida, United States of America

[2]Department of Biostatistics, FIU Robert Stempel College of Public Health and Social Work, Miami, Florida, United States of America

[3]Department of Family and Preventive Medicine, University of Utah School of Medicine, Salt Lake City, Utah, United States of America

Abstract

Since the onset of the coronavirus disease 2019 pandemic, there has been a total of 776 million confirmed infection cases worldwide with both countries, China and the US contributing a substantial number of cases. Aside from the grand number of cases, the pandemic has also demonstrated a worldwide financial toll. Specifically, as of May 20, 2020, China has been reported to obtain a cost of $373.20 million in overall patient hospitalizations. Yet, aside from these hospitalizations, the purchasing of personal protective equipment (PPE) to mitigate one's risk for infection can also be expensive. In addition, the pandemic itself has resulted in a wealth of businesses shutting down worldwide, consequently resulting in job losses and attenuated income for workers worldwide. Thus, exploring the behavior of PPE purchasing by primary respondents of individual households as well as the degree in mediating their expenses following the pandemic was the focus of this study. Specifically, the present investigation sought to examine the association between medical and fitness expenditure toward PPE purchasing behavior for mainland residents of China aged 45+ due to the lack of existing literature examining this relationship from the best of our knowledge. The former relates to both direct and indirect medical expenses whilst the latter refers to the purchasing of exercise equipment and health supplements. Second, these expenditures were further utilized to explore its association with the level of ease in covering expenses following the pandemic as well. This was a secondary data analysis that used cross-sectional data from the China Health and Retirement Longitudinal Study database, wherein generalized linear mixed effects models were applied in examining the associations. Both medical and fitness expenditure were insignificant predictors of PPE purchasing behavior whilst they expressed a significant association toward predicting the degree of ease for the included participants in covering their daily expenses following the onset of the pandemic.

Keywords: Health expenditure; Personal protective equipment; Household expenditure coverage; Coronavirus disease 2019; Economical behaviors

†*These authors contributed equally to this work.*

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***Corresponding author:**
Nan Hu
(nhu@fiu.edu)

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1. Introduction

It is undeniable the coronavirus disease 2019 (COVID-19) pandemic has caused an innumerable amount of infections and to a further extent, some confirmed cases resulting into fatalities as well. To support this, the World Health Organization (WHO) reported a cumulative total of 776 million confirmed infection cases worldwide with China contributing toward a total of 99.4 million and the US contributing 103 million cases(WHO, 2024). In addition, they also reported a worldwide cumulative total of ~7.1 million deaths related to COVID-19 (WHO, 2024).

Regarding China, the Coronavirus Resource Center by Johns Hopkins University of Medicine (2023) reported a cumulative total of 101,356 deaths related to COVID-19. Similarly, the WHO also reported a similar number of ~122,000 deaths, too (WHO, 2024). Despite the various sources having reported confirmed cases and deaths, the cumulative total of hospitalizations remains equivocal.

Nonetheless, addressing the pandemic was not inexpensive, as evidenced by An *et al.* (2022) who reported a single COVID-19-induced hospitalization within China costs a median of RMB 15,438.55 (RMB 14,029.73 – 16,637.47) or $2,158.06 ($1,961.13 – 2,325.65) per patient. In addition, total costs associated with overall patient hospitalizations totaled approximately $373.20 million as of May 20, 2020 (An *et al.*, 2022). Aside from hospitalizations, the worldwide financial burden the pandemic imposed can be further attributed to drastic diagnostic, preventative and medical expenditures for personal protective equipment (PPE) and other preventative measures (Elola-Somoza *et al.*, 2021; Hafidz *et al.*, 2023; Richards *et al.*, 2022). Moreover, not only can the purchasing of this equipment exacerbate the burden, but the pandemic has resulted in job losses and as a result, lessened income, significantly affecting individuals and households in their ability to cover daily expenses during and following the pandemic (Findling *et al.*, 2021; Ruengorn *et al.*, 2021).

Acknowledging this, the financial impact caused by the pandemic can be gleaned, but a question remains if pre-COVID-19 healthcare expenditure (i.e., medical and/or fitness expenditure) is associated with PPE purchasing behavior during the early outbreaks of the pandemic in China within primary respondents of their respective households. In addition, a further question remains as to if these expenditures are associated with any degree of ease amongst individuals/households in covering their daily expenses following the onset of the pandemic.

For context, there is a wealth of research examining the medical expenditure of mainland residents of China pre-pandemic. For one, medical expenditure per capita within China has increased from RMB 513.8 to RMB 1292.2 ($83.6 – $208.2) from 2012 to 2017, with an annual growth rate of 25.6% (Zhang *et al.*, 2018). However, to the best of our knowledge, research examining fitness expenditure (i.e., purchasing of fitness equipment and/or health supplements) remains scarce. In addition, purchasing and wearing of PPE, such as masks, was commonplace even before the pandemic (Zhang & Mu, 2018). One reason was to combat air pollution that is more pronounced within urbanized areas of China (e.g., Beijing and Shanghai). Notably, Zhang & Mu (2018) reported that there were substantial increases in purchases of particulate-filtering facemasks during extreme pollution episodes. Finally, wearing facemasks was the norm for professionals who specifically worked in the healthcare and medical industry to reduce their risk of contracting infections when working with patients (Mukerji *et al.*, 2017).

At present, there have been studies that investigated medical expenditure as a predictor of COVID-19-related outcomes (Khan *et al.*, 2020). In this specific study, Khan *et al.* (2020) examined the association between medical expenditure and COVID-related fatalities within 86 different countries with at least 1,000 confirmed COVID-19 cases as of April 30, 2020. To add to this, Koumpias *et al.* (2022) performed a retrospective cohort study wherein they reported COVID-19 diagnoses being correlated with increased medical expenditure. However, to the best of our knowledge, the use of medical and/or fitness expenditure as a prospective means to predict PPE purchasing behavior and the level of ease in managing daily expenses during and throughout the pandemic is yet to be examined. The conclusions from the former question can shed light on the effects of utilizing the potential association for assessing supplies of PPE in the event of future pandemics. Answers to the latter question can provide information about the association between medical expenditure and ease of covering daily expenses, since medical expenditure may serve as a financial proxy for how individuals can comfortably mediate their life expenses following a future public health emergency.

Regarding the use of fitness expenditure (i.e., purchasing of fitness equipment and/or health supplements) for the proposed associations, there is a paucity of research within the literature suggesting its predictive usage. Nonetheless, fitness expenditure can serve as a financial proxy for how much individuals spend on their health and wellness.

To the best of our understanding, no previous studies have explored these associations among residents in mainland China. Therefore, we plan to enrich the knowledge about health-related expenditures during the COVID-19 pandemic by examining the association

between medical/fitness expenditure on behaviors of PPE purchasing during a 3-day window following the start of the outbreak and ease of maintaining expenses during and following the COVID-19 pandemic among residents aged 45+ of mainland China. In this study, we use the recently released China Health and Retirement Longitudinal Study (CHARLS) wave 5 dataset, which includes many health-related behaviors during the COVID-19 outbreaks in China in 2020.

In the next section, a detailed description of the secondary data we used and our statistical methods for our analyses will be provided. In the Results section, outputs of our models of choice will be provided along with corresponding tables. Finally, our findings will be interpreted and elucidated in the Discussion and Conclusion sections, along with a discussion of the limitations in this study.

2. Data and methods

2.1. Study design

This investigation included CHARLS survey data collected in 2020 following the onset of the COVID-19 outbreak. Datasets within the CHARLS database ranged from income to health conditions, encompassing survey answers from participants aged 18+ (Zhao *et al*., 2023). However, its primary aim was to collect data from participants aged 45+ (Zhao *et al*., 2014). For clarity, its first survey (i.e., wave 1) was disseminated in 2011 – 2012. Subsequently, the following waves 2, 3, 4, and 5 were collected in 2013, 2015, 2018, and 2020, respectively. The survey spanned across 150 counties/districts and 450 villages/urban communities, which included a total of 17,708 individuals within 10,257 households, encompassing both middle-aged and older adults. Specifically, wave 5 includes updated information following the COVID-19 outbreak. Detailed information regarding the purpose, design, sample, and questionnaires of this repository is accessible in other articles (Zhao *et al*., 2014). The CHARLS research team has received ethical approval from the institutional review board at Peking University Health Science Center (approval number: IRB00001052 – 11015).

For our statistical analyses, among the 19,395 participants in 2020, we excluded a total of 7,983 subordinate participants of each household, a total of 128 participants younger than age 45, 9 participants not sampled within the COVID-19 questionnaire, 29 participants not sampled within the household income questionnaire, a total of 442 participants not sampled in the household expenditure questionnaire, and finally, a total of 926 participants who did not provide information on the following covariates: Age, gender, government COVID-19 subsidy, reported building structure, reported social activities within the past month, mask wearing, awareness of COVID-19 risk mitigation, number of chronic diseases and reported poor household subsidy. For all models, a final cohort of 9,878 participants was included in our final analyses. A flowchart of the data procedure is presented in Figure 1.

2.2. Variables

2.2.1. Measurement of PPE purchasing behavior

In the Module-V COVID section of the 2020 CHARLS dataset, we identified the outcome variable for PPE purchase. This question asked study participants whether they had purchased an increased amount of face masks, hand sanitizer, and disinfectant to stockpile during the 3 days following the lockdown of Wuhan, China (Zhao *et al*., 2023). Responses were coded as "Yes" or "No" based on the participants' answers.

2.2.2. Measurement of ease in covering daily expenses

In the Module G1 Household Income section, the dependent variable assessing the ease in covering daily expenses with household income was measured by the question, "From the breakout of COVID-19 to now, can the income of the respondent's household cover daily expenses?" Responses were categorized as either "difficult" or "easy" based on the respondent's assessment.

2.2.3. Measurement of medical expenditure

The first exposure, household medical expenditure (both direct and indirect), was measured using questionnaires from the Module G1 Household Income section. Indirect medical expenses included costs associated with transportation, nutrition, and other family-related expenditures incurred due to medical treatment, excluding amounts covered by Medicare (Zhao *et al*., 2023). Respondents who reported no such expenses were classified as "No expenditure," while those who incurred expenses were classified as "Had expenditure."

2.2.4. Measurement of fitness expenditure

The second exposure, household fitness expenditure, was assessed through Module G1 (Household Income section) of the questionnaires, covering expenditures categorized to fitness activities, fitness equipment, and health supplements (Zhao *et al*., 2023). Respondents who reported no such expenses were classified as "No expenditure," while those who incurred expenses were classified as "Had expenditure."

2.2.5. Confounding and covariates

The selection of covariates and/or confounding variables was primarily based on the present literature that has also used the CHARLS dataset for other analyses (Gong *et al*.,

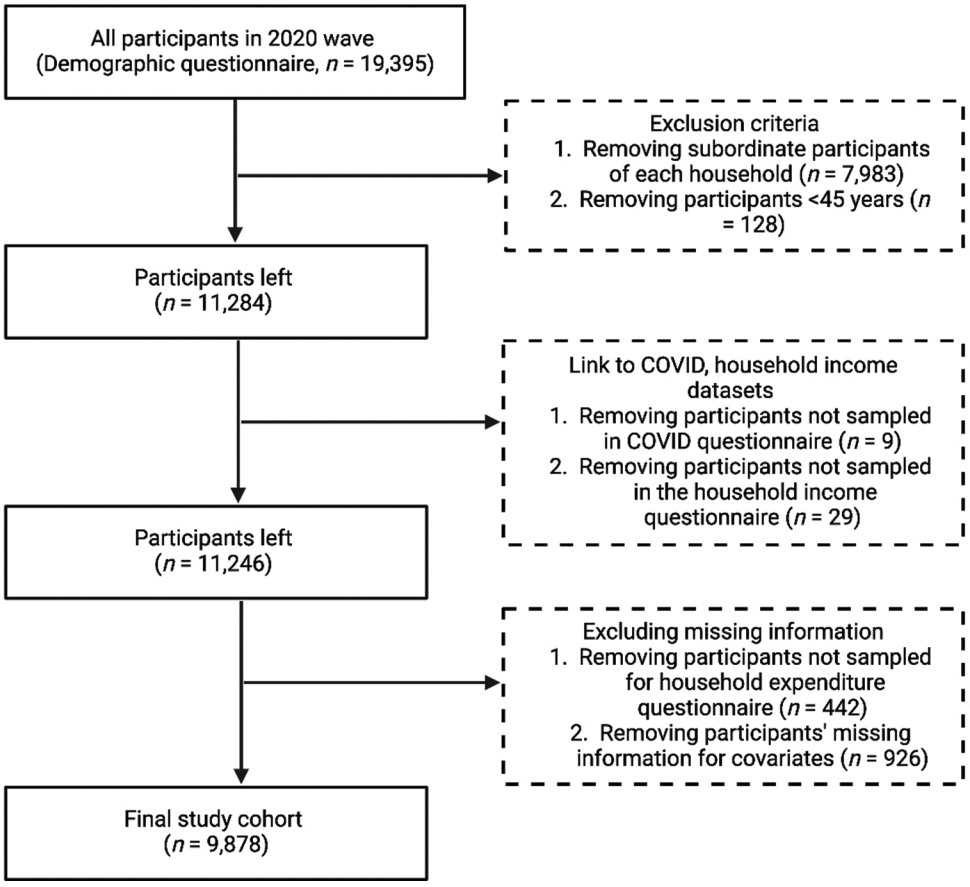

Figure 1. Data extraction and flow chart

2022; Li *et al*., 2022; Zhou *et al*., 2023), as well as subjectively evaluating whether a variable can have a direct causal yet separate effect on both the predictor and outcome variables of interest. Moreover, their selection was subject to the availability of the 2020 CHARLS wave 5 data. Of those that were available, included were demographic features (i.e., age [which was categorized as a binary variable (<61 years and ≥61 years) based on the median age of the study population], sex, structure of housing), characteristics displayed during the pandemic (i.e., whether respondents were aware of COVID-19 risk mitigation practices or if they wore masks), health status and functioning characteristics (i.e., whether main respondent has a history of chronic diseases or participating in social activities), and income and expenditure features (i.e., whether respondent has received government COVID subsidies or poor household subsidies). All covariates were categorical, and in keeping with that theme as well as from previous literature, age was categorized as well because it is not an exposure variable (Yin *et al*., 2025).

The summary statistics of the participants are reflected within Table 1. Further, the definitions and assignments of all variables are shown in Table A1. Finally, the associations between medical/fitness expenditure and PPE purchasing behavior/ease of covering daily expenses are depicted in Tables 2 and 3.

2.3. Statistical analysis

Descriptive statistics of the study population were summarized as mean ± standard deviation (SD) and frequency (*n*) and percentage (%) for continuous and categorical variables, respectively.

Given the hierarchical structure of the CHARLS data, where households (Level 1) are nested within communities (Level 2), we employed a generalized linear mixed-effects model (GLMEM) with random intercepts. GLMEMs are particularly well-suited for analyzing multilevel data, as they incorporate random effects at the community level, thereby accounting for within-group dependencies and improving the precision of fixed-effect estimations. Compared to other statistical models, GLMEM provides a robust framework by simultaneously addressing both fixed and random effects, ensuring more accurate inferences regarding the relationship between

Table 1. Descriptive statistics of participants

Variable	All participants (*n*=9878)	Medical expenditure (*n*=9878)			Fitness expenditure (*n*=9878)		
		0 Yuan (*n*=2309)	>0 Yuan (*n*=7569)	*p*	0 Yuan (*n*=9014)	>0 Yuan (*n*=864)	*p*
Age, Mean±SD	61.82±9.75	60.55±9.97	62.21±9.64	<0.001	61.75±9.71	62.54±10.13	0.023
Age, *n* (%)							
<61 years	4975 (50.36)	1327 (57.47)	3648 (48.20)	<0.001	4552 (50.50)	423 (48.96)	0.387
>61 years	4903 (49.64)	982 (42.53)	3921 (51.80)		4462 (49.50)	441 (51.04)	
Gender, *n* (%)							
Male	4472 (45.27)	1067 (46.21)	3405 (44.99)	0.301	4080 (45.26)	392 (45.37)	0.952
Female	5406 (54.73)	1242 (53.79)	4164 (55.01)		4934 (54.74)	472 (54.63)	
Government COVID subsidy, *n* (%)							
No	9614 (97.33)	2255 (97.66)	7359 (97.23)	0.256	8786 (97.47)	828 (95.33)	0.004
Yes	264 (2.67)	54 (2.34)	210 (2.77)		228 (2.53)	36 (4.17)	
Building structure, *n* (%)							
Concrete and steel/bricks and wood	8978 (90.89)	2104 (91.12)	6874 (90.82)	0.657	8149 (90.40)	829 (95.95)	<0.001
Other	900 (9.11)	205 (8.88)	695 (9.18)		865 (9.60)	35 (4.05)	
Activities in past month *n* (%)							
None	4987 (50.49)	1235 (53.49)	3752 (49.57)	0.001	4637 (51.44)	350 (40.51)	<0.001
At least done one activity	4891 (49.51)	1074 (46.51)	3817 (50.43)		4377 (48.56)	514 (59.49)	
Mask wearing, *n* (%)							
Never	582 (5.89)	166 (7.19)	416 (5.50)	0.003	551 (6.11)	31 (3.59)	0.003
Always or sometimes	9296 (94.11)	2143 (92.81)	7153 (94.50)		8463 (93.89)	833 (96.41)	
Awareness *n* (%)							
None	282 (2.85)	74 (3.20)	208 (2.75)	0.249	266 (2.95)	16 (1.85)	0.064
At least aware of one practice	9596 (97.15)	2235 (96.80)	7361 (97.25)		8748 (97.05)	848 (98.15)	
Number of chronic diseases *n* (%)							
0	6157 (62.44)	1660 (71.89)	4497 (59.41)	<0.001	5674 (62.95)	483 (55.90)	<0.001
1 – 4	3658 (37.03)	640 (27.72)	3018 (39.87)		3282 (36.41)	376 (43.52)	
≥5	63 (0.64)	9 (0.39)	54 (0.71)		58 (0.64)	5 (0.58)	
Poor household subsidy, *n* (%)							
None	8362 (84.65)	2008 (89.96)	6354 (83.95)	<0.001	7587 (84.17)	775 (89.70)	<0.001
At least received one type of subsidy	1516 (15.35)	301 (13.04)	1215 (16.05)		1427 (15.83)	89 (10.30)	

health expenditures and a family's economic behaviors in a nested dataset, such as CHARLS. This approach enhances the validity of our findings by controlling for relevant confounding factors and improving the robustness of the estimated relationships of interest. The *p*-values, odds ratio (OR) estimates, and 95% confidence interval (CI) are reported for the exposure variables and subsequent covariates too.

For the main outcomes of interest, the following depicts the mathematical equation for the GLMEM:

$$\mathrm{E}\left(\mathrm{Y}_{\mathrm{i,\,j,\,k}}\right) = invlogit(\beta_0 + \beta_1 X_{1,i,j,k} + \sum_{n=2}^{m} \beta_n X_{n,i,j,k} + u_{o,j,k} + e_{i,j,k}) \quad \text{(I)}$$

Overall, a total of six statistical models were implemented in our study. The first three were GLMEMs that explored the association of both medical/fitness expenditure on PPE purchasing behavior following 3 days since the onset of the pandemic within Wuhan, China. Model 1 is unadjusted, Model 2 is adjusted for only age and gender, and Model 3 includes Model 2's covariates as well as all other covariates outlined within Table 1. The past three GLMEMs explored the association of both medical and fitness expenditures with the ease in covering daily expenses following the onset of the pandemic. Models 4, 5, and 6 follow the same format as Models 1, 2, and 3 in terms of covariates excluded and included. The definition of the selected covariates is confined to

Table 2. Association between healthcare expenditure and PPE purchases

Medical expenditure	Model 1 estimates			Model 2 estimates			Model 3 estimates		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
	0.98	**(0.89, 1.09)**	**0.760**	**1.03**	**(0.93, 1.14)**	**0.557**	**0.99**	**(0.89, 1.09)**	**0.821**
Age		-		0.62	(0.57, 0.68)	<0.001	0.69	(0.63, 0.75)	<0.001
Gender		-		1.20	(1.10, 1.31)	<0.001	1.21	(1.11, 1.31)	<0.001
Government COVID subsidy		-			-		0.94	(0.72, 1.23)	0.634
Building structure		-			-		1.14	(0.97, 1.35)	0.108
Activities in past month		-			-		1.07	(0.98, 1.16)	0.139
Awareness		-			-		1.59	(1.17, 2.18)	0.003
Mask wearing		-			-		6.38	(4.74, 8.59)	<0.001
Number of chronic diseases (Reference group)		-			-				
- Level 2							1.05	(0.96, 1.15)	0.295
- Level 3							1.21	(0.71, 2.07)	0.483
Poor household subsidy		-			-		0.94	(0.83, 1.07)	0.336
	OR	**95% CI**	***p***	**OR**	**95% CI**	***p***	**OR**	**95% CI**	***p***
Fitness expenditure	1.12	(0.96, 1.30)	0.145	1.12	(0.97, 1.30)	0.125	1.07	(0.92, 1.25)	0.352
Age		-		0.62	(0.57, 0.68)	<0.001	0.68	(0.63, 0.75)	<0.001
Gender		-		1.20	(1.11, 1.31)	<0.001	1.21	(1.11, 1.31)	<0.001
Government COVID subsidy		-			-		0.93	(0.71, 1.22)	0.613
Building structure		-			-		1.14	(0.97, 1.34)	0.114
Activities in past month		-			-		1.06	(0.98, 1.16)	0.153
Awareness		-			-		1.59	(1.16, 2.17)	0.004
Mask wearing		-			-		6.36	(4.72, 8.57)	<0.001
Number of chronic diseases (Reference group)		-			-				
- Level 2							1.05	(0.96, 1.14)	0.321
- Level 3							1.21	(0.71, 2.07)	0.487
Poor household subsidy		-			-		0.94	(0.83, 1.07)	0.345

Note: Definitions of variables in this table are described in Table A1 (Appendix).
Abbreviations: CI: Confidence interval; PPE: Personal protective equipment; OR: Odds ratio.

the CHARLS questionnaire that accompanied the dataset and is located in Table A1.

All statistical analyses were performed using R version 4.3.3 and SAS OnDemand for Academics. All $p < 0.05$ were considered statistically significant.

3. Results

3.1. Participant characteristics

Table 1 demonstrates the descriptive statistics of all covariates for the 9,878 participants, by medical expenditure status and by fitness expenditure status. Among the study participants, 2,309 reported no medical expenditure whereas 7,569 reported expenditure. Moreover, 9,014 reported no fitness expenditure while 864 reported expenditure. In total, the following describes the basic demographics of the participants, in either (mean ± SD) or (*n*; %): Age (61.82 ± 9.75), male (4,472; 45.27%), female (5,406; 54.73%).

3.1.1. Association between healthcare expenditure and PPE purchases

Table 2 displays the OR estimates, 95% CI and the corresponding *p*-values for Models 1, 2, and 3. The unadjusted (i.e., Model 1) and adjusted models (i.e., Models 2 and 3) with specific covariates are outlined within the table. From Model 3, medical and fitness expenditures are suggested to decrease the odds and increase the odds of purchasing PPE, respectively. However, these associations are considered insignificant (OR = 0.99, 95% CI: 0.89 – 1.09, $p = 0.821$) and (OR = 1.07, 95% CI: 0.92 – 1.25, $p = 0.352$).

Table 3. Association between healthcare expenditure and daily expenditure coverage

Medical expenditure	Model 4 estimates			Model 5 estimates			Model 6 estimates		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
	0.77	**(0.69, 0.85)**	**<0.001**	**0.73**	**(0.66, 0.81)**	**<0.001**	**0.74**	**(0.67, 0.83)**	**<0.001**
Age		-		1.65	(1.51, 1.80)	<0.001	1.76	(1.61, 1.93)	<0.001
Gender		-		0.89	(0.82, 0.97)	0.007	0.89	(0.81, 0.97)	0.007
Government COVID subsidy		-			-		1.11	(0.84, 1.46)	0.457
Building structure		-			-		1.08	(0.92, 1.28)	0.351
Activities in past month		-			-		1.21	(1.11, 1.32)	<0.001
Awareness		-			-		1.40	(1.06, 1.86)	0.019
Mask wearing		-			-		0.99	(0.82, 1.21)	0.952
Number of chronic diseases (Reference group)		-			-				
- Level 2							0.84	(0.76, 0.92)	<0.001
- Level 3							0.33	(0.18, 0.62)	<0.001
Poor household subsidy		-			-		0.64	(0.56, 0.73)	<0.001
	OR	**95% CI**	***p***	**OR**	**95% CI**	***p***	**OR**	**95% CI**	***p***
Fitness expenditure	1.37	(1.18, 1.61)	<0.001	1.36	(1.17, 1.59)	<0.001	1.35	(1.16, 1.57)	<0.001
Age		-		1.61	(1.48, 1.76)	<0.001	1.72	(1.58, 1.88)	<0.001
Gender		-		0.89	(0.81, 0.97)	0.006	0.89	(0.81, 0.97)	0.006
Government COVID subsidy		-			-		1.09	(0.83, 1.43)	0.545
Building structure		-			-		1.08	(0.91, 1.27)	0.381
Activities in past month		-			-		1.19	(1.09, 1.30)	<0.001
Awareness		-			-		1.39	(1.05, 1.84)	0.023
Mask wearing		-			-		0.97	(0.80, 1.17)	0.734
Number of chronic diseases (Reference group)		-			-				
- Level 2							0.81	(0.74, 0.89)	<0.001
- Level 3							0.32	(0.17, 0.60)	<0.001
Poor household subsidy		-			-		0.64	(0.56, 0.73)	<0.001

Note: Definitions of variables in this table are described in Table A1 (Appendix).
Abbreviations: CI: Confidence interval; OR: Odds ratio.

3.1.2. Association between healthcare expenditure and daily expenditure coverage

Subsequently, Table 3 shows the OR estimates, 95% CI and the corresponding *p*-values for Models 4, 5, and 6. Further information regarding the covariates of each model are provided within the table. For all three models, both medical and fitness expenditures are suggested to be significant predictors of easily covering daily expenses following the beginning of the pandemic ($p < 0.001$). Specifically, all three individual models suggest medical and fitness expenditures decrease and increase the odds of easily covering daily expenses, respectively. In support of this, Model 4 expresses the following significant associations: Medical expenditure (OR = 0.77, 95% CI: 0.69 – 0.85, $p < 0.001$) and fitness expenditure (OR = 1.37, 95% CI: 1.18 – 1.61, $p < 0.001$). Model 5 displays the following significant associations: Medical expenditure (OR = 0.73, 95% CI: 0.66 – 0.81, $p < 0.001$) and fitness expenditure (OR = 1.36, 95% CI: 1.17 – 1.59, $p < 0.001$). Model 6 displays the following significant associations: Medical expenditure (OR = 0.74, 95% CI: 0.67 – 0.83, $p < 0.001$) and fitness expenditure (OR = 1.35, 95% CI: 1.16 – 1.57, $p < 0.001$).

4. Discussion

Using the CHARLS data, our study suggests no significant association between medical expenditure and PPE purchases. In addition, our results suggest a significant association between both fitness and medical expenditures toward ease in covering daily expenses from the beginning of the pandemic within China for mainland residents aged 45+.

To the best of our knowledge, this is the first study that utilized the CHARLS dataset to explore the impact of health (i.e., both medical and fitness) expenditure on PPE

purchasing behaviors and on the level of ease in mediating individual expenses following the start of the pandemic within China. In our analyses, the main exposure (i.e., healthcare expenditure) was further classified into medical expenditure and fitness expenditure. Both medical expenditure and fitness expenditure variables were dichotomized into cost (expense >0 Yuan) and no-cost (expense = 0 Yuan).

This is the first study to examine the impact of fitness expenditure on PPE purchases and the degree of ease in covering daily expenses during the COVID-19 pandemic. Fitness expenditure is shown to have a significant association with subjects' financial sustainability during the COVID-19 pandemic period, measured by how easy it is for them in mediating daily expenses following the pandemic. This may probably be explained by how fitness expenditures are highly correlated with individuals' level of wealth. Hence, there is no surprise that these individuals are capable of comfortably covering their everyday expenses despite the financial hardships experienced worldwide as a result of the pandemic. To further address the relationship between physical activity (PA) and its PPE purchase, future research is warranted. Conversely, although medical expenditure was reported to be significantly associated with the subjects' financial sustainability as well, it suggests medical expenditure decreases the odds of easily covering daily expenses. This may shed light on prior medical expenses posing a disadvantage for families in covering their daily expenses following a public health crisis, expressing how radical changes in the economy (e.g., sudden lockdowns within some businesses following a pandemic) can impact the financial sustainability of families going through public health crises.

The lack of confounding or mediating influence by expenditures suggests that the relationship between PA and panic PPE purchasing is independent of regular financial investments in health and fitness. It implies that panic buying behavior during the pandemic may be more closely linked to psychological factors, such as fear and uncertainty (Nia *et al*., 2022; Kupcova *et al*., 2023), rather than pre-existing health expenditure patterns. These findings underscore the importance of addressing the psychological drivers of consumer behavior in health crises, particularly among those who are highly health-conscious or physically active.

Finally, this study is not one without limitations: First, adjusting for specific, yet reasonable covariates and potential confounding can drastically reduce the sample size due to the fact that a large proportion of the subjects did not provide responses for the selected covariates. Second, the main outcomes of interest are the PPE purchasing behavior and the degree of ease in mediating daily expenses during the pandemic. The former outcome variable is restricted to a 3-day period after the lockdown in Wuhan, and the latter one includes a window from the start of the pandemic up until this questionnaire was disseminated and answered. Clearly, a substantial temporal variation may exist, thus the questions being asked may oversimplify the measurement of PPE purchase and the financial sustainability of the study subjects. Furthermore, assessing PPE purchasing behavior within the 3-day window may not be fruitful as purchases of supplies could have increased following the 3-day window as more residents are aware of the outbreak and its widespread effects. In response to this, it may be beneficial to explore the association of these predictors and/or other related predictors toward PPE purchasing behavior that transcends this 3-day window. However, the present CHARLS dataset does not include this outcome of interest so other datasets examining a similar outcome but within a longer time scale is warranted.

Finally, this study acknowledges that the internal economic issues within China following the pandemic are prevalent. The financial impact of the pandemic on Chinese households was shaped by employment arrangements, government support measures, and economic disparities (White & Case, 2020; Zhang, 2020; Zhang *et al*., 2022). Unlike some Western countries that provided direct stimulus checks, China implemented targeted economic relief policies, including tax reductions, subsidies for small businesses, and financial support for unemployed workers. However, the effectiveness of these measures varied across different socioeconomic groups. Further, formal employees, especially in state-owned enterprises and large corporations, experienced greater job security and continued income flow, making them more financially resilient. In contrast, informal workers, self-employed individuals, and small business owners faced greater financial uncertainty, leading to cutbacks in healthcare spending while prioritizing essential goods, such as PPE. Furthermore, the government introduced tax exemptions, low-interest loans, and rent reductions for small businesses to maintain employment levels. In addition, local governments provided subsidies for essential healthcare and PPE, particularly in rural and low-income areas. These measures may have influenced household financial behaviors by reducing the out-of-pocket burden for PPE and medical expenses.

Overall, it is unsurprising that PPE purchases increased following the start of the COVID-19 pandemic as evidenced by Cohen *et al*. (2020). These authors suggested that, specifically within the US, the demand for PPE was attributed to a panicked marketplace following the

outbreak. The COVID-19 pandemic is likely not the last pandemic the world will witness. This warrants the need to explore important predictors of behavior during a global pandemic, such as PPE purchasing and individuals' financial sustainability, as it may potentially benefit individuals by providing precautionary measures and possible interventions if another global health crisis were to arise in the future.

5. Conclusion

Our study aimed to explore the association of medical and fitness expenditures with PPE purchases, and of these expenditures with individuals' financial sustainability, measured by the behavioral level of ease in covering their daily expenses, during the COVID-19 pandemic among the mainland Chinese aged 45 and above. There is no significant association between these expenditures and PPE purchasing behavior in China shortly after the lockdown in Wuhan. Conversely, this present study finds a significant impact of medical and fitness expenditures on the individuals' financial sustainability during the pandemic for Chinese mainland residents aged 45 and above.

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Conflict of interest

The authors declare they have no competing interests.

Author contributions

Conceptualization: Nan Hu, Wupeng Yin, Shawn Dinh
Formal analysis: Shawn Dinh, Wupeng Yin, Niliarys Sifre-Acosta
Investigation: Nan Hu, Wupeng Yin, Shawn Dinh
Methodology: Nan Hu, Wupeng Yin
Writing – original draft: Shawn Dinh, Wupeng Yin, Niliarys Sifre-Acosta
Writing – review & editing: Nan Hu, Wupeng Yin

Ethics approval and consent to participate

This study is a secondary data analysis using the CHARLS Wave 5 data. Ethical approval for all waves of CHARLS was granted by the Institutional Review Board (IRB) at Peking University. The IRB approval number for the main household survey is IRB00001052 – 11015.

Consent for publication

Not applicable.

Availability of data

The data for this study were sourced from the publicly available CHARLS database, hosted by the National School of Development at Peking University. Access to the dataset is available through the official website: http://charls.pku.edu.cn/en. (accessed on November 24, 2024).

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Appendix

Table A1. Definitions and assignments of variables

Variable name	Definition	Assignment
Dependent variables		
Personal protective equipment	Stocking up face masks, hand sanitizer, and disinfectant during the 3 days after Wuhan was closed due to the pandemic (from January 24 to January 26).	No=0, Yes=1
Daily expenditure coverage	Degree of difficulty in covering daily expenses with household income.	Difficult=0, Easy=1
Independent variables		
Medical expenditure	Direct and indirect medical expenses with the latter referring to transportation expenses, nutrition expenses, family expenses, etc., incurred due to medical treatment. Payments in part with Medicare are excluded.	0 Yuan=0, >0 Yuan=1
Fitness expenditure	Fitness expenditures, including fitness exercise, fitness equipment, and health supplements.	0 Yuan=0, >0 Yuan=1
Covariates		
Age	Actual date of birth according to the solar calendar	<=61 years=0, >61 years=1
Gender	Biological sex	Male=0, Female=1
Government COVID subsidy	Government COVID subsidy for household members and household	No=0, Yes=1
Building structure	Type of housing structure	Concrete and steel/bricks and wood=1, Others=0
Activities in past month	Having done any listed activities in the past month (e.g., interacted with friends; played mahjong, chess cards or went to community club; provided help to family, friends, and neighbors; went to a sport, social, or other kinds of club; took part in a community-related organization; done charity work; attended an educational/ training course) (multiple choices allowed).	None=0, At least done one activity=1
Mask wearing	Masking during the pandemic	Never=0, Always/Sometimes=1
Awareness	Being aware of any of the listed practices to reduce the risk of coronavirus infection (multiple choices allowed).	None=0, At least aware of one practice=1
Number of chronic diseases	Number of chronic diseases that have been diagnosed by a doctor: hypertension, dyslipidemia, diabetes or high blood sugar, cancer or malignant tumor, chronic lung diseases, liver disease, heart disease, stroke, kidney disease, stomach or other digestive diseases, emotional, nervous, or psychiatric problems, memory-related disease, Parkinson's disease, arthritis or rheumatism, and asthma (multiple choices allowed).	0=0, 1 – 4=1, ≥5=2
Poor household subsidy	Whether household or household members received *Wubao, Dibao, Tekun*, or poor household subsidies (multiple choices allowed).	None=0, At least received of one type of subsidy=1

Notes: *Wubao*: Five Guarantee Program; *Dibao*: Minimum Income Guarantee Scheme; *Tekun*: Assistance for the Extremely Poor Households.

ACCSCIENCE PUBLISHING

Global Health Economics and Sustainability

MINI-REVIEW

Exploring innovative approaches to fundraising for palliative care

Sunjida Shahriah[1,2], Sachin Dwivedi[1,3], Sucheera Amornmahaphun[1,4], Suman Seshkar[1], Somaye Pouy[1,5], Sidharth Puri[1,6], Hemdeep Kaur[1], Shoon Mya Aye[1], Risa Vernette N. Sangma[1,7], and Shyh Poh Teo[1,8,9]*

[1]Fellowship in Palliative Care Programme, Institute of Palliative Medicine, Kozhikode, Kerala, India

[2]Palliative Care Society of Bangladesh, Dhaka, Bangladesh

[3]Center of Excellence in Nursing Education and Research, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India

[4]Karuna Peera Kamthorn Palliative Care Center, Roi Et Hospital, Roi Et, Thailand

[5]Department of Pediatric Nursing, School of Nursing and Midwifery, Guilan University of Medical Sciences, Rasht, Iran

[6]Department of Critical Care Medicine, Paras Hospitals, Panchkula, Haryana, India

[7]Department of Community Medicine, University College of Medical Sciences, Guru Teg Bahadur Hospital, Delhi, India

[8]Geriatrics and Palliative Unit, Department of Internal Medicine, RIPAS Hospital, Bandar Seri Begawan, Brunei Darussalam

[9]PAPRSB Institute of Health Sciences, Universiti Brunei Darussalam, Gadong, Brunei Darussalam

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Mihajlo Jakovljevic M.D. Ph.D. MAE

***Corresponding author:**
Shyh Poh Teo
(shyhpoh.teo@moh.gov.bn)

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Abstract

Palliative care is a holistic approach aimed at improving the quality of life for those facing life-limiting illnesses and their families. Palliative care services often face financial constraints that restrict their ability to reach all those in need. There are difficulties accessing traditional funding mechanisms; therefore, innovative fundraising strategies are required to sustain and expand palliative care initiatives. In this paper, diverse fundraising approaches for palliative care are described, based on group discussions and collective brainstorming sessions by clinicians undergoing a Fellowship in Palliative Care. Fundraising approaches that were deemed innovative, yet feasible to apply in each locality, were shortlisted and described, with their strengths and challenges outlined in detail. These approaches include art and photography exhibitions, "piggy-bank" projects, community-based fundraising, charity shops, lottery and lucky draws, shuttle bus services, grants from international organizations and collaborative networks, the use of tap-on technology, festive events, and restaurant partnerships. It is hoped that through these innovative approaches, collaborative efforts, strategic planning, and resource mobilization, it would be possible to generate funds to develop and provide palliative care services for those in need to fulfill a fundamental human right.

Keywords: Community participation; Fundraising; Healthcare financing; Innovation; Palliative care

1. Introduction

Palliative care is a holistic approach aimed at improving the quality of life for patients facing life-threatening illnesses and their families (Sepúlveda *et al*., 2002). Despite its profound impact on alleviating suffering and providing support during times of immense vulnerability, palliative care services often encounter financial constraints that limit their ability to reach all those in need (Groeneveld *et al*., 2017). Therefore, exploring innovative fundraising strategies is imperative to sustain and expand palliative care initiatives and ensure equitable access to quality end-of-life care.

Traditional funding mechanisms face multifaceted challenges. Constrained health-care budgets, competing priorities, and fluctuating economic landscapes pose significant obstacles to securing sustained financial support for palliative care (Groeneveld *et al*., 2017). The evolving health-care landscape characterized by shifting demographics, changing disease profiles, and emerging health-care needs also result in an ever-increasing need for palliative care services (Axelsson, 2022).

A study looking at online medical crowdfunding in Canada, the UK, and the United States found 3396 crowdfunding campaigns between February 2018 and March 2019. There were racial and gender disparities found for crowdfunding success, with less funds raised for female gender, Black race or routine care, which include palliative services (Saleh *et al*., 2020). A study from Uganda found that the majority (93%) of palliative-care organizations are funded through donations (Amandua *et al*., 2019). A similar study from Taiwan found that palliative care services were mainly funded through individual small donations from a large number of people (Hsu *et al*., 2019). Thus, many hospices and palliative care providers rely on community contributions to run their services; therefore, fundraising efforts should be prioritized.

However, several opportunities remain untapped for fundraising in palliative care. Collective goodwill and community social capital can mobilize grassroots support and develop a culture of philanthropy. Digital technologies and social media enable access to funding contributions beyond geographic boundaries, leveraging connectivity, and social networks (Sleeman *et al*., 2021). Corporate partnerships and forging strategic alliances with businesses and organizations allow access to additional resources, expertise, and networks to scale the potential impact of palliative care provision (Curtis and Morrison, 2009).

This review paper draws on insights from group discussions and collaborative brainstorming sessions by clinicians undergoing a Fellowship in Palliative Care. It describes diverse fundraising modalities, ranging from community-based initiatives to corporate partnerships, highlighting the strengths and difficulties of each fundraising approach.

2. Methods

Group discussions were held online over four 1-h sessions in May 2022 to share fundraising experiences and opportunities for palliative care. The clinicians were from different specialties including orthopedics, anesthetics, community medicine, geriatric medicine, and palliative care, as well as from different regions, including India, Bangladesh, Iran, Thailand, Myanmar, and Brunei. Based on the online discussions and meeting notes, the main fundraising approaches that were innovative yet feasible for the group members to apply in practice were shortlisted and documented. It is hoped that these ideas could be implemented by individual members or piloted in each region, with any progress or lessons learnt to be shared in the subsequent experience sharing sessions among the group members.

3. Fundraising approaches

3.1. Art and photography exhibitions

Funds for palliative care and specific in-need groups can be raised through organizing art and photography exhibitions, with proceeds from ticket sales or auctioned artwork directed towards a suitable cause. Art exhibitions have the potential to attract a wide range of participants, including volunteers, artists, and members of the public. This fosters a sense of community engagement and supports, and provides a platform to showcase diverse cultural, ethnic, and minority groups, promoting inclusivity and cultural appreciation (Ashwell and Cridford, 2019). The same artwork can be used to host regular exhibitions in various cities and rural areas to maximize outreach and potential revenue streams. They can also be adapted to virtual platforms to conduct virtual exhibitions and tours, complemented with online donation options, to enable participation from a wider audience, and transcending geographical barriers. These exhibitions may also serve as a medium to raise awareness and educate the public about palliative care (Macleman, 2007). For example, in Scotland, an alliance called Good Life, Good Death, Good Grief organizes events such as "To Absent Friends," a festival of storytelling, remembrance, and celebration of people who have died but remain important to them (Hazelwood and Patterson, 2018).

However, there is a need to procure creative talent and attractive artwork or photographs to ensure the appeal of the exhibitions. Meticulous logistic planning, including venue selection, scheduling, and operational details, is essential

for smooth execution of these events. A dedicated team is needed to orchestrate and manage various aspects, from curating artworks to marketing and event coordination. It should be noted that during a pandemic, stringent infection prevention measures are implemented to safeguard the health and safety of attendees, adding an additional layer of complexity to event planning and execution.

While careful planning, collaboration and event management are necessary, the benefits of art and photography exhibitions include community engagement, cultural enrichment, and revenue generation potential, which can make a meaningful impact in advancing the goals of palliative care.

3.2. Piggy bank project

In the piggy bank project, piggy banks are gifted to school children, and the savings after a year will be directed toward palliative care. While achieving the fundraising purpose, this project also fosters awareness about palliative care among children, parents, and school staff. Besides, educational materials and information regarding palliative care can be distributed together with piggy banks to the students. The materials may include QR codes linked to palliative care information and details of a designated bank account for larger-sum donations.

This initiative cultivates charitable giving among children, instilling values of empathy, generosity, and social responsibility from a young age. The act of saving toward a charitable cause also instills a sense of accomplishment, while reinforcing financial literacy skills and prudent money management habits. Clay piggy banks can be obtained with low start-up costs, rendering this project affordable as a consistent annual fund collection event. This approach has been used as an innovative fundraising program for pediatric palliative care (Knapp *et al*., 2009).

However, the variable amounts collected from students can lead to unpredictability in whether this fundraising approach should be continued in a consistent annual fashion. Inherent risks such as the potential for misplaced money, theft, or diversion of funds must be addressed through robust safeguards and accountability measures. There is also a risk of a high dropout rate due to loss of interest or other competing priorities, which necessitate ongoing engagement to sustain participation. Resistance from families or school management, whether due to skepticism or logistical concerns, could also pose obstacles to the successful implementation of the project.

3.3. Community-based fundraising

Community-based fundraising involves reaching out to personal contacts, approaching individuals door-to-door or through other communication media such as WhatsApp. This grassroots approach is a time-tested fundraising approach, unlike corporate social responsibility initiatives, which may be limited during times of crisis. Mobilizing personal networks and engaging individuals on a voluntary basis fosters a sense of collective responsibility and solidarity within communities. Contributors are encouraged to give what they can, whether it be monetary donations, medications, food supplies, or educational resources, depending on local needs. An ethos of gratitude and non-judgment is also cultivated regardless of the size of the donation, promoting inclusivity and appreciation for individual contributions. The personalized nature of this fundraising method makes it less intimidating and can facilitate meaningful interactions and discussions on palliative care.

However, at the outset, the amounts collected may be small, and thus, patience and perseverance are required to build a donor base. Scaling its impact and ensuring sustainability require a snowballing effect to establish a critical mass of supporters. The time-intensive nature of contacting individuals and maintaining communication and engagement with donors demands dedicated effort and organizational support. As multiple individuals are involved, transparency and accountability in fund management also requires stringent oversight and adherence to ethical standards.

This grassroots approach leverages personal connections and collective action to effect positive change, builds resilient networks of support and solidarity, and advances the principles of compassion, equity, and social justice in palliative healthcare delivery. This was the foundation of a successful and sustainable yet comprehensive community-based palliative care service in Kerala (Azeez and Anbuselvi, 2021).

3.4. Charity shops

The main advantage of charity shops selling donated goods with proceeds going to palliative care is its affordability, both for donors contributing goods and shoppers purchasing items. The start-up investments required for opening charity shops are minimal, and the individuals from diverse socioeconomic backgrounds who would like to support this cause are free to donate goods according to their financial capability. Reusing second-hand items also contributes to environmental sustainability, reducing waste and carbon emissions associated with production and disposal of goods. Charity shops also foster community belonging and social connectedness, providing opportunities for meaningful interactions between volunteers and community members. These

spaces can also function as venues to reduce social isolation and loneliness (Flores, 2014).

However, quality control and careful curation of items are required, as donated goods vary in condition and lifespan. Cataloging and organizing donated items require efficient management and volunteer coordination to streamline operations. During the COVID-19 pandemic, additional precautions such as disinfecting donated items and adhering to public health guidelines added complexity to running charity shops (Garner *et al*., 2022). The profitability of charity shops may be limited by small profit margins, thus strategic pricing and revenue diversification efforts should be considered.

3.5. Lottery and lucky draw under the red cross chapter

A provision under the Thai law states that the president of the provincial Red Cross Chapter may initiate charity lotteries or lucky draws for fundraising purposes. Fundraising for palliative care by means of charity lotteries under the auspices of the Red Cross, particularly during events like winter fairs, can capitalize on the collective power of government support and private sector donations to generate funds. The participation of government sectors is encouraged to enhance the visibility and impact of the fundraising campaign. The annual nature of charity fairs also ensures a consistent source of funding for a selected cause. In addition, free booths and flea market spaces at the fairs provide more spaces for further fundraising through sales of goods and services.

However, awareness and buy-in are required from local Red Cross societies and committees to secure their support for the cause. Competition with other government sectors and organizations requires strategic positioning and advocacy to prioritize palliative care within their fundraising agenda. The inherent nature of lotteries as a form of gambling may also not be acceptable in certain parts of the world. Consideration should be given towards transparency of funding, responsible gaming practices, and ethical considerations to mitigate potential negative consequences (Scourfield, 2023).

3.6. Running a shuttle bus service

In Myanmar, introducing a shuttle bus service to facilitate transportation between Yangon General Hospital, other downtown hospitals, and U Hla Tun hospice presents a feasible strategy to address transportation challenges faced by patients, visitors, and staff, while concurrently supporting palliative care initiatives. The shuttle bus service provides a convenient and reliable transportation option to a pre-existing customer base, including patients with limited mobility, visitors, and hospital staff who may encounter difficulties navigating crowded public transport systems (Skinner *et al*., 2015). This service also provides an opportunity to raise awareness about palliative care through targeted messaging and information displayed within the vehicle. Donation boxes placed within the shuttle bus also expand the possibility of racking in from passengers, with the proceeds all diverted towards palliative care.

However, this service lacks inclusivity for individuals residing outside the designated route or those with poor mobility, who still require alternative transportation or accommodation to access health-care services. Strategic planning of routes and schedules is necessary to align with public needs and traffic patterns to optimize travel efficiency while minimizing disruptions and delays.

The sustainability of the shuttle bus service, including vehicle maintenance, insurance, and driver salaries, requires careful planning and resource allocation to mitigate financial risks and ensure long-term viability. Collaboration with bus service providers and regulatory authorities may be considered to secure support for the shuttle bus service as a charitable endeavor.

3.7. Partnering with international organizations and collaborative networks

Establishing partnerships with external organizations such as the International Association for Hospice and Palliative Care enhances support for palliative care initiatives by bolstering funding capacity and expertise. External funding opportunities can encompass traveling fellowships, faculty development, and access to essential resources such as books and journals, enriching the educational and professional landscape within the palliative care community. These collaborations stimulate knowledge exchange, technical support, and expertise sharing, thereby enhancing the quality and impact of palliative care projects (Callaway *et al*., 2007). Successfully securing external funding also elevates the reputation and visibility of organizations, attracting further support and recognition from stakeholders.

However, competition among international applicants for these funds may be fierce, requiring compelling project proposals and strategic positioning to stand out in a competitive field. Established institutions and government bodies often have greater awareness and capacity to pursue these opportunities, potentially placing smaller or less-resourced organizations at a disadvantage. Proactively identifying suitable funding opportunities requires dedicated effort, resource allocation and alignment with organizational priorities and capacity.

Securing external funds may involve obtaining permission or approval from relevant authorities,

introducing administrative complexity and potential delays. The criteria and requirements of external funders may also be restrictive in terms of eligible regions, target populations, or the implementing organizations. Therefore, meticulous planning of project proposals, securing external funder agreement, and adhering to project deadlines and budgets are crucial for success in accessing these funding sources.

3.8. Tap-on technology funding

Online fundraising platforms can be established to collect donations for registered palliative organizations through web-based or mobile applications. The organizational setup is often authenticated under regulatory bodies for enhancing transparency, credibility, and accountability. Cashless transactions also simplify the donation process and facilitate international contributions, expanding the reach and accessibility of fundraising efforts (Boles, 2019). Donors may benefit from tax exemptions for their contributions, further incentivizing philanthropic support. The crowdfunding campaigns can also be facilitated through integration with social media channels such as Facebook, Instagram, Twitter, Telegram, and WhatsApp, which can be virally shared to amplify fundraising efforts (Thanapongporn *et al*., 2021).

Expertise in website maintenance, troubleshooting, and technical user support should be available to ensure the platform runs smoothly. Robust cybersecurity measures and risk management protocols to protect donor information and financial transactions are necessary to avoid security issues such as cyber theft, disputes and failed transactions. Financial and accounting support is also required to manage tax calculations, which may present challenges when different tax rates apply to donations from various jurisdictions. Navigating international laws and regulations governing donations requires diligent compliance and legal expertise to ensure adherence to legal requirements and mitigate potential risks associated with cross-border transactions.

3.9. Christmas bash and carol-singing competition in educational institutions

Hosting a Christmas bash and carol-singing competition takes advantage of a heightened charitable spirit among the public and sponsors during celebratory periods (Barnes, 2019; Stehulova and Hommerova, 2020). Targeted participation, such as involvement of educational institutions, enhances the impact of fundraising, fosters community engagement and instills values of empathy and social responsibility among students. Involving the public to vote for winners promotes engagement and participation, raising awareness of the event and the importance of palliative care. Winners selecting a hospice for donating the event proceeds adds a personal and meaningful touch to the fundraising process. This approach can be adapted and customized to different cultural festivities, ensuring relevance and resonance with diverse audiences and communities. The events can also be hosted live online on Instagram or YouTube to reduce resource and logistical requirements.

However, proactive collaboration is required to garner buy-in and support from the management of these institutions. Relying on votes for winner selection may prioritize popularity over performance quality, potentially compromising the integrity of the competition. Planning, coordination, and advertising such events require a dedicated team, adequate resources and robust organizational support. Organizers may have limited control over the eventual allocation of funds to ensure they reach those most in need of palliative care. The seasonal nature of festivities, such as Christmas, also restricts the frequency of fundraising opportunities, necessitating strategic planning to maximize the impact during these festive periods.

3.10. Restaurant partnerships

Engaging restaurants in corporate social responsibility (CSR) initiatives to support palliative care offers mutual benefits. Restaurants can expand their customer base and cultivate a generous image, while simultaneously contributing to a meaningful cause (Shahriah *et al*., 2024). The partnerships can take various forms: donating a percentage of profit derived from dine-in or takeaway meals towards palliative care, donating meals to palliative care recipients or events, and creating themed menus around a cause such as cancer awareness. Youth volunteers may also be engaged to gain culinary experience and provide food to those in need.

However, menu selection and food quality are crucial to attract customers and maximize sales. Negotiating profit-sharing agreements and setting menu prices appropriately is also important to balance the interests of both parties. Socializing and marketing the CSR initiative, as well as simplifying the donation and booking process to enhance the customer experience, is important.

4. Reflections

The fundraising approaches described were art and photography exhibitions, piggy bank projects, community-based fundraising, charity shops, lottery or lucky draws, shuttle bus service, partnering with international organizations, tap-on technology funding, Christmas bash and carol-singing competitions in educational institutions, and restaurant partnerships.

Based on a follow-up discussion a year after the Fellowship, the COVID-19 pandemic significantly affected palliative care providers in the participant's localities with a need to rebuild the provision of clinical palliative services (Aye *et al*., 2023). While fundraising appears to be a competing priority for palliative care providers and organizations, it is a group consensus that fundraising is an essential activity to ensure sustainable provision of palliative care services.

There were several reflections based on the move from planning to implementation of these fundraising initiatives. Each fundraising approach is a project, which requires dedicated time and personnel. The majority of funds obtained from each locality were not large donations but were micro-donations from civil society. Thus, ongoing networking and sensitization of the community toward palliative care are important to gain traction and automate the process of receiving ongoing funds.

In Bangladesh, an Art and Photography exhibition was held for World Hospice and Palliative Care Day 2023. This was in parallel to an online event organized by high school and university students for the compassionate communities and those caring for older family members. The Palliative Care Society of Bangladesh also held a painting event, participated by local children, as well as those living in slums. Some of the children had autism, and many had had the chance to play with and use paint and paper for the first time in the event. The paintings were published in a book, which were sold in addition to the artwork (unpublished data). This showcases the feasibility of proactive fundraising campaigns to generate funds in addition to raising community awareness of palliative care.

5. Future directions

There is a need for continued exploration of the intersection between fundraising strategies and health-care delivery models, with a focus on identifying synergies, best practices, and innovative approaches to mobilize resources. Further research is required to improve the understanding of the impact of fundraising initiatives on patient outcomes, caregiver experiences, and community well-being. Given the disparities in access to palliative care, assessments of fundraising strategies are necessary to ensure the funds and donations reach marginalized populations. Finally, it is important to enhance partnerships between palliative care providers, policymakers, philanthropic organizations, and the private sector to optimize sustainable fundraising and the delivery of palliative care services.

6. Conclusion

There is a diverse array of innovative fundraising approaches that can be considered to advance palliative care provision. Through innovative approaches, collaborative efforts, strategic planning and resource mobilization, it is possible to generate funds for developing and providing palliative care services for those in need to fulfill a fundamental human right.

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The authors declare they have no competing interests.

Author contributions

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Consent for publication

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Availability of data

Not applicable.

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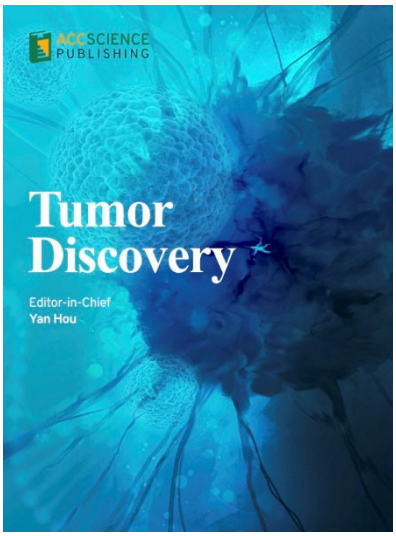

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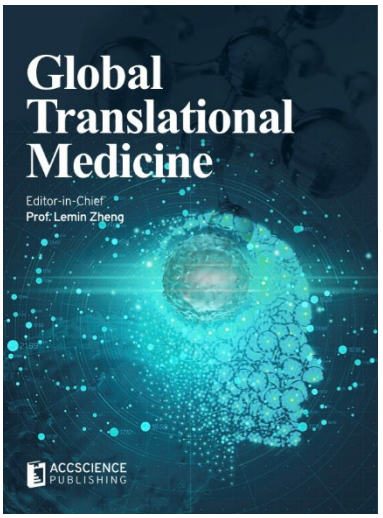

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