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CONTENTS

- 1** **Childlessness: A review of the theoretical frameworks and a proposition of general pathways** *PERSPECTIVE REVIEW*
Victor A. Leocádio
- 14** **Gender gap in life expectancy at birth and the role of socioeconomic indicators in South and East Europe, 1991 – 2020: Evidence from a dynamic panel model** *RESEARCH ARTICLE*
Goran Miladinov
- 33** **Exploring assimilation as a combination of objective and subjective processes: A case study of rural-to-urban migrants in China** *RESEARCH ARTICLE*
Zhenxiang Chen
- 47** **Residential inequalities in child mortality in Ethiopia: Multilevel and decomposition analyses** *RESEARCH ARTICLE*
Negussie Shiferaw Tessema, Chalachew Getahun Desta, Nigatu Regassa Geda, Terefe Degefa Boshera
- 60** **On the empirical study of fertility transition: A case for application of age-adjusted measures in multivariable analysis** *RESEARCH ARTICLE*
Pedzisai Ndagurwa, Clifford Odimegwu
- 71** **Market traders' knowledge, attitude, and practices of solid waste disposal in Calabar Municipality, Nigeria: New implications for global health education** *RESEARCH ARTICLE*
Beatrice Okoi Ekoru, Olajumoke Esther Olanrewaju, Ugbe Maurice-Joel Ugbe, Favour Achi Inyang-Ogim, Faith Ubi Okoi
- 80** **Modeling, simulating, and comparing biased archaeological mortuary assemblages** *REPORT*
C. L. Kieffer
- 93** **Factors associated with knowledge, attitudes, and practices of the general Lebanese population toward the coronavirus disease 2019** *RESEARCH ARTICLE*
Chadia Haddad, Sandrella Bou Malhab, Diana Malaeb, Hala Sacre, Danielle Saadeh, Christine Bou Tayeh, Pascale Salameh

PERSPECTIVE REVIEW

Childlessness: A review of the theoretical frameworks and a proposition of general pathways

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Abstract

The literature on childlessness has received increasing prominence in demographic studies because, with increasing levels of childlessness, it helps the understanding of important demographic concerns, such as reproductive behavior, family formation, and gender relations. Although a growing number of empirical studies on low fertility have been discussing childlessness, less research has attempted to discuss it from a theoretical perspective. This work has, therefore, the objective of debating theoretically important and recurrent issues in the literature on childlessness. This general aim is divided into three specific objectives: First, to discuss a range of contexts, aspects, and theoretical approaches that explain childlessness, second, to document the association between childlessness and important sociodemographic variables, and third, to develop a proposition of general pathways to childlessness. This study shows that several socioeconomic factors together with important correlated theories help to explain increasing childlessness. It also documents how childlessness is especially related to higher levels of education, singlehood, being African descents, living in urban areas, and having no religious affiliation. This work also finds and discusses four general pathways to childlessness in the proposed framework. This study contributes to the development of the theoretical framework on childlessness and encourages further research into this topic.

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1. Introduction

The study of childlessness has gained greater relevance in demographic analyses due to its increasing levels (Hayford, 2013; Leocádio *et al.*, 2022; Reher & Requena, 2018; Tanturri *et al.*, 2015). Historically, a U-shaped curve has characterized childlessness in developed countries. After reaching high levels (15 – 25%) at the turn of the nineteenth century, it decreased around the middle of the 20th century and increased again after the 1960s (Festy, 1980; Poston & Trent, 1982; Rowland, 1998; Sobotka, 2017). Some studies show recent high levels of childlessness also in developing countries with low fertility (Cavenaghi & Alves, 2013; Leocádio *et al.*, 2022; Pardo *et al.*, 2020; Rosero-Bixby *et al.*, 2009). As it is an important and increasingly frequent feature of these low-fertility societies (characterized as fertility below the replacement level (OECD, 2016; United Nations, 2003)), a further comprehension of childlessness (characterized as an

non-event, that is, no biological child (Houseknecht, 1987) helps to understand better reproductive behavior and the correlated consequences in family formation and gender relations (Billari *et al.*, 2009; Hayford, 2013; Sobotka & Beaujouan, 2014; Sobotka & Testa, 2008).

Part of the literature on childlessness presents the topic through a broad discussion that focuses on low fertility and new family patterns (Sobotka, 2004; Sobotka & Testa, 2008); other studies focus on empirical analyses of childlessness and its trends (Hayford, 2013; Leocádio *et al.*, 2022; Reher & Requena, 2018). Fewer in number are those that discuss the topic through a theoretical approach (Agrillo & Nelini, 2008; Kreyenfeld & Konietzka, 2017; Tanturri *et al.*, 2015). Complementing this still incipient type of analysis (theoretical discussions), this work aims to debate, through an analytical approach, some important and (most) recurrent issues in the literature that deal somehow with childlessness. Although it does not seek to exhaust the whole literature, to assess this general aim, this study has the following specific objectives: 1) discussing different contexts, aspects, and theoretical frameworks that help explain childlessness; 2) discussing the association between childlessness and important (and recurrent in literature) sociodemographic variables; and 3) proposing a general framework of pathways to childlessness, developed from the discussion of the main types of childlessness. In this vein, this study contributes to the development of the theoretical framework that discusses childlessness and encourages further research into this topic.

The contextual and geographical focus of this theoretical discussion is on countries with low fertility and higher levels of development, on which there is also greater demographic academic production when it comes to the topics discussed. It is worth mentioning, however, that the proposition of the general pathways to childlessness (third specific objective) can also be applied to contexts of different levels of development. Although it also discusses biological reasons for childlessness, this study focuses particularly on key factors and theoretical frameworks that are correlated to each other and that have a greater appearance in the social and (especially) demographic scientific literature devoted to discussing low fertility and childlessness. Furthermore, this research focuses on women and the reason for this is two-fold. First, the highest share of studies targets women. Second, the proposition of the general framework of pathways to childlessness takes into consideration the restricted women's reproductive period and the temporary versus permanent childlessness distinction.

This work uses literature review as a method, which is a type of review that qualitatively describes and discusses

published materials on the topic analyzed. Although this approach does not explicitly aim to maximize the scope of the discussed main topic and does not include comprehensive searching, it provides an examination of different aspects and enables covering a wide range of subjects (at various levels of completeness and comprehensiveness), which is ultimately the objective of this theoretical work (Grant & Booth, 2009). In addition to this Introduction, Section 2 presents and contextualizes childlessness in low-fertility countries, based on the discussion of its past and current trends. It also discusses important aspects and theoretical approaches that help explain these trends. Section 3 discusses the relationship between childlessness and important sociodemographic variables that are most recurrent in the literature. Section 4 presents, first, the main types and characterizations of childlessness, and, based on them, proposes a framework of general pathways to childlessness. Section 5 concludes the study.

2. Contexts, aspects, and theoretical approaches capable of explaining childlessness

2.1. Contexts and aspects

Childlessness is a feature increasingly present in low-fertility contexts. The fertility transition changed the patterns of family formation, and the increase in childlessness is an important outcome of this process (Sobotka & Testa, 2008). The share of women who end their reproductive period (women's reproductive period comprises the 15 – 49 age interval (WHO, 2022)) without a child in Italy reaches 25%. In countries such as Germany, Finland, Austria, and the United Kingdom, around one-fifth of cohorts of women born around 1965 are childless. In other countries such as Sweden, Denmark, The Netherlands, Spain, and Greece the percentages range between 15% and 20% (Tanturri *et al.*, 2015). Childlessness is also increasing among cohorts that have not yet completed the reproductive period. And, even if part of these women ends up having children, another share may not be able to fulfill their reproductive plans as a result of a set of factors that involve postponement of fertility, decreasing fecundity, or changes in reproductive intentions (Miettinen & Szalma, 2014).

Regarding the historical childlessness trend, in several European countries, at the end of the 19th century and the beginning of the 20th century, around 20% of women ended the reproductive period without a child (Kreyenfeld & Konietzka, 2017). This high percentage was due (in part) to the European pattern of marriage (Hajnal, 1965), in which young adults left their parents' homes to work and accumulate capital, which consequently raised the

age of marriage. Considering that total fertility in this period was basically composed of marital fertility, higher levels of childlessness emerged (Kreyenfeld & Konietzka, 2017). Similarly, in the United States, there are estimates that 25% of cohorts born between the end of the 19th century and the beginning of the 1920s were childless (Kreyenfeld & Konietzka, 2017). Rowland (1998) argues that childlessness among these cohorts is closely related to the socioeconomic period that characterized the post-Great Depression, from the end of the 1920s. Another factor that may have contributed is the sudden drop in the sex ratio resulting from the Second World War. Thereafter, the cohorts of women born between the late 1930s and the 1940s entered their reproductive period in a period known as the “Golden Age of Marriage,” and childlessness decreased (Festy, 1980). It rose again afterward, especially among cohorts born after the 1960s. Poston & Trent (1982) characterize this childlessness trend as a U-shaped curve, that is, high levels at the beginning of the 20th century followed by a fall toward the mid of the century and a subsequent increase to the current high levels.

Some authors understand that social and economic aspects are the most important for the emergence of the current context of increasing levels of childlessness. For example, the wide transformations that took place in the second half of the 20th century, when the availability of contraceptive methods and the greater participation of women in the labor market expanded the range of options offered to women, who no longer saw motherhood as a unique or main alternative. In parallel, the educational systems expanded, which also contributed to increasing the levels of empowerment and wages among women (Agrillo & Nelini, 2008; Frejka, 2017; Livingston & Cohn, 2010). On top of that, globalization and digitalization not only accelerated these socioeconomic advances, but also facilitated communication and dissemination of different thinking, ideals, and norms, including those that value, to a greater extent, smaller families and childlessness. Increasing cohabitation and individualization, for instance, are two important outcomes (closely correlated to the Second Demographic Transition discussed in more detail in Subsection 2.2) coming from this context of continuous socioeconomic advances and globalization that contributes to increasing childlessness (Lesthaeghe, 2010; Tanturri *et al.*, 2015; Zaidi & Morgan, 2017).

In addition to these advances, other socioeconomic aspects such as contexts of instability and economic stagnation can also lead to increased levels of childlessness (Frejka, 2017). Furthermore, uncertainty and globalization, for example, can be thought together when it comes to explaining low fertility and childlessness. If globalization, on the one hand, has provided an enlargement of working

options and arrangements, it has also deteriorated labor conditions, enhanced unemployment, and increased inequality, especially among the less skilled (Slaughter & Swagel, 1997). The uncertainty and stability stemming from these processes, particularly in times of economic stagnation, has a negative outcome in fertility, increasing, therefore, childlessness (accordingly, the Uncertainty Theory discusses in Subsection 2.2 some explanations for childlessness).

Other authors discuss these socioeconomic factors that contribute to the increase in childlessness through a closer relationship with fertility postponement. To achieve these advances, such as higher education and consolidation in the labor market, women continually postpone the transition to their first child. As they act in this way, the possibility of indecision in becoming mother increases. That is, initially, women postpone until they achieve a certain goal, but gradually, they can adapt themselves to childlessness, and eventually, no longer be interested in motherhood. In addition to this, it is known that women's fecundity is inversely proportional to age, so fertility postponement can lead to an impossibility of achieving reproductive desires (Miettinen *et al.*, 2015; Nicoletti & Tanturri, 2008; Tanturri *et al.*, 2015). Accordingly, Tocchioni (2018) focuses on the couple's relationship to explain childlessness. Late unions, for example, could again postpone the birth of a first child, and eventually, considering the age of the union together with the decreasing fecundity levels and changes in fertility intentions, a person may end up childless. Another associated element is the interruption of the relationship, which can lead to the dissolution of previously made reproductive plans. Miettinen *et al.* (2015) also emphasize the lack of a partner, considering difficulties in finding a suitable one. Given the strong association between partnership and childbearing (as discussed in Section 3), involuntary singlehood could also lead to childlessness. Finally, the lack of understanding between both parties of the couple regarding the ideal family size is also another important aspect of the increasing childlessness (Miettinen *et al.*, 2015).

Therefore, acting together with different socioeconomic aspects, fertility postponement, as a biological constraint, becomes another important factor in the explanation of childlessness. The quantity and quality of women's eggs diminish with increasing age. Moreover, poor-quality eggs in younger women could also cause childlessness. Additional biological reasons for childlessness (among women) include blocked fallopian tubes, abnormal menstruation, and other medical conditions such as disorders of the ovaries and the endocrine system, and uterine problems (Ford *et al.*, 2000; WHO, 2020). Other risk factors for childlessness are derivative from a mix of

biological, environmental, and socioeconomic factors, for example, stress, smoking, excessive alcohol consumption, and obesity (Gore *et al.*, 2015; Segal & Giudice, 2019).

If this set of factors that includes biological, socioeconomic, and environmental domains works in favor of the increase in childlessness, assisted reproductive technologies (ART), for instance, *in vitro* fertilization (IVF), can work in the opposite direction. These technologies consist of techniques for handling eggs and embryos, and, in general, the procedures involve the surgically removing of eggs from a woman's ovaries, the combination of these with sperm in the laboratory, and the subsequent returning to the woman's body (or donating to another woman) (CDC, 2019). Techniques such as these ones can provide a woman (or a couple) the chance of having a first child. They are, nonetheless, expensive, and, as consequence, reachable by only a small proportion of the population (Crawford *et al.*, 2016). On top of that, given the current rising trend of childlessness, the socioeconomic advances, including the fertility postponement coming from these changes, seem to play a more important role in the scenario of childlessness in low-fertility countries (Tanturri *et al.*, 2015).

2.2. Theoretical approaches

In addition to these socioeconomic and biological aspects related to childlessness, some theoretical approaches can also corroborate the explanation of this feature. Although these were not conceived, a priori, with the main purpose of explaining childlessness, they are useful for the debate as they present certain reasoning in which childlessness also fits somehow (Tanturri *et al.*, 2015).

The first of these is the Second Demographic Transition (SDT) (Lesthaeghe, 2010), characterized by: fertility below the replacement level, development of different family arrangements and increasing cohabitation, decoupling of marriage from fertility, increase in the number of divorces, postponement of unions, increased non-marital fertility and the emergence of a greater number of childless women (Lesthaeghe, 2010; Zaidi & Morgan, 2017). The main driver of the SDT is the cultural change that made possible the development of postmodern norms and attitudes, evidencing, especially, individualism. Thus, the SDT understands that the decrease in the power of family-related values and norms is explained by the search for greater individual decision-making power accompanied by an accentuated process of secularization. It focuses on ideational changes, which are the main causes of family loss of importance (Lesthaeghe, 2010; Zaidi & Morgan, 2017). McAllister & Clarke (1998) show evidence of childless women who aspire to independence and freedom, which is directly in line with the STD proposal. Therefore, according to this theory, ideational changes are the main

driving forces of new behaviors and family arrangements, among which childlessness is found (Balbo *et al.*, 2013).

The Preference Theory (Hakim, 2000; 2002), similarly to the Second Demographic Transition, also understands that fertility behavior is defined by personal values and individual preferences. In this vein, factors such as secularization, the emergence of individual aspirations, and the weakening of traditional social and moral norms help women to make their own decisions, including the postponement or denial of childbearing (Tanturri *et al.*, 2015). Hakim (2000; 2002) proposes the distinction of three groups of women, divided according to their preferences regarding family and work. The first group, with a family-oriented bias, has the home environment and children as priorities in life, which make them choose not to work (except for situations of economic emergencies). Women who prioritize their careers make up the second group. They preferentially focus on the work environment, and, on several occasions, may end up remaining single or without children. The third group does not have a single inclination. It is, therefore, composed of women who want to enjoy both work and family. Women tend to be more family or career-oriented according to what they experience at the beginning of the socialization process. Moral and social changes may encourage them to follow their own desires. Thus, the preference for a life without children gradually becomes a more acceptable behavior (Hakim, 2000; 2002; Tanturri *et al.*, 2015).

The two theoretical approaches discussed so far are guided by cultural issues and post-materialist values in this effort to understand female reproductive behavior. Individualism, secularization, and self-fulfillment help individuals more freely assess different courses of action during their life histories, including remaining childless. The next two approaches use economic perspectives. The Rational Choice Theory assumes that couples tend to consider income and personal preferences in the decision to have more or fewer children so that they end up weighing the costs and benefits in a final rational decision. Although according to the economic paradigm, fertility and income are positively associated, this theory argues that couples tend to invest in quality rather than quantity, which leads to a smaller number of children. Even though both quality and quantity have positive elasticity with income, and quantity tends to increase with economic development, the demand for quality is more elastic and increases with greater speed. This context leads to an increase in the price of the child sufficiently enough to reduce the number of children (Becker, 1960; Lee, 2015).

In addition to the quantity-quality trade-off, the Rational Choice Theory discusses the opportunity costs

of having a child. Given that societal advances happened faster and on a larger scale in the labor market than in the private sphere of the household, the cost of time and effort spent on children increased, which resulted in a reduction in women's fertility levels (Becker, 1960; Lee, 2015). It is worth noting that this line of reasoning tends to fit even better among women with higher levels of education, who choose to have fewer children, as the costs of giving up career and labor market opportunities are higher. Thus, childlessness may be a likely consequence of the increasing economic costs of a child that end up outweighing the social-psychological benefits of childbearing (Tanturri *et al.*, 2015).

The Uncertainty Theory, in turn, understands that decision-makers, in this case, couples (or unique individuals), adopt a risk minimization posture whenever the economic, social, and personal context is uncertain. It is possible to highlight three variations of uncertainty that can affect couples' decisions. The first of these variations, and perhaps the most recurrent, is the economic one. Decision makers may understand that they find themselves in a situation where their income earnings are not enough to support a child. Temporal uncertainty, on the other hand, is centered more on the impossibility of engaging in something as complex and enduring as having a child. The third type of uncertainty, which is closely related to the first one, understands that, when employment conditions are somewhat precarious, there is the possibility of opting for the continuous postponement of fertility or its denial (Mills & Blossfeld, 2017; Tanturri *et al.*, 2015).

Among others, gender approaches are also important in the debate about explanations for low fertility, and, consequently, childlessness. According to these theories, very low levels of fertility are a product of the gap between gender equity in the public sphere (education and the labor market) and gender equity in the private sphere (household) (Goldscheider *et al.*, 2015; McDonald, 2000). Moreover, as discussed so far, low levels of fertility are accompanied by high levels of childlessness. According to gender theories, greater equity in the private sphere, that is, greater male participation in performing household tasks would be necessary to increase fertility, which, in theory, would decrease childlessness.

As presented throughout this whole Section (2.1 and 2.2), different social, economic, ideational, cultural, biological and environmental factors contribute (together or alone) to the increase (or decrease) of childlessness. Table 1 summarizes the contexts, aspects, and theoretical approaches discussed in this section with the aim of contributing to the development of a framework focused on explaining childlessness.

Table 1. Overview of the contexts, aspects, and theoretical approaches discussed that help explain the increasing levels of childlessness

Contexts and Aspects	Greater availability of contraceptive methods
	Greater involvement of women in the labor market
	Increasing levels of education
	Globalization and digitalization
	Increasing cohabitation
	Increasing individualization
	Economic uncertainty and instability
	Fertility postponement
	Lack of partner
	Biological reasons (together with fertility postponement, and environmental reasons; despite the assisted reproductive technologies that work in the opposite direction)
Theoretical Approaches	Second Demographic Transition
	Preference Theory
	Rational Choice Theory
	Uncertainty Theory
	Gender Equity Theories

Source: Author's own elaboration

3. The relationship between childlessness and important sociodemographic variables

This section aims to present the relationship between childlessness and important sociodemographic variables (of greater recurrence in the literature) in low-fertility societies, where the highest levels of childlessness are found, and, therefore, for which there is also greater academic production.

Historically, the relationship between education and childlessness is one that most interests scholars (Burkimsher & Zeman, 2017). Childlessness is often shown to be positively associated with the woman's educational level (Kreyenfeld & Konietzka, 2017), and the main explanations often focus on the individual level. As discussed in Section 2, the Rational Choice Theory argues that opportunity costs are higher for women with higher education. Therefore, it is expected that the increase in the level of education is associated with the increase in childlessness. There is also the argument that women become more economically and personally independent as they devote more time to education (Oppenheimer, 1994). In this sense, women would be less likely to start a partnership, and, as discussed below, marital status is still

the variable with the highest association with childlessness. These explanations also reflect the scenario of the First Demographic Transition, marked by the decrease in fertility (Kreyenfeld & Konietzka, 2017). Another possible explanation for the association between childlessness and education stems from the SDT, already detailed in Section 2. After the first stage of demographic transition, the cultural and normative changes and the expansion of different lifestyles create conditions for levels of childlessness even higher. Finally, the association between childlessness and education can also be related to fertility postponement. Increasing levels of education is equal to a greater share of the reproductive period dedicated to personal training and qualification, which increases the need to postpone the birth of the first child. Since fecundity is inversely associated with the age of the woman, the likelihood of childbearing decreases (Kravdal, 2001).

Präg *et al.* (2016) relate childlessness not only with the level of education but also with female participation in the European labor market. The expansion of education is accompanied by increasing proportions of women in higher positions and with higher wages, which leads to rising levels of childlessness. A positive educational gradient is observed, that is, more educated women are more likely to not experience childbearing. However, there are exceptions. Some countries, such as Finland, for example, have registered a reversal in the educational gradient among some younger birth cohorts, that is, the group of more educated women has a lower chance of not having a child. A hypothesis that tries to explain these exceptions argues that more educated women, in some contexts, are more likely to start family formation processes earlier in life (Präg *et al.*, 2016).

Esteve & Florez-Paredes (2018) reinforce the idea that, through education, women's ideals, expectations, and opportunity costs can be transformed, which leads to a decrease in the desire for large families and an increase in interest in a life without children. Education not only reduces the *quantum* but also delays the *timing*, which ultimately affects levels of childlessness. Still on the relationship with education, the authors also emphasize the importance of adequate knowledge of contraceptive methods for childlessness.

The marital status variable is the one with the strongest association with childlessness (Hayford, 2013; Tanturri *et al.*, 2015). Births also occur outside formal or informal unions, but a stable partnership usually precedes childbearing. Therefore, not having a stable partner, never having been partnered, and being divorced are situations that increase the likelihood to become childlessness. Moreover, although children are traditionally born in formal unions,

cohabitations have increasingly been associated with the birth of a child (Jalovaara & Fasang, 2017). Miettinen *et al.* (2015) enhance the importance of marital status to explain childlessness, considering it more relevant than variables such as education and social status. Keizer *et al.* (2008) show that European women who have never had a stable partner are more likely to remain childless. Despite that, the association between being in a partnership (mainly formal marriage) and childbearing seems to lose strength over the last few decades. Although most children are still born within unions, the reproductive behavior of single women seems to contribute to increasing levels of childlessness (Leocádio *et al.*, 2022).

When it comes to race and ethnicity, Frejka (2017) finds a reversal of the association in the United States. Higher levels of childlessness have been found in cohorts of African American women born between 1883 and 1942. This relationship reaches its peak among the cohorts born in 1924 and 1925 when African American women were 2.4 times more likely to remain childless compared to white women. However, among cohorts born after 1940, childlessness is more likely between white women. Veevers (1979) found similar results, showing that in the past, childlessness used to be higher among African American women, which has been reversed. It is understood that the living conditions of African American women at the beginning of the 20th century were much worse compared to white women. This scenario marked by segregation and racial discrimination is described as a possible explanation for the greater association among African American women in the past (Frejka, 2017; Veevers, 1979). And these findings for race are closely linked to the discussion that shows a U-shaped trend for childlessness. The early 20th century was characterized by socioeconomic disadvantages (compared to current times), which kept childlessness higher. This period was followed by a period of increasing marriages and partnerships, which decreased the levels of childlessness (as previously discussed, marital status has a strong negative association with childlessness). Thereafter, childlessness started increasing again due to socioeconomic advantages, including the already-discussed advances in education and labor market (Festy, 1980; Poston & Trent, 1982; Rowland, 1998).

Regarding geographic location, most studies indicate that childlessness prevails in urban areas. In addition, the greater the population density in urban spaces, the greater the chance of a woman not having a child. The discussion about this variable also exposes that the propensity of childlessness in the urban area may be, in a way, inflated due to the selective migration of people who previously lived in rural areas and seek environments with greater levels of tolerance regarding different types of family arrangement

(Veevers, 1979). Furthermore, in general, people residing in rural areas are oriented, to a greater extent, to traditional family values. Communities are smaller, family ties closer, and the bond with the church deeper. Conversely, living in an urban area enables the adoption of individualistic and less traditionalist practices (Bloom & Pebley, 1982).

Finally, the literature recurrently discusses the relationship between childlessness and religion and documents a consistent negative relationship between these variables. Usually, those who do not attend religious services, without affiliation, and who do not read the Bible are more likely to be childless (Heaton *et al.*, 1992; Veevers, 1979). Tanturri & Mencarini (2008) show that women without strong religious beliefs are also more likely to be childless (or have one child). Accordingly, Veevers (1979) discusses that the most important distinction does not seem to be between different religious affiliations, but between two larger groups: those who manifest having a religious affiliation and those who do not; and evidence points to a greater propensity for childlessness among the latter. In a similar vein, religious affiliation, religious attendance, and religious salience tend to be negatively associated with attitudes toward childlessness (Uecker *et al.*, 2022).

4. Different types of childlessness: developing a proposition of general pathways to childlessness

Overall, childlessness is characterized in the literature as a non-event, or, in other words, the absence of biological children, that includes a variety of situations and can arise from different contexts and motivations (Houseknecht, 1987), as also previously discussed in Section 2. An important differentiation of types of childlessness involves the aspect of timing. According to this perspective, childlessness can be divided into *temporary* or *permanent*. The first takes the form of a momentary and reversible status, almost always resulting from the postponement of childbearing; the second means that the reproductive period has ended, and there is no longer the possibility of pregnancy (Bloom & Pebley, 1982). Differentiating childlessness according to a *tempo* perspective is important for understanding the fertility levels of a population (Agrillo & Nelini, 2008). Including young women in an analysis that aims to measure irreversible childlessness, for example, even if this group has reported not desiring (at all) to have a child, can generate problems, since their life trajectories could lead them to change their fertility preferences.

Probably the most frequent differentiation between types of childlessness is *voluntary* vs. *involuntary* childlessness. According to Veevers (1979), women

without children due to involuntary reasons fit into situations of sterility, while voluntary childlessness is due to continuous control of fertility through contraceptive methods. In this second case, the individual deliberately decides to renounce childbearing, a decision that remains throughout life. Veevers (1979) also suggests that women who do not have children voluntarily tend to belong to a more independent group, with different attitudes and values. Similarly, Waren and Pals (2013) conceptualize voluntary childlessness as a biologically capable person who chooses not to have children. Moreover, following the line of thought of Veevers (1979), other authors define involuntary childlessness strictly as a physiological disability, while voluntary childlessness deals with other possibilities associated with the conscious rational decision to never have children (Carmichael & Whittaker, 2007; Hakim, 2002).

Different from the definitions of involuntary childlessness exposed so far, the U.S. National Survey of Family Growth (a survey that collects information on marriage, contraceptive use, infertility, and pregnancy) proposes a broader characterization, not only restricting it to sterility but including other feasible situations (focused on women), such as difficulty in finding a suitable partner to share the willingness for childbearing; medical counseling to not to become pregnant, since this could lead to a situation that puts the woman and the baby in danger; and women in a formal or informal union with at least 3 years of unprotected and uninterrupted sexual intercourse who have never become pregnant. Voluntary childlessness, on the other hand, is defined as a context in which fertile women do not have any expectations of having children (Abma & Martinez, 2006).

Waren & Pals (2013) and Bloom & Pebley (1982) also do not limit themselves to sterility when defining involuntary childlessness and discuss that other circumstances active throughout the life course can also generate this specific situation. Involuntary childlessness, in this sense, would include not only all individuals biologically unable to have children but also those who are forced by other situations, in which it is not possible to have full control. These situations include financial obstacles, difficulty in finding a partner who shares the same family ideals, the need to allocate time and resources to child care, as well as other responsibilities such as ongoing pressure at work and careers, which relates to the discussion of opportunity costs held in Section 2.

Hence, as demonstrated, different situations and obstacles active throughout the life course can contribute to if and how an individual remains childless, which makes the differentiation between involuntary and voluntary

childlessness a complex task (Miettinen *et al.*, 2015; Rowland, 1998). The scenarios discussed below exemplify and delve into this complexity. The first scenario deals with women who postpone pregnancy to the point where it is no longer possible due to fecundity constraints (permanent postponers). In this case, an originally voluntary behavior (of not wanting or having children) may end up becoming involuntary (Berrington, 2017; Rowland, 1998). Marika and Eva (2017) emphasize that childlessness is rarely defined at the beginning of the reproductive period, but it stems from successive postponement decisions, which, in the end, can result in permanent childlessness. Not having children is, therefore, not necessarily a consequence of the preferences of a woman, man, or couple (the focus of the discussion is generally on women, due to the higher complexity involving the reproductive period).

Another scenario occurs when the boundary between choice and constraint is unclear. For example, the inability to enter into a union may be choice-dependent, that is, individuals have little propensity for family life; or it may depend on the circumstances, meaning the inability (regardless of the reason) to find a suitable partner (Tanturri & Mencarini 2008). A third scenario in which becomes difficult to define childlessness has women who are not fertile and, at the same time, do not have the desire to have a child. If, on the one hand, sterility can define the absence of a child as involuntary, its own preference indicates a voluntary character (Mcallister & Clarke, 2000).

Carmichael & Whittaker (2007) further discuss what could be the fourth scenario presented here. This is described by a couple, in which the woman or the man is infertile or has chosen not to have a child. In some way, this impossibility or unwillingness to have a child will impact the respective partner, given that this situation was not chosen by him or her, making it difficult to characterize the absence of children of this second individual in the relationship. In the context of a union, therefore, an individual's choices and preferences can directly or indirectly impact those of their partner. Consequently, it is possible that changes occur along the couple's life course, such as one of the parties convincing the other not to have a child, which, ultimately, produces voluntary childlessness for both of them.

The discussion about these definitions (voluntary vs. involuntary) and difficulties in characterizing childlessness is also linked to the historical contextualization of childlessness discussed in Section 2. The trend of childlessness would follow something similar to a U-shaped curve, that is, a decrease between the beginning and middle of the 20th century and a subsequent increase among the cohorts born mainly after the 1960s (Festy,

1980; Poston & Trent, 1982; Rowland, 1998). In Spain, England, Wales, and France, for instance, around 18–20% of the women born around the 1920s were childless. These percentages dropped to something between 10 and 15% among the birth cohorts from 1940 to 1950 and increased again to somewhat around 20% in the 1960s and onward (Reher & Requena, 2018). This pattern would result from the process of socioeconomic development. The high levels of childlessness observed initially (the first peak of the “U”) would have occurred, mostly, due to involuntary childlessness caused by malnutrition, infectious diseases, and the absence of structural and economic conditions in societies and families. With the socioeconomic progress observed throughout the century, those high levels entered a downward trend. From the cohorts born in the 1960s onward, a rising trend in childlessness began to be observed. Moreover, in opposition to the other (first) period of high levels observed, childlessness would be largely an outcome of “voluntary” reasons. Urbanization, increasing levels of education, greater opportunities for employment, higher wages for women, and a greater presence of individualistic and secular values compose a set of explanations for why the new and current levels of childlessness could be mainly defined as voluntary childlessness (Festy, 1980; Poston & Trent, 1982; Rowland, 1998).

Now, specifically about the current rising trend in voluntary childlessness, this section discusses some significant points that will eventually lead to the proposition of general pathways to childlessness. The first one is about the relationship between the *temporary* versus *permanent* distinction of childlessness. At the beginning of the reproductive period, it is possible that a certain woman chooses not to have a child temporarily, which usually occurs for reasons of work or studies, characterizing this situation as temporary and voluntary. It so happens that this scenario admits changes, while gradually and consciously this same woman may end up deciding not to have a child at any time, a context characterized as permanent and voluntary. As already discussed, the continuous postponement of childbearing can cause the transformation of a desire once temporary into something permanent (Miettinen & Szalma, 2014; Nicoletti & Tanturri, 2008; Tanturri *et al.*, 2015).

The second significant point to stress about the recent levels of voluntary childlessness deals with the terms and concepts usually used to refer to childlessness. Due to the increase in the number of women who voluntarily do not want to have children, some studies have started to use the term “childfree” to refer to voluntary childlessness, since it would better characterize a person who has no intention, plan, or desire for a child, even if she or he has biological and economic conditions to do so. It was

initially used in 1972 by the National Organization for Non-Parents as a form of opposition to the term childless, which should refer to those who wish to have children but are unable to because of biological constraints (Agrillo & Nelini, 2008). According to feminist perspectives, in situations of voluntary childlessness, the term childless should be replaced by childfree, since, in English, the suffix “less” can indicate a situation in which something is “missing,” ultimately leading to a meaning of “unhappiness.” Considering that in these situations childlessness is a result of people’s own and deliberate choices, childfree would be the most appropriate term (Kreyenfeld & Konietzka, 2017). There are also negative stereotypes related to women choosing a childfree life. In different contexts and societies, the deliberate choice of childlessness violates the social norm, generating harmful labels for these women (Agrillo & Nelini, 2008).

As already mentioned, involuntary childlessness can be due to a set of factors that include sterility, lack of an adequate partner, medical recommendations, financial difficulties, professional pressure, or the transformation of a situation that was once temporary into a permanent one (due to continuous postponement). Voluntary childlessness, on the other hand, has a wider range of motivations. The third significant point on voluntary childlessness to highlight here talks about this. Houseknecht (1987) discusses that a life free from a series of responsibilities that follow the birth of a child, greater opportunities for self-fulfillment, and easier mobility between residences would encompass almost all the motivations behind voluntary childlessness. According to Frejka (2017), men and women decide to remain childless (or childfree) due to their own subjective reasons. In this sense, the main causes of voluntary childlessness would be compliance and satisfaction with life and with the relationship (in the case of partnered individuals), the appreciation of freedom and independence, the lack of responsibilities regarding raising a child, the absence of a paternal or maternal instinct, and the desire to experience moments in life in which, at least in these individual’s views, the presence of a child could become an obstacle.

The main objective of this section was to analyze the most discussed types of childlessness in the literature, highlighting the particularities of the *voluntary* versus *involuntary* distinction. Using this discussion as background, this study develops a summary of possibilities among which individuals can become childless. Namely, from the different characterizations and situations in which childlessness can arise, a set of general pathways to childlessness is proposed. Obviously, this framework does not encompass all possible combinations of situations that could cause childlessness, however, using the set of the

main concepts discussed above (*temporary* vs. *permanent* and *involuntary* vs. *voluntary*), a proposition of general pathways to childlessness is developed. This proposition focuses on the female population, given their limited reproductive period, and, therefore, of greater impact on the temporary versus permanent distinction. The numbered paragraphs and Figure 1 ahead describe and illustrate this proposition of general pathways to childlessness.

1. Involuntary childlessness (since earlier ages) due to sterility, failed treatment of infertility, medical recommendations, financial difficulties, or professional pressure – the main causes discussed in the literature presented above. This first general example outlines a situation in which there is no reversal from temporary to permanent childlessness, because, due to any of these causes, this woman was unable to become a mother throughout the entire reproductive period. Even if she wanted to have a child, it was never possible as a result of one or of a mix of these causes, hence, involuntary and permanent childlessness (it was permanent from the beginning).
2. Involuntary childlessness due to a continuous postponement of childbearing. When younger, the woman had a desire or intention to have a child, however, the birth of this first child remained on hold for some reason, for example, job market constraints, the pursuit for higher levels of education, or lack of a suitable partner. When then, she decides to have her first child; it is no longer possible, whether due to biological constraints, the lack of a suitable partner, or other reasons. In this case, therefore, there is a reversal of temporary childlessness to permanent childlessness, and, since there has been the desire to become a mother at some point, this is characterized as involuntary childlessness.
3. Voluntary childlessness from earlier ages. In this situation, the woman deliberately chooses to not have children since she is young, therefore, there is no reversal from temporary to permanent childlessness, and her childless (or childfree) “state” is considered voluntary.
4. Voluntary childlessness at older ages. In this case, the deliberate decision to not have children happens at an older age (close to the end of the reproductive period). When she was younger, the desire for becoming or not a mother had not yet been fully formed, and for some reason (e.g., the partner convinced to not have children, or the woman herself adapted to a life without a child), the woman deliberately chose to remain childless (or childfree) later in life. Therefore, there is voluntary childlessness with a reversal from temporary to permanent childlessness.

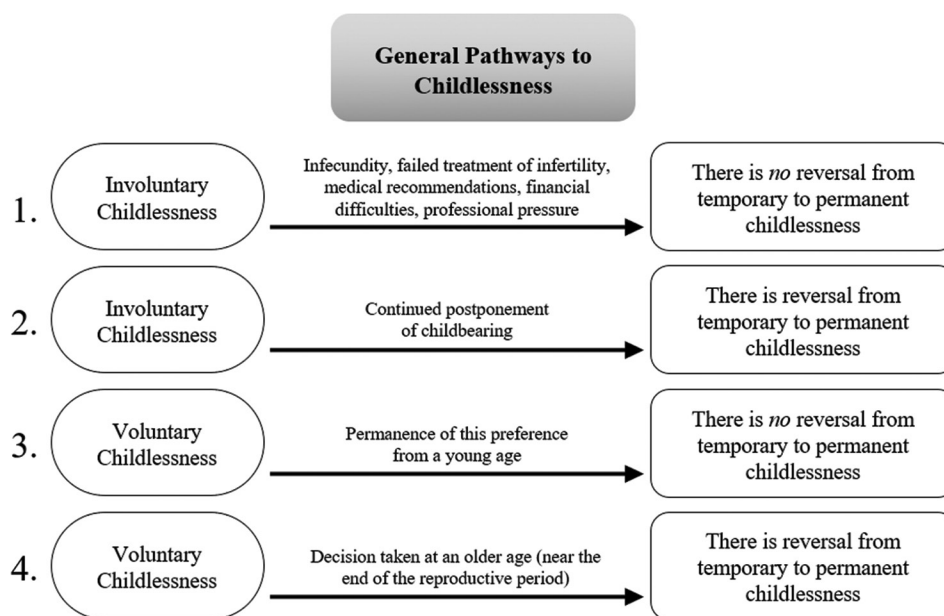


Figure 1. Proposition of general pathways to childlessness (using the main types and concepts of childlessness). Source: Author's own elaboration.

5. Concluding remarks

This study aimed to analyze theoretically a set of important and recurrent issues discussed in the literature on childlessness. In the absence of a theoretical background developed specifically to explain childlessness, Section 2 contributes by providing an overview of different aspects and theoretical approaches that, to some level, relate to childlessness and help explain this non-event. It showed that in addition to some biological explanations, socioeconomic advances catalyzed by a continuous process of globalization contribute, to a great extent, to explaining childlessness, especially its current rising trend in developed countries. Table 1 compiles all the explanations, not only these contexts and aspects but also the theoretical approaches. Some of the aspects discussed, such as greater participation of women in the labor market, increasing education and salaries, higher cohabitation, individualism, and secularization, are closely correlated to the explanations provided by some theoretical approaches, especially, the Rational Choice Theory, the Second Demographic Transition, and the Preference Theory.

Section 3 presented the association between childlessness and important (and recurrent) sociodemographic variables. This section contributes by particularly showing how the literature has been documenting that childlessness prevails between the higher educated; the ones who have never been partnered; the African American and urbanized women; and the subgroups without a religious affiliation or with lower religious attendance.

Section 4, by presenting and discussing important types of childlessness, proposes a general framework of pathways to childlessness. The distinctions between *temporary* versus *permanent* and *voluntary* versus *involuntary* childlessness were critical to the development of this framework. Four different pathways were proposed. The first one points to a scenario in which involuntary childlessness was present from the beginning, due to several reasons, for example, sterility, failed treatment of infertility, or financial difficulties. In this case, there is no reversal from temporary to permanent childlessness. In the second scenario, involuntary childlessness is a consequence of continuous fertility postponement; therefore, there is a reversal from temporary to permanent childlessness. The third one describes a general setting in which voluntary childlessness was a characteristic from earlier ages; consequently, there is no reversal from temporary to permanent childlessness. Finally, voluntary childlessness at older ages as a consequence of events taking place during the life course, which points to a reversal from temporary to permanent childlessness.

As emphasized, the number of studies discussing childlessness theoretically is low, and, different from the theories developed to explain the fertility transition, it lacks a theoretical framework exclusively and consistently devoted to discussing childlessness. Therefore, by discussing this series of subjects, this work contributes to the ongoing process of establishing a theoretical framework for childlessness. As a consequence, while it raises different approaches to studying childlessness, it also contributes by encouraging further research on this topic, particularly considering projections that indicate a future

increase in childlessness (Tanturri *et al.*, 2015). Moreover, it contributes by proposing a general framework of pathways to childlessness. The intent of such endeavor is not only to debate different scenarios that could lead to childlessness, which by itself is another original contribution but also to function as a background for future studies on childlessness, whether empirical ones (using longitudinal data, for example) or, again, theoretical ones, delving into these specific scenarios and pathways.

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RESEARCH ARTICLE

Gender gap in life expectancy at birth and the role of socioeconomic indicators in South and East Europe, 1991 – 2020: Evidence from a dynamic panel model

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Abstract

The purpose of this paper is to explain the role of socioeconomic development, economic, employment, and demographic factors on gender gap in life expectancy at birth (LEAB) in 24 South and East European countries. Aggregated yearly time series mainly from the UN and World Bank database for the period 1991 – 2020 were used. The generalized method of moments/dynamic panel data (GMM/DPD) model, a dynamic panel model, was used to explore the role of socioeconomic development, economic, employment, and demographic factors on sex differences in LEAB. The study shows that in these countries, a narrowed gender gap in LEAB is associated with a higher percentage of urban population in total population. There was found a significant impact of GDP *per capita* with a 2-year lag and Gini index with a 2-year lag as well as to LEAB on the gender gap in LEAB. There was not found a significant relationship between employment and education variables on gender gap in LEAB. However, the findings are important for policy discussions in terms of population health, labor policy, etc. The results are supported by the number of studies which show the relationship between socioeconomic development, economic, and demographic indicators and employment issues with gender gap in LEAB.

Keywords: Gender gap; Life expectancy at birth; Generalized method of moments/dynamic panel data; South-East Europe; Panel data

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1. Introduction

For long time, it has been known that the spatial distribution of the population reflects the social and political contextual link with the place of residence and has been considered an important factor influencing a person's exposures to health-associated risks, gain access to health services, as well as with educational and economic set of circumstances over an individual's life course (Graetz & Elo, 2021). Bloom and Canning (2006) pointed out the biggest demographic upheaval in history from the 1950s to 1960s, an upheaval that is still ongoing. In a few developed societies, the sharp post-war rise in fertility was followed by an equally sharp decline. As a result of the shifts in fertility, age structures were transformed with the formation of a "baby boom" generation. Furthermore, the aging of this generation and continued declines in fertility and old-age mortality have led to a shift in the population age structure in developed societies

from the young to the old. Thus, the proportion of old-age population has been increasing rapidly and the process of population aging (Bloom & Canning, 2006). Meanwhile, the developing world experienced a population boom, as a result of improved nutrition and public medical infrastructure as well as health care (Bloom & Canning, 2006). In parallel, the levels of fertility and mortality in many developing countries have also witnessed substantive declines in the same period, and thus, population aging has been taking place in both developed and developing countries, although it was faster in the developed world (United Nations, 2022). However, it should be noticed that these demographic changes were followed as a result of the economic and social development. Accordingly, understanding of future demographic trends (e.g., changes in lifespan) is extremely important for the development of good policies.

Mortality risks across age range fell dramatically during the 20th century, leading to an unprecedented increase in life expectancy at birth (LEAB) (and life expectancies at all ages) for both males and females in most countries in the world (Wilmoth, 2005; Aburto & van Raalte, 2018). Efforts to explain the observed gender differences in mortality are not new and efforts to explain these differences are evident in the empirical and theoretical reports and reviews in various scientific disciplines as demography, anthropology, epidemiology, economics, and evolutionary biology as well as in actuarial studies and reports (Cullen *et al.*, 2015).

International publications and researchers nowadays regularly make use of LEAB in the analysis and the description of the level of mortality. To describe mortality, LEAB (e_0) is generally considered as the most used indicator (Horiuchi *et al.*, 2013; Luy *et al.*, 2020), and it is also an excellent indicator for comparing the mortality of two or more populations (e.g., Kouaouci *et al.*, 2005; SORS, 1997; WHO, 2014), because it is age standardized and is easy to interpret. Thus, LEAB is based on the fixed age-specific death rates, which is calculated by dividing the number of people who die in a given year and age group by the number of people on average living in that year and age group (Luy *et al.*, 2020). When investigating changes and differences in LEAB between two populations or more, it is helpful at times to estimate what mortality differences in a specific age group contribute to the total difference in LEAB (Preston *et al.*, 2001). Thus, one of the estimation methods is decomposing a difference in LEAB.

Using available datasets and UN estimates and models, Attané and Barbiéri (2009) pointed out that accurately measuring gender differences in mortality or longevity were difficult, although in most countries, they noted gender differences. Among the several causes of death, it

is difficult to understand whether gender differences act as a biological discriminant or determine different lifestyles and hence different exposure to risk of death. Höhn *et al.* (2018) demonstrated that females have a mortality advantage over all ages and all causes of death, and that beginning with the age of 50, there is an increasing number of diseases and disabilities among people, as well as the incidence of most unfavorable health conditions increases.

This paper aims to explore how development and employment factors affect the gender gap in LEAB (females' LEAB – males' LEAB) in South and East Europe. It is well known that on average, females live longer than males, and that the gender gap in LEAB varies across countries and changes over time. The objective of this research is to explore to what degree these distinctions and changes are explained by development and employment issues? Therefore, an important research question is whether the economic inequity between the sexes plays a role in differentiating gender-specific LEAB? There is no doubt that these matters are important for policy purposes, like the circumstances in the domain of health and labor issues.

Why these countries? These 24 countries under study are economically and culturally heterogeneous and, for this reason, one would expect to find differences in the influence of factors of economic development on the gender gap in LEAB, cross-sectionally. In addition, although many of the countries within our research come from the European Union and share common goals and values and function in a common economic environment, severe inequalities in LEAB exist (Pinho-Gomes *et al.*, 2022). In addition, the region of South and East Europe was chosen because it is interesting, that is, this region shows unusual periods of sudden change of mortality and considerable LEAB changes, and because the age pattern of mortality change is different from that observed in other Western countries (Aburto & van Raalte, 2018). To assign the countries to specific groupings, the M49 standard of the Statistics Division of the United Nations was used (UNSD, 2021). Thus, according to this classification, South European countries include Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Macedonia, Malta, Montenegro, Portugal, Serbia, Slovenia, and Spain. East European countries include Bulgaria, Czechia, Hungary, Poland, Romania, Slovakia, Russian Federation, Ukraine, Belarus, and Moldova. In the opinion of the author, Türkiye and Cyprus are additionally included in the group of countries as the closest Mediterranean Southeast European neighbors, even though according to the United Nations Statistics Division (2021), they are classified as Western Asian countries. This research concerns a political entity known as the Republic of Macedonia, which declared independence in 1991, and is

consequently one of the successor states after the breakup of the Yugoslav Federation. Türkiye is a transcontinental country. Only a small portion of Türkiye is located within Balkans in Southeast Europe. In addition, Türkiye has the status of candidate country for EU membership since 1989 and is among the oldest member states of the Council of Europe (since 1950). Cyprus has been an EU country since May 1, 2004.

The paper is structured as follows: Section 1.1 provides a broad theoretical background on the research topic. Section 1.2 presents the research context of the explanatory variables. Section 2 shows data and methods with 2.1 about data sources and measurements and 2.2 about methods used. Section 3 presents results; Section 3.1 describes the trends of the gender gap in LEAB within South and East European countries. In Section 3.2, the application of the generalized method of moments/dynamic panel data (GMM/DPD) method and main findings are presented. Section 4 discusses the results and Section 5 provides major conclusions.

1.1. Theoretical background

LEAB is a well-acknowledged indicator of the general population's health. It is impossible to disentangle LEAB with working and living conditions, exposure to pollution, access to education, health care, income, as well as the social support (Pinho-Gomes *et al.*, 2022). The gender gap in LEAB continues to be a reality across the whole world. Females on average have 5 – 7 years higher LEAB than males (Kavanagh *et al.*, 2017). Females' LEAB exceeds males' LEAB in almost every country throughout the world (United Nations, 2022). The decline in mortality worldwide has always occurred with a change in the gender gap. Attané and Barbiéri (2009, pp.68-69) indicate that: "A situation of broadly equal male and female life spans, gradually gives way to one in which females have a clear advantage over men, albeit varying in size between cultures and regions and the excess female mortality, common at younger ages and in the childbearing years, gradually diminishes and eventually disappears altogether."

In most developed countries, females are expected to live about 4 – 5 years longer than males. The roots of the gender gap in LEAB seem to appear in biological differences among males and females and as well as modified by social-based norms and roles, obstacles, lifestyles, and epidemiological conditions that allow behavioral patterns and differences in the environmental surroundings to have an effect on health (Zarulli *et al.*, 2021). When looking at the variations in the gender gap between different countries, Medalia and Chang (2011) suggested that the biological component is likely to be directly conditional by social factors. Existing evidence shows that regardless of better

health, males experience a shorter longevity than females, because of both biological and environmental differences that involve behavioral, cultural, and social factors (Alberts *et al.*, 2014). This gender health survival paradox was well documented at the end of the last century within high-income countries in Europe, Japan, and the United States. The reasons why females have greater longevity but with poorer conditions of health than males are compound and are in general ascribed to differences in socioeconomic position, genetic and acquired risks, responses of the immune system, function of hormones, prevention and the type of disease, change in health, and health behavior (Gu *et al.*, 2009; Oksuzyan *et al.*, 2008). In addition, according to these scholars, studies confirmed that it is more probable for males to pass away immediately and that it is more likely to be the case for females to be exposed to a slow process of physical deterioration. Thus, Cambois *et al.* (2001) explained this to a certain extent by gender-related differences in the type of widespread diseases: Males had a greater prevalence of fatal diseases and females had suffered more from disabling diseases. Furthermore, research on populations regarding the health survival paradox suggests the female disadvantages in health and functioning and that males are physically stronger, report a small number of diseases, and have not many constraints in the daily living activities at older ages than females.

No matter how, the question of gender differences in morbidity has been considered as more complicated than the scheme in daily living activities and physical performances. This is so because of variation in the acuteness of diseases and the measure of severity, diagnostic procedures, as well as the age-related change in incidence and prevalence of many diseases (Alberts *et al.*, 2014). As an example, these scholars mentioned the incidence of coronary heart disease that starts to rise earlier for males than for females, but the gender differences in heart disease are small at the oldest ages.

Glei and Horiuchi (2007) demonstrated that the differences in LEAB between males and females could broaden even when the differences in age-specific death rates lessen. This is possible if the level of mortality dispersion is dissimilar between males and females, because the relation between the gain in LEAB and mortality change depends on mortality dispersion. Glei and Horiuchi (2007) disclosed that the increase in LEAB as a consequence from mortality decline has a tendency to be slighter if adult mortality rises more sharply with age. Thus, for a given rate of mortality decline, the gain in LEAB is greater if the age pattern of mortality is more dispersed. In other words, if the level of mortality dispersion differs between the males and females, the same age-specific rates of mortality decline for both sexes could change the gender differences in LEAB.

The research of Luy (2004) on Bavarian communities in Germany estimated that around 80% of the sex difference in LEAB in general population was indeed a gender difference, with earlier mortality for males. In 2003, a mortality analysis for the period 1890 to 1995 was carried out by Marc Luy to address the question to which degree biological factors provide explanation to the existence of the extensive differences in LEAB by sex. Luy (2004) made a comparison of the data on mortality of more than 11.000 Catholic nuns and monks in Bavarian communities which have had very similar living situations in terms of their behavior and surrounding with the life table data of the German's general population. Therefore, as stated by Luy (2004), the higher differences noted in the general population in Germany could not be ascribed to biological factors but to some other explanations, such as the risk gained by the social roles, environmental conditions, and behavior. In addition, variations in the gender gap in longevity across time and countries may be the first indication that the same ones cannot be explained as a purely biological phenomenon (Schünemann *et al.*, 2016). The widening gap in LEAB by gender was occurring with the considerable rises in the sex ratio of age-specific death rates (Glei & Horiuchi, 2007). Accordingly, these rises are generally associated with gender differences in trends of behavioral and social risk factors such as smoking, abundant drinking, violence, and occupational dangers (Glei & Horiuchi, 2007).

The gender gap, which implies that females are in a more favorable position than males when it comes to LEAB, was first noticed in developed countries in the 20th century, but during the 21st century, it was basically a universal phenomenon (Barford *et al.*, 2006; United Nations, 2022a). This outstanding achievement that females in all places of the world can likely to happen to have longer lives than males became certain.

In human history, all over Europe, females' LEAB has been always greater than males' LEAB from recorded data available, for example, Sweden since 1751, Denmark since 1835, and England and Wales since 1841 (Barford *et al.*, 2006; Luy, 2004). It is also important to emphasize that in West Europe and North America, the LEAB gaps between females and males have begun to narrow since the 1980s (Glei & Horiuchi, 2007). Throughout the last century, both males' and females' LEABs were with a stable growth with exceptions for World War II, but the gender difference in LEAB has widened considerably in favor of females in most of the second half of the century. Similar to many other countries of the world, the gender gap in LEAB continued to persist among East European countries during the 1970s and the late 1980s with a lesser scale among South European countries and Ireland (Glei & Horiuchi, 2007).

The study by Trovato and Heyen (2006) found a narrowing gender gap in LEAB in the late 1990s for the populations of six countries that belong to the G7 group countries: Italy, France, Canada, Germany, United Kingdom, and the United States. Accordingly, the continuation of this trend was considered a prominent characteristic of the epidemiological shape of the countries with high income. The basic measure for this analysis was the central age-specific death rate. The analyses of this research show the role of age pattern of change in the contribution of five large age groups to the change LEAB in the late 1990s as well as in the period when the gender gap reached the highest levels. In addition, the study found that the contribution of age groups under 35 was negligible.

In the early and mid-2000s, the gender differences in LEAB begun to decline in West Europe and flattened off among several countries in South Europe and the United States, even though it continues to rise in Japan (Crimmins *et al.*, 2016; Glei & Horiuchi, 2007). As stated by Glei and Horiuchi (2007), both causes of death, behavioral and medical factors contributed to the narrowing of the gender gap in mortality rates and as a result of that the narrowing of the gender differences in LEAB. These factors include increased smoking among females and decreased prevalence among males and the progress in medical treatments for cardiovascular disease that may have greater benefit for males than females (Crimmins *et al.*, 2016; Glei & Horiuchi, 2007). There was considerable debate about whether gender is best viewed as an instrument for behavioral and lifestyle issues, or as a proxy for an unobserved acquired survival advantage (Sickles & Taubman, 1997). The US and international empirical data strongly suggest that human LEAB varies by gender. In the United States, the disparity in LEAB between males and females remained fairly constant over the last several decades of the 20th century in spite of the conventional view that the male survival disadvantage is associated with behavioral patterns modified through public education and even with the considerable boost in female labor force participation rates, as well as female adoption of dominantly male lifestyle behaviors such as smoking (Crimmins *et al.*, 2016; Crimmins *et al.*, 2019; Sickles & Taubman, 1997).

Research has pointed out that health improvements are not omnipresent and that the changed patterns, to some extent, are regarded as being caused by the phase of the epidemiologic transition in a specific country (Gu *et al.*, 2009; Mercer, 2018; Omran, 2005). In terms of a concept, epidemiological transition theory focuses on the compound change in patterns of health and disease as well as the interactions between these patterns and their demographic, economic, and societal factors and

outcomes (Omran, 2005). As claimed by Omran (2005), the epidemiological transition is in line with demographic and technological transitions in the developed countries and it is still in progress in less developed countries. According to the epidemiological transition or health transition theory, deaths from cerebrovascular and cardiovascular diseases, cancers, and other non-communicable diseases increasingly become leading causes for death since mortality due to infectious diseases reaches a low level (GBD 2017 Causes of death Collaborators, 2018; Gu *et al.*, 2013; Mercer, 2018).

1.2. Research contexts of the explanatory variables

The economic and social development, economic related and employment variables, as well as demographic indicators are one of the major determinants for the gender gap in LEAB but they have not been studied sufficiently in the literature. If the gender gaps in longevity are analyzed at the level of cross-country differences, socioeconomic factors should play a decisive role (Fedotenkov & Derkachev, 2020). As pointed out by Fedotenkov and Derkachev (2020), some studies based on a large group of countries found that higher inequality in the income as well as a higher degree of economic development quantified by GDP *per capita* widens the gender gap in longevity (Fedotenkov & Derkachev, 2020). Fedotenkov and Derkachev (2020) themselves found that in developed countries, a higher economic development level in terms of GDP *per capita* has a negative effect on the sex gap in longevity. This means that if income rises, there is an increase in their health investment, for both males and females, but as their study showed, the impact on males is more pronounced. Therefore, higher incomes lead to a narrowing gender gap in longevity. In addition, Schünemann *et al.* (2016) pointed out that in developed countries, the gender gap in LEAB appears to be strongly and negatively correlated with GDP *per capita*. Nevertheless, some studies have also shown that economic development is more beneficial to females because the absolute as well as relative increases of LEAB occur with increases in income (Bai *et al.*, 2018; Borah, 2021).

The enormous inequality and harsh environmental conditions in cities are an important feature of urban areas, leading to high heterogeneity in socioeconomic circumstances and resources (Santana *et al.*, 2015). This means that the consequences of urbanization are not the same for everyone. Several studies that focus on urbanization and mortality come to some conclusions about their associations, such as higher urbanization is associated with ischemic heart disease, infectious disease, chronic liver disease, and cirrhosis, and that the lower levels of urbanization are associated with suicide, stomach cancer, diabetes, and dementia (Santana *et al.*, 2015, p.2). In

addition, it was also found that a higher level of urbanization and better environmental conditions are associated with a smaller gender gap in longevity (Fedotenkov & Derkachev, 2020). The dominant conventional literature on urbanization and urban poverty increasingly discusses gender issues (e.g., Borrell *et al.*, 2014; Masika *et al.*, 1997; Margaras, 2019; Veneri & Ruiz, 2013). Therefore, Masika *et al.* (1997) emphasized that urbanization tends to affect gender roles, relations, and inequalities (although with differences in the intensity). Urban growth can be driven by factors such as growth in total income, technological advances, and declining travel costs (Veneri & Ruiz, 2013). However, urbanization is a double-edged sword and can have undesirable consequences. Due to the high aggregation of the population, many urban areas are exposed to a range of environmental issues that can have an effect on their sustainability and the quality of life of those who live and work in them (Margaras, 2019). Thus, the agglomeration of population in certain urban areas led to undesirable side effects, for example, overcrowding, rising housing prices, pollution, and deterioration of the quality of life. In addition, air pollution in many European cities still remains a health risk and a lot of the cities do not comply with EU air quality directives. Hence, Borrell *et al.* (2014, p. 246) highlight the special characteristics of cities: Cities have high population density, typically higher within the central part of city, and national, cultural, and religious diversity; cities have a lot of human resources, cities provide services to the population such as medical care, education, or social services that are usually absolutely accessible; and socioeconomic inequalities in health tend to be greater in urban areas, with poor groups of people in disadvantaged circumstances concentrated in marginalized neighborhoods, typically on the periphery of the city or in the very center of the city.

Other indicators related to social development are very important, therefore, in that regard, there will be examined the link between the gender gap in LEAB and the indicators related with social development. The gender gap in mortality attracted researchers from the natural and social sciences. Clearly, the related health economics literature provides relatively little theory-based discussion of the gender gap in mortality. One of the reasons for this was certainly that the health capital model dominated the literature for several decades (Schünemann *et al.*, 2016). Because health capital is a latent variable, which is exclusively used by economists; hence, it was reasonable why it was alien and problematic to use by the medical and biological sciences (Schünemann *et al.*, 2016). Appropriately, Schünemann *et al.* (2016) found that health and health investment preferences can contribute about 70% to the gender gap. When these scholars extended the model with gender-

specific preferences for unhealthy consumption, their experiments suggested that up to 88% of the gender gap could be due to gender-specific preferences. According to Fedotenkov and Derkachev (2020), the education factor, for example, female enrollment in secondary school has less important effect on the gender gap in longevity in developed countries, since all girls there have the right to secondary education.

The prior research also focuses on other economic-related indicators. The positive correlation between LEAB and income is one of the most primary relationships in the areas of population health and development (Bloom & Canning, 2006). Bloom and Canning (2006) mentioned a strong positive relationship between levels of national income and LEAB in poorer countries, although the relationship is non-linear in wealthier countries as the levels of LEAB are less responsive to variations in average income. However, these scholars also observed that LEAB is increasing over time at all income levels. No matter how, when the economy grows, the difference between males' and females' incomes decline, lessening the differences in time and health goods allocations between the genders (Fedotenkov & Derkachev, 2020) and this leads to a narrowing gender gap in LEAB. Furthermore, Fedotenkov and Derkachev (2020) also emphasize that income inequality is one of the factors affecting LEAB. Thus, the relative-income hypothesis posits that the gender gap in LEAB may also depend on income distribution. Fedotenkov and Derkachev (2020) tested this hypothesis and confirmed that higher income inequality increases the gender gap in LEAB at the national level.

Differential health behaviors from involvement in dangerous occupational and vocational activities are the obvious explanations for at least some of the gender differences in mortality now and historically (Cullen *et al.*, 2015; Schumacher & Vilpert, 2011). The increase in mortality among working-age males was first detected in Hungary, but it quickly became clear that it was a more general trend shared by many countries of the former Soviet Union and some other countries in Central and East Europe (Botev, 2012). In the opinion of Botev (2012), this is probably the first case of a sustained and significant increase in mortality in the history of the world population that is not associated with a serious epidemic or war. According to Fedotenkov and Derkachev (2020), it is also widely accepted that the most dangerous and demanding work is usually performed by males, which means that males are at greater risk of environmental- and pollution-related hazards than females. Moreover, these scholars emphasized that males are more often faced with unhealthy working conditions than females. Other studies also suggested that the different social roles of the two sexes influence their respective

mortality rates, emphasizing that males tend to engage in more dangerous, harmful, stressful, or difficult occupations than females (Gjonça *et al.*, 1999). These attitudes based on socioeconomic differences and socio-occupational factors may explain some of the variation in LEAB between the two sexes. While some of these studies have shown that females' participation in the workforce positively affects their health and mortality, some other studies have found that work-family antagonism can lead to increase stress and mortality (Medalia & Chang, 2011). Finally, Fedotenkov and Derkachev (2020) revealed that the greater difference between female and male aggregate unemployment rates increases the female advantage in LEAB.

The gender gap may differ in different demographic transition stages. As mentioned earlier, females' more favorable position LEAB was first observed in developed countries in the history, but it has been a universal phenomenon since the 21st century (Barford *et al.*, 2006; Schünemann *et al.*, 2016; United Nations, 2022a). The rapid improvement of LEAB in the developed world was accompanied by a widening of the gap between male and female survival and this widening of sex difference was mainly due to the higher rate of improvement for females rather than to a decrease in LEAB for males (Gjonça *et al.*, 1999). All these likely suggest that gender gap may vary in different demographic transition stages.

2. Data and methods

2.1. Data sources and measurements

Data were used from the following sources: World Bank Development Indicators (World Bank, 2022), National System Accounts from the United Nations Statistics Division (UN, 2022b), the World Population Prospects (WPP) 2022 from the United Nations, Population Division (UN, 2022a), World Health Organization (WHO, 2022a; 2022b), and from Our World in Data platform (OWiD, 2022). The focus of this research was on South and East European countries. The period examined is 1991 – 2020 (inclusive); and the data represent an unbalanced panel.

Aggregate annual data about the LEAB by sex have been obtained from the country-specific life tables in WPP 2022. The annual aggregate data on GDP *per capita* in constant prices – 2015 US Dollars and for annual GDP growth rate have been acquired from the United Nations Statistics Division. In addition, the yearly aggregate data about employment rate in total population 15+ by sex, unemployment rate by sex as percentage of total labor force, the percentage of urban population in total population, as well as percentage share of the completion of the secondary education by females among school-age population aged 15 – 18 were retrieved from the World Bank Open database

(<http://data.worldbank.org/indicator>). Furthermore, data about the Gini index have been obtained from the Our World in Data platform whose data are based on the World Bank Poverty and Inequality Platform. Finally, data about the health expenditure as percentage of GDP have been retrieved from World Health Organisation databases and additionally from other WHO data link.

Conceptually, these nine indicators should be differentiated into at least three groups. In reality, they were classified into four groups: GDP *per capita* and the percentage of the urban population are preferably categorized under economic development and as indicators related to social development are included secondary education (% females) and health expenditure as percentage share of GDP). Two of our explanatory variables – difference in employment rate in total population 15+ and the difference in unemployment rate by sex as percentage of total labor force – are related to the issue of employment. These two employment variables have been defined as a simple difference between sexes of employment rate in total population 15+ and as a difference between sexes in unemployment rate, separately for each of the countries and for each year. In addition, as economic-related indicators within this study are included GDP growth rate and Gini index as a proxy measure of income inequality. Mortality gender gap as the dependent variable was calculated by the author as a difference of the LEAB between females and males (i.e., females' LEAB – males' LEAB) from the UN database, from 1991 to 2020, separately for each of the countries and for each year.

2.2. Methods

This research uses the GMM/DPD, an estimation technique commonly used in econometrics (Arellano & Bond, 1991; Baltagi, 2005; Wooldridge, 2001a), to analyze related factors associated with the gender gap in LEAB. GMM panel estimators are based on moments of the general form in Eqs. 1 and 2:

$$g(\beta) = \sum_{i=1}^M g_i(\beta) = \sum_{i=1}^M Z_i' \epsilon_i(\beta) \quad (1)$$

Where, Z_i is a $T_i \times p$ matrix of instruments (i.e., exogenous explanatory variables) for cross-section country i ($i=1, 2, \dots, M$); g_i is $T_i \times k$ derivative matrix of β coefficients estimator; T refers to the total number of time periods; k refers to the number of regressors; $\sum_{i=1}^M$ represents total sample moments; and $\epsilon_i(\beta)$ represents a vector of errors of coefficients for cross-section i , and

$$\epsilon_i(\beta) = (Y_{it} - f(X_{i,t}, \beta)), \quad (2)$$

Where, $f(X_{i,t}, \beta)$ is the function of k -vector of regressors and its coefficients for cross-section i , at period t ; and Y_{it} is the dependent variable for cross-section i at period t . The fundamentals of GMM estimation include a clear identification of the instruments Z and a selection of the weighting matrix H and determining an estimator for coefficient covariance Λ (Baltagi, 2005; Wooldridge, 2002).

The linear dynamic panel data specification can be considered as given by Eq. (3):

$$Y_{it} = \sum_{j=1}^p \rho_j Y_{it-j} + X_{it}' \beta + \delta_i + \gamma_t + \epsilon_{it} \quad (3)$$

Where, Y_{it} is the dependent variable for cross-section i at time t ; Y_{ij-j} is the dependent variable at lag j for cross-section i and time t ; p is the total number of instruments; ρ_j is the average of the j -th order auto-covariance; X_{it} is the k -vector of regressors for cross-section i at time t ; β represents the coefficients that vary across cross-sections and periods; δ_i and γ_t represent cross-section and period-specific effects (fixed or random), respectively, and ϵ_{it} is the error term for cross-section i at panel period t . First, differencing of the specification in Eq. (3) removes the individual effect and generates an expression of the form shown in Eq. (4), where denotes the difference operator:

$$Y_{it} = \sum_{j=1}^p \rho_j Y_{it-j} + X_{it}' \beta + \epsilon_{it}, \quad (4)$$

which can be estimated using GMM techniques (Wooldridge, 2002). An efficient GMM estimation of this type of equation should commonly use a different number of instruments for each period, with the period-specific instruments corresponding to the different number of lagged dependent and pre-specified variables accessible in a given period. Therefore, despite all strictly exogenous variables, one should use period-specific instrument sets that correspond to the lagged values of the dependent and other predetermined variables. Given estimates of the residuals from the one-step Arellano-Bond estimator, where it is assumed that ϵ_{it} are not autocorrelated, the optimal GMM H^d weighting matrix for the differenced specification may be given as in Eq. (5):

$$H^d = \left(M^{-1} \sum_{i=1}^M Z_i' \Xi Z_i \right)^{-1} \quad (5)$$

Where, Ξ is the matrix and Z_i contains a mix of strictly exogenous and predetermined instruments (Wooldridge, 2002). It is noteworthy to observe that this weighting matrix is the one employed in the one-step Arellano-Bond estimator. The weighting matrix is a major component for an efficient GMM analysis. The weighting matrix can be

acquired by inversion of the consistent estimator of the variance-covariance matrix of the moment conditions. As further stated by Wooldridge (2001a), if there are $m > k + 1$ total moment conditions, where, k represents the number of covariates in the model, the weighting matrix would have $m \times m$ dimensions. In addition, if concerns are existed about heteroskedasticity, there are methods for calculating standard errors and testing statistics that are robust to heteroskedasticity of not known form. The usual approach when facing heteroskedasticity of unknown form is to use the GMM (Baum *et al.*, 2003). The GMM estimator using weighting matrix places no restrictions on either the unconditional or conditional (on Z_i) variance matrix of u_i , that is, the asymptotically efficient estimator can be obtained without making additional assumptions (Wooldridge, 2001b). First, differencing is applied to remove the unobserved effect, and thereafter, lags are utilized as instrumental variables for the differenced lagged dependent variable. Wooldridge (2001a) added further that since the original time-varying errors are supposed to be serially uncorrelated, the differenced errors must have serial correlation. GMM is well fitted for securing efficient estimators that consider for the serial correlation (e.g., Arellano and Bond (1991). As specified by Lucas *et al.* (1997), the approach of Arellano and Bond (1991) supports consistent estimates under very weak distributional assumptions. Developed by Arellano and Bond (1991), GMM techniques can control for both unobserved country-specific effects and first difference non-stationary variables, and further to overcome the problem with endogeneity of the explanatory variables using instruments and test for the presence of autocorrelation (Adusei, 2013). For dynamic model estimation using yearly data, it is found that GMM with additional moment conditions can provide more accurate estimates than two-stage least squares (Wooldridge, 2001a).

For models estimated by GMM, the first- and second-order serial correlation statistics initiated by Arellano and Bond (1991) were used as a method to test for serial correlation. The test has in effect two different statistics, one for first-order correlation and the other for second-order correlation. If the innovations are *i.i.d.*, it is expected the first-order statistic to be significant (with a negative autocorrelation coefficient), and the second-order statistic to be not significant (Arellano & Bond, 1991). The test statistics proposed by Arellano and Bond is calculated as shown in Eqs. (6-8):

$$m_j = \frac{\rho_j}{\sqrt{\text{VAR}(\rho_j)}} \quad (6)$$

$$\rho_j = \frac{1}{T-3-j} \sum_{t=4+j}^T \rho_{ij} \quad (7)$$

$$\rho_{ij} = \rho_{ij} = E(\epsilon_{i,t}, \epsilon_{i,t-j}) \quad (8)$$

Where, m_j is the test statistics of j -th order of serial correlation and ρ_j is the average j -th order auto-covariance.

3. Results

3.1. Trends of the gender gap in LEAB in South and East European countries

Solid evidence has shown that a spectacular rise in LEAB for South and East European countries that started since 1965 has continued to progress and some of South European countries (e.g., Spain, Italy, Malta, Portugal, and Cyprus) are now the leaders of LEAB in Europe (Caselli *et al.*, 2014; Eurostat, 2021; United Nations, 2022a).

Figure 1A and 1B presents LEAB levels and the gender gaps in LEAB for 24 countries in the study region. The figures show that the group of South and East European countries is heterogeneous in different levels of LEAB. In general, LEAB for both sexes is lower for Russia, Ukraine, Belarus, Moldova, Türkiye, Bulgaria, Romania, Montenegro, Bosnia and Herzegovina, Macedonia, Serbia, and Hungary, whereas it is higher in Italy, Portugal, Spain, Malta, Cyprus, Greece, and Slovenia. The group of countries as Albania, Croatia, Czechia, Slovakia, and Poland is more or less in an intermediate position. In South Europe, not only the gains in LEAB in the period 1991 – 2020 vary greatly but geographical inequalities are more pronounced than elsewhere. During the period of our research study (1991 – 2020), Türkiye, Croatia, and Malta are the three countries where the expected LEAB increased the most (by 9.5, 8.1, and 7.8 years, respectively), unlike Montenegro and Bulgaria, where the increase was only 0.5 years and 3.7 years, respectively.

One characteristics of mortality in the study period 1991 – 2020 are the stagnation of LEAB in 1991 – 1995 due to the increase in probability of dying at almost all age groups that were resulted from impacts of collapse of previous socioeconomic systems in these countries. During the beginning of the 1990s, many East European countries even underwent decrease in LEAB, while other parts of Europe witnessed an increase (SORS, 1997). The considerable increase of LEAB in the mid- or late-1990s is probably the response of that earlier stagnation in mortality trends that are generally attributed to an end of health crises of the transitional period. As Avdeev *et al.* (2011) stated, across Europe, females have a longer life than males, but the range of the gap in LEAB between the two sexes varies extensively, as does the development in the region throughout the time. Thus, South Europe follows the same trend of East Europe but with greater

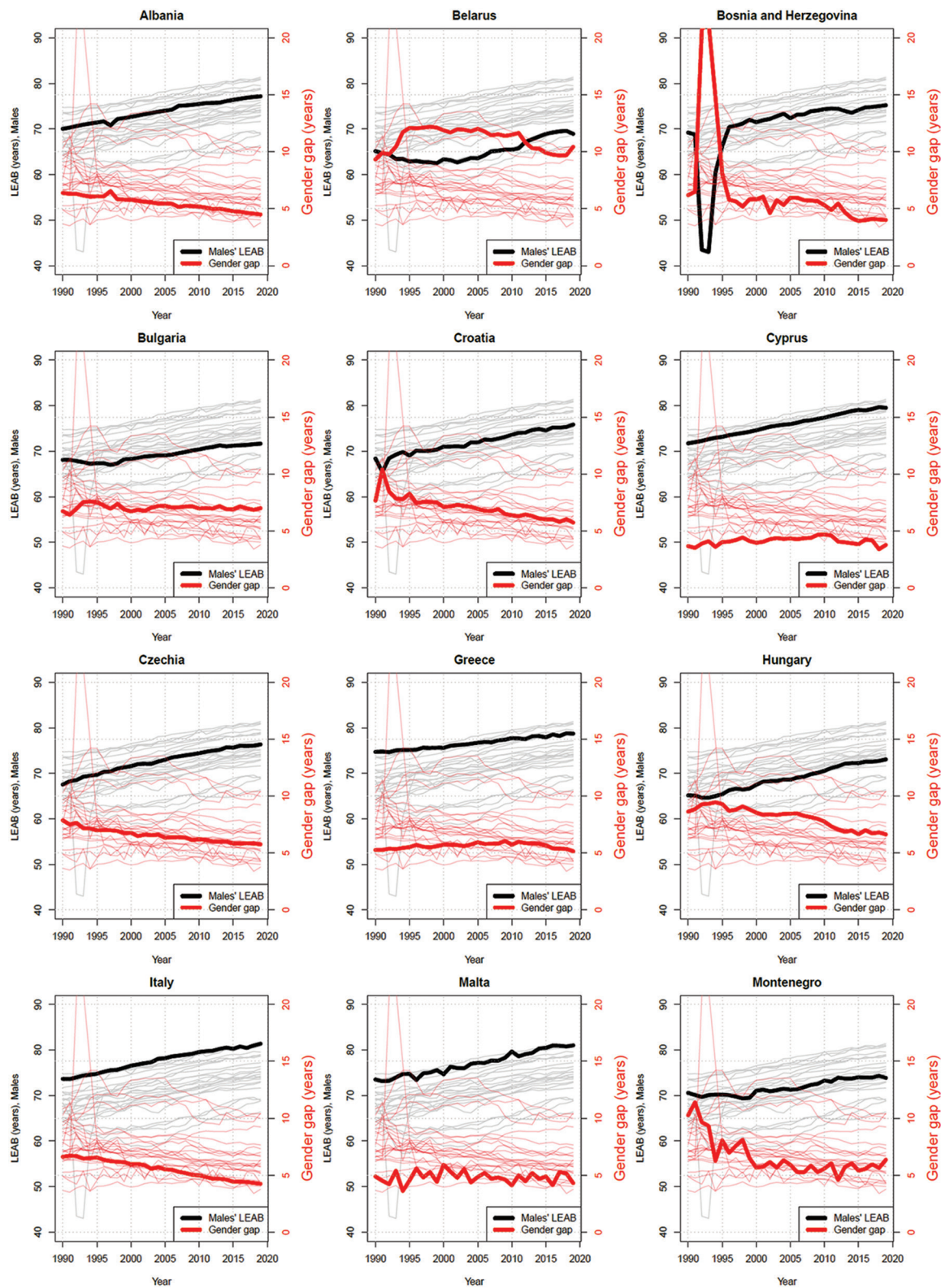


Figure 1A. Males' LEAB and the gender gap in LEAB in South and East European countries, 1990 – 2019

Source: World Population Prospects 2022 (United Nations, 2022a).

Note: The names of the countries/areas are directly taken from WPP 2022.

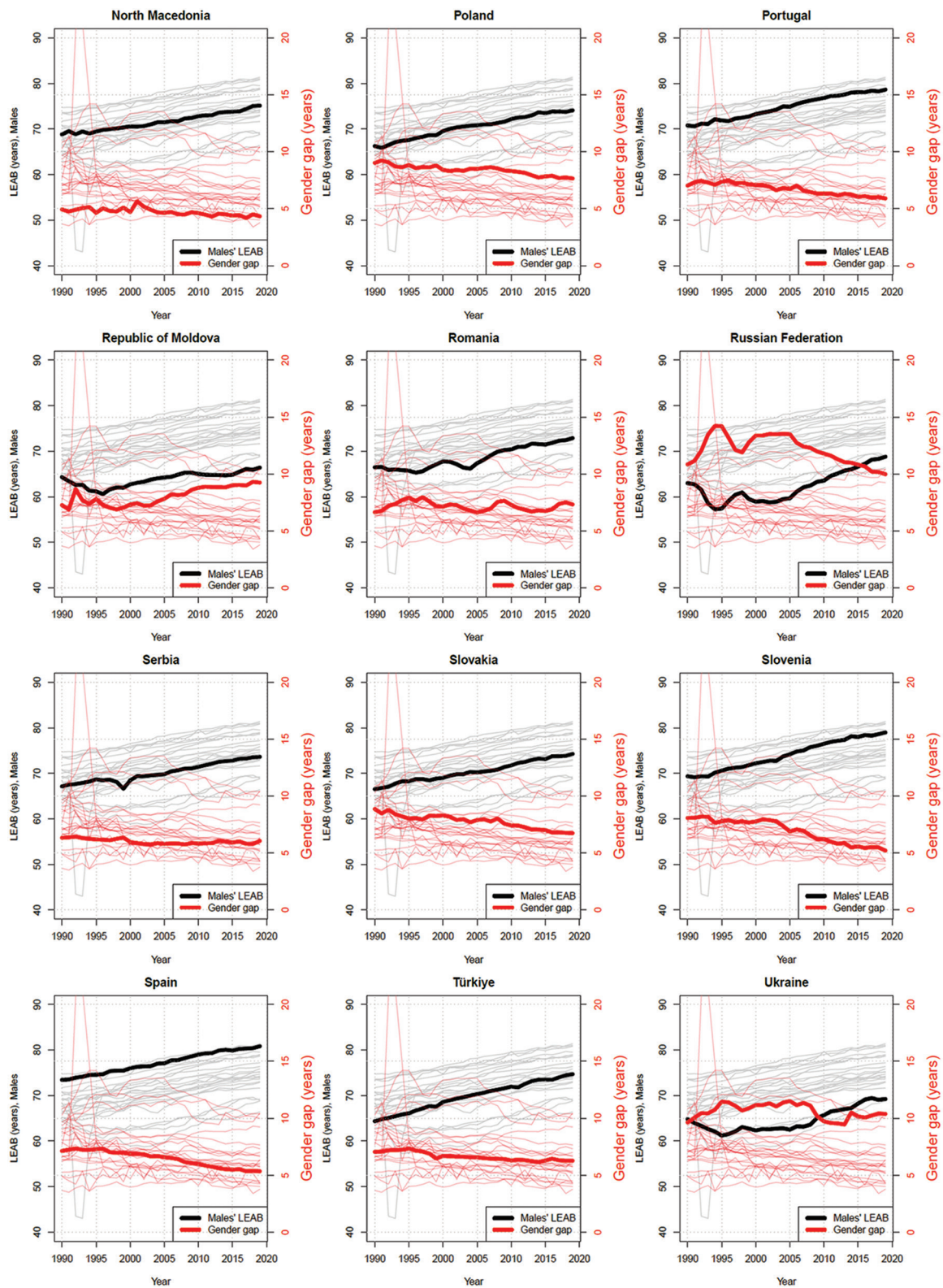


Figure 1B. Males' LEAB and gender gap in LEAB in South and East European countries, 1990 – 2019, continued

Source: World Population Prospects 2022 (United Nations, 2022a).

Note: The names of the countries/areas are directly taken from WPP 2022.

internal dissimilarities: In most of the South European countries, there has been a reduction in male's excess mortality since the mid-1990 except for Portugal where the reduction occurred only after 2000. By contrast, a stabilizing gender gap in life expectancy has been observed in South European countries such as Croatia, Macedonia, and Greece. In Romania, males lost exactly 1 year in LEAB between 1991 and 1996, the deterioration can be related to the economic and social problems with which this country was, and the same can be noticed for Bulgaria as well (1.1 years). The greatest loss among males is observed in Russia and Moldova (2.8 years), Ukraine (2.4 years), and Belarus (1.7 years) for the same period 1991 – 1996. In contrast, Bosnia and Herzegovina and Türkiye gained about 2 years, that is, 2.0 and 2.3 years, respectively, in males' LEAB between 1991 and 1996. In the period 1991 – 2001, LEAB in South and East European countries plus Türkiye improved from year to year, with average 0.32 years for males and 0.36 for females annually.

While the stagnation was found in the early 1990s for most countries in the region, the stagnation was found in the entire decades (1991 – 2001) in several countries with the most noticeable in Bulgaria (0.06 years) annually, followed by Romania (0.13 years), Macedonia (0.13 years), Greece (0.14 years), and Serbia (0.15 years). In the period 1991 – 2001, four East European countries saw an annual decrease in LEAB, and an annual average of 0.23 years for Russia, 0.07 years in Ukraine, 0.05 years in Belarus, and about 0.01 year in Moldova. Montenegro even experienced a sharp decline of 3 years in LEAB in 1991 – 2001 for both sexes. The largest annual decline among males for this period (1991 – 2001) was observed in Russia (0.33 years) followed by annual decline of 0.14 years in Belarus and 0.11 years for Ukraine. The largest annual decline in females' LEAB was recorded in Russia (0.14 years). The largest annual gains in LEAB during this period from 1991 to 2001 were recorded by Türkiye (0.36 years), Croatia (0.35 years), Poland (0.31 years), and Bosnia and Herzegovina (0.31 years). Males gained more than females. The largest annual gain in male's LEAB in the period was found in Croatia (0.50 years), followed by Türkiye (0.38 years), Poland (0.34 years), and Bosnia and Herzegovina (0.34 years). The largest increases in females' LEAB were witnessed by Bosnia and Herzegovina (0.30 years), Poland (0.28 years), Italy (0.26 years), Portugal (0.26 years), Malta (0.26 years), and Hungary (0.26 years).

By the end of the decade 1991 – 2001, the highest LEAB was found in females in Spain (83.2 years), Italy (82.8 years), and Greece (81.8 years). LEAB for both sexes exceeded 78 years in Spain and Italy in 1995 and in Greece in 1997. If LEAB for both sexes in Italy, Spain and Greece during the period 1995–1997 were compared with those in Romania, Türkiye, Hungary, Bulgaria, Ukraine, and Belarus for the

same period, differences were over 7 years. If these levels of LEAB in Italy and Spain from 1995 to 1997 are compared with the levels of LEAB in Russia and Moldova from 1995 to 1997, then, the differences are higher for more than 12 years. In this period, a high gender difference in LEAB was recorded in some countries. For instance, sex difference in LEAB was over 20 years in 1992 – 1993 in Bosnia and Herzegovina, over 12 years for Russia during 1992 – 2001, over 10 years in 1991 for Croatia and Montenegro, in Ukraine (1991 – 2001), Belarus (1993 – 2001), and over 9 years in 1992 – 1993 in Hungary and Poland.

The gender gap in LEAB during the period 2002 – 2020 (with the exception of 2020 because of the COVID-19 pandemic) was somewhat different from the previous periods. The highest LEAB in our study group was found in the southern countries. Italy had the highest males' LEAB in 2019 (81.4 years) followed by Malta (81.0 years) and Spain (80.8 years). The level of males' LEAB was comparable to that of some West and/or North European countries, such as Norway and Sweden and Switzerland (United Nations, 2022a). In addition, females' LEAB in 2019 in Slovenia and Greece (84.2 and 83.9 years, respectively) was the same as that in Austria, and also females' LEAB in Italy (85.6 years) was exactly the same as that of France in 2019 (United Nations, 2022a). However, within the group of South and East European countries, disparity in LEAB is large. For example, LEAB for both sexes combined, Bulgaria and Romania were about 8 and 7 years lower from that for Italy and Spain, which were (83.5 years for both countries) in 2019. When Italy's LEAB for both sexes in 2019 is compared with the LEAB in Russia, Belarus, and Ukraine, it is higher for more than 9 years and even for 12 years higher than Moldova's LEAB. Further, a child born in 2019 in Bulgaria as an EU country is “deprived” of more than 6 years of life if compared to a child born in Slovenia and Greece. The difference was even larger (10 years) between Bulgaria and Italy.

Within the 30-year period of analysis, the gender difference in LEAB had a substantial reduction in some countries: More than 4 years in Montenegro, 2.5 years in Italy, 2.4 years in Bosnia and Herzegovina, 2.3 years in Croatia, and about of 2 years in Russia. By contrast, the gender gap in LEAB in Moldova, Bulgaria, and Romania was increased by 1.7 years, 0.6 years, and 0.5 years, respectively. For the remaining countries, the gender gap in LEAB for the whole period was more or less constant. Several authors related the narrowing gender gap in LEAB observed in UK, Denmark, the Netherlands, Norway, and Sweden to the significant changes in the lifestyle, education, family roles, and employment of females (Spijker *et al.*, 2007). Over the study period (i.e., 1991 – 2019), LEAB was prolonged for all study countries not with the same length.

LEAB gained the most in Türkiye (10 years for males and 9 years for females) and least in Bulgaria (3.5 years for males and 3 years for females) and Montenegro (4 years for males). The largest gender gap in LEAB was found in Russia, Ukraine, and Belarus with mostly 10 – 12 years, then in Croatia, Hungary, Poland, Slovakia, Moldova, and Romania with mostly between 7 and 9 years, whereas the smallest gap was found in Cyprus, Macedonia, Malta, and Greece, with mostly between 4 and 6 years. Due to the wars and military actions in Bosnia and Herzegovina in 1992 – 1994 and in Croatia in 1991 in the study period, these couple of years were not taken into account these years in comparisons and analyses about LEAB.

The COVID-19 pandemic outbreak from January 2020 onward has apparently altered mortality rates a lot and consequently LEAB for both sexes across the whole world. Our study countries have not been any exception from this pandemic. Because of this shock to mortality rates and LEAB in 2020, this mentioned year was excluded from the GMM/DPD analyses. In that direction, the data in 2020 about the LEAB show that there was a drastic decrease in LEAB for almost all countries. Countries with the largest decreases in LEAB between 2019 and 2020 were Russia (2.5 years), Macedonia (2.1 years), Albania (2 years), and Türkiye and Ukraine (1.9 years). Malta was the only country that registered an increase of the total LEAB of 0.2 years, and Cyprus has stayed at the same level between these 2 years, without any changes in the total LEAB. If we observe the reductions by gender compared for these 2 years (2019 and 2020), the greatest reduction in LEAB was observed among males in Albania (2.6 years) and Russia (2.6 years), Macedonia (2.2 years), Türkiye (1.9 years), Ukraine (1.6 years), Belarus (1.6 years), Bulgaria (1.5 years), Italy (1.4 years), Serbia (1.4 years), Slovenia (1.4 years), and Romania (1.4 years). On the other side, the greatest losses in LEAB in 2020 were observed among females in Russia (2.4 years), Ukraine (2.2 years), Macedonia (2 years), Albania (1.9 years), Türkiye (1.9 years), and Belarus (1.5 years). As quite the opposite, for females in Malta and Cyprus, an increase in LEAB was observed for the period by 0.9 and 0.1 years, respectively (United Nations, 2022a).

3.2. Applications of dynamic panel model using GMM: Main findings

GMM/DPD model was applied to find out the relationship between gender gap in LEAB and explanatory variables for 24 South and East European countries from 1991 to 2019. The estimation was based on the unbalanced 339 observations panel of country level data. The analysis fits the gender gap in LEAB (MGG, measured by females' LEAB – males' LEAB) to the difference in employment

rate by sex in total population 15+ with a 1-year lag, as females – males DIFFEMPL(-1), the difference in unemployment rate by sex as percentage of total labor force, as females – males (DIFFUNEMPL), Gini index with a 2-year lag Gini(-2), the urban population as a percentage of total population (URBANPOP), GDP *per capita* – constant 2015 US\$ with a 2-year lag GDPPC(-2), health expenditure as percentage of GDP (HEGDP), GDP growth rate (GDPGR), life expectancy at birth with a 1-year lag LEAB(-1) and the percentage share of the completion of the secondary education by females among the school-aging population aged 15 – 18 with a 1-year lag SEDUF(-1). Since the model was assumed to be dynamic, the Dynamic Panel Wizard tool for estimating GMM/DPD was applied. Our dependent variable was MGG (gender gap in LEAB), and the first lag of MGG (i.e., MGG (-1)) was an explanatory variable. Furthermore, to remove the cross-section fixed effects of the dynamic panel model, the first difference transformation was specified. In addition, period-specific (predetermined) instruments (i.e., MGG with one lag and the remaining exogenous instruments) were specified as well. Finally, the weighting and coefficient covariance calculation was specified. Therefore, 1-step GMM iteration was selected for *i.i.d* innovations to calculate the Arellano-Bond 1-step estimator. In this case, fixed weights standard errors from estimation were computed. The coefficient estimates and summary statistics of the output of the GMM/DPD model are provided in Table 1. The standard errors presented in Table 1 are the standard errors of the 1-step Arellano-Bond estimator. In the literature, there is proof that the standard errors for the 1-step estimator are most reliable.

The results of the GMM estimation presented in Table 1 indicate that the estimated coefficients of Gini index up to 2-year lag and GDP *per capita* with 2-year lag have a positive and significant effect on gender gap in LEAB at $p < 0.01$ and $p < 0.05$, respectively. Nevertheless, the coefficient of GDP growth rate also remains positive, and the corresponding p value is close to the 10 percent significance level. The coefficients of URBANPOP and LEAB (-1) both have a negative impact on gender gap in LEAB at $p < 0.05\%$ and $p < 0.01$, respectively. The employment variables, education variable, and health expenditure as percentage of GDP have all statistically insignificant coefficients. However, within the model specification, the difference in unemployment rate by sex and the health expenditure as percentage of GDP has both negative sign and therefore insignificant negative impact on the gender gap in LEAB. On the contrary, positive sign but with insignificant impact on gender gap in LEAB was found for the coefficient of the difference in employment rate by sex with a 1-year lag and for the female share of the completion of secondary

Table 1. Estimation output of the GMM/DPD model^{abc}

Variable	Coefficient	Standard error	t-statistic	p
Gender gap in LEAB (MGG, -1)	-0.1107	0.0626	-1.7681	0.0780
Difference in employment rate by sex (-1)	0.0061	0.0142	0.4266	0.6699
Difference in unemployment by sex	-0.0155	0.0212	-0.7311	0.4652
Gini index (-2)	0.2621	0.0989	2.6509	0.0084
Percent of urban population in total population	-0.0506	0.0250	-2.0253	0.0436
GDP per capita (-2)	0.6038	0.3032	1.9913	0.0473
Health expenditure as percentage of GDP	-0.0074	0.0277	-0.2671	0.7895
GDP growth rate	0.0066	0.0043	1.5349	0.1258
LEAB (-1)	-0.2479	0.0663	-3.7347	0.0002
Percent of females completed secondary education (-1)	0.0222	0.0349	0.6371	0.5245
Instrument specification:				
Gender gap in LEAB (MGG,-1)				
Difference in employment by sex (-1)				
Difference in unemployment by sex				
GDP per capita (-2)				
Gini index (-2)				
Percent of urban population in total population				
Health expenditure as % of GDP				
GDP growth rate				
LEAB (-2)				
Percent of females completed secondary education (-1)				
Constant added to Instrument list				
Cross-section fixed (first differences)				
Mean dependend var	-0.0377			
S.E.of regression	0.2736			
J-statistic	2.4129			
S.D. dependend var	0.1634			
Sum squared resid	24.621			
Instrument rank	10			

Note: The coefficients were obtained from GMM/DPD with gender gap in LEAB (MGG) as the dependent variable and the first differences as transformation from the 339 unbalanced panel observations among 24 countries in South and East Europe in 1995 – 2019. A Negative values in the parentheses refers to the number of lag of the given variable. ^aFixed weights standard errors from estimation. ^bTransformation: First differences. ^cDifference specification instrument weighting matrix.

education with the 1-year lag. Furthermore, the lagged variable of the dependent variable MGG is significant and negative at $p < 0.10$.

Table 2 displays the results for a serial correlation test of both the first- and second-order serial correlation. The tests results show that the first-order statistic is statistically significant at $p < 0.05$ and with a negative auto-correlation coefficient which is what is expected if the model error terms are serial uncorrelated in levels. In our case, the second-order statistic is statistically not significant at $p < 0.1$. These results are expected if the error terms of the model are serial uncorrelated in levels (Arellano & Bond, 1991).

Table 2. Arellano-Bond serial correlation test outputs

Test order	m-Statistic	rho	SE (rho)	p
AR (1)	-2.1669	-1.5263	0.7043	0.0302
AR (2)	0.6763	0.6616	0.9784	0.4989

Note: The test includes 339 unbalanced panel observations for 24 South and East European countries from 1994 to 2019. Pearson's product moment correlation coefficient rho is a measure of the linear relationship and m-statistic denotes the population and sample mean.

4. Discussion

Our findings concerning economic development and demographic factors and their effect on gender gap in LEAB

in 24 South and East European countries are generally consistent with the established literature on the link between economic development and gender gap in LEAB, such as Fedotenkov and Derkachev (2020) and Schünemann *et al.* (2016). There is consistence with the findings of Fedotenkov and Derkachev (2020) that GDP *per capita*-positive affects the sex gap in longevity. To be specific and very simple, our results show that a lower economic development level widens the gender gap in LEAB and that a higher economic development level leads to a narrowing of the gender gap in LEAB in South and East European countries. Therefore, the GMM/DPD model indicates that higher GDP *per capita* considered with a 2-year lag narrows the gender gap in LEAB. Generally speaking, higher GDP *per capita* allows people to build up larger savings over their lifetimes, as well as in public and private pension funds. In turn, higher savings lead to a better quality of life and the ability to afford medical treatment, which can have long-term effects on people's health. Specifically, our empirical results show that the Gini coefficient up to 2-year lag is positively associated with gender gap in LEAB, implying that it has time-related effects on gender gap in LEAB. Greater income inequality within countries is associated with a wider gender gap in LEAB and that a lower level of Gini index, that is, less income inequality within countries leads to a narrowed gender gap in LEAB. Indeed, these empirical results may be explained in a way that the GDP per capita and Gini index may affect male's LEAB more than female's LEAB.

Our empirical results for the other economic development or demographic indicator, that is, the percentage of urban population in total population, revealed a negative statistically significant effect on the gender gap in LEAB. This finding clearly means that a higher percentage of urban population in total population leads to a narrowing of the gender gap in LEAB. In the literature, there are numerous empirical confirmations of such findings such as the studies by Borrell *et al.* (2014); Santana *et al.* (2015); and Veneri and Ruiz (2013). Herewith, it is worth mentioning the opinion of Borrell *et al.* (2014), as argued that when implementing public health policies and investigating the economic, social, political, and health changes occurring in a country, it is important to understand these processes because the majority of Europeans live in cities. In this regard, it is worth highlighting the observation also by Spijker and Van Wissen (2010) that the mortality-increasing effects of urbanization and industrialization succeeded to hide the mortality-reducing effects as a result of a high living standards as well as country-specific factors, for example, dietary habits acted as a confound.

Furthermore, it may be put forward for consideration that the not significant effect for some employment and

education variables may be explained by the presence of some other included economic or demographic factor in the model, such as, for example, the percentage of urban population in the total population. Hence, as a result of gender constraints and opportunities in terms of access to income, resources and services, reduced job creation, and downward pressure on real wages, males and females respond to urban poverty in different ways. For that reason, unemployment and underemployment are a major concern for many urban economies (Nierenberg, 2005). Conventionally, the movement to cities contributed to economic growth and global integration, as more people found homes close to schools, medical clinics, workplaces, and communication networks (Nierenberg, 2005). The persistence of poverty, and social and health inequalities despite the general improvement in all health and social indicators, proceeds from previous social and political conditions that, at different levels, are also present in some metropolitan areas or cities in European countries; mainly in those that have had delayed industrialization and urbanization (Santana *et al.*, 2015).

The difference in employment rate by sex and the difference in unemployment rate by sex have not significant effect on gender gap in LEAB. In general, our results about the impact of gender differential in employment on gender gap in LEAB are consistent with the theoretical concepts in the literature (e.g., Fedotenkov & Derkachev, 2020; Gjonça *et al.*, 1999). For this variable of difference in employment by sex with a 1-year lag, there is a consensus with the findings of Schumacher and Vilpert (2011), Cullen *et al.* (2015), and Botev (2012) that the gender differences in health behaviors and in mortality as a result of hazardous occupational and employment activities have been obvious explanations of the gender gap in LEAB, which is more relevant when historically speaking versus when seen from today's perspective or during recent decades the backward effect of these employment variables is less pronounced. Furthermore, it can be said that our results about the employment variables may be due to less risky jobs in these sectors for both sexes.

In addition, since it is known that employed persons as well as the unemployed belong to working age, that is, up to 65 years old and considering the advanced character of the epidemiological transition in these countries, it is likely to expect that in most part the dynamics regarding gender differences in LEAB started to occur in the 60s and older life (Trovato & Heyen, 2006; Zarulli *et al.*, 2021). In addition, if we accept the belief that most of the unemployed belong to a younger age group, due to further education, job search, or so, then in proving the validity of our results about not significant effect of the difference of unemployment by sex will be mentioned again the findings by Zarulli *et al.*

(2021). Accordingly, since the death cases between the ages of 15 and 40 are insignificantly low, the proportion of male to female mortality rates at that age has a negligible impact on the sex differences in LEAB. In addition, it was also clearly added by Trovato and Heyen (2006) and; Attané and Barbiéri (2009), that the contribution of age groups under 35 on sex differences in LEAB is insignificant.

Finally, the model results clearly show that an increase in LEAB for an increase in LEAB for both sexes is associated with a decline in the gender gap in LEAB. This finding suggests that when LEAB reaches a high level or a plateau such as in South and East European countries (i.e., a later demographic transition stage), the advantage in mortality for females over males tends to reduce. This is interesting. However, to understand and disentangle, some root causes of such phenomenon need a global analysis with a much longer analytical time period.

The study limitations include the lack of focus on different sets of countries separately but only using a large pool to measure gender gap in LEAB. For that reason, some of our results seem to be contradictory, but this is so since these regions within East and South Europe provide different cultural and historical backgrounds as well as various economic challenges, which may have an impact on not only country-specific fixed effects but also to the slopes of the economic development factors. Future research can address these shortcomings and give strength to the conclusions of their research. Therefore, our suggestion is that the future cross-country research in this field includes a focus on different sets of countries: Developed versus less developed countries, Balkan countries versus other countries in these regions, etc.

5. Conclusions

In accordance with the present time trend of worldwide population aging, this research work has provided a new perspective to confirm the relationship between the gender gap in LEAB and socioeconomic development, economic, and demographic indicators. This paper analyses the relation of these indicators and conditions in South and East Europe on the gender gap in LEAB. The results suggest that the difference in employment rate of males and females does not have statistically significant impacts on the differences in LEAB by sex. The not significant effect was found for the difference in unemployment of males and females as well as to social development indicators in relation to the sex gap in LEAB. Therefore, in general, it can be concluded that the economic inequality between the sexes does not play some special role when it comes to the gender gap in LEAB within these countries. The same is with the impact of the social development

indicators. In this regard, urban growth, the economic development through GDP *per capita*, and economic indicators, especially income inequality of population with the Gini index as a proxy measure, have significant impact on gender gap in. Comparing these results for these countries can provide a clearer understanding of the dynamics of the gender gap in LEAB. The findings of this study may be useful to propose some policy recommendations to reduce the economic risks within different economic circumstances as well as in the domain of population health. This research also calls for a more comprehensive study with all countries of the world with longer time periods for more robust findings.

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Conflict of interest

The author has no conflicts of interest to declare.

Author contributions

This is a single-authored paper.

Ethics statement

Not applicable as this study involves the analysis of secondary data collected by the UN and World Bank websites.

Availability of supporting data

Data utilized to this paper are from secondary sources and available to the public. The data can be freely accessed online from the World Bank Indicator database (<http://data.worldbank.org/indicator>), the UN databases (<https://population.un.org/wpp> and <https://unstats.un.org/unsd/snaama/Basic>), and the WHO databases (<https://apps.who.int/nha/database/ViewData/Indicators/en> and <https://gateway.euro.who.int/en/datasets/european-health-for-all-database>).

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RESEARCH ARTICLE

Exploring assimilation as a combination of objective and subjective processes: A case study of rural-to-urban migrants in China

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Abstract

This paper explores assimilation as a two-path process, in which its objective and subjective components are studied simultaneously using structural equation modeling for rural-to-urban migrants in China. This model considers the choice of reference group by the migrants themselves and the assimilation process into the reference group. Structural equation modeling results show that it can be beneficial for assimilation studies to allow migrants to choose their own reference group and to include the subjective path (i.e., assimilation into the migrants' chosen reference group) along with the objective path (i.e., assimilation into the mainstream). This can be achieved as follows: (1) The intertwining between the subjective and objective paths can disentangle assimilation into a process driven by two forces; (2) major stratification factors affecting the objective path through the subjective path may be identified; and (3) the impacts of assimilation on important migrant outcomes, such as subjective well-being, can be studied and separated into subjective and objective components.

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1. Introduction

Assimilation, defined as the process in which people with distinct cultural backgrounds adopt the cultural practice of another, has been an essential concept in studying migrants' settlement experience after migrating in the past several decades (Gan, 1973; 1992; Gordon, 1964). The general concept of assimilation has been widely studied in sociology, and the theory has been developed over time. Gordon (1964), in addition to proposing seven dimensions or stages of assimilation, established the fundamental distinction between acculturation and structural assimilation. He also suggested that assimilation is a multidimensional process. Gans (1973) further modified the theory by adding the dynamic or generational dimension to the theory and introduced the idea of "straight line assimilation," in which each successive generation of migrants assimilates further into the mainstream. However, "straight line assimilation" has been criticized, given its underlying premise of linear advancement in assimilation over generations. Recognizing this limitation, Gans (1992) proposed "bumpy line assimilation," meaning that it no longer needs to be linear. Portes and Zhou (1993) further considered the possibility of second-generation immigrants assimilating into different sectors of American society,

some of whom can experience downward assimilation if they assimilate to the bottom of the society.

The contributions of all these major modifications are significant, because they make the assimilation theories more comprehensive and have guided scholars in thinking about the assimilation process of newcomers. Nevertheless, all of these theories are based on a presumption of the reference group that the researchers have chosen for the migrants. For example, Gordon (1964) presumed that the reference group was the group with the core culture, while Gans (1973; 1992) presumed that the reference group was the parents. While not explicitly stated, these presumptions about the reference group assume that assimilation is an objective process. However, assimilation could be a combination of both subjective and objective processes (as described below). Therefore, it is important for assimilation studies to take into account the reference group chosen by the migrants themselves as well as how they assimilate into their chosen group.

This research studies assimilation as a combination of both objective and subjective processes. Specifically, it applies a subject-centered approach (Lee & Zhou, 2015; Zhou *et al.*, 2008). This research considers migrants' selected reference groups and investigates the impact of assimilation into the reference group on assimilation into the mainstream using structural equation modeling. The results show that migrants' choices of the reference group matter for their assimilation into the mainstream, suggesting that assimilation is a mixture of objective and subjective process. First, the choice of the reference group is shown to be subjective and intentional. In addition, assimilation into the mainstream (the objective path) is shown to be largely dependent on the level of assimilation into the reference group (the subjective path). The results also suggest that there are major stratification factors that affect the objective path through the subjective path. The total effects of these factors will not be captured if the subjective path is not considered. Finally, the results also show the differential impacts of both objective and subjective assimilation on subjective well-being as an application after considering and disentangling the two paths. By taking both the objective and subjective paths into account, this research significantly improves our understanding about the assimilation process, thereby contributing to the literature on assimilation.

1.1. A theoretical framework

1.1.1. The role of the reference group in assimilation

While the precise definition of assimilation can vary, the fundamental idea behind assimilation is an increasing similarity or likeness (Brubaker, 2001). Nevertheless, this

similarity or likeness is always a relative term. For example, while migrants may not be similar to the mainstream residents of the host society, they may be similar to a particular group of citizens within the host society. This is also known as segmented assimilation, in which certain groups of migrants become more similar to the mainstream society, but other groups become similar to the minority society (Porter & Zhou, 1993). Hence, segmentation applies in the sense that not all migrants are becoming similar to the mainstream, but it does not apply in the sense that all migrants are becoming similar to a particular reference group in the host society. In other words, if the researchers focus on migrants who become similar to the minority residents and select the minority residents as the reference group, the migrants are undoubtedly assimilated. However, if the mainstream residents are selected as the reference group, the migrants do not appear to be assimilated. Thus, the central question is "compared to whom?" The assimilation outcome can be significantly different depending on the chosen reference group (Kasnitz *et al.*, 2009). Therefore, the migrant reference group is an indispensable component for either understanding assimilation or even arguing for its existence.

1.1.2. Scholar-selected reference groups

Migrant reference groups are usually chosen by migration scholars rather than the subjects – the migrants – of the assimilation process. It is important to clarify that the scholars do not choose the reference group without any basis; to the contrary. For example, Kasnitz *et al.* (2009) argue that the most obvious reference group for the second generation is composed of other young people who share their racial backgrounds. In this case, the foundation is the racial background. However, the critical limitation is that the foundation depends on the scholars' own observations or understandings of migrants. No study on assimilation formulates the reference group by asking migrants which group that they want to choose as their reference group.

By definition, assimilation is about one group adopting the practice of another. There is no explicit statement on whether this "another" should be chosen by the "one group" or someone else. Therefore, based on the definition, scholars may choose the reference group for the migrants and observe their objective assimilation process (i.e., the simple fact that one group becomes more similar to another, whether consciously or unconsciously). This existing practice would not be an issue if assimilation was an entirely objective process. However, if assimilation includes a subjective component, this renders the process explored incomplete. In this case, the reference group chosen by the migrants and their subjective willingness to assimilate into the reference group should be taken into

account. Thus, the central question becomes: is assimilation objective or subjective?

1.1.3. Subjective versus objective assimilation

Before analyzing whether assimilation is subjective or objective, it is important to clarify that, here, the terms “subjective” and “objective” differ from what scholars classified as “subjective assimilation” and “external assimilation” (Feather & Rudzitis, 1974; Feather & Wasyluk, 1974; Johnston, 1963; Teske & Nelson, 1974). They defined “subjective assimilation” as similar to acculturation or assimilation in values and attitudes, while external assimilation is assimilation that can be observed. The key difference is that their definitions of “subjective” and “objective” do not depend on whether assimilation is observable or not, or whether it is internal or external. Instead, it focuses on the distinct roles that migrants play in their own assimilation process. If it is a subjective process, then assimilation will depend on who the migrants want to become similar to. If it is an objective process, then assimilation will not depend on the migrants’ choice of reference group.

However, assimilation is a mixture of both subjective and objective processes. Two main arguments support assimilation as a subjective process. The first argument is that migration itself is almost always intentional, with upward social mobility as the most common motivation. With US immigration, for instance, most migrants come with the hope of realizing the American Dream, while others come after seeing the success of their family members or friends who migrate earlier (Bates, 1997; Clark, 2003; Haug, 2008; Light & Bonacich, 1991). Those who come with the American Dream may look to middle-class residents as their reference group. However, those who come with the help of migrant social networks may take earlier migrants from the same origin as their reference group. In either case, they will have a reference group for themselves, which will serve as their target for assimilation. Essentially, migrants can aspire to their reference group and will try to be more like them, as suggested by the reference group theory (Merton, 1968). Thus, their assimilation will be affected by their own choice of reference group. This point has also been tested empirically. In particular, compared with mainstream local residents, migrants aspire to a higher degree of assimilation and achieve it by working longer (Chen, 2021).

The second argument is that how migrants think and feel about their assimilation will affect their feelings of belonging, which later affects their assimilation. People’s sense of belonging is highly determined by group memberships, which are formed by similarity (Bersheid &

Reis, 1998). They may feel that they are similar to the local residents with whom they interact and, thus, may want to have a bond with them. However, they may not feel the same if they compare themselves with another group of residents from different classes with whom they hardly interact. Kasnitz *et al.* (2009) argued that migrants would have different feelings compared to different groups. In this case, the sense of belonging may not be built up. Based on Gordon’s theory of multidimensional assimilation, these feelings of belonging can be part of the identificational assimilation stage (Gordon, 1964), so how they feel about assimilation will affect their assimilation. In fact, as Schachter (2016) argues, assimilation is a process in which what he called symbolic belonging – developing a subjective sense of social similarity with one another – is part of the outcome. This argument is also further supported by the idea that assimilation includes a subjective component based on identification with members of the host group (Frazier, 1957). In this case, *which* host group, they choose will affect their identification process and thus affect their assimilation.

Two arguments also support assimilation as an objective process. The first posits that while migration is intentional, assimilation may not be. Both acculturation and assimilation can be unintentional outcomes (Alba, 1999; Gans, 2007). When economic assimilation happens consciously with the goal of higher social mobility, cultural assimilation usually happens unconsciously through interactions (for the first generation) and education (for the second and later generations) (Gordon, 1964). Thus, a part of the assimilation can be entirely independent of whatever migrants do, think, and feel. There is a part of assimilation that occurs without subjective willingness. In the second argument, assimilation can be an objective phenomenon. Even if the process is subjective, part of the outcome can always be objective, making it possible to observe the phenomenon that migrants are becoming more similar to destination residents.

Although assimilation has an objective component, it is misleading and incomplete to rely on selecting the migrant reference group solely from the scholars’ perspective. For example, scholars may observe that migrants are becoming more similar to Group A, but the migrants may pick Group B as their reference group for assimilation and become more similar to Group B, which happens to be similar to Group A. As a result, it may not be fully accurate to argue that migrants are assimilating into Group A. In this example, assimilation into A is objective assimilation (i.e., assimilation that scholars observe), while assimilation to B is subjective assimilation (i.e., assimilation that migrants aim to realize). The potential consequences of omitting

the subjective assimilation process include the bias with the wrong comparison group, and the failure to detect the right comparison group. This raises doubts about whether this seemingly objective phenomenon is truly objective. In other words, the mere observation of migrants who are similar to Group A may not necessarily be interpreted as assimilation. Assimilation should be treated as including both objective and subjective processes, rather than a purely objective process. This is why it is important to account for the migrant-selected reference group and their assimilation into their chosen reference group. This provides a more comprehensive understanding of assimilation and makes it possible to explore how the two paths are intertwined, how factors affect assimilation through different paths, and how assimilation affects outcomes through different paths.

1.2. Hypotheses

The primary goal is to explore assimilation as the combination of subjective and objective paths. Based on the proposed theoretical framework, the choice of the reference group is expected to be subjective or intentional. The following hypothesis tests this idea:

Hypothesis 1: Migrants who intend to become permanent migrants are willing to choose local residents as their reference group.

In addition, because the migrants may consciously assimilate into the reference group while unconsciously assimilating into the mainstream, the latter (i.e., objective process) is likely affected by the assimilation into the reference group (i.e., subjective). Thus, the following hypothesis is proposed:

Hypothesis 2: Economic assimilation into the mainstream is mainly dependent on the economic assimilation into the reference group.

Moreover, by considering the subjective path in assimilation, there could be pathways that affect assimilation into the mainstream by affecting assimilation into the reference group. This gives rise to the following hypothesis:

Hypothesis 3: There are major stratification factors, such as gender and education, that affect economic assimilation into the mainstream through economic assimilation into the reference group.

Finally, after disentangling the subjective path from the objective path, their further impacts can be explored. Since economic assimilation already reflects objective well-being, it is helpful to investigate its impact on subjective well-being as well. According to the literature, assimilation or integration has a positive impact on subjective well-being (Angelini *et al.*, 2015; Herrero &

Gracia, 2011; Neto, 1995; Zheng *et al.*, 2004). Moreover, relative income compared to the reference group is more likely to affect subjective well-being than absolute income (Ferrer-i-Carbonell, 2005; Luttmer, 2005; McBride, 2001). Therefore, while both may promote subjective well-being, it is likely that the subjective path of assimilation will have a stronger impact on subjective well-being than the objective path of assimilation. The corresponding hypothesis is proposed:

Hypothesis 4: Both economic assimilations into the mainstream and into the reference group have positive impacts on subjective well-being, but the impact of economic assimilation on the reference group is stronger.

1.3. China's rural-to-urban migration: assimilation

To test the hypotheses, this paper focuses on China's rural-to-urban migration. It tests whether the concept of assimilation can be applied to China's internal migration, because internal migrants may not face the same barriers due to citizenship and significant cultural differences as international migrants.

In China, rural-to-urban migrants do face strong institutional, economic, cultural, and social barriers once they migrate to the host city, largely due to the household registration system – *Hukou* (Wang & Fan, 2012). This system restricts where people can live and which resources and benefits, they can access. Although it is not as formidable as citizenship, it does put these internal migrants in a similar position as international migrants. Moreover, rural-to-urban migrants share a key similarity with most disadvantaged international migrants – economic and social marginalization (Wong *et al.*, 2007). They usually take on low-skilled occupations that are physically demanding and dangerous (Yang & Guo, 1996). Their occupational outcomes largely depend on whether they can change their hukou status, similar to the case of changing legal status in international migration (Chen *et al.*, 2022). Furthermore, language and dialects differ significantly across regions in China. Finally, there are significant differences between rural and urban culture (Zhong *et al.*, 2016). The applicability of assimilation, integration, separation, and marginalization has been tested in China's social context and has shown that both assimilation and integration are applicable (Xie *et al.*, 2016).

2. Data and methods

2.1. Data sources

This study used the Chinese Household Income Project for the year 2013. The sample was collected using a systematic

sampling method with three layers of east, center, and west, covering 15 provinces, 126 cities, and 234 counties. In total, it includes 18,948 households and 64,777 individuals. The 18,948 households are comprised 7175 urban households, 11,013 rural households, and 760 migrant households, with 2210 migrant samples in total. However, the analyses were restricted to heads of households and their spouses, because the data on subjective well-being were only collected from them. The total eligible sample size is 726. Among these 726 respondents, only 367 provided a clear choice of their reference group who are the total valid sample size of the present study.

The sample selection procedure may raise a concern about external validity. The distribution of the basic characteristics of each sample group (selected and all) was compared (Table A1) to understand the extent that the selected samples can be representative of the entire migrant sample in the data. The distributions are almost identical between the selected samples and all migrant samples, suggesting that the selected samples are likely representative of all migrant samples in the data.

2.2. Reference group and assimilation measures

The survey includes a question about the respondents' reference group: "Generally speaking, when you evaluate your family's economic and life condition, with whom are you comparing mainly?" The responses include "relatives and friends, people in the same community/street/village, people in the same district/county, people in urban areas, people in rural areas, people in the country, and unsure/no answer." It is important to understand these answers based on the Chinese context. People in the same community/street/village are probably refer to the migrants' neighbors, who may include rural-to-urban migrants and local residents in the specific urban areas, where the respondents are living, given their marginalized status (Feng, *et al.*, 2002; Wong, *et al.*, 2007). People in the same district/county are most likely urban residents and may include some migrants in the specific urban areas, where the respondents live. People in urban areas are the "urban residents" only. People in rural areas most likely refer to people in the home province, because migrants were mainly exposed to rural areas in their home province. The inclusion of rural people as one of the reference groups is essential, because it is normal for migrants to form a dual frame of reference – there is a tendency for migrants to evaluate their lives in the host destination by referencing the living conditions in their home location (Waldinger & Lichter, 2003). Within this context, the variable was reconstructed and changed from categorical to ordinal, with 1 = "rural areas," 2 = "people in the same community/street/village," 3 = "people in the same district/county," and

4 = "people in urban areas." Thus, a higher value reflects a stronger willingness to become "urban residents."

Since a clear reference group must be identified to measure assimilation, the other three options were excluded, because it is difficult to identify the reference groups that the migrants are referring to. "Relatives and friends," may refer to "relatives and friends" in the host destination or the home origin. For "people in the country," the reference group is too general to make sense. Finally, for those who choose "unsure/no answer," any reference group can be a potential option, and their reference group is essentially not observed. These ambiguous reference groups were not imputed because, given the significant role of selecting the reference group, the imputation (for example, multiple imputations) on the reference group neither is appropriate nor leads to more accurate results.

This research only focuses on economic assimilation. As mentioned previously, there are other assimilation dimensions and income may be instrumental. Nevertheless, given the limitation of the data and the importance of economic assimilation in the literature, the analysis will center on economic assimilation. Exogenous variables that are highly connected with income were controlled to further alleviate the instrumental component of income in the assimilation. Economic status was measured by yearly income as suggested in the literature (Brown, 2006; Fischer-Neumann, 2014; Kalmijn, 1996; Tienda, 1980). Education is another common measure of assimilation for second-generation migrants (Brown, 2006; Fischer-Neumann, 2014; Jacob & Kalter, 2013; Kalmijn, 1996; Weller, 1974). The information on education in contracting the outcome variable was not used, because the samples are composed of mostly first-generation migrants with education levels set before migration.

The gap or "distance" between migrants and the comparison group was constructed to transform the yearly income into economic assimilation (Chen & Liu, 2018). This generated a variable to measure the gap between the respondent's yearly income and the average income of the reference group. While the average income of the reference group is not provided directly, the data include multilevel geographical information on where each respondent was residing at the time of the survey. Moreover, the data also provide the migrants' province of origin. This information was used to trace and identify people in the migrants' place of origin. For those respondents who selected "people in rural areas" as their reference group, their income was measured by the average income level of the rural residents in their province of origin. For respondents who selected "people in the community/street/village" or "people in the district/county" as their reference group, their income

was measured by the average income level of both urban residents and migrants living in the same street or in the same county. Finally, for respondents who selected “people in urban areas,” the income was measured by the average income level of urban residents (only) living in the same province.

Because “people in urban areas” represent “urban residents,” they were also used to represent the mainstream population in urban areas. Thus, the average income level of the mainstream population in urban areas is the same as that of urban residents living in the same province. All of the 64,777 individuals are included in these averages. While the National Bureau of Statistics of China (NBS) can provide the average income level for the urban population, it cannot provide this information at different levels (for example, same street or same county in an urban area). The assimilation was constructed by measuring the gap between the respondent’s yearly income and these averages. Finally, these assimilation measures were transformed into interval variables with 12 scales to deal with the few outliers.

2.3. Measures of subjective well-being

Subjective well-being is captured by how people experience and evaluate their lives (Stone & Mackie, 2013). The respondents were asked three questions: (1) All things considered; do you feel happy? (2) Which of the following do you think best describes the living standard of your household? and (3) Which of the following do you think best describes the economic condition of your household? The responses to this set of questions are reverse coded so that 1 = “not happy at all” and 5 = “very happy” for the first question, 1 = “does not have enough to live comfortably and cannot afford some basic things” to 3 = “lives very comfortably and can afford extra things” for the second question, and 1 = “cannot deal with some basic economic shocks to your household” to 4 = “can deal with all economic shocks to your household” for the third question.

Two adjustments were made to these three variables. First, for happiness, “not happy at all” and “not very happy” were merged as one category “not happy,” and for capable, “can deal with many economic shocks to your household” and “can deal with all economic shocks to your household” were merged as one category “capable,” because both “not happy at all” and “can deal with all economic shocks to your household” only have a handful of respondents choosing them. Second, for comfort and capable, there is one relatively neutral category, with more than 70% of respondents choosing it. For comfort, it is the option “is basically comfortable but cannot afford many extra things,” and for capable, it is the option “cannot deal with many economic shocks, but can deal with some basic economic

shocks to your household.” Both comfort and capable were adjusted based on the subjective social standing of the respondents (“Compared to the average living standards of households in your city/town/county, do you consider your household’s living standards to be...”) so that both have five scales. In particular, the options that more than 70% of respondents picked were split into two categories depending on whether their living standards are below or above the average.

These three variables then form the latent variable in structural equation modeling. This is also one of the two reasons why this paper used structural equation modeling. A more detailed justification for the structural equation modeling is presented in the Data Analytical Strategies section. Factor analysis was implemented to check for internal consistency. All of the factor loadings are above 0.45 (factor loading = 0.45 for happiness, factor loading = 0.71 for capable, and factor loading = 0.75 for comfort). The internal consistency is also verified with Cronbach’s alpha of 0.70. Although happiness has a lower factor loading, it should be included as it is the most common measurement for subjective well-being (Krueger & Schkade, 2008).

2.4. Control variables

The basic demographic variables include the respondents’ age, gender (male = 1), and education. Other variables include the year of migration and the motivation for permanent migration. The year of migration is not given directly; however, the number of years since the initial migration was estimated using the year the respondent left and the present year. A proxy measured permanent migration motivation: the willingness of migrants to stay in the city permanently if they were granted a local *hukou* quota. In addition, the average income for the mainstream urban population is also controlled for assimilation into the mainstream account for provincial differences.

2.5. Data analysis strategies

Structural equation modeling was applied to explore assimilation as a combination of objective and subjective processes, for two reasons. The first is the ability to estimate the direct, the indirect, and the total effects. This is essential to exploring assimilation as a combination of both objective and subjective processes. The second is that subjective well-being is a latent variable. The working model is shown in Figure 1. The choice of the reference group is expected to directly affect both economic assimilation into the reference group and economic assimilation into the mainstream. Nevertheless, the effect could be weak because, on the one hand, migrants are more motivated to assimilate with urban residents, while, on the other hand, their target is harder to reach. It will, then, depend on the portion

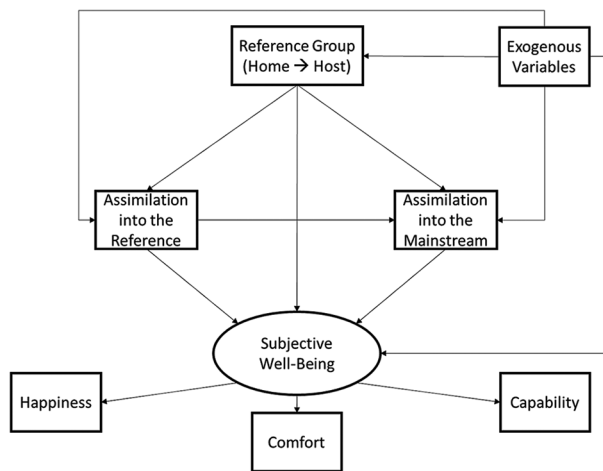


Figure 1. Framework of assimilation of rural-to-urban migration

of direct impact being canceled out by the two forces. In either case, it is important to consider this subjective choice in the process. The subjective path of economic assimilation is reflected by economic assimilation into the reference group, while the objective path of economic assimilation is reflected by economic assimilation into the mainstream. The link between economic assimilation into the reference group and economic assimilation into the mainstream is where the two paths intertwine and show the percentage of objective outcomes explained by the subjective process. The link between the reference group and subjective well-being was included since the reference group is shown to have a strong effect on subjective well-being (Knight & Gunatilaka, 2010). Some of the impacts of exogenous factors on the objective path are reflected in the subjective path. Finally, the theory of subjective well-being was combined and tested. The results show differential impacts on subjective well-being from each path.

The working model for this analysis is tested using the maximum-likelihood estimation for structural equation modeling in Stata 17. However, the multivariate normality assumption should be satisfied to apply the maximum-likelihood estimation. Mardia's multivariate normality tests (skewness and kurtosis) were applied to test the multivariate normality assumption. The results show that the multivariate normality assumption is not satisfied. Therefore, the Satorra–Bentler estimation was applied to adjust for the non-normality (Satorra & Bentler, 1994).

The goodness of fit of models was evaluated using the Satorra–Bentler scaled Chi-square test, the Satorra–Bentler scaled comparative fit index (CFI), and the Satorra–Bentler scaled root mean square error of approximation (RMSEA). A CFI > 0.95 and an RMSEA less than 0.05 are considered a good model fit.

3. Results

The summary statistics of these variables based on the chosen reference group are shown in Table 1. Notably, migrants with different reference groups do differ. In particular, migrants, who selected a reference group closer to the mainstream reference group (i.e., urban people), tended to be younger or male, and had higher education levels, a longer migration duration, and a stronger intention to stay. It was observed that the economic assimilation into the reference group differed across the reference groups (Table 1). However, the economic assimilation into the mainstream is generally higher for those who chose reference groups closer to the mainstream reference group. The patterns in subjective well-being measures are less clear.

The results with unstandardized coefficients from structural equation modeling are shown in Table 2, and the results with standardized coefficients are shown in Table 3. While both standardized and unstandardized coefficients are shown, because they present different and mutually exclusive information, this research focuses on the unstandardized coefficients, given its purpose. Specifically, the goal is not to compare the size of the effects, but mostly to test whether the effects are significant or not. The model provides a good fit for the data (Chi-square test, $P = 0.188$; CFI = 0.986; RMSEA = 0.026). However, alternative models may exist. These may include 1) the exclusion of the link between the subjective and objective path and 2) the traditional model, in which neither the reference group nor the subjective path is considered.

A comparison of the three models on the basis of the goodness of fit resulted in the following outcomes, as shown in Table 4: proposed model (Chi-square test, $P = 0.188$; CFI = 0.986; RMSEA = 0.026); alternative model 1 (Chi-square test, $P = 0.000$; CFI = 0.739; RMSEA = 0.111); and alternative model 2 (Chi-square test, $P = 0.000$; CFI = 0.736; RMSEA = 0.105). These results suggest that the proposed model is the best fit for these data. This also indicates that it is important to account for both subjective and objective paths in the assimilation process since the proposed model, based on the theoretical framework, fits much better than the traditional assimilation models.

The analysis of the proposed structural equation modeling results is described below. The coefficients for age ($\beta_{d/t} = -0.202$), education ($\beta_{d/t} = 0.114$), and intention to permanently migrate ($\beta_{d/t} = 0.290$) on the reference group indicate that the reference group choice is highly subjective and intentional. This is because the intention to permanently migrate has the strongest impact on choosing a reference group that is closer to the mainstream urban residents. These results support Hypothesis 1 that migrants

Table 1. Sample characteristics by reference group

Variable	Rural	Same community	Same district	Urban
Age				
17 – 40	57%	61%	70%	70%
40 – 65	41%	37%	28%	29%
65+	2%	2%	2%	1%
Gender				
Male	51%	48%	47%	47%
Female	49%	52%	53%	53%
Education				
Elementary or below	36%	30%	26%	25%
Middle school	44%	48%	35%	45%
High school	10%	12%	21%	11%
College or above	10%	10%	18%	20%
Years of Migration				
0 – 5 years	70%	73%	66%	64%
5 – 10 years	10%	10%	11%	15%
10 – 20 years	15%	11%	21%	16%
20+years	5%	7%	2%	5%
Intention to stay				
No	85%	77%	80%	68%
Yes	15%	23%	20%	32%
Economic Assimilation				
Assimilation into the reference group	0.64	-2.12	0.16	0.25
Assimilation into the mainstream	-0.12	-0.13	0.34	0.25
Subjective well-being				
Happiness	2.56	2.74	2.50	2.47
Capable	2.74	3.02	2.91	2.86
Comfort	2.48	2.71	2.40	2.54
N	86	171	61	49

Note: Few missing data were replaced using the mean at the closest geographical unit.

who intend to become permanent migrants are willing to choose local residents as their reference group. While the intention to permanently migrate may be affected by assimilation into the mainstream instead of the other way around, this potential limitation may not undermine the conclusion. The selected reference group is intentional as long as the positive correlation between the intention to permanently migrate and the reference group choice is confirmed. For example, suppose those with a stronger intention to settle are more likely to choose mainstream urban residents as their reference group. This strongly indicates that the reference group choice itself is also

intentional. In addition, the coefficient on age shows that older migrants (either temporary or permanent) may be more likely to compare themselves with people from the place of origin rather than residents in the host destination. The coefficient on education suggests that the selected reference group is also based on capability and inspiration. That is, migrants with more education may be more capable and inspired to integrate into the city.

This focus on factors that affect economic assimilation into the mainstream and especially the link between the objective and the subjective path makes it clear that economic assimilation into the mainstream is highly determined by economic assimilation into the reference group ($\beta_{dt} = 0.350$). This finding supports Hypothesis 2 that economic assimilation into the mainstream is mainly dependent on the economic assimilation into the reference group. In addition, while not many factors affect economic assimilation into the mainstream through the economic assimilation into the reference group (i.e., affecting the objective path through the subjective path), the indirect coefficient for gender ($\beta_i = 0.258$) on the mainstream economic assimilation suggests that the subjective path should be taken into account, not only because it directly affects the objective path but also because other factors may affect the objective path through the subjective path. This finding supports Hypothesis 3 that a major stratification factor like gender can affect the economic assimilation into the mainstream through economic assimilation into the reference group. As shown in Table 2, around 30% of the total impact may be omitted if the subjective path is not considered. This two-path approach also shows that men are more inspired to assimilate with the people to whom they compare themselves and may be more capable of assimilating into the mainstream.

Finally, an examination of the factors affecting subjective well-being shows that, economic assimilation into the mainstream ($\beta_{dt} = 0.063$) and economic assimilation into the reference group ($\beta_i = 0.022$), both affect subjective well-being, but in different ways. It is helpful to look at the standardized coefficients to understand better how their impacts differ in size. The standardized coefficients show that the direct or the total effect of economic assimilation into the mainstream is 0.294, while the indirect effect of economic assimilation into the reference group is 0.138. Economic assimilation into the mainstream affects it directly, while economic assimilation into the reference group produces an indirect effect. This finding rejects Hypothesis 4 and indicates that subjective well-being is affected by economic assimilation into the mainstream. This is probably because there are positive externalities accompanied by a higher level of economic assimilation into the mainstream. While testing this hypothesis is beyond the

Table 2. Direct, indirect, and total effects: results of sem (unstandardized)

	Reference group	Assimilation into the reference			Assimilation into the mainstream			Subjective Well-being		
	Direct/Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Exogenous variables										
Age	-0.202*	-0.002	0.007	0.005	-0.222	-0.006	-0.228	0.007	-0.009	0.002
Gender (male = 1)	0.055	0.735***	-0.002	0.733***	0.586***	0.258***	0.844***	-0.058	0.041**	-0.017
Education	0.114*	0.224	-0.004	0.220	0.117	0.081	0.199*	0.006	0.007	0.013
Years of migration	-0.015	-0.003	0.001	-0.002	0.048	-0.002	0.046	0.008	0.004	0.012
Intention to stay	0.290*	-	-0.010	-0.010	-0.245	0.007	-0.238	0.141**	-0.022	0.119*
Mainstream income	-	-	-	-	-0.093***	-	-0.093***	-	-0.006**	-0.006**
Mediating variables										
Reference group	-	-0.033	-	-0.033	0.036	-0.012	0.024	-0.025	0.002	-0.023
Assimilation into the reference group	-	-	-	-	0.350***	-	0.350***	-0.014	0.022***	0.008
Assimilation into the mainstream	-	-	-	-	-	-	-	0.063***	-	0.063***
Model fit										
Chi-square test	0.188									
RMSEA	0.026									
CFI	0.986									
N	367									

Note: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. Standard errors, P values, Model Fit statistics are all based on Satorra–Bentler adjustments.

Table 3. Direct, indirect, and total effects: Results of sem (standardized)

	Reference Group	Assimilation into the reference group			Assimilation into the mainstream			Subjective well-being		
	Direct/Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Exogenous variables										
Age	-0.114*	-0.001	0.002	0.001	-0.074	-0.002	-0.076	0.012	-0.015	-0.003
Gender (male = 1)	0.029	0.173***	-0.001	0.172***	0.184***	0.081***	0.265***	-0.086	0.061**	-0.025
Education	0.110*	0.096	-0.002	0.094	0.067	0.046	0.113*	0.015	0.017	0.032
Years of migration	-0.016	-0.002	0.001	-0.001	0.030	-0.001	0.029	0.024	0.010	0.034
Intention to stay	0.137*	-	-0.002	-0.002	-0.068	0.002	-0.066	0.186**	-0.029	0.157*
Mainstream income	-	-	-	-	-0.177***	-	-0.177***	-	-0.052**	-0.052**
Mediating variables										
Reference group	-	-0.015	-	-0.015	0.021	-0.007	0.014	-0.071	0.006	0.065
Assimilation into the reference group	-	-	-	-	0.468***	-	0.468***	-0.086	0.138***	0.052
Assimilation into the mainstream	-	-	-	-	-	-	-	0.294***	-	0.294***
Model fit										
Chi-square test	0.188									
RMSEA	0.026									
CFI	0.986									
N	367									

Note: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. Standard errors, P -values, model fit statistics are all based on Satorra–Bentler adjustments

Table 4. Goodness of fit by model

	Main model	Alternative Model 1 (Link between subjective and objective path excluded)	Alternative Model 2 (Neither reference group nor subjective path included)
Model fit			
Chi-square test (<i>P</i> -value)	0.188	0.000	0.000
RMSEA	0.026	0.111	0.105
CFI	0.986	0.739	0.736
N		367	

Note: **P*<0.05; ***P*<0.01; ****P*<0.001. Standard errors, *P*-values, Model Fit statistics are all based on Satorra–Bentler adjustments.

scope of this paper, this argument, as an example, shows how the inclusion of the two-path assimilation model can benefit the study of assimilation in general.

4. Discussion

Using a dataset of rural-to-urban migrants in China, this study explored whether assimilation is a combination of both objective and subjective processes, with four specific hypotheses (1) migrants who intend to become permanent migrants are willing to choose local residents as their reference group, (2) economic assimilation into the mainstream is mainly dependent on the economic assimilation into the reference group, (3) there are major stratification factors that affect economic assimilation into the mainstream through economic assimilation into the reference group, and (4) both economic assimilations into the mainstream and into the reference group have positive impacts on subjective well-being, but the impact of economic assimilation on the reference group is stronger. Overall, our empirical evidence supports Hypotheses 1 to 3, whereas it rejects Hypothesis 4.

Specifically, this study shows that assimilation is not purely an objective process, as the major assimilation theories have implicitly assumed (Gans, 1973; Gordon, 1964; Portes & Zhou, 1993). From the researchers' perspective, it is important not to simply assign a reference group to a group of migrants and explore whether they are assimilated. Nevertheless, although such methodology can provide insight on objective assimilation outcomes – whether migrants are truly assimilated into the reference group selected by the researchers, this approach will blur the process of assimilation. As shown in this paper, the objective assimilation outcomes depend on the subjective assimilation process – migrants assimilating into their chosen reference group. Migrants' aspiration

and willingness, stemming from their intentional choice of reference group, could be the main force driving their outcomes (Chen, 2021; Chen & Fan, 2022; Zhou *et al.*, 2008). However, this process could be overlooked and possibly even omitted if the subjective assimilation process is not considered.

Our results of the effects of subjective and objective assimilation on subjective well-being also suggest meaningful findings in how the migrants' subjective well-being is formed. The literature suggests that the migrants' subjective well-being is highly shaped by their relative status (for example, relative income), which is affected by their choice of reference group (Knight & Gunatilaka, 2010). This paper shows that the migrants' subjective well-being is mainly influenced by their relative status compared to the mainstream host residents (in this case, urban residents), despite their relative status compared to their chosen reference group. Therefore, regardless of whether or not the migrants choose the mainstream host residents as their reference group, their subjective well-being will be affected due to their observations of or interactions with the mainstream host residents.

Finally, the empirical findings focus on economic assimilation, which may be the most important dimension of assimilation. The subjective and objective processes may differ for other dimensions of assimilation. Nonetheless, this does not mean that the value of accounting for both subjective and objective processes is only restricted to economic assimilation. This theoretical framework may apply to most, if not all, of the assimilation dimensions. For example, with cultural assimilation (acculturation), we may expect a stronger subjective process. We have learned that intrinsic acculturation (i.e., acculturation in values) could be hard for rural-to-urban migrants (Chen & Liu, 2018). Nonetheless, this could be largely due to their chosen reference group. In sum, different conclusions could have been reached by accounting for the subjective acculturation process. To fully understand the assimilation process, researchers must not simply assign a reference group to a group of migrants and explore whether they are assimilated. Assimilation is a mixture of objective and subjective processes.

When interpreting our results, following caveats should be taken into account. First and foremost, there are about half of the heads of the sample households and their spouse who did not answer the question on subjective well-being, which may bias our results. Nevertheless, we expected such biases might not be substantial in that their profiles in other key study variables are more or less the same as those who answered the question. Second, relatedly, even if all samples answered the subjective well-

being question, the sample size is still relatively small. Future relatively large sample surveys and studies are clearly warranted to verify our results. Third, due to the data limitation, characteristics of local destinations, which could shape migrants' reference group choice, are not accounted in the analyses. These may include the welfare system in the destination, neighborhood conditions in the destination, and local attitudes toward migrants. Fourth, the choice of reference group may change over time. Because this research is based on cross-sectional data, it cannot account for this dynamism. If panel data with reference group choice of migrants are available, future studies can rely on such data and explore factors that affect the change of reference group choice. That is, how migrants' choice of reference group may change and in what circumstances, they will change their choice of the reference group.

Despite of these limitations, our findings can provide some important policy implications to facilitate migrants' assimilation. By differentiating between subjective and objective paths, policymakers can efficiently target each path separately. For example, they may come up with policies that inspire migrants to assimilate into the reference group (or aspiring migrants may pick the mainstream as their reference group) and thus the mainstream through the subjective path, or come up with policies that can elevate the migrants' conditions and expand their ability to assimilate into the mainstream. This is not possible without implementing the two-path approach, given how specifically they intertwine. While the migrants' conditions are elevated, they may be more inspired to assimilate. The two-path approach can identify the complete structure, and an efficient policy can follow.

For future research, it is important to apply this two-path approach to different contexts to (1) better understand, test, and improve the model in general and (2) further explore the process of assimilation with the two-dimensional lens. For example, as shown, the role of gender is significant in the economic assimilation of rural-to-urban migrants in China. Therefore, further investigation is needed to fully understand gender differences in terms of assimilation outcomes. If men are more inspired to assimilate into the reference group and more capable of assimilating into the mainstream, what could be the reasons? Is it due to self-esteem and fewer occupational barriers or something else? Future research should also explore the different dimensions of assimilation. While this paper focuses on economic assimilation, objective and subjective processes could differ for other dimensions, such as cultural assimilation (or acculturation). Which of the two processes is more important for the other dimensions?

How are the two processes related in other dimensions? These questions will be important to explore and will be hard to answer without fully applying the lens of this dual framework to different dimensions of assimilation.

5. Conclusions

In sum, this research shows that assimilation is not purely an objective process, as the major assimilation theories have implicitly assumed and highlight that assimilation studies can generally benefit by allowing migrants to choose their own reference group and then including the subjective path along with the objective path in the following ways: (1) understanding assimilation as a two-force driven process which includes both objective and subjective paths; (2) identifying major stratification factors that not only directly affect objective assimilation but also indirectly affect objective assimilation through subjective assimilation; and (3) separating the impacts of assimilation on migrants outcomes such as subjective well-being into subjective and objective components.

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The data that support the findings of this study are openly available in "China Institute for Income Distribution" at <http://ciidbnu.org/chip/chips.asp?year=2013>.

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Appendix

Table A1. Sample selection representativeness

Variable	All migrant samples	Migrant sample used
Age		
17 – 40	64%	63%
40 – 65	34%	35%
65+	2%	2%
Gender		
Male	48%	49%
Female	52%	51%
Education		
Elementary or below	29%	30%
Middle School	43%	45%
High School	14%	12%
College or above	14%	13%
Years of Migration		
0 – 5 years	67%	70%
5 – 10 years	12%	11%
10 – 20 years	16%	14%
20+years	5%	5%
Intention to stay		
No	75%	78%
Yes	25%	22%
N	2210	367

Note: Few missing data were replaced using the mean at the closest geographical unit

RESEARCH ARTICLE

Residential inequalities in child mortality in
Ethiopia: Multilevel and decomposition analysesNegussie Shiferaw Tessema*, Chalachew Getahun Desta, Nigatu Regassa Geda,
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Abstract

Ethiopia is among the five countries which account for half of the global under-five deaths, with the under-five mortality rate of 67 deaths/1000 live births in 2016. Ethiopia had significant inequalities in child mortality between rural and urban areas where the risk of child mortality is largely higher in rural than urban areas. Inequalities in the distribution of factors influencing child mortality need to explain the gap between and within urban-rural areas. The study used the risk of child mortality as an outcome variable. Multilevel logistic regression was used as a standard model for assessing the effect of socioeconomic and contextual factors on child mortality. Furthermore, the Blinder-Oaxaca decomposition technique was used to explain the urban-rural, intra-rural, and intra-urban inequalities in child mortality. The birth order and sanitation type seem to be the most important explanatory factors, followed by wealth status in explaining the rural-urban inequality of 39 deaths/1000 children. Mean proportion indicates that there would be 47 deaths/1000 children for urban poor and 21 deaths/1000 children for urban non-poor, resulting in 26 deaths/1000 children change in urban poor when applying the urban non-poor coefficient and characteristics to urban poor behavior. The findings showed that some residential inequalities in child mortality occur at a level that could be addressed by targeting children, households, and some occurs at a community level that could be addressed by targeting regions. Therefore, any residential sensitive and specific interventions should consider child's and household's characteristics, and geographical location.

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Keywords: Child mortality; Inequality; Residence; Intra-rural; Intra-urban; Rural-urban; Ethiopia

1. Introduction

Inequality in child mortality is a global priority. Socioeconomic inequality in child mortality has been a concern of the United Nations since the adoption of the World Population Plan of Action in 1974 and its implementation agreed on at the International Conference on Population in 1984 (United Nations, 1991). The 1984 International Conference on Population strongly urged all governments, regardless of the mortality levels of their population to reduce mortality levels and socioeconomic and geographical differentials in their countries and to improve health among all population groups, especially among those groups where the mortality levels are the highest (United Nations.

Department of International Economic and Social Affairs, 1985). The 1994 International Conference on Population and Development also urged governments to reduce child mortality inequalities between and within developed and developing countries by promoting child health and survival, and eliminating preventable mortality among children (United Nations, 1995). Moreover, the United Nations had set a Millennium Development Goal (MDG4) to reduce the child mortality rate by two-thirds between 1990 and 2015 (UNICEF, 2015). Although MDG4 was targeted to reduce the under-five mortality rate (U5MR) by 67%, the target was not achieved and reduced by 53% reduction reached globally (United Nations Inter-agency Group for Child Mortality Estimation [UN IGME], 2020), from 91 deaths/1000 live births in 1990 to 43 deaths/1000 live births in 2015 (UNDP, 2016). Apart from the low reduction, there are inequalities across regions and countries.

Due to different efforts exerted by governments and development partners, the number of under-five deaths dropped from 12.5 million in 1990 to 5.2 million in 2019 globally. As a result, 14,000 children died before age 5 every day in 2019 compared to 34,000 in 1990 and 27,000 in 2000 (United Nations Inter-agency Group for Child Mortality Estimation [UN IGME], 2020). Despite the progress in child mortality, the 2019 figure is still large and alarming to the Sustainable Development Goal (SDG) targets and efforts to eliminate preventable child deaths between birth and age 5. In this regard, the SDG aims to reduce the under-five mortality rate to at least as low as 25 deaths/1000 live births by 2030 (WHO, 2015). However, Sub-Saharan Africa (SSA) remains the region with the highest under-five mortality rate in the world (United Nations Inter-agency Group for Child Mortality Estimation [UN IGME], 2020). In 2019, the region had an average under-five mortality rate of 76 deaths/1000 live births, which was 20 times higher than that of the region of Australia and New Zealand (United Nations Inter-agency Group for Child Mortality Estimation [UN IGME], 2020). Moreover, the SSA countries had high child mortality rates with significant urban-rural differences (Yaya *et al.*, 2019).

Ethiopia is one of the Sub-Saharan Africa countries with high burden of child mortality, ranking third in Africa (Dheresa *et al.*, 2022). Ethiopia was among the five countries which account for half of the global under-five deaths in 2019 (UN IGME, 2020). The child mortality was declined by 76% from 96 deaths/1000 live children in 1990 to 23/1000 live children in 2015 (Yohannes *et al.*, 2017). Ethiopia had significant inequalities in child mortality between rural and urban areas where the risk of child mortality is largely higher in rural than urban areas (Gebresilassie *et al.*, 2021). The overwhelming urban-rural

inequality in child mortality can be explained by the individual, household, and community-level factors. The different approaches employed by various governments may make community-level factors influence under-five mortality differently. Therefore, this study attempts to answer the research question “*What are the key factors that explain the rural-urban, intra-rural, and intra-urban gaps in child mortality in Ethiopia?*” Answering this question is instrumental to explain the inequalities in child mortality between and within urban-rural areas. Thus, the objective of this paper was to examine the key factors that explain both between and within rural-urban inequalities in child mortality in Ethiopia.

1.2. Theoretical framework

This study is based on the two theoretical frameworks formulated to identify determinant factors and their relationships on child survival (Mosley & Chen, 1984; Schultz, 1984). Schultz (1984) is one of the pioneering researchers who developed the theoretical framework on child survival. Schultz’s theoretical framework focused on the structural relationship between child survival and the individual’s behavioral variables along with both observed socioeconomic (such as social, economic, community, and religious) and biomedical (breastfeeding patterns and hygiene), and unobserved biological factors. In Schultz’s framework, biomedical factors are modeled as having direct effect on child mortality, while socioeconomic factors affect child survival indirectly as they work through the biomedical factors (Schultz, 1984). Likewise, Mosley and Chen (1984) classified the determinants of child survival as socioeconomic (such as social, economic, community, and regional determinants) and biomedical factors (such as maternal, environmental, nutrition, injuries, and personal illness). In Mosley and Chen’s framework, socioeconomic factors are proposed to indirectly affect child survival as they pass through the proximate factors while proximate determinants affect child mortality directly (Mosley & Chen, 1984). Mosley and Chen categorized a set of proximate determinants into maternal factors (age, birth order, and birth intervals); environmental hygiene factors (source of water and type of sanitation); nutrient deficiency (calories, protein, and micronutrient deficiency); injury (related to physical, burn, and poisoning injury); and personal illness control (immunization, bed net, etc.). In addition, Mosley and Chen also classified the socioeconomic determinants of child survival into individual-, household-, and community-level variables (Mosley & Chen, 1984).

Several studies have applied hierarchical models that are rooted in Mosley and Chen (1984) to analyze how micro (i.e., individual and household level) and macro/contextual (community level) factors influence

child mortality at different levels. For example, in South Asia, Zakaria *et al.* (2019) examined the effects of socioeconomic, demographic, and environmental variables on child mortality, and found that urbanization reduce child mortality. In South-Central Asia, Dendup *et al.* (2020) investigated the factors associated with child mortality in rural and urban Bhutan and the roles of the factors in explaining child mortality disparities using the 2012 National Health Survey. Logistic regression models were applied to investigate the determinants and the analysis revealed that children of younger mothers born in households without safe sanitation and electricity had increased odds of childhood mortality in the rural areas of the country. Larger number of births and smaller household sizes are associated with an increased odd of mortality irrespective of rural-urban residence (Dendup *et al.*, 2020).

In Bangladesh, Rahman & Alam (2021) examined the role of socioeconomic indicators on child mortality and found that urbanization had a positive effect on child mortality; whereas maternal education hurt child mortality rate. Noor & Uddin (2021) also found out that mother's education, higher birth order, and size of child at birth had a significant effect on child mortality in Bangladesh. Jayathilaka *et al.* (2021) explored socioeconomic and demographic factors associated with child mortality in Sri Lanka, and the improved source of drinking water had a lower risk of child mortality. In Afghanistan, place of residence, wealth index, age at first birth, and household size were found to be key determinants of child mortality (Shonazarova & Eshchanov, 2020). In Ghana, maternal age, mother's education, household wealth index, place of delivery, and birth order are found to be the most significant socioeconomic determinants that influence child mortality in rural-urban Ghana (Sarkodie, 2021).

In Ethiopia, Zewudie *et al.* (2020) examined determinants of child mortality and found that place of residence, mother's educational level, religion, breastfeeding status, sex of the child, birth order, and household size were found to be significant predictors of child mortality. Likewise, Fenta and Fenta (2020) in their study examined that individual-level factors, including maternal educational background and age of the mother at first birth, are associated with the small number of child death. On the other hand, higher birth order is associated with a higher number of child death (Fenta & Fenta, 2020).

More specifically, a few recent studies explored factors that determine child mortality including rural-urban inequalities (Adeyinka *et al.*, 2020; Dendup *et al.*, 2020; Gebresilassie *et al.*, 2021; Yaya *et al.*, 2019). In Sub-Saharan Africa, Yaya *et al.* (2019) examined the rural-urban gap in

child mortality using the Demographic and Health Survey (DHS) in 35 SSA countries. The data were analyzed using Oaxaca-Blinder decomposition to depict urban-rural gap in the factors of under-five mortality. The results of the decomposition analysis revealed that the urban-rural differentials were due to demographic, socioeconomic, and proximate factors. Yaya *et al.* (2019) also explored that very young age at first birth, children of higher birth order, and those with small size at birth had a higher risk of child mortality. Children from the richest households and births from educated women had a lower risk of under-five mortality. Maternal age, maternal education, wealth index, total children ever born, and size of child at birth had contributed toward explaining urban-rural gap in child mortality (Yaya *et al.*, 2019). In Nigeria, a study conducted by Adeyinka *et al.* (2020) highlighted that children residing in different communities are likely to have different mortality risks. The study employed a multilevel multinomial logistic regression analysis method to identify the social determinants of age-specific childhood mortalities and to estimate the within- and between-community variations of mortality among under-five children. The multilevel analysis revealed that maternal education and household wealth index accounted for high variation in childhood mortalities across communities (Adeyinka *et al.*, 2020).

Despite the widely acknowledged rural-urban differential in child mortality, not all urban or all rural populations are homogenous. Living in socioeconomically disadvantaged urban areas might be associated with increased child mortality risks, as living in resource-rich and environmentally healthy rural areas might be associated with a lower risk of child mortality. In this regard, a few studies documented intra-urban differentials in child mortality in the developing countries (Antai & Moradi, 2010; Das, 2021; Touré *et al.*, 2020). For example, a study in Nigeria found that urban-area disadvantage was independently associated with the risk of child death even after controlling for individual child- and mother-level demographic and socioeconomic characteristics (Antai & Moradi, 2010). A study in Ghana also examined intra-urban spatial variation in child mortality rates and pointed out that non-traditional toilet types and water supply sources are associated with high rates of under-five mortality rates (Touré *et al.*, 2020). In India, Das (2021) showed that poverty, low female literacy, and unsafe delivery in the community are associated with a higher risk of child mortality in urban areas. The economic inequalities in child mortality are higher in urban poor than in rural but inequality is widened in urban poor in India (Das, 2021).

In Ethiopia, Gebresilassie *et al.* (2021) examined the factors behind the rural-urban differentials in under-five mortality using Fairlie's decomposition technique to analyze data from the three-round of the Ethiopian DHSs. The child size at birth, mother's education, and household size contributed to narrowing the disparity in child mortality rate (Gebresilassie *et al.*, 2021).

To sum up, although the previous studies (Dendup *et al.*, 2020; Ekholuenetale *et al.*, 2020; Yaya *et al.*, 2019), including the study conducted in Ethiopia (Gebresilassie *et al.*, 2021), have examined the rural-urban inequalities in child mortality risks, the determinants contributing to intra-rural and intra-urban inequalities in child mortality were not covered. On the other hand, a few studies (Antai & Moradi, 2010; Das, 2021; Touré *et al.*, 2020) assessed only intra-urban differentials in child mortality in the developing countries. However, the determinants contributing to intra-rural and intra-urban inequalities in child mortality have not been previously well documented in Ethiopia. Therefore, this paper seeks to contribute evidence on the major factors explaining the rural-urban inequalities in child mortality, including the intra-rural and intra-urban gap in Ethiopia.

2. Data and methods

This section highlights the data sources, study variables, and statistical methods used for the present study. Study context and design and data sources are presented under data source subsection. Description of study variables is explained under study variable subsection while the overall data diagnosis and analysis techniques are discussed in statistical methods subsection.

2.1. Data sources

We used data from the 2016 Ethiopia DHS (EDHS) which was collected from January 18, 2016, to June 27, 2016 (Central Statistical Agency [CSA] [Ethiopia] and ICF, 2016). The 2016 EDHS is a large-scale and cross-sectional survey conducted in a nationally representative sample of households from all regions of Ethiopia. Ethiopia is the second most populous country in Africa, after Nigeria and characterized by enormous diversity (FMOH-FDRE, 2016). The EDHS 2016 data were collected based on a two-stage stratified cluster sampling technique. In the first stage, 645 clusters (202 urban and 443 rural) were selected. In the second stage, a fixed number of 28 households per cluster were selected to gather the socioeconomic and health status of children below the age of 5 and their mothers of reproductive ages (15 – 49 years). The 2016 EDHS used standardized questionnaires to collect detailed information on birth histories, health, nutrition, and related information on mothers and children. Accordingly, a total

of 10,641 under-five children born during the past 5 years preceding the survey date were included in the children's database. Of these, 8162 children (12 – 59 months of age) data were extracted from the children's dataset for this study.

2.2. Study variables

The outcome variable of the present study was the risk of child mortality. The outcome variable was measured in EDHS as the probability of dying between the exact age of 1 and the 5th birthday, and assigned a value of 1 if the child died between 12 and 59 months, and 0 if the child was alive at least until the age of 59 months. To explore the effects of individual, household, and community level characteristics on child mortality and to examine their influences and relationships between rural-urban effects, the explanatory variables were grouped into individual, household, and community-level factors.

The individual-level factors included in this paper are as follows: Sex of child; child size at birth as reported subjectively by mother; breastfeeding initiation; birth order; place of delivery; maternal education; maternal age at first birth; number of children ever born; and mother's religion. Please refer to the detailed categories in Table 1.

The household-level factors comprise of sex of household head; household size; source of drinking water; type of toilet facility; type of cooking fuel; and combined wealth status. In 2016 EDHS dataset, the urban/rural asset scores are standardized in relation to a standard normal distribution with a mean of zero and a standard deviation of one. Finally, the standardized urban/rural wealth index scores of the poorest, poorer, middle, richer, and richest levels are further regrouped into poor and non-poor for the analysis of intra-urban and intra-rural inequalities in child mortality.

The community-level factors consist of administrative regions and place of residence (urban vs. rural). For the sake of simplicity, the 11 administrative regions of Ethiopia are categorized into three regional categories: Emerging regions (Afar, Somali, Benishangul-Gumuz, and Gambella), developed regions (Amhara, Oromia, Harari, Southern Nations Nationalities, and People's Region [SNNPR], and Tigray) and fully urban (Addis Ababa and Dire Dawa City Administrations). Here, it is good to note that the emerging regions are drought-affected areas, pastoralists, and marginalized in terms of basic infrastructure as well as least developed as compared to developed and urban regional categories (Bareke *et al.*, 2022). Moreover, to analyze the child mortality inequality gaps between and within rural-urban, the place of residence was assigned as a dummy variable.

2.3. Statistical methods

We used STATA version 15.1 for statistical data processing and analysis. We checked missing values, and there were no missing values for the outcome variable, but children with unknown birth places and children from not de jure residents were excluded from the analysis, which accounted for 3.2% of the cases. In this study, de jure residents refer to those residents who are usually living in a given area and who were counted as the resident of that area. We used a correlation matrix to test multicollinearity effect of the explanatory variables using a cutoff of 0.6 known to cause concern in multicollinearity (Senaviratna & Cooray, 2019). Due to high and strong collinearity with a place of residence ($r = 0.8077$) and sex of household head ($r = 0.6236$), the total children ever born variable was removed from the model. Place of residence cannot be removed since it is the key identifier in investigating residential inequality in child mortality. After removal of the total number of children ever born, an absolute correlation coefficient of <0.6 was observed among predictors indicating the absence of multicollinearity. Although the variable 'total children ever born' was removed from the model, the birth order was included in the model to explore the relative effects of fertility on child mortality.

Considering the hierarchical nature of the 2016 EDHS dataset into account, we used multilevel (i.e., three level: Community, household, and individual level) analysis technique to get unbiased estimates of standard errors and enable the modeling of between-level interactions by treating every effect at the appropriate level. A multilevel modeling explicitly accounts for the clustering of the units of analysis. Besides, the multilevel modeling provides a unified treatment for effects at individual, household, and community levels. Since the outcome variable is binary, a multilevel logistic regression (Balluerka *et al.*, 2010; Gelman & Hill, 2010) was used as a standard model for assessing the effect of socioeconomic and contextual factors on child mortality in this study. Accordingly, four models were fitted, including null model. The null model was fitted to determine whether the use of multilevel modeling was appropriate in the analysis. Further, all models were checked through interclass correlation (ICC) and criteria information tests (AIC and BIC) and their values were used to select the best model fitted for multilevel analysis. We used likelihood ratio (LR) test to test statistically significant difference between two models based on the ratio of their likelihoods.

We also used decomposition analysis to quantify the contribution of observed and unobserved heterogeneity at the individual, household, and community levels. The decomposition analysis helps understand variance estimates whether regressors are random or fixed, which

is based on multiplying regression coefficients using regressors. And hence, to explain the urban-rural, intra-urban, and intra-rural inequalities in child mortality, we used the Blinder-Oaxaca decomposition technique for a non-linear variable. This technique allows for quantifying the gap between the advantaged and the disadvantaged groups (Ameyaw *et al.*, 2021; Bazen *et al.*, 2016; Fairlie, 2005; Jann, 2008; Bado & Appunni, 2015; Sinning *et al.*, 2008; Yaya *et al.*, 2019).

3. Results

3.1. Background characteristics of the study participants

Table 1 shows the background characteristics of the study population. Table 1 shows that 45.47% of children were born to mothers residing in emerging regions and almost the same proportion was born to mothers in developed regions, and 81.8% of children were born in rural areas. The majority (78.56%) of respondent women were from male-headed households; 83.09% of children were born to households that had unimproved sanitation facilities; only 5.28% of children were born to households that had clean cooking fuel; and 55.49% of households had six or more members. Table 1 also depicts that more than half (54.8%) of children were born to households grouped with poor wealth status; 45.5% of children were born to households that had improved sources of drinking water. Most (70.7%) children were born at home; a slightly higher proportion (52.1%) of children were female. Table 1 also illustrates that 19.7%, 43.9%, and 36.4% of children were born in the 1st, the 2nd – 4th birth order, and 5th and above birth order, respectively. More than 80% of mothers had initiated breastfeeding with their kids immediately after birth. About 6% of mothers had given birth before entering the age of 18 years. More than 66% of children were born to uneducated mothers. Nearly 29% of children were born to mothers of Orthodox religion and 51.2% were born to mothers of Muslim religion followers (Table 1).

3.2. Results from multilevel analyses

Table 2 presents results from the multilevel regression analysis. Here, it is crucial to understand that all individual and household level factors are nested within the community (place of residence), hence, it needs to explain the residential inequalities using multilevel analysis. With this understanding, four multilevel models were fitted using only variables with $P < 0.2$ (Heinze & Dunkler, 2017) from the bivariate analysis (not presented in this paper). The overall multilevel analysis was conducted with random intercept (only) model for both community and household levels. First, the null model (Model 0, i.e., a model without explanatory variables) was fitted and showed statistically

Table 1. Background characteristics of study participants in Ethiopia, 2016

Variable (N=8,162)	Category	N	%
Regional category	Emerging	3,703	45.47
	Developed	3,706	45.41
	Urban	753	9.23
Place of residence	Rural	6,680	81.8
	Urban	1,482	18.2
Sex of household head	Male	6,412	78.56
	Female	1,750	21.44
Household size	<6	3,633	44.51
	6+	4,529	55.49
Combined wealth status	Poor	4,473	54.8
	Non-poor	3,689	45.2
Source of drinking water	Improved	3,550	45.5
	Unimproved	4,612	56.5
Type of sanitation facility	Unimproved	6,782	83.09
	Improved	1,380	16.91
Type of cooking fuel	Solid fuel	7,731	94.72
	Clean fuel	431	5.28
Place of birth	Home	5,770	70.7
	Health facility	2,392	29.3
Sex of child	Male	3,910	47.9
	Female	4,252	52.1
Breastfeeding initiation (N=6911)	Delayed	1,331	19.26
	Immediately	5,580	80.74
Size of a child at birth	Large	2,592	31.8
	Average	3,403	41.7
	Small	2,167	26.5
Birth order	First	1,609	19.7
	2 – 4	3,579	43.9
	5 th and above	2,974	36.4
Age at child birth	<18	459	5.62
	18 and above	7,703	94.38
Maternal education	No education	5,399	66.2
	Primary or above	2,763	33.8
Total children ever born	1 – 4	4,665	57.16
	5 and above	3,497	42.84
Religion	Orthodox	2,342	28.7
	Muslim	4,181	51.2
	Others	1,639	20.1

significant variation in child mortality across individual and household levels by place of residence justifying the applicability of multilevel models for analysis.

Second, Model I was fitted after including community-level predictors in the null model. Significant mortality differentials were observed by place of residence and regional category in Model I. Statistically significant ($P < 0.001$) lower risks of death were found among children born in the urban areas relative to children in the rural areas. Children from the emerging regions had higher risks of death compared with their counterparts in the developed regions of the country.

Third, Model II was fitted after including household-level predictors into the Model I. Similar to Model I, children born in urban areas had statistically significant ($P < 0.001$) lower risks of death than those children in the rural areas. Children living in the emerging regions had statistically significant ($P < 0.001$) higher risks of death as compared with their counterparts in the developed regions of the country. Children living within small household size (<6 members) had a significantly ($P < 0.001$) higher risk of death as compared to those from households of large size (six and above members). Children from households with improved sanitation facilities had significantly lower ($P < 0.001$) risk of death than their counterparts living in households with unimproved sanitation facilities.

Finally, the full model (Model III) with all proposed explanatory variables including individual-level predictors was fitted to examine the effect of residential location on child mortality. Significant mortality differentials were observed at community-, household-, and individual-level attributes. In Model III, we found that children from the emerging regions had higher risks of death compared with their counterparts in the developed regions of the country. Similarly, the lower risks of death were found among children born in the urban areas as compared with children in the rural areas as observed in Models I and II.

As we found in Model II, children from the small household size (<6 members) had a significantly ($P < 0.001$) higher risk of death as compared to those from households of large size (six and above members). Likewise, children from households with improved sanitation facilities had significantly lower ($P < 0.001$) risk of death than their counterparts living in households with unimproved sanitation facilities. Children born with large and medium size at birth had a significantly ($P < 0.001$) lower risk of death as compared to small size at birth. This study also revealed that children born at health facilities had a lower risk of death as compared to their counterparts born at home. Children born to Orthodox Christianity follower women had a statistically significant lower risk of death than children born from Muslim

Table 2. Binary mixed effects multilevel regression model (N=8162), EDHS, 2016

Attributes	Model 0	Model I	Model II	Model III
	Coef. [CI]	Coef. [CI]	Coef. [CI]	Coef. [CI]
Constant	-3.015 [-0.60, -2.43]***	-2.84 [-3.001, -2.0681]***	-3.081 [3.30, -2.87]***	-2.457 [-2.94, -1.97]***
Community-level attributes				
Place of residence (rural)				
Urban		-0.883 [-1.216, -0.549] ***	-0.768 [-0.045, -0.006]***	-0.543 [-0.929, -0.156]***
Region: Emerging (ref)				
Developed		0.4261 [0.237,0.615] ***	0.472 [0.272,0.672]***	0.3381 [0.112,0.565]***
Urban		0.230 [-0.188,0.649]	0.353 [-0.074,0.780]	0.329 [0.110,0.769]
Household-level attributes				
Household size (+6) (ref)				
< 6			0.482 [0.301, 0.663]***	0.853 [0.622, 1.083]***
Type of sanitation (unimproved)				
Improved			-0.535 [-0.894, -0.175]***	-0.498 [-0.857, -0.139]***
Wealth status: Poor (ref)				
Non-poor			0.0616 [-0.150,0.272]	0.008 [-0.051, 0.390]
Individual-level attributes				
Child sex: (Male)				
Female				0.2515 [0.068,0.434]***
Birth weight: (Small)				
Large				-0.168 [-0.402,0.064]
Average				-0.232 [-0.452, -0.015]**
Birth order (5 th & above)				
First				-0.626 [-0.96, -0.29]***
2 nd – 4 th				-0.624 [-0.866, -0.382]***
Place of birth: Home (ref.)				
Health facility				0.195 [0.452, 0.063]
Religion: Muslim (ref)				
Orthodox				0.346 [0.613, -0.079]**
Others				0.048 [0.297, 0.200]
Education: No education (ref)				
Primary or above				-0.121 [-0.358, 0.114]
Age at first birth (<18+)				
18 and above				-0.269 [-0.655, 0.117]
Random effect				
Community-level variance	161 [0.020,01.334]	9.74e ³⁶	4.21e ³⁵	3.58e ³⁵
Household-level variance	104 [0.025,0.434]	0.111 [0.028,432]	0.101 [0.023,0.444]	0.102 [0.023,0.455]
ICC	0.074	0.033	0.030	0.30
AIC	3857.55	3833.27	3801.94	3766.10
BIC	3878.57	3868.31	3857.99	3829.21
LR test (χ^2)	-	28.27***	37,34***	55.86***

Note: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

mothers ($P < 0.05$). In this study, maternal education, maternal age at birth, and wealth status had no statistically

significant difference to explain child mortality inequality by place of residence (Table 2).

3.3. Results from decomposition analyses

The multilevel analyses have provided evidence for the existence of a statistically significant higher risk of child death in rural areas as compared to those living in the urban areas in Ethiopia. However, the rural-urban residential gap and the intra-rural and intra-urban gaps are not known yet. For this purpose, the present study employed Blinder-Oaxaca decomposition analysis based on the place of residence and urban/rural wealth status, separately. Table 3 presents the decomposition of the rural-urban inequalities in child mortality grouped by place of residence. The rural-urban decomposition analysis showed the mean predictions by groups and their difference. For the sake of understanding, we converted mean prediction into proportion per 1000. The decomposition result showed that the mean proportion of the child death was 71 deaths/1000 children for rural and 32 deaths/1000 children for urban areas, resulting in rural-

urban differential of 39 deaths/1000 children. There would be 39 deaths/1000 children change in rural areas when applying the urban areas coefficient and characteristics to rural areas' behavior/characteristics. In the rural-urban decomposition analysis, child size at birth, birth order, type of sanitation facilities, and wealth status contributed to explaining the rural-urban gap in child mortality. On the other hand, child sex, religion, household size, and regional categories contributed to widening the child mortality gap.

Table 4 depicts the decomposition of the intra-rural inequalities in child death grouped by rural wealth status. The intra-rural decomposition analysis revealed that the mean proportion of child death was 76 and 64 deaths/1000 children for rural poor and rural non-poor, respectively. As a result, there would be 12 deaths/1000 children change in rural poor when applying the rural non-poor coefficient and characteristics to rural poor characteristics. The intra-

Table 3. Blinder-Oaxaca decomposition of rural-urban in risk of child death, EDHS, 2016

Child mortality	Coefficient	Standard error	z statistic	P-value	95% confident	Interval
Overall						
Rural	0.071	0.003	22.750	0.000	0.065	0.077
Urban	0.032	0.005	7.080	0.000	0.023	0.041
Difference	0.039	0.006	6.970	0.000	0.028	0.049
Explained	0.017	0.060	0.280	0.777	-0.100	0.134
Unexplained	0.022	0.060	0.360	0.716	-0.095	0.139
Explained						
Child sex	-0.000	0.000	-0.750	0.451	-0.000	0.000
Child size	0.008	0.007	1.110	0.267	-0.006	0.022
Birth order	0.047	0.034	1.380	0.167	-0.020	0.114
Religion	-0.009	0.009	-1.010	0.314	-0.027	0.009
Household size	-0.032	0.022	-1.460	0.144	-0.074	0.011
Toilet type	0.027	0.038	0.700	0.481	-0.048	0.101
Wealth status	0.018	0.051	0.350	0.725	-0.081	0.117
Regional cat.	-0.042	0.029	-1.430	0.154	-0.099	0.016
Unexplained						
Child sex	0.000	0.005	0.100	0.923	-0.010	0.011
Birth weight	0.019	0.041	0.460	0.644	-0.061	0.098
Birth order	0.027	0.060	0.460	0.646	-0.090	0.145
Religion	-0.020	0.044	-0.460	0.646	-0.106	0.066
Household size	-0.033	0.072	-0.450	0.652	0.174	0.109
Toilet type	0.001	0.015	0.090	0.927	-0.027	0.030
Wealth status	-0.015	0.023	-0.680	0.495	-0.060	0.029
Regional cat	0.019	0.051	0.370	0.709	-0.081	0.119
_cons	0.023	0.047	0.490	0.627	-0.070	0.115

Note: The models were based on 8,162 observations using logistic regressions, with 6,680 observations from rural samples and 1,482 observations from urban samples.

Table 4. Blinder-Oaxaca decomposition of intra-rural in risk of child death, EDHS, 2016, rural

Child mortality	Coefficient	Standard error	z statistic	P-value	95% Conf.	Interval
Overall						
Rural poor	0.076	0.004	18.330	0.000	0.068	0.084
Rural non-poor	0.064	0.005	13.500	0.000	0.054	0.073
Difference	0.012	0.006	1.900	0.058	-0.000	0.024
Explained	0.013	0.009	1.360	0.175	-0.006	0.031
Unexplained	-0.001	0.010	-0.080	0.939	-0.021	0.020
Explained						
Child sex	-0.000	0.000	0.580	0.562	-0.000	0.000
Child size	0.001	0.002	0.390	0.699	-0.003	0.005
Birth order	0.000	0.001	0.640	0.521	-0.001	0.001
Religion	-0.001	0.001	-0.720	0.473	-0.003	0.001
Household size	-0.001	0.001	-2.160	0.031	-0.002	0.000
Toilet type	-0.002	0.003	-0.830	0.405	-0.007	0.003
Regional cat	0.016	0.008	2.000	0.045	0.000	0.031
Unexplained						
Child sex	-0.301	115.735	0.000	0.998	-227.138	226.535
Birth weight	-0.117	44.892	0.000	0.998	-88.103	87.870
Birth order	-0.685	263.195	0.000	0.998	-516.537	515.167
Religion	-0.550	211.166	0.000	0.998	-414.427	413.327
Household size	-0.056	21.473	0.000	0.998	-42.143	42.030
Toilet type	0.202	77.716	0.000	0.998	-152.118	152.523
Regional cat	0.429	164.569	0.000	0.998	-322.121	322.979
_cons	1.077	414.172	0.000	0.998	-810.685	812.840

Note: The models were based on rural 6,680 observations using logistic regressions, with 4,045 observations from poor families and 2,635 observations from non-poor families.

rural decomposition analysis revealed that child size at birth and regional category contributed to explaining the intra-rural gap in child mortality. On the other hand, child sex, religion, household size, and type of sanitation facilities contributed to widening the intra-rural child mortality disparity.

Table 5 presents the decomposition result of the intra-urban inequalities in child mortality grouped by urban wealth status. The intra-urban decomposition illustrated the mean proportion of urban child death by poverty difference. On average, there would be 47 deaths/1000 children for urban poor and 21 deaths/1000 children for urban non-poor, resulting in 26 deaths/1000 children change in urban poor when applying the urban non-poor coefficient and characteristics to urban poor behavior. In intra-urban decomposition analysis, birth order and type of sanitation facilities contributed to widening the intra-urban gap in child mortality. On the other hand, household size and regional categories contributed to explaining the intra-urban child mortality gap.

4. Discussion

To the best of our knowledge, this is the first paper that examined residential inequalities in child mortality taking intra-urban and intra-rural inequalities into account in Ethiopia. We employed multilevel and decomposition analyses techniques to explore the key factors that widen the rural-urban, intra-rural, and intra-urban gaps in child mortality in the country. We found statistically significant higher child mortality in rural areas than in urban areas which are also consistent with the previous studies (Adeyinka *et al.*, 2020; Dendup *et al.*, 2020; Gebresilassie *et al.*, 2021; Yaya *et al.*, 2019). This might be due to difference in access and distance to public health service, population living standards, health conditions, child healthcare-seeking behavior, and exposure to media by place of residence in Ethiopia.

Our findings also provided the confirmatory evidence that the largest part of the rural-urban inequality in child mortality was attributable to individual, household, and community

Table 5. Blinder-Oaxaca decomposition of intra-urban in risk of child death, EDHS, 2016, urban

Child mortality	Coef.	Std. Err.	z statistic	P-value	95% Conf.	Interval
Overall						
Urban poor	0.047	0.008	5.640	0.000	0.030	0.063
Urban non-poor	0.021	0.005	4.330	0.000	0.012	0.031
Difference	0.026	0.010	2.620	0.009	0.006	0.044
Explained	-0.082	0.074	-1.110	0.266	-0.227	0.063
Unexplained	0.107	0.077	1.390	0.164	-0.044	0.258
Explained						
Child sex	-0.003	0.003	-1.190	0.235	-0.008	0.002
Child size	-0.000	0.000	-0.010	0.990	-0.001	0.001
Birth order	-0.060	0.034	-1.770	0.077	-0.126	0.006
Religion	-0.007	0.030	-0.240	0.813	-0.067	0.052
Household size	0.019	0.016	1.230	0.218	-0.011	0.050
Toilet type	-0.041	0.048	-0.840	0.400	-0.135	0.054
Regional cat.	0.009	0.034	0.260	0.792	-0.057	0.075
Unexplained						
Child sex	-0.031	0.022	-1.420	0.154	-0.074	0.012
Birth weight	0.018	0.047	0.380	0.707	-0.075	0.110
Birth order	-0.070	0.051	-1.380	0.169	-0.169	0.030
Religion	-0.028	0.033	-0.840	0.399	-0.093	0.037
Household size	0.078	0.060	1.300	0.192	-0.039	0.195
Toilet type	0.059	0.059	1.000	0.317	-0.056	0.174
Regional cat.	-0.049	0.073	-0.660	0.507	-0.193	0.095
_cons	0.130	0.125	1.040	0.298	-0.115	0.376

Note: The models were based on urban 1,482 observations using logistic regressions, with 643 observations from poor families and 839 observations from non-poor families.

level factors. At individual level, child's size at birth and birth order contributed to explaining the rural-urban gap in child mortality similar to other studies (Gebresilassie *et al.*, 2021; Yaya *et al.*, 2019). This could be due to relatively high prevalence of home delivery in rural settings where the child size at birth may not be recorded. Another potential reason might be due to high prevalence of early marriage in rural area that could lead to teenage delivery with a lower physical preparedness for pregnancy, and difference in access to public health services including family planning, antenatal care, childhood immunization, and health education services provided in rural and urban areas of Ethiopia.

At the household level, the household wealth status and type of sanitation facilities were found to be the key factors in explaining rural-urban inequality in child mortality in line with the previous studies (Dendup *et al.*, 2020; Touré *et al.*, 2020). This could be due to the child mortality in urban areas which can be influenced by relatively higher education attainment and income as compared to rural settings in the country.

At a community level, our analysis revealed significant mortality inequalities by regional category and place of residence. Children from the emerging regions (Afar, Somali, Benishangul-Gumuz, and Gambella) had higher risks of death compared to children in the developed regions (Amhara, Oromia, Harari, Southern Nations Nationalities, and People's Region (SNNPR) and Tigray) of the country (Gebresilassie *et al.*, 2021). This might be due to the reason that the emerging regions are drought-affected areas, pastoralists, and marginalized in terms of basic infrastructure development (Bareke *et al.*, 2022).

Moreover, this study revealed that child size at birth, birth order, and regional category by wealth status are key factors to explaining intra-rural inequalities in child mortality. This might be due to difference in socioeconomic status of the poor and non-poor rural residents, where the rich (non-poor) could have access to improved water and sanitation facilities that affect the risk of child mortality in Ethiopia. This study also found that the intra-urban inequality in child mortality was explained by the household and

community level factors. For example, the household size was found to explaining intra-urban inequalities in child mortality by wealth status. This might be linked to having larger household size may reduce access to clean water and improved sanitation facilities and childhood nutrition status within poor urban households as compared to non-poor, which, in turn, affects child survival in Ethiopia. Regional categories by wealth status were another contributing factor to explain intra-urban inequality in child mortality in this study. One of the potential reasons for this could be existence of urban slums with environmentally and economically poor dwellers in emerging and developed regions as well as urban regional categories, including Addis Ababa, the capital of Ethiopia. And hence, the present paper suggests that substantial efforts to reduce residential inequalities in child mortality shall focus more on child's birth size, birth order, sanitation facility, and socioeconomic status of different population subgroups of the country.

The present paper is not free from any limitations. For example, we focused on well-known and extensively reported determinants of child mortality in the literature, whereas others such as childhood nutrition status (including exclusive breastfeeding for the first 6 months and appropriate complementary feeding) as well as the households' affordability and accessibility to care and the food insecurity and distance to the nearest health facility remain unexplored. In this regard, the necessity of assessing the factors related to the urban and rural disparity in child mortality may not be well explained. And hence, the authors agree that the present work may represent just an early attempt to a much more integrated investigation of the determinants of child mortality in Ethiopia. More studies are needed in the near future to disentangle the complex relationships among the factors contributing to urban and rural inequalities in child mortality in Ethiopia.

5. Conclusions

This study attempted to answer the research question that inquires the key factors that explain both between and within rural-urban inequalities in child mortality. The findings suggest that there is statistically significant residential inequality in child mortality in rural than urban settings. The findings also showed that some residential inequalities in child mortality occur at a level that could be addressed by targeting children, households, and some occurs at a community level that could be addressed by targeting regions. Following the findings of decomposition analysis, critical multifaceted regionally specific interventions are suggested to be a potentially better approach for addressing the intra-rural and intra-urban differential in child mortality with policies tailored to the disadvantageous specific condition in emerging regions, that is, Afar, Somali, Benishangul-Gumuz,

and Gambella. Furthermore, the present paper suggests that substantial efforts to reduce intra-urban inequalities in child mortality shall focus more on household size. Finally, the importance of the finding, if taken into cognizance and extended to cover the entire country, will not only reduce inequality in child mortality but also will bring the country close to achieving SDG targets by 2030.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Negussie Shiferaw Tessema

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Ethics approval and consent to participate

For the original conduct of the 2016 Ethiopia Demographic and Health Survey (DHS), ethical approval was obtained from the ethical committee of the ICF. The enumerators obtained informed consent and authorization to anonymously use the data from all survey participants. In our study, we obtained permission to use the data from the DHS program. No further ethical approval was required, as our study solely involved secondary data analysis of publicly available data that do not contain any identifiable information that links to the actual survey participants. Authors also confirm that all methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Availability of data

The dataset can be accessed at <https://dhsprogram.com/data/available-datasets.cfm>.

Further disclosure

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RESEARCH ARTICLE

On the empirical study of fertility transition: A case for application of age-adjusted measures in multivariable analysis

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Abstract

Among studies of factors driving fertility transitions, the cumulative children ever born (CEB) has been treated as the dependent variable in multivariable models. Some of these studies have cited total fertility rates (TFRs) in their rationales for investigating the determinants of fertility transition. However, CEB and TFR (which are computed from age-specific fertility rates) are notably disparate measures of fertility. The aim of this study was to argue that where TFRs are cited as a basis for an investigation of driving factors of fertility transitions, the dependent variable in the multivariable modeling ought to be an adjusted measure of fertility. The study applied trend analysis to examine the extent to which CEB and age-specific marital fertility rates (ASMFR) reflected trajectories of the trends of total marital fertility rates (TMFRs) in Ghana, Kenya, Rwanda, and Zimbabwe. Multivariable analysis based on the two-fold Oaxaca-Blinder decomposition technique was applied to examine how using ASMFR compared to CEB impacts the understanding of factors of fertility change, using the case of Zimbabwe. Trend analysis showed that ASMFR was more effective in reflecting fertility trends and measuring the role of associated factors. The results from multivariable analyses show that a case can be made for the use of adjusted measures in the understanding of factors of fertility transition.

Keywords: Marital fertility; Children ever born; Age-specific marital fertility rate; Total marital fertility rate; Decomposition analysis

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1. Introduction

The interest in understanding fertility, the most studied of the demographic events, carries various purposes which include to understand the factors driving trends in birth rates, health implications of childbearing, and to predict future childbearing patterns based on prevailing fertility schedules (Ariho, *et al.*, 2018; Ariho & Nzabona, 2019; Colleran & Snopkowski, 2018; Liu & Raftery, 2020). In many cases, scholars have used the total fertility rate (TFR) to highlight the need for the investigation of the determinants of fertility, and conducted multivariable analyses using the cumulative children ever born (CEB) as the dependent variable (Adhikari, 2010; Al-Balushi, *et al.*, 2020). While many of these studies analyzed fertility at one point in time, those which compared two points in time with the aim of understanding drivers of fertility decline also relied on

CEB as the depended variable (Ariho, *et al.*, 2018; Ariho & Nzabona, 2019). However, some scholars have analyzed the TFR as the dependent variable, although such studies have been few (Liu & Raftery, 2020; Retherford, *et al.*, 2005; Retherford & Rele, 1989).

The use of CEB instead of TFR or its constituent parts, the age-specific fertility rate (ASFR), has several conceptual and technical advantages. Conceptually, the CEB is a measure of actual births that a woman has had. Technically, the CEB can be analyzed in its raw form without the need to transform it into a state that can be analyzed in a multivariable model. However, there are disadvantages associated with CEB, especially in multivariable analyses aimed at establishing the factors influencing trends in fertility rates. First, the CEB is not an age adjusted measure, and therefore, the change in its average estimate between two time points may contradict that of the TFR which one may have used to argue for the need to investigate determinants of fertility transition. Second, the CEB is an historical measure which may be ineffective in capturing short-term changes in fertility patterns. When a birth cohort has unusually high birth rate compared to those older and younger than them, its CEB estimate will potentially inflate the average CEB estimate for a country despite that the country may be experiencing a continuous decline in fertility rates. Due to its inability to capture short-term changes in fertility, it can be argued that the use of age adjusted measures may be preferable in studies seeking to understand the driving factors of fertility transition.

The age-adjusted measures, namely, the ASFR and age-specific marital fertility rate (ASMFR) in the case of marital fertility, present a viable alternative for the investigation of potential drivers of fertility transition in multivariable models. Conceptually, age-adjusted fertility rates are aligned to the TFR or total marital fertility rate (TMFR) when one is studying marital fertility as is the case in this study. The advantage of ASMFRs is that they reflect contemporary fertility patterns based on recent births and are thus more reflective of prevailing fertility determinants compared to historical fertility measures like CEB. However, the main criticism of ASMFRs is that they are a synthetic measure which does not reflect actual number of births that have been recorded. Nonetheless, the ability of ASMFRs to reflect short-term changes in fertility provides a better opportunity for investigating time-dependent drivers of fertility rates. The study of time-dependent drivers is important in understanding the changing profile of determinants of fertility rates, thus providing a platform for designing policy responses accordingly. This paper was conceived to comparatively test this property of ASMFRs

in comparison to the CEB using data from Ghana, Kenya, Rwanda, and Zimbabwe. The study explored a multivariable decomposition equation using the case of Zimbabwe to demonstrate the extent to which the choice of a fertility measure impacts the nature of the findings about driving forces of marital fertility trends.

2. Methods

2.1. Data

This study analyzed DHS data from Ghana, Kenya, Rwanda, and Zimbabwe collected between 1988 and 2015, focusing on women who reported that they were in a union at the time of data collection. This meant that women living with a male partner as husband and wife in cohabitation or living together arrangements were considered married. The sample sizes from each survey for each country are reported in [Table 1](#). Ghana and Kenya collected their first DHS surveys in 1988 and 1989, respectively, and thereafter in 1993, 1998, 2003, 2008, and 2014. Rwanda collected its DHS surveys 1992, 2000, 2005, 2010, 2014/15, and 2019/20, but the latest was not included in the study for comparison with other countries and Zimbabwe's surveys were collected in 1988, 1994, 1999, 2005/06, 2010/11, and 2015. The selection of the countries was based on three considerations: (1) to have one country from each of the four sub-regions of sub-Saharan Africa, (2) a country must have at least five rounds of DHS data, and (3) a country must have experienced significant fertility transition for at least one defined period between 1988 and 2015. All the DHS waves collected between 1988 and 2015 were analyzed.

The DHS surveys were collected with funding from the United States Agency for International Development (USAID) and implemented by host countries' statistical agencies with technical support from the Inner-City Fund (ICF) Macro International Inc., usually cited as ICF International (<https://dhsprogram.com/>). The DHS surveys collect data from nationally representative samples of households on a variety of socioeconomic indicators which include fertility, maternal and child health, mortality, and family planning among others (ICF International, 2016). The DHS uses a standardized instrument across all the countries that it is implemented. This makes the DHS datasets comparable across countries and over time. The surveys have been instrumental in the study of the demographic transitions of SSA countries, allowing for detailed investigations of the determinants of fertility rates and drivers of transitions, especially in the African countries, where there are unreliable and incomplete vital registration data (Be-Ofuriyua & Emima, 2002; Bongaarts, 2015; Cleland, *et al.*, 2011; Gould & Brown, 1996; Indongo

Table 1. Myer's Indices of age misreporting in the DHS data for women from Ghana, Kenya, Rwanda, and Zimbabwe

	DHS1988	DHS1993	GHS1998	GDHS2003	GDHS2008	DHS2014
Ghana						
n	3,156	3,204	3,229	3,694	2,950	5,456
MI	15.6	12.3	12.6	10.7	12.8	9.0
	DHS1989	DHS1993	DHS1998	KDHS2003	KDHS2008	DHS2014
Kenya						
n	4,778	4,583	4,847	4,876	5,041	19,036
MI	10.6	8.3	9.6	7.0	9.9	9.6
		DHS1992	DHS2000	RDHS2005	RDHS2010	DHS2014
Rwanda						
n		3,698	4,891	5,458	6,834	6,890
MI		6.8	6.8	6.8	6.8	6.8
	DHS1988	DHS1994	DHS1999	DHS2005/06	DHS2010/11	DHS2015
Zimbabwe						
n	2,973	3,469	4,203	6,154	6,543	6,015
MI	8.5	8.6	10.8	6.2	8.8	6.1

& Pazvakawambwa, 2012; Locoh, 2002; Potts & Marks, 2001; Upadhyay & Karasek, 2012). The DHS data are publicly available on Measure DHS portal.

2.1.1. Ethics requirements

This study did not require ethics clearance, because it was based on secondary data. The DHS data are collected with ethics clearance from each host country's relevant institutional review boards (IRBs). The data are publicly available on Measure DHS website <https://dhsprogram.com/data/available-datasets.cfm>. To access the data, researchers must register as a DHS data user. The access to the datasets is granted to legitimate research purposes.

2.2. Variables

The dependent variables for this study were ASMFRs and CEB. These two variables were used, because they represent age-adjusted and cumulative and non-adjusted measures of fertility, respectively. The ASMFRs constitute the constituents of the TMFR. Because the TMFR is derived from ASMFRs, it is defined as the total number of live births that a woman is expected to have by the end of her reproductive career if she remains married and experiences the given ASMFRs. The CEB measures that the cumulative total number of children a woman has given birth to in her lifetime, thus reflects actual achieved fertility.

The independent variables were age group and education. Age is the main demographic characteristic used as the basis for calculating fertility indicators, because it does not change its form from population to population

and has a predictable constant change over time. Socioeconomic variables such as household wealth status, rural-urban residence, and contraceptive which are widely used in fertility analysis do not have a constant rate of change over time and are, therefore, not reliable for basing fertility rates on. However, they are important factors for understating fertility transitions. We used education as one of the independent variables, because it has been widely shown to play a significant role in the onset and progress of fertility transition in sub-Saharan African countries.

2.3. Data quality analysis

The first consideration when conducting fertility analysis using DHS data is the quality of the data. The early surveys especially from the DHS Phases I and II from some SSA countries have been noted to have problems of data quality due to misreporting of dates and ages which adversely affect the accuracy of fertility rates for age. The adverse impact of poor quality in DHS data is that if subsequent surveys have improved quality, demographic trends may be erroneously shown to have occurred when in fact it was only improvements in the data. The previous assessments of quality issues in DHS data have indeed highlighted the problem of age heaping whereby respondents showed bias toward stating ages ending in digits zero and five (Pullum, 2006). In analyzing fertility rates, age misreporting can have an adverse effect on the resulting age distribution of fertility rates and can distort the results on the differences/similarities between two time points of the same country. Given that this study was designed to determine the accuracy of two types of measures of fertility levels which

can be used in multivariable analysis fertility transitions, it was important to make sure that the data were of acceptable level of quality. Consequently, we analyzed the quality of the age data for the 23 surveys used in this study using the Myer's Index (MI). The findings from this analysis are presented under results section and they show that the quality of the data from the four countries meets the minimum expected standards for this study.

2.4. Computation of fertility measures

The fertility measures used in this study have different computational demands. The CEB, because it measures achieved fertility, is obtained by finding the average number of children born to a defined birth cohort which can be single-year or 5-year. The CEB measure is computed by dividing the total number of CEB by a cohort of women by the total number of women as indicated in the formula below:

$$\overline{CEB}_{n-n+5} = \frac{C_{n-n+5}}{W_{n-n+5}} \quad (1)$$

Using this measure, the average number of CEB to the 45 – 49 age group, called completed family size, is the equivalent of the total fertility rate. The downside of this, however, is that one must wait for 45 years to obtain the total fertility rate of a birth cohort aged 15 – 19 years. To obtain a measure of the total fertility rate of a population without having to wait for 35 years, the age-adjusted measures, namely, TMFR and its widely cited equivalent, TFR, are often computed. It should, however, be acknowledged that data on marital fertility may not be easily accessible, especially in countries that do not collect DHS data and do not make marital status data publicly available from their censuses.

The estimation of the TMFR and its constituents ASMFRs, equations [2] and [3], take a different approach from that for CEB. When computing the TMFR and ASMFRs using the DHS data, the recommended approach is to use births occurring in the 3 years preceding the year of survey data collection (Croft, *et al.*, 2018). Despite producing a TMFR which is considered a synthetic measure, this approach provides a current picture of the age patterns of fertility at any given time. Calculating ASMFRs involve dividing the number of live births occurring to a cohort during a specified period by the total number of person-years of exposure for the women of the given age cohort. Schoumaker (2013) developed a Stata programme, *tfr2*, which computes fertility rates using this approach by applying a Poisson regression model on birth history data. This program first transforms birth history data into a person-period table such that births are counted for the

age group the mother belonged to at the time of giving birth. This is illustrated in the figure below, supposing one is computing fertility rates using data from a survey conducted in the year 2010. The figure also illustrates the point of difference between the ASMFR and CEB.

Figure 1 shows six births delivered from 2004 to 2010 by three women (W1 – W3). For the calculation of ASMFRs following the standard procedure recommended for DHS data analysis, only three of these births which are highlighted in red would be considered. The numerator for the ASMFR for the age group 15 – 19 will comprise one birth by woman number two (W2) and four person-years of exposure distributed as two for W2 and two for W3. For the 20 – 24 age group, the numerator will be two births by W1 and W2 who contribute three and one person-years of exposure to the denominator, respectively. Using the birth history data transformed into person-periods, the ASMFRs are computed as:

$$\lambda_i = \exp \left[\alpha + \sum_{k=20-24}^{45-49} b_k A_{ki} \right] \quad (2)$$

Where α is a constant term, b is the intercept, A_{ki} is dummy variables for 5-year age groups from 20 – 24 to 45 – 49 years with the 15 – 19-year age group being used as the reference category (Schoumaker, 2013). Using the same Poisson model, the TMFR is computed by multiplying the exponentiated sum of the constant term and the regression coefficients for the respective age groups by five as follows:

$$TMFR = 5 * \left(\exp[\alpha] + \sum_{k=20-24}^{45-49} \exp[\alpha + b_k] \right) \quad (3)$$

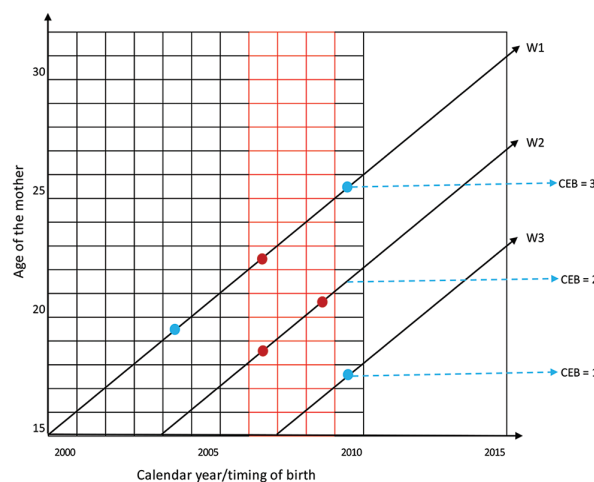


Figure 1. Lexis diagram illustrating birth history data for individual women for a DHS survey conducted in 2010
Note: Adapted from Schoumaker (2013).

The equation [3] was used to compute the point estimates of TMFRs which were used in the comparative assessment with the average CEB₄₅₋₄₉ to show trends in fertility levels.

2.5. Multivariable analysis of fertility

We demonstrated the effect of a fertility measure on the results of multivariable regression analysis by exploring a two-fold Oaxaca-Blinder (OB) decomposition method on both CEB and ASMFRs. The OB decomposition technique partitions a change in the mean estimate of an outcome measure into a part explained by changes in compositional characteristics of the sample and a part that is attributed to the behavioral changes of the sample. This regression-based decomposition method was used to comparatively examine how the choice of a fertility measure can affect the findings from the analysis of drivers of marital fertility change in situations, where the CEB and ASMFRs have followed different trends. The OB technique is a counterfactual decomposition which estimates conditional contributions of characteristics and coefficients associated with the independent variables in relation to the dependent variable. Applied to this study, it, therefore, means that it estimates the expected magnitude of change in the mean of CEB and ASMFRs based on the observed change in the distribution of the sample by age and education status, and differences in reproductive behaviors associated with identified age groups and education status.

When the change in the dependent variable is not consistent with the change in the independent variables, the OB decomposition produces illogical results. Furthermore, when the difference in the mean outcome is underestimated, the OB decomposition tends to overestimate the role of the independent variables. The overestimation of the effect of independent variables can potentially lead to erroneous determination of the depth and focus of investment in fertility management programs. The two features of the OB decomposition relating to illogical results and overestimation of factors' impact can, thus, be used to determine the comparative suitability of CEB and ASMFRs in the multivariable analysis of drivers of marital fertility trends.

3. Results

3.1. Data quality and sample distribution

The quality of data was generally good for Kenya, Rwanda, and Zimbabwe, where the proportions of women whose ages were potentially misreported were mostly below 10%. It was only Ghana which had higher indices of digit preference with the GDHS1988 showing the highest score. However, the differences in the Myer's Indices between

the successive GDHS surveys were very small. When successive surveys have comparable levels of data quality, the impact on fertility measures is minimal. Therefore, the potentially spurious trends in demographic indicators due to improvements in data quality could not have occurred in Ghana. These spurious demographic trends due to improvements in data quality occur when there is sudden positive change in the quality of the data.

The sample distribution shows that for all the countries, the age distribution of the married women has been shifting toward predominance of older age groups (Figure 2). The proportions of women in unions aged 15 – 24 progressively decreased in the four countries. The pattern of education status was markedly different among the countries. In Ghana and Zimbabwe, an overwhelming majority of the women have secondary education while, in Kenya and Rwanda, they have primary education only.

3.2. Trends in fertility levels

The results from the comparative analysis of TMFRs and average CEB₄₅₋₄₉ are presented in Figure 3 below. The trends of marital fertility levels obtained from TMFRs were notably different from those constructed from average CEB₄₅₋₄₉. A notable observation is the inability of CEB to capture stalls in the marital fertility transitions in all the four countries. The marital fertility transition of Ghana has stalled post 1998 with inter-survey increases in TMFRs 1998 – 2003 and 2008 – 2014 periods. In these periods, the average number of CEB to women in the 45 – 49 age group decreased, suggesting a continuous decline in marital fertility. We find the same contradictions between CEB and TMFRs in Kenya between the KDHS1998 and KDHS2003. This 1998 – 2003 period is shown by CEB to have been marked by decreasing marital fertility in Kenya. The trends of CEB₄₅₋₄₉ and TMFRs for Rwanda also followed different trajectories reflecting differences in their ability to capture short- and medium-term changes in birth rates. The pre-2005 era in Rwanda, which was characterized by sociopolitical instabilities and the 1990s genocide, saw the disruption of family planning and health infrastructures which resulted in crisis fertility-driven upsurge in birth rates. The CEB₄₅₋₄₉ is unable to capture this increase in fertility as effectively as TMFR. If one argues that the rise in crisis fertility in Rwanda was potentially concentrated among young women, this increase would be reflected when considering the mean CEB for all women 15 – 49 years. However, this too is unable to effectively capture the increases in fertility in Rwanda pre-2005. The trends of CEB₄₅₋₄₉ and TMFRs for Zimbabwe were more different compared to the other countries. The rapid marital fertility transition from 1988 to 1999 reflected by TMFRs is shown to be mild by CEB. The difference between the CEB₄₅₋₄₉

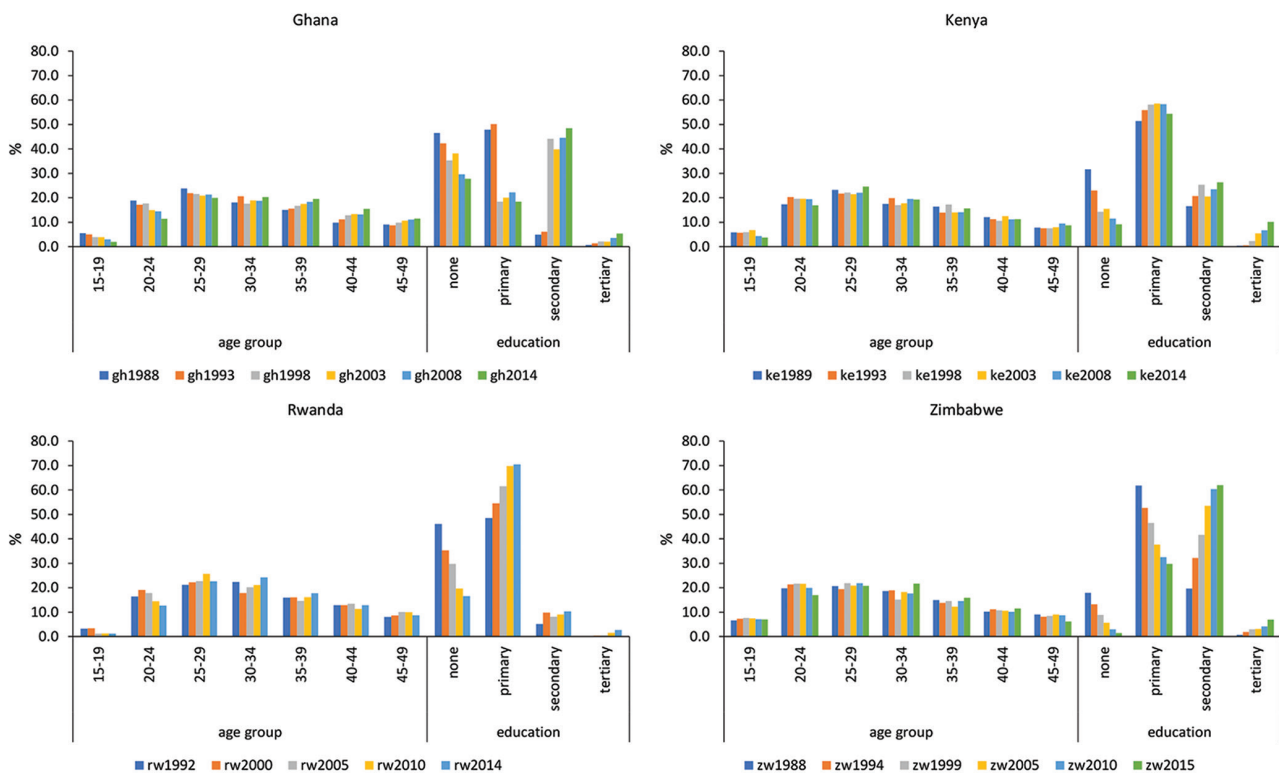


Figure 2. Sample distribution by age group and education status in Ghana, Kenya, Rwanda, and Zimbabwe

and TMRs trends continued post-1999 with the former indicating a continuous decline in marital fertility, while the latter revealed a stalled transition. From 2005 to 2014, Zimbabwe experienced rebounds in marital fertility rates, a stark contrast with the accelerated decline depicted by CEB. The mean CEB₁₅₋₄₉ starts to capture the stall in marital fertility transition of Zimbabwe about 10 years after the TMR did so. Just like the case in Rwanda, the CEB₄₅₋₄₉ and CEB₁₅₋₄₉ measures were not sensitive to the occurrence of stalls and rapid decreases of marital fertility in Zimbabwe.

3.3. Age patterns of fertility

The trends presented in the preceding section can be further unpacked by analyzing the underlying age patterns of fertility. This was accomplished by comparatively analyzing the differences in the age patterns of fertility between successive DHS surveys. We draw particular attention to the inter-survey periods characterized by notable differences between CEB and TMRs. These were 2008 – 2014 in Ghana, 1998 – 2003 in Kenya, 2000 – 2005 in Rwanda, and the three inter-survey periods after 1999 in Zimbabwe [Figure 4]. During all the periods, there were stalls in marital fertility transition as shown by TMRs, while CEB₄₅₋₄₉ indicated decreases in marital fertility.

Ghana’s 2008 ASMRs for especially for age groups 25 – 29 and 30 – 34 were notably lower than those in 2014. This is arguably the source of the higher the TMR in 2014 than in 2008 in Ghana. Meanwhile, there were no differences in the average number of CEB for all age groups between the GDHS2008 and GDHS2014 except for the 45 – 49-year age group. The CEB₄₅₋₄₉ estimate for GDHS2014 was lower than that for GDHS2008, thus giving the impression that completed fertility continued to decrease in Ghana which was contrary to the stall indicated by TMRs.

The fertility stall which occurred in Kenya in the early 2000s is a widely reported phenomenon in demographic literature. As also shown in this study, this stall was well defined among married women as reflected by the increase in TMRs between the KDHS1998 and KDHS2003. The stall in the marital fertility transition of Kenya was likely because the ASMRs for the 25 – 29, 30 – 34, 35 – 39, and 45 – 49-year age groups were lower in KDHS1998 compared to the KDHS2003. On the contrary, the age patterns of average CEB were the same between the KDHS1998 and the KDHS2003 from age group 15 – 19 to 35 – 39, and slightly lower in the KDHS2003 for the 40 – 44 and 45 – 49 age groups.

The notable increase in TMR of Rwanda from the RDHS2000 to the RDHS2005 is well reflected in the

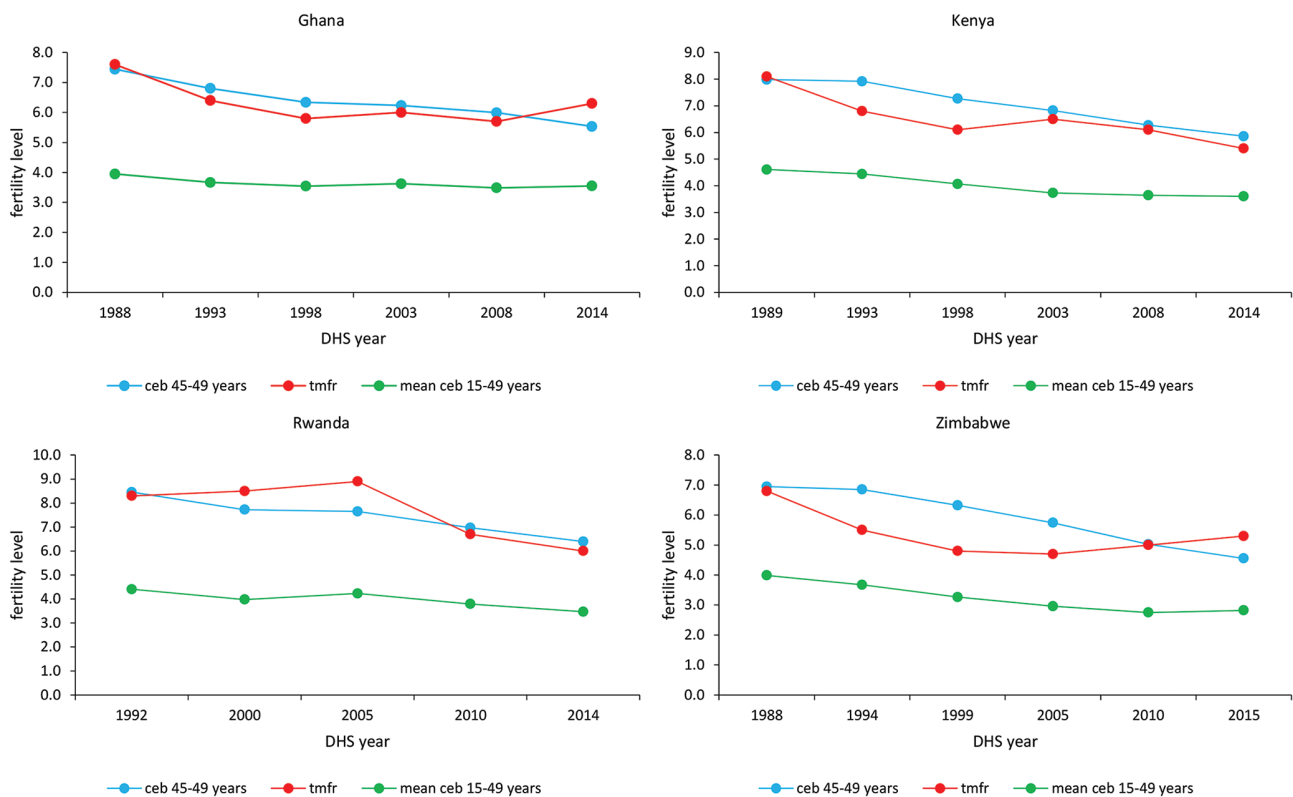


Figure 3. Trends in children even born (CEB) versus total marital fertility rate (TMER)

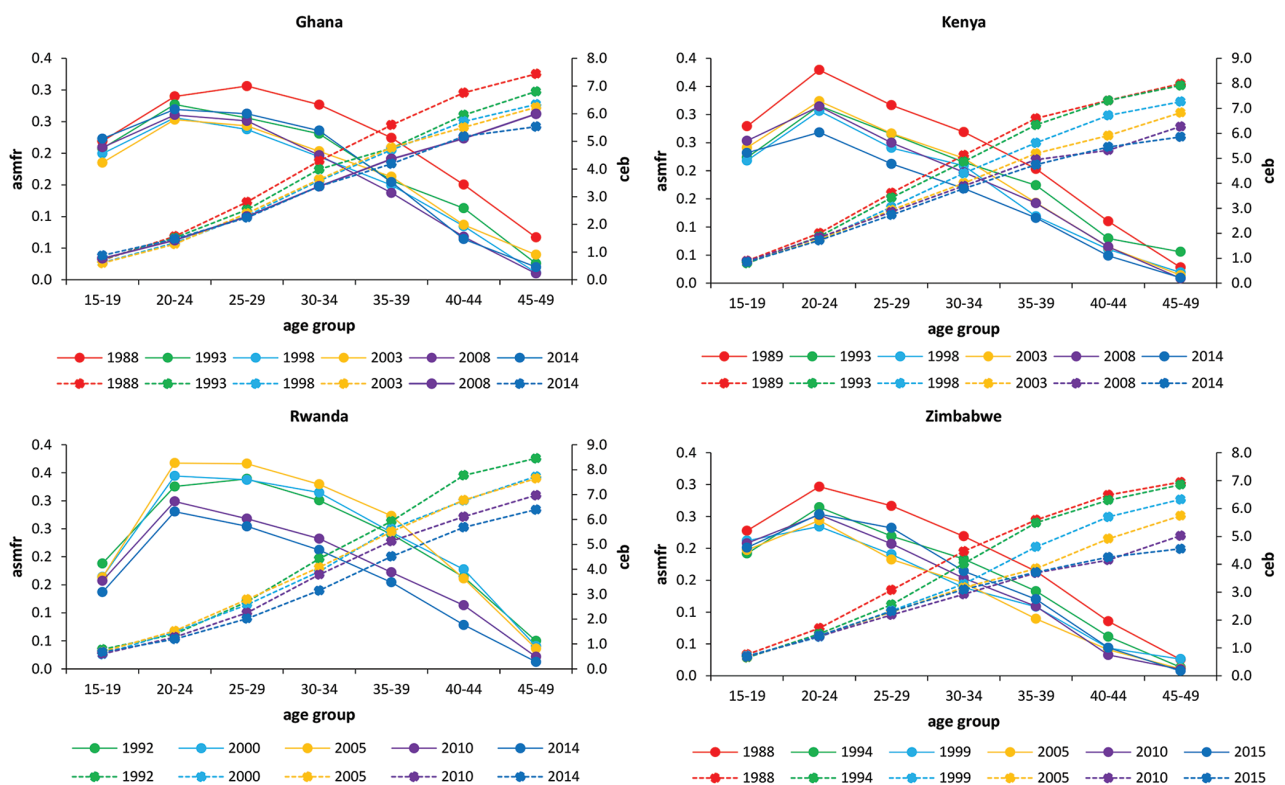


Figure 4. Age patterns of fertility according to average children even born (CEB) and age-specific marital fertility rates (ASMFRs)

schedules of the ASMFRs from the two surveys. The RDHS2005 clearly had higher ASMFRs for the peak childbearing age groups of 20 – 24, 25 – 29, as well as the 30 – 34 and 35 – 39 compared to the RDHS2000. These clear differences were absent when comparing the two surveys' age patterns of average CEB. There were no differences between RDHS2000 and RDHS2005 in terms of CEB across all the age groups, which, further, strengthens the argument that the CEB measure is not robust to capture changes in fertility rates.

Zimbabwe displayed the most defined contradictions between ASMFRs and average CEB. The ASMFRs of the first three ZDHS surveys were consistent with the rapid decrease in TMFRs from 1988 to 1999, something which CEB also suggested especially for the age groups 30 – 34, 35 – 39, and 40 – 44. However, after 1999, TMFRs for Zimbabwe stalled and started to increase. These increases were more defined during the 2005 – 2010 and 2010 – 2015 inter-survey periods, where TMFRs notably increased. The ASMFRs reflect these stalls as shown by the schedules of the ZDHS2020 and ZDHS2015 which had higher rates than the preceding the ZDHS2005 and ZDHS2010, respectively. While the ASMFRs proved effective at capturing marital fertility stalls in Zimbabwe, the cumulative CEB measure was unable to do so. For all the surveys post 1988, the CEB₄₅₋₄₉ was higher than that of the preceding survey. This was also the case for most of the age groups from 25 – 29 to 40 – 44. The results for Zimbabwe thus further confirm that CEB is not an effective measure for capturing trends in fertility rates, especially where these trends are characterized by episodes of stalls and rebounds.

3.4. Differences between CEB and ASMFR in multivariable analysis

We executed the OB decomposition using education and age group as the independent variables to explain the change in the marital fertility levels as measured by CEB and ASMFR. This analysis determined how the difference between CEB and ASMFR affects the nature of the conditional contributions from a decomposition analysis of change in the level of fertility. The analysis focused on two inter-survey periods from Zimbabwe, the 1988 – 1994 which was a period of rapid marital fertility transition and the 2010 – 2015 which was characterized by stalled marital fertility transition. We used Zimbabwe as a case in this study because it had the most defined differences in the trends of its unadjusted and adjusted measures of fertility. The aggregate results from decomposition analysis were that in the 1988 – 1994 period, the mean ASMFR decreased by 16%-points, while the mean CEB declined by 8% points, showing an underestimation of the decline by the latter (Figure 5). In the 2010 – 2015 period, ASMFR showed a rebound of marital fertility rates equivalent to 6% points, while the mean CEB was found to increase by 3% points. As was the case in the 1988 – 1994 period, the CEB underestimated the rebound of marital fertility by 50% compared to the mean ASMFR.

In interpreting the results of the decomposition, where the difference in the mean estimate of CEB/ASMFR between the ZDHS1988 and ZDHS1994 is negative and the changes in characteristics and coefficients supported the decrease (denoted by negative sign), the percentage

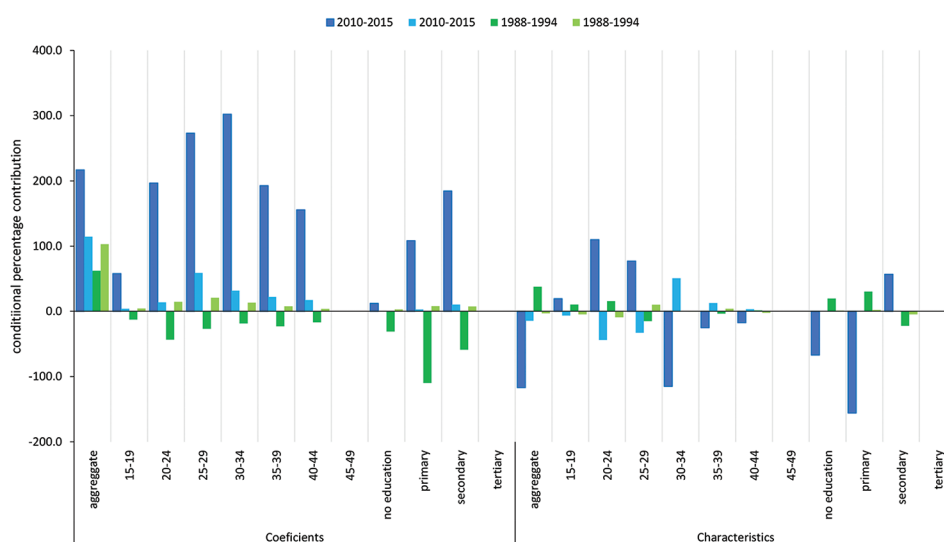


Figure 5. Differences in fertility change determinants based on type of fertility measure

*Constants for CEB are -1.413 and -0.698 for 1988-1994 and 2010-2015 respectively. For ASMFR, the constants are -0.006 and -0.005 for 1988-1994 and 2010-2015 respectively.

conditional contribution is positive. This means that the characteristics and the coefficients were positively associated with the decrease in marital fertility. The results reported in Figure 5 that highlights how the use of CEB and ASMFR as dependent variables affects the results. In the period 1988 – 1994, the results based on ASMFR suggest that the changes in characteristics of the sample by age group and education did not positively support the rapid decrease in marital fertility rates of Zimbabwe. This was in complete contrast with the results based on the analysis of CEB which suggested that compositional characteristics had a notable positive impact on the decrease of marital fertility. Because characteristics measure the distribution of the sample, a look at the changes in the sample distribution reveal that the results based on ASMFR are more realistic compared to those from CEB.

4. Discussion

This study found that the CEB and ASMFRs (TMFRs) have fundamental implications on the nature of findings from the investigation of drivers of marital fertility transition. The main finding of this study was that, compared to the cumulative CEB, ASMFRs represent an arguably more effective outcome measure in the multivariable analysis of the determinants of marital fertility transition. Compared to the ASMFR, the CEB tended to underestimate the magnitude of marital fertility decline and stall and this impacts on the relative importance of the determinants of fertility change. The superior effectiveness of ASMFRs emanates from the reference time period it is derived from, which is considered current. Consequently, the ASMFRs capture the period changes in the age patterns of fertility. The period changes are also associated with the changing socioeconomic characteristics of the women and their wider communities of residence. For instance, in communities lacking education and health infrastructure, many women may have more unwanted births thus inflating the average number of CEB as well as period fertility rates. If over a 15-year period, there is high investment in social infrastructure and many women start having access to schooling, adult education, and family planning programs and health services, the impact will be a reduction of unwanted births which reduce the levels of period fertility. When analyzing the fertility change using CEB, births which occurred before education, health infrastructure, and family planning services were introduced are also counted in the outcome measure such that unwanted births from 15 years ago will continue to influence the estimate of the level of fertility in the current period. This nature of CEB is the underlying reason why the CEB was found to underestimate the change in marital fertility levels between successive DHS surveys. The ASMFRs, contrary to CEB

in the abovementioned example, will treat births from 15 years ago to produce a distinct measure of fertility rate separate from the measure based on a time period after the introduction education, health, and family planning infrastructures. This is the reason why ASMFRs were more effective at reflecting the marital fertility transition and stalls presented in the results section.

The results from the illustrative multivariable decomposition analysis showed that the conditional percentage contributions based on the analysis of ASMFRs were intuitive, while those from the analysis of CEB were sometimes counterintuitive. The reason for this is linked to an extent with the 15-year illustration in the preceding paragraph. In this study, we used education as one of the predictor variables. Suppose a cohort of women with only primary schooling completed had an average CEB of three births before their 20th birthday during a period when there was no access to education and health services. This cohort then goes on to have access to secondary education and health services from their 20th birthday such that by age 25 their average CEB remains at three, but they have completed secondary schooling. In this case, there is no change in the outcome variable, but the independent variable education status has changed significantly. Analyzing this relationship between CEB and education using the OB decomposition will produce large and counter intuitive conditional percentage contributions of education status. This is because the predictor variable, has improved but the dependent variable remains unchanged, giving the impression that education did not have any effect on fertility. Substituting CEB with ASMFRs in this case, the latter will be able to decrease in the births due to the increase in education status and the change in the reproductive behavior associated with the shift from primary to secondary education. Consequently, the OB decomposition will produce percentage contributions which are not counterintuitive. This is because the changes in the education status and ASMFRs will have commensurate period references unlike the case with CEB, where both primary and secondary education attainment will be associated with three births.

The importance of using age-adjusted measures is apparent when critically reflecting on the findings of the present study in relation to those from existing literature. In this study, the coefficients which measure behavior change effects on fertility were shown to be more closely associated with the trends in marital fertility rates. This contrasts somewhat with the studies by Ariho, *et al.* (2018) and Ariho & Nzabona (2019) which reported that changes in characteristics drove the decline in the mean number of CEB in Uganda between 2006 and 2011, thus concluding

that the composition of the female population of the country underlay the decrease in TFRs. It therefore can be argued that had the study by Ariho, *et al.* (2018) analyzed ASFRs as the dependent variable instead of CEB, the findings of the study would have observed a more pronounced effect of behavioral changes than compositional characteristics. This is because it has already been shown in different studies that the trends in fertility decline in African populations have been parallel across the age-groups and socioeconomic classes (Garenne & Zwang, 2006; Udjo, 1996). The study by Liu & Raftery (2020) which used TFR as a dependent variable employing Granger causality found moderate effects of modern contraceptives on fertility transition and we found similar results elsewhere by analyzing ASMFRs, finding that changes in reproductive behaviors have been more influential than compositional characteristics (Ndagurwa & Odimegwu, 2019).

5. Conclusions

This study sought to investigate the relative benefits of analyzing cumulative and age-adjusted measures of fertility in multivariable analysis of drivers of fertility trends. The CEB and ASMFRs were used to represent the cumulative and age-adjusted measures of fertility respectively. Data were obtained from all the DHS surveys from Ghana, Kenya, Rwanda, and Zimbabwe collected between 1988 and 2015 were analyzed. The results of the study suggest that ASMFRs are more effective at identifying short term changes in marital fertility rates and associated factors compared to the average CEB. In conclusion, the study recommends that the multivariable analysis of drivers of marital fertility transition, as also for fertility transition in general, should look to use age adjusted fertility measures as dependent variables instead of the cumulative CEB measure.

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Conflict of interest

The authors certify that they have no conflicts of interest to declare.

Author contributions

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Formal analysis: Pedzisai Ndagurwa

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Supervision: Clifford Odimegwu

Writing – original draft: Pedzisai Ndagurwa

Writing – review & editing: Clifford Odimegwu

Ethics approval and consent to participate

Not applicable. The study analysed publicly available secondary data.

Consent for publication

Not applicable.

Availability of data

Data analyzed in this study are publicly available on the Measure DHS website <https://dhsprogram.com/data/available-datasets.cfm>. To access the data, researchers should register as a DHS data user. The access to the datasets is granted for legitimate research purposes.

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RESEARCH ARTICLE

Market traders' knowledge, attitude, and practices of solid waste disposal in Calabar Municipality, Nigeria: New implications for global health education

Beatrice Okoi Ekor¹, Olajumoke Esther Olanrewaju¹, Ugbe Maurice-Joel Ugbe^{1*}, Favour Achi Inyang-Ogim¹, and Faith Ubi Okoi²¹Department of Public Health, University of Calabar, Nigeria²Faculty of Clinical Sciences, University of Calabar, Nigeria**Abstract**

Poor environmental sanitation practices in markets are a serious public health concern, as solid waste poses municipal level and global health risks. Solid wastes also add to the growing issue of global climate change. This study sought to determine the sociodemographic correlates of solid waste disposal knowledge, attitude, and practices among market traders in Calabar Municipality, Nigeria. This was a cross-sectional study of 480 traders across six markets in Calabar Municipality. Data were collected using semi-structured questionnaire and analyzed using descriptive and inferential statistics. Overall, 54% of respondents had good knowledge, 45% had an acceptable attitude, and a significantly low number of respondents (16%) practiced good solid waste disposal. Sociodemographic characteristics that were statistically significant in the bivariate analyses were modeled for the outcomes. The multivariable analyses found that age, primary education, being married, being separated/divorced, being Muslim, and being a traditionalist were statistically significantly associated with knowledge, attitude, and practices of solid waste disposal among market traders. Solid waste disposal practices were poor. Market sensitizations on environmental sanitation need to be carried out. There is also a need to enforce laws stating disciplinary measures for offenders who dump wastes indiscriminately.

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1. Introduction

As population density per capita waste accumulation rises, the available space for disposal of waste decreases accordingly and as an implication sanitation has emerged as a critical sector for maintaining healthy cities and populations (Iwu *et al.*, 2016). Solid wastes comprise organic and inorganic unwanted materials that are usually free-flowing as derivatives of human and animal action (Chengula *et al.*, 2015). Solid wastes have become one of society's major problems of the 21st century as it has led to several outbreaks of diseases such as dengue fever, cholera, Lassa fever, and malaria as well as contributing significantly to the global climate change. In many cities around the

world, inadequate waste collection and disposal facilitate the multiplication of disease pathogens and provide breeding channels for disease vectors (Chengula *et al.*, 2015). Globally, 2.6 billion people lack access to proper sanitation. The world generates 2.01 billion tonnes of municipal solid waste annually with this figure projected to double by 2050 with the current trends (World Bank, 2022). These numbers have been projected to increase to 3.4 billion tonnes by 2050 (Agbefe *et al.*, 2019). Increased generation of solid wastes is triggered by increasing urbanization, population growth in major cities, change in food consumption patterns, and improvement in the wealth quartiles of some nations (Agbefe *et al.*, 2019). The disposal of solid wastes in developing nations has continually posed a threat to the health and quality of life of the human population due to the non-existence of organized waste disposal facilities, culture, and technology that are determined largely by financial constraints. Sub-Saharan Africa generates about 62 million tonnes of solid waste annually, a serious issue that implicates several factors, chief among them being a lack of political will (Chinedu *et al.*, 2018). Because the increased human population has been implicated severally in the generation of solid wastes, the United Nations Habitat Watch opined that this problem may escalate beyond what it is, as Africa's population is projected to more than triple over the next 4 decades (Bakare, 2021). The United Nations Habitat (2022) stated that municipal solid wastes make the cities unattractive to investors as well as causing flooding, water, and air pollution, and many health conditions. This will cause the slow achievement of the United Nation Sustainable Development Goal (SDG)-17 aimed at sustaining cities and communities.

In Nigeria, waste generation rates amount to 0.65 – 0.95 kg/capita/day with a mean of 42 million tonnes of solid waste generated every year (Chinedu *et al.*, 2018). These high volumes of solid wastes have overwhelmed many cities' waste collection structures and have defied many solutions while only 20 – 30% are collected (Bakare, 2021; Sunday, 2013). The collection of wastes in the country has been monopolized by state/province actors who possess limited capacity to handle the waste management problems in their respective cities (Chinedu *et al.*, 2018). In addition, the lack of knowledge and awareness among the general public on waste management has also played a role in the problem of indiscriminate waste disposal from commercial sources in Nigeria. In a Nigerian study, it was found that despite the high knowledge level of market traders toward market sanitation (62.8%), there were still poor practices of open dumping and other forms of indiscriminate dumping of market wastes (Abejegah *et al.*, 2013). This, however, is perceived to be a function of poor knowledge of available waste disposal systems in the surrounding and poor attitude or perceptions of market traders toward

indiscriminate dumping. In essence, perceptions are said to be learned attributes and can, therefore, be modified through education for proper knowledge acquisition (Chengula *et al.*, 2015). In another instance, the level of education of individuals has played a role in their ability to comprehend relevant details about their environmental and how to preserve its structures. Chengula *et al.* (2015) found that the perceptions and attitudes of a significant number of persons override their knowledge of population health in such a way that these persons would not partake in the cleaning of their environments due to the perceptions that the municipal council bore that responsibility.

Markets are important centers of the economic landscape of every nation as they serve as locations for not only commodity exchange but for information sharing, health education, health promotion, traffic generation, and other forms of social interactions. Due to the increasing population in urban enclaves and a proportionate increase in the market population, waste generation around the markets is inevitable (Worlanyo, 2013). However, the handling of solid wastes in and around markets has posed a threat to human health and the environment as the market remains a vulnerable structure with the convergence of many individuals, attracting significantly large gatherings of sellers and buyers. The poor handling of waste in many markets across Nigeria may be due to poor knowledge of solid waste disposal and a lack of educational programs to modify traders' attitudes toward favorable sanitation practices (Iwu *et al.*, 2016). Formal education emerging from different levels can aid good understanding of proper waste management practices (Chengula *et al.*, 2015).

In essence, it is imperative that a complex waste management strategy that bridges identified gaps in knowledge, attitude, and practices (KAP) toward traders' waste disposal process is critically important. There is a paucity of studies on the KAP of market traders in the ever-busy Calabar. To the best of our knowledge, this present study is the first to conduct KAP among traders regarding solid waste management in the study area while studying demographic correlations of these outcomes.

Accordingly, this study aimed to assess market traders' KAP toward solid waste disposal in the ever-busy markets in Calabar Municipality, Nigeria. We also hypothesized that there was no statistically significant relationship between sociodemographic characteristics and KAP of the study's respondents.

2. Methods

2.1. Data sources

The study was conducted among traders in markets in Calabar Municipality Local Government Area, Cross

River State, Nigeria. Calabar municipality is a Local Government Area in Cross River State, South Nigeria. It is the capital city of Cross River State bounded to the North by Odukpani LGA; to the West by Akpabuyo LGA; to the East by Kwa River; and in the South by Calabar South LGA. The common occupation practiced among the people is trading and fishing. Christianity is the widely practiced religion in the area. From a census conducted in 2006, Calabar Municipality has a population of 183,681 people. The following markets are found in the area; 8 miles Market, Marmi Market, Ikot Ishie market, Marian market, Akim market, and Edim-otop Market.

This cross-sectional descriptive study employed a quantitative approach to determine the KAP of 480 sampled market traders toward solid waste disposal in the study area. The sample size was determined using Fisher's formula for estimating the sample size for cross-sectional studies as cited in Charan & Biswas (2013). A semi-structured questionnaire which was the interviewer administered was utilized. Distribution of the questionnaires for data collection was done based on a derived interval from one shop or stand in each selected line to another until the required number of respondents in each of the markets was reached.

2.2. Measurements

Data were first entered into Microsoft Excel 2016 to compute the knowledge scores. Data were transferred to and analyzed using SPSS Version 23. The outputs were subjected to descriptive and inferential statistical analysis and quantitative data were summarized in means and standard deviation while being presented on frequency tables. Seven practical questions assessed the knowledge of respondents with the questions requiring "yes," "no," or "I don't know" responses. The questions elicited information on traders' knowledge of appropriate measures, types of disease outbreaks that can occur, disease transmission, and health implications. The expected maximum total knowledge score was 7. A higher score implied a better knowledge of solid waste disposal. Each correct knowledge response was allotted a score of 1 while incorrect responses were allotted a score of 0. Four practical questions were used to assess the attitude of participants. This section elicited information on reactions due to proximity of appropriate disposal points, lack of sanctions, use of abandoned lands, and time factor when considering dumping waste. A correct statement with options "Strongly agree," "Agree," "Disagree," or "Strongly disagree" was given 4, 3, 2, and 1, respectively. The expected maximum total attitude score was 16 and the minimum score was 4. Four practical questions were used to assess the practice of participants. This section elicited information on dumping

routes and methods of disposing wastes such as burning, dumping in gutters, or dumping in open places. A correct statement with options "Always," "sometimes," or "never" was given 3, 2, and 1, respectively. The expected maximum total practice score was 12 and the minimum score was 4. The Cronbach's alpha coefficients of the KAP were 0.84, 0.85, and 0.90, respectively, denoting acceptable internal consistency (Taber, 2018). Mean scores were used to categorize KAP into two levels such that respondents who scored within and above the mean had good knowledge, acceptable attitude, and good practice while those who scored below the mean had poor knowledge, unacceptable attitude, and poor practice of solid waste disposal.

2.3. Analytical strategy

Associations between respondents' sociodemographic characteristics (gender, age, educational level, marital status, and religion) and KAP level were analyzed using a Chi-square of independence. These variables were selected based on our theoretical assumption that these factors are relevant in studying solid waste management in the specified population (Agwu, 2012; Al-Khatib *et al.*, 2009; Jatau, 2013). All sociodemographic characteristics and their respective categories are found in Table 1. Variables identified to be statistically significant in the Chi-square analyses were inputted in three separate multivariable logistic regression models for all three outcome variables (KAP). The statistical significance threshold was set at $\alpha = 0.05$.

3. Results

3.1. Sociodemographic data of respondents

Four hundred and eighty respondents ($n = 480$) participated in this study accounting for a 100% response rate. The sociodemographic characteristics of the participants are presented in Table 1. Slightly over half (54.4%) of the respondents were female. The average age of participants was 28.35 years \pm 8.73 (with a range of 16 – 50 years). A little over half of the respondents (51.0%) had attained secondary education. More respondents in this present study were single (47.9%). In terms of religion, most of the respondents (77.3%) were Christians.

Table 2 outlines the KAP levels of respondents according to the scores obtained. Slightly over half of the market traders (54.0%) had good knowledge of solid waste disposal and management after obtaining satisfactory knowledge scores ($M = 3.66$, $SD = 1.70$). Almost half of the market traders (46%) had poor knowledge of solid waste disposal and management. In terms of attitude, most of the market traders (55.0%) had an unfavorable attitude toward solid waste disposal and management ($M = 9.22$, $SD = 2.41$). Regarding practices, a high 84% of

Table 1. Sociodemographic characteristics of the study participants

Variables	Frequency (n = 480), n (%)
Gender	
Male	219 (45.6)
Female	261 (54.4)
Age (years), mean age ± SD	28.35±8.73
15 – 19	90 (18.8)
20 – 29	182 (37.9)
30 – 39	158 (32.9)
≥ 40	50 (10.4)
Educational attainment	
No formal education	52 (10.8)
Primary	47 (9.8)
Secondary	245 (51.0)
Tertiary	136 (28.3)
Marital status	
Single	230 (47.9)
Married	182 (37.9)
Widowed	47 (9.8)
Divorced/separated	21 (4.4)
Religion	
Christianity	371 (77.3)
Islamic	51 (10.6)
Traditional	58 (12.1)

SD: Standard deviation

Table 2. Level of knowledge, attitude, and practice on solid waste management among respondents

Level of KAP	Minimum and maximum scores	Frequency, n (%)
Knowledge level		
Good	3.5–7	259 (54.0)
Poor	0.0–3.4	221 (46.0)
Mean ± SD	3.66 ± 1.70	
Attitude level		
Acceptable	10–16	216 (45.0)
Unacceptable	4.0–9.9	264 (55.0)
Mean ± SD	9.22 ± 2.41	
Practice level		
Good	8.0 – 16	77 (16.0)
Poor	4.0-7.9	403 (84.0)
Mean ± SD	5.65 ± 1.49	

SD: Standard deviation, KAP: Knowledge, attitude, and practice

the respondents had poor practices of solid waste disposal and management (M = 5.65, SD = 1.49).

3.2. Relationship between KAP levels toward solid waste disposal and sociodemographic factors of market traders in Calabar Municipality

From the cross-tabulated *P*-values presented in Table 3, significant associations were found between educational attainment ($\chi^2 = 17.74$, *df* = 3, *P* < 0.001), religion ($\chi^2 = 30.07$, *df* = 2, *P* < 0.001), and marital status ($\chi^2 = 22.09$, *df* = 3, *P* < 0.001) with the knowledge of solid waste management in the study area. We, however, reject the null hypothesis of no significant relationship between educational level, religion, and marital status with the knowledge of market traders on solid waste management in the study area. Other sociodemographic such as age and gender of respondents had no significant associations with the outcome of interest.

Furthermore, in Table 3, significant associations were found between the age ($\chi^2 = 8.74$, *df* = 3, *P* = 0.033) and education ($\chi^2 = 12.74$, *df* = 3, *P* = 0.005) of the market traders and their attitude toward solid wastes disposal in the study area. We, however, reject the null hypothesis of no significant relationship between age and educational level with the attitude of market traders toward solid waste management in the study area. All other sociodemographic factors were not significant.

Finally, Table 3 also highlights the Chi-square analysis of the association between respondents' practices of solid waste management and their sociodemographic characteristics. Age ($\chi^2 = 9.52$, *df* = 3, *P* = 0.023) and religion ($\chi^2 = 8.91$, *df* = 2, *P* = 0.045) were found to be statistically significantly associated with the practice of solid waste disposal and management among market traders. We, therefore, reject the null hypothesis of no statistically significant association between age, religion, and the practices of solid waste disposal among traders in the study area. All other sociodemographic factors were not significant.

Table 4 presents data regarding the multivariate logistic regression analysis of the demographic characteristics and KAP of respondents following the inclusion of all covariates that were identified to be statistically significant in the bivariate analyses. Age and gender were factored into all three models due to their biological importance. Age was inputted into the model as a continuous variable. The multivariable analysis showed that respondents who had attained primary education were 1.07 times more likely than those with no formal education to express good knowledge of solid waste management, *P* = 0.045, AOR = 1.07 (95% CI: 1.02, 2.11). Respondents who were married were less likely than single respondents to express good knowledge of solid waste management, *P* = 0.002, AOR = 0.47 (95% CI: 0.29, 0.76). Furthermore,

Table 3. Bivariate analysis of sociodemographic characteristics and knowledge, attitude, and practice toward solid waste management among respondents

Sociodemographic characteristics	Knowledge level			Attitude level			Practice level		
	Good, n (%)	Poor, n (%)	P	Acceptable, n (%)	Unacceptable, n (%)	P	Good, n (%)	Poor, n (%)	P
Gender									
Male	113 (43.6)	106 (48.0)	0.342	98 (45.4)	121 (45.8)	0.496	29 (37.3)	190 (47.1)	0.126
Female	146 (56.4)	115 (52.0)		118 (5.6)	143 (54.2)		48 (62.3)	213 (52.9)	
Age (years)									
15 – 19	45 (17.4)	45 (20.4)	0.249	43 (19.9)	47 (17.8)	0.033*	10 (13.0)	80 (19.9)	0.023*
20 – 29	108 (41.7)	74 (33.5)		69 (31.9)	113 (42.8)		23 (29.9)	159 (39.5)	
30 – 39	78 (30.1)	80 (36.2)		74 (34.3)	84 (31.8)		30 (39.0)	128 (31.8)	
≥ 40	28 (10.8)	22 (10.0)		30 (13.9)	20 (7.6)		14 (18.2)	36 (8.9)	
Educational attainment									
No formal education	21 (8.1)	31 (14.0)	< 0.001**	25 (11.6)	27 (10.2)	0.005**	10 (13.0)	42 (10.4)	0.080
Primary	16 (6.2)	31 (14.0)		10 (4.6)	37 (14.0)		2 (2.6)	45 (11.2)	
Secondary	134 (51.7)	111 (50.2)		112 (51.9)	133 (50.4)		38 (49.4)	207 (51.4)	
Tertiary	88 (34.0)	48 (21.7)		69 (31.9)	67 (25.4)		27 (35.1)	109 (27.0)	
Marital status									
Single	147 (56.8)	83 (37.6)	< 0.001**	98 (45.4)	132 (50.0)	0.736	37 (48.1)	193 (47.9)	0.454
Married	87 (33.6)	95 (43.0)		85 (39.4)	97 (36.7)		33 (42.9)	149 (37.0)	
Widowed	20 (7.7)	27 (12.2)		22 (10.2)	25 (9.5)		4 (5.2)	43 (10.7)	
Divorced/separated	5 (1.9)	16 (7.2)		11 (5.1)	10 (3.8)		3 (3.9)	18 (4.5)	
Religion									
Christianity	225 (86.9)	146 (66.1)	< 0.001**	169 (78.2)	202 (76.5)	0.673	66 (85.7)	305 (75.7)	0.045*
Islamic	18 (6.9)	33 (14.9)		20 (9.3)	31 (11.7)		6 (7.8)	45 (11.2)	
Traditional	16 (6.2)	42 (19.0)		27 (12.5)	31 (11.7)		5 (6.5)	53 (13.2)	

* $P < 0.05$, ** $P < 0.01$. P : Probability value, Chi square statistic analysis was used to obtain the P value.

separated/divorced respondents were less likely than single respondents to express good knowledge of solid waste disposal in the study area, $P = 0.005$, AOR = 0.18 (95% CI: 0.06, 0.60). Muslims ($P = 0.048$, AOR = 0.52; 95% CI: 0.27, 0.99) and traditionalists ($P = 0.001$, AOR = 0.30; 95% CI: 0.15, 0.61) were statistically significantly less likely to express good knowledge about solid waste disposal compared to Christians in the study area.

In terms of attitude, respondents with primary education were 1.06 times more likely than those with no formal education to possess an acceptable attitude toward solid waste disposal in the study area, $P = 0.017$, AOR = 1.03 (95% CI: 1.03, 1.88). Regarding practice, for every one point increase in age, the log-odds of respondents engaging in good practice of solid waste disposal significantly increased by 0.049 ($B = 0.049$, $P = 0.001$). In other words, with every point increase in age, the odds of engaging in good practice of solid waste disposal increased, $P < 0.001$, AOR = 1.08 (95%

CI: 1.04, 1.17). Respondents who had attained primary education were 1.49 times more likely than those with non-formal education to engage in good solid waste disposal practices, $P = 0.022$, AOR = 1.49 (95% CI: 1.29, 2.76). Widowed respondents were 1.19 times more likely than single respondents to engage in good practice, $P = 0.011$, AOR = 1.19 (95% CI: 1.05, 1.68). Finally, traditionalists were significantly less likely than Christians to engage in good solid waste disposal practices in the study area, $P = 0.031$, AOR = 0.34 (95% CI: 0.13, 0.91).

4. Discussion

The present study explored the KAP of market traders toward solid waste disposal in Calabar Municipality, Nigeria. To the best of our knowledge, this is the first study exploring the KAP of solid waste disposal across all markets in the ever-busy and increasingly populated Calabar Municipality. In general, the study's results identified a slightly good knowledge of solid waste disposal. Good

Table 4. Multivariable analysis of sociodemographic characteristics and KAP toward solid waste management among respondents

Sociodemographic characteristics	Knowledge level			Attitude level			Practice level		
	AOR	95% CI	P	AOR	95% CI	p	AOR	95% CI	P
Gender									
Male	1	-	-	1	-	-	1	-	-
Female	1.31	0.88 – 1.93	0.183	0.98	0.68 – 1.42	0.982	1.608	0.95 – 2.73	0.080
Age (years)	1.02	0.99 – 1.05	0.207	1.02	0.99 – 1.04	0.085	1.08	1.04 – 1.17	< 0.001**
Educational attainment									
No formal education	1	-	-	1	-	-	1	-	-
Primary	1.07	1.02 – 2.11	0.045*	1.06	1.03 – 1.88	0.017*	1.49	1.29 – 2.76	0.022*
Secondary	1.08	0.57 – 2.14	0.857	1.04	0.55 – 1.99	0.896	0.76	0.33 – 1.77	0.524
Tertiary	1.63	0.79 – 3.33	0.183	1.20	0.63 – 2.29	0.581	0.83	0.35 – 2.00	0.683
Marital status									
Single	1	-	-	1	-	-	1	-	-
Married	0.47	0.29 – 0.76	0.002*	0.99	0.63 – 1.57	0.978	0.59	0.31 – 1.12	0.108
Widowed	0.50	0.22 – 1.12	0.096	0.91	0.42 – 1.98	0.803	1.19	1.05 – 1.68	0.011*
Divorced/separated	0.18	0.06 – 0.60	0.005*	1.16	0.42 – 3.22	0.781	0.33	0.08 – 1.39	0.131
Religion									
Christianity	1	-	-	1	-	-	1	-	-
Islamic	0.52	0.27 – 0.99	0.048*	0.87	0.46 – 1.66	0.678	0.66	0.27 – 1.62	0.362
Traditional	0.30	0.15 – 0.61	0.001*	0.92	0.49 – 1.73	0.788	0.34	0.13 – 0.91	0.031*

*P < 0.05, **P < 0.01. CI: Confidence interval, AOR: Adjusted odds ratio, P: Probability value

knowledge of solid waste disposal has proven to improve individuals' overall knowledge about the population health and has also helped to reduce their propensity to indulge in poor waste disposal (Orhorhoro & Oghoghorie, 2019). Good overall knowledge found in this study, however, did not translate to the respondents' attitude and practice as the study found poor attitude and extremely poor practices toward solid waste disposal among the respondents. This finding is consistent with cross-sectional studies by Abejegah *et al.* (2013) and Oladejo & Amosu (2013) which found that despite the high knowledge of market traders and residents regarding solid waste disposal in Benin City and Lagos, Nigeria, the practice of indiscriminate dumping of wastes was high (60%). Another cross-sectional study in North Thailand by Laor *et al.* (2018) found that despite the market traders' high overall level of knowledge, their practices toward proper solid waste disposal were nearly below average. This may be a portrayal of the lack of policies that guide the disposal of waste in public places. In essence, where policies against indiscriminate dumping of solid wastes do not exist or are sparsely enforced, market users, and indeed traders who know the proper way of discarding wastes will rather dump them indiscriminately for convenience's sake since no penalties accrue for their actions. Furthermore, there may be issues of lack of facilities for waste separation and prompt collection; lack of will

power by waste agencies to engage in the right practice; and lack of motivation driven by poor incentives for waste disposal companies to discharge the duties judiciously.

This present study did not find any associations between secondary or tertiary education and better knowledge of solid waste disposal. This contrasts a study by Laor *et al.* (2018) which found higher educational attainment to be statistically significantly associated with good knowledge of solid waste disposal among traders. Another cross-sectional study in Jos, Nigeria, by Jatau (2013) found a higher level of education to be associated with traders' increased knowledge level of solid waste disposal. This association can be attributed to a different level of exposure achieved on the academic ladder whereby individuals are exposed to different levels of teachings and awareness leading them to develop a better overall understanding of hygiene. The improvement in knowledge of market traders toward solid waste disposal through formal education or other means is necessary to improve the perceptions of traders toward bearing responsibility for the hygienic situation of their environments (Chengula *et al.*, 2015). The reasons for this contrasting finding are not clear and require further investigation. However, respondents who had attained primary education had better knowledge than those with non-formal education. In addition, being married was associated with poorer knowledge. This

contrasts with findings by Al-Khatib *et al.* (2009) which suggested that married persons had better knowledge of solid waste disposal than other marital groups. The association between being married and knowledge level found in this study requires further scientific investigation. Furthermore, being divorced or separated was significantly associated with poor knowledge of solid waste disposal among the study respondents. This is consistent with a study Al-Khatib *et al.* (2009) which found that divorcees were more likely to have poorer knowledge of solid waste management. Furthermore, Muslims and traditionalists expressed poorer knowledge of solid waste disposal in the study area. This disagrees with research by Al-Khatib *et al.* (2009) who found that Muslims possessed high overall knowledge of solid waste disposal because their religion places a strong emphasis on neatness to the extent that this is done as an act of worship. The association found between Islamic religion and knowledge of solid waste disposal in this present study is, however, unclear, likewise the association with traditionalism.

This study identified a significant correlation between traders' acceptable attitude toward solid waste disposal and educational level. In essence, higher educational attainment was associated with higher attitude scores. This is consistent with two observational studies which found a positive correlation between the attitude of individuals toward solid waste management and educational attainment (Iwu *et al.*, 2016; Laor *et al.*, 2018). Higher education creates better exposure for individuals, hence this finding. Age was found to influence the good practice of solid waste management in the study area. In essence, as age increased, respondents were more likely to engage in good practice of solid waste disposal. This agrees with an observational study Agbefe *et al.* (2019) that found good waste disposal practices to be strongly associated with increasing age. This agrees with another study by Laor *et al.* (2018). This could be attributed to maturity and social stability with increasing age which may have reduced their tendency to litter. The younger populations are, in turn, more likely to litter. We also found that traders who had attained primary education were more likely than those with no formal education to engage in good practice toward solid waste disposal, whereas those who had attained secondary or tertiary education had no difference in practice than those with no formal education. The reasons for this finding are unclear, which deserve more research.

Our study found no significant relationship between higher levels of education and practices of solid waste disposal, hence a need for further research on this subject. In addition, those who were widowed were more likely than those who were single to engage in good practice in this study. This is consistent with findings

by Al-Khatib *et al.* (2009) who found that compared to singles, widowed respondents were more likely to get involved in environmental sanitation. This finding may be attributed to the fact that widowed respondents who are more commonly at advanced ages are expected to be at a higher level of maturity, thus reducing their tendency to be involved in indiscriminate waste disposal. Finally, traditionalists in this present study were more likely to have poor practices. Poor practices are connected to their poor knowledge as found in this present study. No previous studies have been found to contrast or support this finding.

4.1. Limitations

This was a cross-sectional study which is non-temporal nature, and causality cannot be inferred. Furthermore, other factors such as market location and waste bin availability were not analyzed in this study, giving room for bias due to confounding.

4.2. Implications for intervention and future research

The implications of these findings highlight and set the pace for evidence-based studies that outline the determinants of the complex phenomenon of solid waste disposal and the need to mitigate health risks for the wider population exposed to disease outbreaks in the ever-busy resource-poor settings. The study shows the interaction between KAP and demographic factors. Other factors, in addition to demographic characteristics, need to be considered in future research to complement this present study. This study should also enlighten all actors in the socioecological niche about the progress level of the SDG-11 in our markets so as to develop sustainable means of solving the problem of indiscriminate waste disposal in and around the markets, which are major locations for several types of exchanges and interactions.

5. Conclusion

Calabar has experienced rapid urbanization over the past decades and this situation has increased the population in markets, the generation of solid wastes, and changed the characteristics of these solid wastes around the markets. This study highlights the KAP of market traders toward solid waste management in Calabar Municipality, Nigeria. The findings suggest that the low attitude level and very poor practices toward solid waste management are related to the sociodemographic characteristics of market traders. These create a looming outbreak of diseases and may cause an increase in the morbidity and mortality burden on the economy of Cross River State and Nigeria as a whole. Regularly planned health education should be presented to the traders where the benefits of proper solid waste disposal will be emphasized. There is also a

need to expound health promotion activities to traders in markets through social marketing campaigns and advocacy meetings with the market leaders. Furthermore, there is a need to enforce laws stating disciplinary actions for offenders who dump solid wastes indiscriminately. To further reduce the chances of poor practices, compulsory ownership of temporal waste containers by all traders should be implemented in markets.

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Conflict of interest

There are no conflicts of interest to declare.

Author contributions

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Ethics approval and consent to participate

This study involves human participants and was approved by Ethics and Research Committee of the Department of Public Health, University of Calabar, Nigeria, with approval number UC/CM/PUH/ETH/1916. Participants gave informed consent to participate; hence, this study was in line with the 1964 Declaration of Helsinki and its later amendments.

Consent for publication

Not applicable.

Availability of data

Data have been made available in the results section of this study.

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Report

Modeling, simulating, and comparing biased archaeological mortuary assemblages

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Abstract

This paper uses a novel approach to compensate for inherent sampling biases and to compare the age profiles of two ancient Maya sacrificial assemblages to expectations from a model life table for traditional horticultural populations. It seeks to statistically rule out the possibility that either site is accumulated due to a standard mortality process experienced in horticulturalist populations. This analysis utilizes data from Midnight Terror Cave (MTC), Belize and Chichén Itzá (CI), Mexico to compare the observed versus expected death counts by age. Monte-Carlo based estimates of preservation bias were modeled assuming a normal distribution with mean and variance based on expert opinion. This model was used to up-adjust age-specific death counts for both sites to make more robust sample sizes, which were compared to those expected from a model life table at the 5th, 50th, and 95th percentiles of the resampled distribution of preservation bias. At low levels of estimated bias (5th percentile), neither MTC nor CI assemblages could be distinguished from the null-mortality model. At average to higher levels of estimated bias (50th and 95th percentiles), both populations could be statistically distinguished from the null mortality model either across all age intervals or within specific age ranges. After accounting for preservation bias, the findings suggest that both MTC and CI assemblages were unlikely to have accumulated due to a normal mortality pattern experienced within traditional horticulturalist populations, further supporting the ethnographic and archaeological evidence that indicates that the sites are accumulated due to cultural practices related to human sacrifice.

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1. Introduction

The previous examinations of the Midnight Terror Cave (MTC) site, Belize, have concluded that there is strong archaeological evidence suggesting that the assemblage is accumulated due to cultural practices associated with human sacrifice (Kieffer, 2011; 2015; 2018). The assemblage associated with Chichén Itzá (CI), Mexico, is widely considered being accumulated primarily due to human sacrifice practices (de Anda Alanís, 2007; Tozzer, 1941; Tiesler, 2005). However, to date no research has ruled out the possibility that either site is accumulated due to a typical mortality pattern associated with horticultural populations. This study fills the existing gap in the literature by making a statistical comparison between sacrificial assemblages and

normal mortuary assemblages and asking the question of whether the MTC and CI assemblages are clearly different from a horticulturalist model life table, thus ruling out the simplest possible alternative explanation for their accumulation. The focus of the paper is to test the null hypothesis that these assemblages accumulated through such a standard mortality process. A rejection of this null hypothesis would securely establish the standing of these sites as examples of assemblages accumulated due to human sacrifice.

1.2. Background

1.2.1. Mortuary assemblages

Mortuary assemblages from archaeological sites should not be assumed to reflect the typical J-curve age at death distributions that is expected in the mortuary assemblages of living populations (Chamberlain, 2006; Weiss, 1973). Differences may exist due to unanticipated disasters such as epidemics, warfare, and human sacrifice (Chamberlain, 2006) or they may accumulate for taphonomic reasons related to culture-specific mortuary practices (Saunders *et al.*, 1992; Scrimshaw, 1984), soil conditions (Gordon & Buikstra, 1981; Haglund & Sorg, 1997; 2002) or even as artifacts of excavation methods (Paine & Harpending 1998). For all of these reasons, bioarchaeologists have long been suspicious about the assumption that mortuary assemblages directly represent mortality processes (Angel, 1966; Bocquet-Appel & Massett, 1982; Weiss, 1973). McCaa (2002) goes as far as to call this the “Whopper Assumption.”

In addition to the challenges associated with differential preservation of materials, mortality analysis often makes very specific assumptions about demographic non-stationarity, differences in frailty across subsets of the population, and the role of selective mortality (Wood *et al.*, 1992) that is not always acknowledged in any given analysis in the literature of bioarchaeology and paleodemography (Keckler, 1997). A common approach has been to use the strategy of “model life-tables” (Bocquet-Appel & Massett, 1982; Paine & Harpending, 1996) to correct for deficiencies in bioarchaeological data. This approach is common in demographic approaches to population analysis with incomplete data (Coale & Demeny, 1966; Preston *et al.* 1994; Shryock *et al.*, 1980); however, the choice of an acceptable model can have important impacts on any analysis (Hill & Hurtado, 1996; Howell, 1976; Keckler, 1997).

What we observe in a mortuary assemblage is not mortality; rather, it reflects a proportional relationship between mortality and the probability that we observe any specific death in the context of bioarchaeological

investigation (Wood *et al.*, 1994; 2002). This relationship is viewed through a specific filter introduced by the choice of a model life table and specific demographic model by which to analyze these data (Hill & Hurtado, 1996; Keckler, 1997; Wood *et al.*, 1994).

An acceptable consideration of the relationship between what we observe in a mortuary assemblage and what we expect must, therefore, present a specific strategy for dealing with bias in the probability of observing deaths and the utilization of a model life table with high plausibility. In this paper, we address both concerns in comparing the MTC and CI assemblages to a reference mortality process associated with traditional, horticulturalist populations. First, an expert-based model of preservation bias was employed that explicitly addresses the probability of observation of each death in the assemblage. This model includes an examination of both the average anticipated probability of observation as well as high and low variants that capture a range of uncertainty. These estimates were combined in the context of a normal distributed Monte Carlo model (Graham & Talay, 2013; LeMieux, 2009) of the probability of observations that is reported in this paper and, therefore, could plausibly be re-adjusted by readers using our tables if they prefer to explore different levels. The model grows out of the work of Saunders *et al.* (1992; 2002) in which comparisons of cemetery populations and parish records were made that provided explicit starting estimates for considering these issues. It is based in the theory behind Horvitz-Thompson estimators (Horvitz & Thompson, 1952), in which observed data may be up-weighted to reflect unobserved data in calculating summary statistics (Longford, 2005) Here, fellow colleagues experienced in bioarchaeology and paleodemography were consulted by the author to form estimates of the average, high, and low ranges of bias that could be present and these estimates formed the basis of our analysis.

To adequately choose a model life table for developing expected distribution of age at death for each site, this method built upon the analysis of traditional horticulturalist mortality patterns presented by Gurven & Kaplan (2007). Their model comprehensively reviews what is known about mortality in traditional, horticulturalist populations and estimates the mortality schedule using the Siler competing hazards model (Siler, 1979; 1983), which parameterizes the life table by estimating effects associated with known differences in early-life, adult, and old-age mortality patterns. As such, the Siler model provides a biologically plausible basis for a model life table that speaks to species-specific mortality patterns experienced as part of the human life course (Hill &

Hurtado, 1996; Siler, 1979; 1983). This model also has been argued to be the most biologically plausible mortality model for traditional anthropological populations (Gage, 1988; Wood *et al.*, 2002).

By choosing model parameters based on Gurven & Kaplan's (2007) average for horticulturalist populations, we arrive at the most plausible model life table for use in discriminating sacrifice-related assemblage formations from a background mortality process that characterized the populations from which the MTC and CI assemblages were most likely to be drawn. When combined with the explicit modeling of the probability of observing a death using the Monte-Carlo approach described above, this paper not only provides a significant step forward in understanding the MTC and CI assemblages, but it also provides new tools for bioarchaeologists and paleodemographers seeking to understand the anthropology of similar groups. The approach is general and paleodemographers who implement this method may adjust estimates of preservation bias or the specific model life table chosen to fit their purpose. As such, this paper provides both new insights and new methods to the bioarchaeological and paleodemographic literature.

1.2.2. Demographic patterns of Central America

In addition to the archaeological evidence at the site, the known normal burial patterns in the Maya area further suggest that the MTC assemblage resulted from human sacrifice. While caves have been documented as locations of ossuary assemblages, this pattern is primarily restricted temporally to the Postclassic (950 CE-1539 CE) and spatially to the southern periphery of the Maya area in Honduras and western periphery in Chiapas, Mexico (Blom, 1954; Ruz, 1968:165). This type of cave burials was suggested by many to be an elite privilege (Dahlgren de Jordan, 1966; Moser, 1975). This elite appropriation of caves for tombs and elite burial has been documented throughout Guatemala and Mexico (e.g., Brady, 1989:348; Burgoa, 1934; Dahlgren de Jordan, 1966; Moser, 1975; 1976; Kieffer, 2009; Thompson, 1938). Ruz Lhuillier (1965) also noted secondary burials at cave sites in Guatemala and Yucatan, Mexico. Caves in the Southern Lowlands and Peten, Guatemala, were commonly used for sacrifice (Gibbs, 1997; Owen, 2005; Moyes & Gibbs, 2000; Saldana & Kieffer, 2009; Scott & Brady, 2005). Commoner burials are typically found in house mounds (Rathje, 1970) and rockshelters (Bonor Villarejo, 1995; Bonor Villarejo & Martínez Klemm, 1995; Glassman & Bonor Villarejo, 2005; Prufer, 2002; Saul *et al.*, 2005).

There are several Maya cave sites that have been interpreted as including sacrificed individuals. These sites include Eduardo Quiroz Cave (Pendergast, 1971), Naj Tunich, Guatemala (Brady, 1989), Petroglyph Cave, Belize (Reents-Budet & MacLeod, 1986), Actun Tunichil Muknal, Belize (Gibbs, 2000), Cueva de Sangre, Guatemala (Scott & Brady, 2005), La Iluminada and Hun Nal Ye, Guatemala (Woodfill, 2007). However, many of these sites only have a few individuals, which make any statistical comparison to them difficult if not impossible. Only the Cenote Saratoga at CI, Mexico, has a large enough assemblage to be used for statistical purposes. What is unique about this site and what makes it an ideal example for the expected demography of sacrifice is the ethnohistoric literature that documents sacrifice occurring there (Tozzer, 1941).

2. Methods

2.1. Data sources

Numerous studies on the CI assemblage, Mexico, demonstrated large percentages of infants and men were recovered at the site (de Anda Alanís, 2007; Hooton, 1940; Tiesler, 2007). At least 127 individuals have been recovered, 88 were children or juveniles under 18 years of age (de Anda Alanís, 2007). Unfortunately, this dataset could not be used in this study because de Anda Alanís has not yet published the exact age distribution of his reanalysis. Therefore, the original analysis conducted by Hooton (1940) was used as the dataset in this study. Demographic data used for MTC consists of the 118 individuals (the majority were young adults and children between 5 and 12 years of age) that have been previously published by the author (Kieffer, 2015; 2018).

2.2. Age adjustments and sample characteristics

Methods for assigning ages to skeletal remains are not without uncertainties (Bass, 1995; Sattenspiel & Harpending, 1983; Saunders *et al.*, 1992; 2002) and this often allows interval-based estimates of age as the only available option. Since demographic analyses of mortality are facilitated by assignment of individuals to more fine-grained groupings, such as 5-year age intervals, data utilized in this analysis were subjected to the method of rectangular proration (Brass, 1960; Shryock *et al.*, 1980). Rectangular proration is built upon the assumption of rectangularity which assumes that within a 5-year age group, every year has equal proportional distribution (Shryock *et al.*, 1980). In this analysis, rectangular proration was utilized to assign individuals to 5-year age categories from more coarse-grained ones and the summarized counts of deaths by age utilized in the remainder of the analysis. The resulting "observed" death

counts for both the MTC and CI assemblages are reported in Table 1.

2.3. A Horticulturalist model life table using the Siler competing hazards method

The Siler model is a competing hazards approach to life-table estimation, with each individual potentially dying from forces associated with infant mortality, initial adult mortality, and shifts in the force of mortality as senescence occurs (Siler, 1979; 1983). In formulaic terms, the Siler model formulates the force of mortality as:

$$\mu(a) = \alpha_1 e^{-\beta_1 a} + \alpha_2 + \alpha_3 e^{\beta_3 a}$$

Here, β_1 represents the rate of decline in early mortality with age, associated with the parameter α_1 , which represents the force of mortality associated with neonatal life, together this represents a term that reflects early-life mortality risk that is decelerating with age (Siler, 1979; 1983). The second term parameter α_2 reflects a constant force of mortality across the life span (Makeham, 1860). The third term-- $\alpha_3 e^{\beta_3 a}$ --reflects the senescent component of mortality which is the constant force of mortality (α_2) with an acceleration component ($e^{\beta_3 a}$) reflecting increased risks of mortality across the aging spectrum (Gompertz, 1825). The model is reviewed in greater detail in Gage and Dyke (1989), Gurven & Kaplan (2007), and Wood *et al.* (2002), to which interested readers with an inclination for mathematics are referred. In this analysis, we used the parameters suggested by Gurven & Kaplan (2007): $\alpha_1 = 0.2798$, $\beta_1 = 1.1037$, $\alpha_2 = 0.0223$, and $\beta_3 = 0.1274$ as a model life table, predicting the anticipated number of deaths in each age interval, we would expect to see within the MTC and CI assemblages.

Table 1. Age-adjusted (post rectangular proration) datasets utilized in this analysis

Age (year)	Midnight Terror Cave	Chichen Itza
0 – 1	6	7
2 – 4	18	7
5 – 9	17	2
10 – 14	5	8
15 – 19	3	5
20 – 24	15	2
25 – 29	12	2
30 – 34	12	2
35 – 39	12	2
40 – 44	4	2
45 – 49	4	2
> 50	4	2

2.4. A Monte-Carlo model of preservation bias and statistical comparisons

Expert-based ranges for the analysis of preservation bias utilized in this study are reported in Table 2. The approach builds out of results from the study of Saunders *et al.* (2002), who compared cemetery assemblages to parish records and record discrepancies that suggest a proportionality between observed cemetery assemblages and those expected in a register-type tracking of deaths (Saunders *et al.*, 2002, p144: Figure 5.4). Using this as an initial basis, interviews with several experienced bioarchaeologists were conducted to arrive at best-guess estimates of observability bias by age, including both a most-likely “average” as well as the upper and lower bounds of the distribution. This approach is commonly utilized in stochastic simulation studies where estimates of a phenomenon are not available, when a research topic is new, and when a paucity of literature exists (Graham & Talay, 2013; LeMieux, 2009). They are presented for each 5-year age category, truncated at the 50 Plus years due to a paucity of available individuals beyond this age. These values were used to operationalize a set of Monte Carlo based estimates of the probability of observing a death. The basis for the Monte Carlo model was a random resampling of rates under a binomial probability model (Chiang, 1964; 1984), operationalized as a normal random variable (Graham & Talay, 2013; LeMieux, 2009). Each Monte Carlo experiment resampled the assumed distribution 1,000 times and we accounted for autocorrelation in random number generation (“burn-in” bias) by excluding the first 500 resampled estimates and thinning to each 100th iteration (LeMieux, 2009; Linstrom

Table 2. The ranges of observability bias utilized in the Monte-Carlo simulations to determine if differential preservation may exist within an assemblage

Age Cohort (year)	5 th Percentile	50 th Percentile	95 th Percentile
0 – 1	0.05	0.43	0.80
2 – 4	0.07	0.31	0.55
5 – 9	0.03	0.19	0.35
10 – 14	0.03	0.09	0.15
15 – 19	0.03	0.07	0.10
20 – 24	0.03	0.07	0.10
25 – 29	0.03	0.07	0.10
30 – 34	0.03	0.07	0.10
35 – 39	0.03	0.09	0.15
40 – 44	0.03	0.14	0.25
45 – 49	0.07	0.21	0.35
> 50	0.07	0.26	0.45

et al., 2010). These distributions were utilized in the analysis at the 5th, 50th, and 95th percentiles to account for uncertainty in the expert-based judgments (Graham & Talay, 2013). Graphically, this produced survival plots that were visually inspected (Figures 1 and 2) to qualitatively assess the impact of the Monte Carlo based adjustments. In both cases, the adjusted datasets appear to be significantly different from the observed age-distribution once the Siler model is fit to both using maximum likelihood methods with code custom-written in the R software package (r-project.org). These qualitative observations suggest that if preservation is present in these assemblages, which is a significant likelihood, directly modeling should impact our assessment of hypotheses.

To test the null hypothesis of no differences in the age at death structure between null models and adjusted death counts by age for the MTC and CI assemblages, we employed simple categorical and parametric data analysis.

3. Results

Tables 3-5 present the results of statistical comparisons of the adjusted age-specific death counts to those expected under the null model of horticulturalist mortality. Table 3 captures analyses made using the 5th percentile of the modeled distribution of observability bias, Table 4 those from the 50th percentile (the average and “most-likely” value), and Table 5 reviews results associated with comparisons at the 95th percentile. Across all age intervals, statistically significant differences are observed at the 50th and 95th percentiles only for the CI assemblage (50th percentile: Chi-square = 25.18, $P = 0.02$; 95th percentile: Chi-square = 149.27, $P = 0.001$). Overall, only a weak significant difference was observed for the MTC site at the 95th percentile (Chi-square = 15.88, $P = 0.1$).

Within specific age-intervals, however, both sites deviate significantly from the horticultural model life table, but those deviations depend upon levels of observability bias incorporated into the estimation. At the 5th percentile of the modeled distribution for MTC significant differences were noted for newborns to 1 year of age ($P = 0.007$), 11 – 15 years old ($P = 0.005$), and 36 – 40 years old ($P = 0.008$). At the 50th and 95th percentiles, the 11 – 15 ($P = 0.002$) and 36 – 40 ($P = 0.005$) age intervals demonstrated significant differences. At the 50th percentile of the modeled distribution, a significant difference was noted for the 6 – 10 age intervals for CI ($P < 0.001$). At the 95th percentile, significant differences were noted for the 11 – 15 ($P < 0.001$), 16 – 20 ($P = 0.002$), and 36 – 40 ($P = 0.003$) age intervals for the MTC models. While the CI models at the 95th percentile had significant differences for

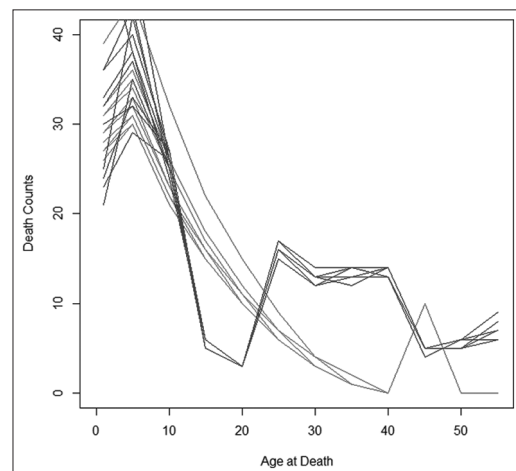


Figure 1. Graphical depiction of a Siler Model for the Midnight Terror Cave assemblage based on adjusted (black) (a steep spike composed of multiple lines that range along the Y axis at just under 30 individuals and over 40 at 5 years of age along the X axis, then dramatically dropping to ~5 individuals at 15 – 20 years of age, followed by a slight peak of ~15 individuals at ~25 – 40 years of age, before dropping to ~5 individuals at 45 years of age) and unadjusted (grey) (a steep slope of multiple lines that range along the Y axis from ~25 to a little under 40 individuals at birth, that increases by 5 individuals at 5 years of age before sloping down to ~10 at 20 years of age, then almost no individuals at 40 and 50-years-old, with a brief spike of 10 individuals at 45 years of age) datasets.

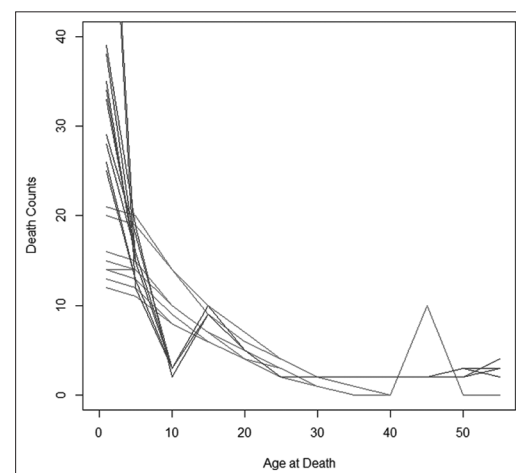


Figure 2. Graphical depiction of adjusted (black) (a steep curve composed of multiple lines that range along the y axis at ~25 to over 40 individuals at birth along the beginning of the x axis, then dramatically dropping to <5 individuals at 10 years of age, followed by a slight peak of ~10 individuals at ~15 years of age, then flattens to ~3 individuals from 25 – 50 years of age before a slight increase in death counts) and unadjusted (gray) Siler curves (a gradual slope of multiple lines that range along the y axis from ~11 to a little over 20 individuals at birth, then decreases to a range of 5 – 10 individuals by 20 years old, almost no individuals at 40 and 50 years old, with a brief spike of 10 individuals at 45 years of age) for CI.

the newborn to one ($P < 0.001$), 6 – 10 ($P < 0.001$), and 51 and above ($P = 0.01$) age intervals.

Table 3. Comparisons of sacrifice assemblages to reference mortality schedule of small-scale horticulturalists at the 5th percentile of the Monte-Carlo modeled p. Observed and expected counts are given for every age cohort and Z-score and P values given for the statistical differences between observed and expected

Age	5 th percentile monte-carlo modeled P (observation)	Gurven-Kaplan Reference Mortality			Midnight Terror Cave			Chichen Itza					
		n expected MTC	Proportion expected MTC	n expected Chichen Itza	Proportion expected Chichen Itza	n observed	Proportion	Z	P-value	n observed	Proportion	Z	P-value
0 - 1	3.29	28	0.262	13	0.262	20	0.128	2.703	0.007	23	0.335	-0.860	0.390
3 - 5	1.70	26	0.245	12	0.245	31	0.198	0.802	0.424	12	0.173	0.887	0.373
6 - 10	1.42	19	0.176	9	0.176	24	0.157	0.465	0.638	3	0.041	2.441	0.015
11 - 15	1.10	13	0.124	6	0.124	5	0.036	2.792	0.005	9	0.128	-0.169	0.865
16 - 20	1.06	9	0.085	4	0.085	3	0.021	2.452	0.014	5	0.077	0.154	0.881
21 - 25	1.06	6	0.054	3	0.054	16	0.103	-1.368	0.171	2	0.031	0.832	0.407
26 - 30	1.05	3	0.031	2	0.031	13	0.082	-1.867	0.061	2	0.031	0.329	0.741
31 - 35	1.06	2	0.015	1	0.015	13	0.082	-2.244	0.025	2	0.031	-0.309	0.757
36 - 40	1.10	1	0.006	0	0.006	13	0.086	-2.647	0.008	2	0.032	-1.214	0.226
41 - 45	1.27	0	0.001	0	0.001	5	0.033	-1.882	0.060	3	0.037	-1.493	0.136
46 - 50	1.35	0	0.000	0	0.000	5	0.035	-1.882	0.060	3	0.039	-1.493	0.136
>51	1.57	0	0.000	0	0.000	6	0.041	-2.066	0.038	3	0.046	-1.493	0.136
						Chi-square P-value		12.418 0.400		Chi-square P-value		8.840 0.700	

Table 4. Comparisons of sacrifice assemblages to reference mortality schedule of small-scale horticulturalists at the 50th percentile of the Monte-Carlo modeled p. Observed and expected counts are given for every age cohort and Z-score and P values given for the statistical differences between observed and expected

Age	50 th percentile monte-carlo modeled P (observation)	Gurven-Kaplan reference mortality				Midnight Terror Cave				Chichen Itza			
		n expected MTC	Proportion expected MTC	n expected Chichen Itza	Proportion expected Chichen Itza	n observed	Proportion	Z	P-value	n observed	Proportion	Z	P-value
0 - 1	5.05	33	0.262	24	0.262	30	0.166	1.979	0.048	35.349	0.402	-1.963	0.050
3 - 5	2.28	31	0.245	22	0.245	41	0.224	0.321	0.749	15.979	0.182	0.942	0.347
6 - 10	1.53	23	0.176	16	0.176	26	0.142	0.854	0.395	3.061	0.035	4.122	0.000
11 - 15	1.18	16	0.124	11	0.124	6	0.032	3.093	0.002	9.431	0.107	1.389	0.165
16 - 20	1.12	11	0.085	8	0.085	3	0.018	2.888	0.004	5.601	0.064	1.178	0.238
21 - 25	1.12	7	0.054	5	0.054	17	0.092	-1.269	0.204	2.240	0.025	1.642	0.101
26 - 30	1.11	4	0.031	3	0.031	13	0.073	-1.541	0.124	2.226	0.025	0.775	0.441
31 - 35	1.12	2	0.015	1	0.015	13	0.073	-2.264	0.024	2.231	0.025	-0.046	0.960
36 - 40	1.17	1	0.006	1	0.006	14	0.077	-2.802	0.005	2.344	0.027	-0.622	0.535
41 - 45	1.33	0	0.001	0	0.001	5	0.029	-1.896	0.057	2.669	0.030	-1.787	0.073
46 - 50	1.53	0	0.000	0	0.000	6	0.033	-2.080	0.038	3.061	0.035	-1.787	0.073
>51	1.83	0	0.000	0	0.000	7	0.040	-2.251	0.024	3.669	0.042	-2.069	0.038
						Chi-square		15.375		Chi-square		25.178	
						P-value		0.200		P-value		0.010	

Table 5. Comparisons sacrifice assemblages to reference mortality schedule of small-scale horticulturalists at the 95th percentile of the Monte-Carlo modeled p. Observed and expected counts are given for every age cohort and Z-score and P values given for the statistical differences between observed and expected

Age	95 th percentile monte-carlo modeled P (observation)	Gurven-Kaplan Reference Mortality				Midnight Terror Cave				Chichen Itza							
		n expected MTC	Proportion expected MTC	n expected Chichen Itza	Proportion expected Chichen Itza	n observed	Proportion	Z	P-value	n observed	Proportion	Z	P-value	n observed	Proportion	Z	P-value
0 - 1	9.057	41.334	0.262	51.857	0.262	54.343	0.240	0.459	0.646	63.401	0.515	-4.752	0.000	63.401	0.515	-4.752	0.000
3 - 5	2.850	38.683	0.245	48.531	0.245	51.306	0.227	0.482	0.631	19.952	0.162	1.672	0.047	19.952	0.162	1.672	0.047
6 - 10	1.670	27.861	0.176	34.954	0.176	28.394	0.125	1.457	0.144	3.341	0.027	4.030	0.000	3.341	0.027	4.030	0.000
11 - 15	1.255	19.654	0.124	24.658	0.124	6.273	0.028	3.839	0.000	10.036	0.082	1.171	0.121	10.036	0.082	1.171	0.121
16 - 20	1.177	13.384	0.085	16.791	0.085	3.530	0.016	3.028	0.002	5.883	0.048	1.185	0.117	5.883	0.048	1.185	0.117
21 - 25	1.176	8.577	0.054	10.760	0.054	17.638	0.078	-0.856	0.390	2.352	0.019	1.690	0.046	2.352	0.019	1.690	0.046
26 - 30	1.190	4.957	0.031	6.219	0.031	14.283	0.063	-1.347	0.177	2.381	0.019	0.746	0.227	2.381	0.019	0.746	0.227
31 - 35	1.173	2.415	0.015	3.030	0.015	14.078	0.062	-2.379	0.017	2.346	0.019	-0.111	0.456	2.346	0.019	-0.111	0.456
36 - 40	1.237	0.896	0.006	1.124	0.006	14.842	0.066	-2.898	0.004	2.474	0.020	-1.044	0.149	2.474	0.020	-1.044	0.149
41 - 45	1.443	0.219	0.001	0.275	0.001	5.770	0.025	-2.064	0.039	2.885	0.023	-2.241	0.025	2.885	0.023	-2.241	0.025
46 - 50	1.737	0.029	0.000	0.036	0.000	6.949	0.031	-2.233	0.026	3.474	0.028	-2.241	0.025	3.474	0.028	-2.241	0.025
>51	2.240	0.002	0.000	0.002	0.000	8.959	0.040	-2.538	0.011	4.479	0.036	-2.592	0.010	4.479	0.036	-2.592	0.010
						Chi-square		15.884		Chi-square		149.272		Chi-square		149.272	
						P-value		0.100		P-value		0.001		P-value		0.001	

If we relax the power level cut off for statistical significance to $P = 0.05$ or even $P = 0.1$ for the z-score test results at the level of age-groups, the number of age intervals that are statistically significant increases. This increase is more noticeable among the MTC cohorts, which would then have significant differences for more than half the age intervals in the 5th, 50th, and 95th percentiles. Given the small sample sizes involved and the investigative nature of the analysis reported here, that relaxation may be justified.

4. Discussion

By examining which age cohorts have statistically significant differences, it becomes possible to rule out particular causes and further verify that these assemblages were most likely the work of sacrifice. Modern examples of warfare demography are seen in the cases of mass deaths in Palestine and Srebrenica (Bosnia), where civilian mortality was the greatest for individuals between the ages of 15 and 25, with the highest numbers being in 20s (Brunborg *et al.*, 2003; Radlauer, 2002). However, this does not explain the differences between children and adults. The elevated number of children is not typical for pre-industrial societies (Chamberlain, 2006, p64: Figure 2), nor is it expected for periods of famine (Chamberlain, 2006, p72: Figure 3).

For both the MTC and CI assemblages, at varying percentiles of the modeled distribution, we have noted statistical differences among the very young children, older children, young adults, and older adults. These age cohorts tend to be those ethnohistorically chosen for sacrifice (older children and young adults) (Fuentes & Guzmán, 1932; Roys, 1943; Scholes & Roys, 1968; Tozzer, 1941), and those not typically targeted for sacrifice (older adults). These cohort specific statistical differences indicate that their presence or absence in the assemblage is observable. However, these differences do not necessarily show levels of significance at high powers. This is especially when the models for the site of MTC are compared to each other.

The cohort-specific differences for MTC and CI also aid in ruling out the possibility that the bimodal age distribution of the assemblages is due to some sort of “accident hump” within the once living population that attributed to these assemblages. Gage and Mode (1993) note that when “accident humps” are noticeable they should only have miniscule mortality increases. As the simple Z-score test results indicate (Tables 3-5), there are statistically significant differences among specific cohorts for both MTC and CI compared to what a normal horticultural society should display. These significant differences rule out the possibility that these are miniscule mortality increases and thus dismisses the likelihood of an accident hump.

It is interesting that the cohort specific differences documented for MTC do not correspond perfectly with the statistically significant differences for results from CI’s demographic data. This indicates that preferred ages of sacrificial individuals may not be consistent throughout the Maya area. The weak difference noted between the MTC models could also be due to a variety of cultural choices relating to sacrifice at the site. For instance, if sacrificial preference changed over time or a more randomized selection process for sacrificial individuals, then these choices may be contributing to why the models are not different, but a number of differences are noted at specific age intervals.

Before the development of the types of statistical analysis employed in this research, bioarchaeologists could look at overall patterns of mortality curves and determine if mortality for a site was normal or not. Data that reflected a J-shaped or “bath-tub shaped” curve demonstrated a relatively normal distribution with high infant mortality that decreases before rising again for older individuals (Weiss, 1973). This pattern is seen in Mesoamerican mortuary assemblages interpreted as burials at Caves Branch Rockshelter, Belize (Glassman & Bonor Villarejo, 2005) and Teotihuacan, Mexico (Storey, 1992). However, this is not the type of pattern demonstrated by MTC or CI. The analysis and modeling introduced by this article provide a visual and statistical means to determine if an assemblage is normal for a horticultural society. The specific age intervals where statistical differences were noted also allowed for affirmation that sacrifice could have contributed to the formation of the assemblage.

Because the two different assemblages did not demonstrate the same statistical differences, it suggests that there may not always be an obvious way to statistically demonstrate differences between mortuary assemblages accumulated through natural processes and those that accumulate due to human sacrifice. Demographic relationships are complex, and not every site or assemblage is bound to be created or influenced by processes in the same manner. Overall, the number of statistical differences demonstrated across the percentiles of the modeled distributions at the age interval level as well as the comparison of models (Tables 3-5) leads us to reject the null hypothesis that either the MTC or CI assemblages accumulated as the result of a standard mortality process experienced within a traditional, horticulturalist population. Thus, the demographic analysis can be used to further support the archaeological and ethnohistoric evidence from these sites that indicate sacrifice as a contributing cause of death for the people represented by these assemblages.

Since this methodology is capable of correcting for preservation bias, it could be used to look at other perishable assemblages such as floral and faunal artifacts to gain insight into the degree of human interaction. Beyond archaeology, this statistical methodology could be useful in other fields of study (i.e., public health, political science, and retail science) where known or estimated inherent biases of over or under representation occur, the methodology used in this paper could be utilized to make more detailed and informed comparisons between large groups of individuals by age cohorts. Care should be taken in establishing estimates as well as basing conclusions on models that produce estimates that deviate significantly from the original data set, as they then may lead to inaccurate assumptions.

5. Conclusions

This paper examines differences in the distribution of age at death of two ancient Maya assemblages (MTC, Belize and CI, Mexico) and what would be expected from a normal mortality pattern for a horticultural population. A model life table suggested by Gurven & Kaplan (2007) in their summary of existing data on mortality in such populations was utilized as a null expectation against which death counts by age for each site were compared.

The fact that the Monte Carlo simulations correct for preservation bias and are significantly different in a variety of ways from the Siler modeled age distributions for MTC and CI indicates that these mortuary assemblages probably did not form from a normal horticultural population. This suggests that some factor (other than preservation bias) contributed to the mortality irregularities observed at these two sites.

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Conflict of interest

There is no conflict of interests to declare.

Author contributions

This is a single-authored paper.

Ethics approval and consent to participate

This study did not involve any living individuals. All data are from the archaeological record and no approval by an Institutional Review Board was needed. Research at the archaeological site of MTC, which allowed the author to conduct this analysis, was done under a permit granted by the Belize Institute of Archaeology.

Consent for publication

Not applicable.

Availability of data

Data from CI were obtained from previously published data. Data from MTC were obtained through analysis conducted by the author as part of her dissertation research. Raw data for how minimum number of individuals was calculated can be found in the author's dissertation, which can be downloaded at https://digitalrepository.unm.edu/anth_etds/145/. R Code is available in the author's dissertation Appendixes C and D. This research was done with the permission of the Belize Institute of Archaeology.

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RESEARCH ARTICLE

Factors associated with knowledge, attitudes, and practices of the general Lebanese population toward the coronavirus disease 2019

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Abstract

People's practice, including adherence to disease prevention strategies, is influenced by their knowledge and attitude, which differ by sex. This study aimed to validate a tool that measures knowledge, attitude, and practice (KAP) toward COVID-19 and explore the related factors, including socioeconomic features and sex disparities. An online cross-sectional study conducted between December 20, 2020, and January 5, 2021, enrolled 405 participants from the general Lebanese population using a snowball sampling technique. The COVID-19 KAP scales were constructed and validated. After confirming the validity of the generated scales, the results showed that a university education level (adjusted odds ratio [aOR] = 3.90) was related to a better knowledge of COVID-19. A higher household crowding index (aOR = 0.41), a higher anxiety (aOR = 0.88), and do not know if there was an indirect contact with a COVID-19 patient (aOR = 0.44) were significantly associated with low knowledge of COVID-19. Having a family member working in the medical field (aOR = 1.76) and higher COVID-19 fear scores (aOR = 1.04) were associated with a more acceptable attitude toward COVID-19. Furthermore, higher knowledge scores (aOR = 1.14), higher attitude scores (aOR = 1.41), higher COVID-19 fear scores (aOR = 1.10), and more time spent on COVID-19 information (aOR = 1.91) were associated with good practice during the COVID-19 pandemic. However, these associations differed by sex, except for the crowding index, which were inversely associated with knowledge in both sexes, while education level and indirect exposure to COVID-19 were significant only among females. Knowledge about COVID-19 did not affect attitudes, but a good attitude was related to better practice in both sexes. Moreover, higher fear and more time spent on COVID-19 information were significantly associated with better practice among females. Overall, this study validated tools to highlight the

knowledge, attitude, and practice among the general population during the COVID-19 outbreak in Lebanon. Our findings suggest the need for health education programs tailored differentially according to sex, taking into account education, age, and socioeconomic status to raise awareness of COVID-19 and promote more acceptable attitudes and sustained safe practices among the general Lebanese population.

Keywords: Coronavirus disease 2019; Knowledge; Attitude; Practice; Fear of COVID-19; General population

1. Introduction

Caused by the SARS-CoV-2 virus, coronavirus disease (COVID-19) is a rapidly spreading disease that led to a global public health issue classified as a pandemic in March 2020 by the World Health Organization (WHO) (WHO, 2020). In September 2022, the WHO which declared that the end of the pandemic is now in sight (United Nations, 2022). In Lebanon, the first confirmed COVID-19 case was reported on February 21, 2020 (Bizri *et al.*, 2020), and on March 10, the first coronavirus-related death was recorded. On March 15, the Lebanese government declared a state of medical emergency to control and curb the rapid spread of the COVID-19 outbreak in the country (Bizri *et al.*, 2020). As of November 30, 2022, the total of COVID-19 deaths in Lebanon was 10,736 from a total number of 1,220,443 reported cases (WHO, 2022).

Public health and social interventions are required to prevent disease transmission. Several measures were adopted, such as the ban on public gatherings and the closures of borders (the airport, seaports, and land entrances), daycare centers, schools, universities, nightclubs, pubs, gyms, theaters, malls, restaurants, and public gardens (Bizri *et al.*, 2020). These measures were successful in handling the pandemic at its beginning. However, people's commitment to these measures, which is influenced by their level of knowledge, attitudes, and practices (KAP) regarding COVID-19, is crucial for their success (Al-Hanawi *et al.*, 2020).

It is well known that a confused understanding and a pessimistic outlook toward an emerging infectious disease will contribute to unnecessary worry and chaos, even excessive panic, thus exacerbating the disease outbreak (Blendon *et al.*, 2004). Prior evidence indicates that good public knowledge, behaviors, and practices are crucial for effective pandemic management and disease avoidance (Tooher *et al.*, 2013; Bell, 2004; Lau *et al.*, 2003; Tang & Wong, 2003), such as the 2003 severe acute respiratory syndrome (SARS) outbreak (Bell, 2004). Understanding perception and current practices can help determine the factors that encourage the population to adopt healthy practices and responsive behaviors; also, adequate control of COVID-19 relies on community involvement, which influences the application of preventive measures.

According to the literature, people are more likely to practice prevention if they have confidence in its effectiveness, have a good level of knowledge and awareness of the disease, and perceive the risks (Lin *et al.*, 2014, Brug *et al.*, 2004, Aburto *et al.*, 2010). Previous findings indicate that a higher level of knowledge is associated with the use of prevention strategies and behaviors and subsequent better attitudes (Afzal *et al.*, 2020; Papagiannis *et al.*, 2020; Tamang *et al.*, 2020). Moreover, fear of the consequences of the pandemic and the perception of risks are crucial in decision-making to halt disease progression and transmission (Baldassarre *et al.*, 2020). Lessons from the SARS epidemic in 2003 in China show that people's lower attitudes and knowledge of infectious illnesses are related to more panic feelings, making preventative efforts more difficult (Zhong *et al.*, 2020).

Furthermore, contagious disease propagation rates might vary depending on several demographic and socioeconomic characteristics and aspects of health-care system of a society (Buja *et al.*, 2020). Public health systems should identify these factors to provide reliable information that can guide mitigation strategies since viruses have deleterious effects on the economy and health (Buja *et al.*, 2020). The latter can be significantly affected by deteriorated economic situations through lower income and more unemployment, leading to increased morbidity and decreased use of private health-care services (Musgrove, 2004). For example, poor economic and demographic conditions contributed to the spread of the Ebola virus through restricted access to food, education, and adequate living conditions (Mun, 2017).

Another notable factor is sex. Indeed, males and females differ in their preventive practices, attitudes, and perceptions of COVID-19 (Galasso *et al.*, 2020; Li *et al.*, 2020). Women seem to be more knowledgeable and have a better attitude toward disease preventive measures (Alnakli, 2016; Alshammery *et al.*, 2021; Sultana *et al.*, 2022). They are more likely than men to apply the restrictions and perceive the epidemic as a severe health issue (Galasso *et al.*, 2020). Men appear to be more ready than women to tolerate the disease risks and often have lower estimations of COVID-19-related threats (Lewis & Duch, 2021). Thus, it is decisive to understand the differences in knowledge,

attitude, and behaviors toward COVID-19 for better and more focused public health measures among subgroups.

A knowledge (K), attitude (A), and practice (P) study can be used to understand public awareness of COVID-19 and evaluate preventive measure gaps. It also gives insights into the characteristics and perceptions of society and subgroups, which, in turn, enables authorities to take effective action. The number of KAP studies in Eastern Mediterranean countries during the COVID-19 pandemic is limited (Abdelhafiz *et al.*, 2020; Al Ahdab, 2021; Alnasser *et al.*, 2021; Kakemam *et al.*, 2020). At the time of the COVID-19 breakout, the general public in Iran had a positive perception of the disease (Kakemam *et al.*, 2020), while in Syria, KAP toward COVID-19 was modest (Al Ahdab, 2021).

The present study was conducted in Lebanon for several reasons, most importantly, the accessibility to the population and the unique context of severe economic crises, which have resulted in a decline in the quality of medical care and likely contributed to the sharp rise in COVID-19 cases (Shallal *et al.*, 2021) and more deaths since hospitals have had to ration their supplies or risk closing (United Nations, 2021). To the best of our knowledge, six studies measured KAP toward COVID-19 in Lebanon in English (Abou-Abbas *et al.*, 2020; Domiati *et al.*, 2020; Saadeh *et al.*, 2020; Sakr *et al.*, 2021; Zeenny *et al.*, 2020). Of those, five probed youth (Sakr *et al.*, 2021), nurses (Saadeh *et al.*, 2020), hospital pharmacists (Zeenny *et al.*, 2020), physicians (Abou-Abbas *et al.*, 2020), and community pharmacists (Zeenny *et al.*, 2021). The sixth study used non-validated measures to evaluate KAP in a sample of 410 Lebanese adults from the general population, of whom 75% reported having adequate knowledge to protect themselves from COVID-19 (Domiati *et al.*, 2020). Thus, given the limited evidence about factors related to KAP during the COVID-19 pandemic in Lebanon and the scarce information regarding sex disparities, the assessment of KAP toward COVID-19 was deemed essential as it helps evaluate preventive measures and health education needs among Lebanese individuals (Raina, 2013).

Therefore, this study aimed to validate a scale that measures KAP toward COVID-19 among the general Lebanese population and to explore KAP-related factors and sex disparities.

2. Data and methods

2.1. Data sources

2.1.1. Study design and methods

A cross-sectional online survey was carried out in Lebanon between December 20, 2020, and January 5, 2021, using

a snowball sampling technique to recruit a sample of 405 Lebanese adults. An anonymous self-administered questionnaire was created on Google Forms and then shared on different social media platforms (WhatsApp, Facebook, and Instagram). All Lebanese adults with access to the internet were eligible to participate. Participants were informed of the study objectives before they enrolled, and participation in the study was voluntary.

2.1.2. Sample size calculation

The G-Power software version 3.1.94 calculated a minimum sample of $n=395$ with an effect size of 0.02 (small), considering an alpha error of 5%, a power of 80%, and allowing for 15 predictors to be included in the model. A total of 405 participants were included in the study.

2.2. Methods

2.2.1. Questionnaire and scales

The online survey included two sections and was available in English and Arabic.

The first section of the questionnaire consisted of sociodemographic characteristics, that is, age, sex, marital status (currently married vs. no), education level (university level vs. not), employment status (employed in medical field, employed in non-medical field, and unemployed), religion (Christian, Muslim, and others), the number of occupants and the number of rooms in the house, excluding the kitchen and bathrooms, and whether or not any family member worked in the medical sector. It also included questions about having tested positive for COVID-19 versus not, having ever tested for COVID-19 versus not, and having a family member who has been infected with COVID-19 (yes, no, and do not know). The household crowding index was calculated by dividing the number of people living in the home by the number of rooms (excluding the kitchen and bathrooms). The second section included the following assessment scales:

2.2.1.1. Knowledge, attitude, and practice (KAP) toward the COVID-19 pandemic

The KAP toward COVID-19 scales was inspired by the previous studies conducted among health practitioners and the general population (Domiati *et al.*, 2020; Ferdous *et al.*, 2020; Al-Hanawi *et al.*, 2020; Reuben *et al.*, 2020; Saadeh *et al.*, 2020; Saefi *et al.*, 2020; Sindkhedkar *et al.*, 2020; Zeenny *et al.*, 2021). More details on the items used for each of the below scales can be found in the supplementary file.

2.2.1.1.1. Knowledge scale

A set of 14 multiple-choice items with single- and multiple-option answers was used to test general knowledge of COVID-19. All answers were coded as binary variables

(1= Yes and 0= No); multiple-option questions were considered separate variables. The correct answers to the multiple-choice questions were scored 1 point for yes and 0 points for no. The total score was created by summing the correct answers to the multiple choice with those of the binary variables. The total score ranged from 0 to 22, where a higher score indicated higher knowledge about COVID-19 (Supplementary File, Table S1).

2.2.1.1.2. Attitude scale

Six questions measured attitudes toward preventive measures, adherence to government actions, and adaptation toward COVID-19. All are graded on a 3-point Likert scale from 1 (disagree) to 3 (agree). The total score calculated by summing the six responses ranged from 6 to 18. A higher score indicated a more acceptable attitude toward COVID-19 (Supplementary File, Table S2).

2.2.1.1.3. Practice scale

Twenty-three items assessed good practice and behavior regarding preventive measures against COVID-19. All were graded on a 5-point Likert scale from the worst (1 = never) to the best (5 = always). The total practice score calculated by summing the 23 items ranged from 23 to 115, with higher scores indicating good practice toward COVID-19 (Supplementary File, Table S3).

2.2.1.2. Fear of COVID-19 scale (FCV-19S)

The FCV-19S is a 7-item scale that evaluates the fear of COVID-19 among the general population (Ahorsu *et al.*, 2020). The Arabic-validated version of the FCV-19S was used in this study (Alyami *et al.*, 2020). Items are rated on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). A higher score indicates higher fear of COVID-19 (Ahorsu *et al.*, 2020).

2.2.1.3. Coronavirus Anxiety Scale (CAS)

The CAS is a 5-item self-report scale rating the frequency of physiologically-based symptoms caused by COVID-19-related facts and thoughts (Lee, 2020). The survey is graded on a 5-point Likert scale from 0 (not at all) to 4 (extremely). The overall score is obtained by summing the five items, with higher scores indicating higher anxiety caused by COVID-19 (Lee, 2020).

2.2.1.4. Translation procedure

The used scales were translated from English to Arabic using the forward and backward translation process except for the FCV-19S scale. The translation from English to Arabic was done by two authors, and the back-translation was done by two others. Discrepancies between the original English version and the translated edition is resolved by consensus.

2.2.2. Statistical analysis

Data were analyzed on SPSS software version 24. A descriptive analysis was performed using absolute frequencies and percentages for categorical variables and means and standard deviations (SD) for quantitative measures. Construct validity of the knowledge, attitude, and practice scales was evaluated using principal component analysis (PCA). This method shares many similarities with exploratory factor analysis to determine the efficacy of the model and the validity of KAP scales. Kaiser–Meyer–Olkin’s measure of sampling adequacy and Bartlett’s test of sphericity were calculated to ensure the model’s adequacy. Factors with eigenvalues values larger than 1 were retained, and the scree plot method was used to determine the number of components to extract (Kanyongo, 2005). Only items with a factor loading >0.4 were considered (Ellis, 2017). This procedure helped generate the KAP scales. Cronbach’s alpha was also used to evaluate the internal consistency of the studied scales; values of ≥ 0.9 , $0.8 - 0.9$, $0.7 - 0.8$, $0.6 - 0.7$, and <0.6 indicate that reliability is excellent, good, good to acceptable, acceptable, and not acceptable, respectively (Ursachi *et al.*, 2015).

Bivariate analyses were then conducted. For each independent variable, medians (interquartile range [IQR]) were used to compare between categories: Due to non-normal distribution of the outcome continuous variables (KAP scores), non-parametric tests were used to compare the ranks of these outcome continuous variables (Kruskal–Wallis to compare between three groups and Mann–Whitney to compare between two groups). In addition, the Spearman test was used to correlate between continuous variables. Significant results were defined as $p < 0.05$.

Afterward, since the transformation of the KAP scores did not normalize their distribution, they were dichotomized into two groups at the median level of each scale, since they were not normally distributed. Dichotomization was done as follows. First, the knowledge score was dichotomized into low (values less than 17.00) versus high knowledge (values greater than or equal to 17.01). Second, the attitude score was dichotomized into fearful (values less than 17.00) versus acceptable attitude (values greater than or equal to 17.01). Third, the practice score was dichotomized into flawed (values less than 104.00) versus good practice (values greater than or equal to 104.01). Other categorizations of each scale only altered the results slightly, indicating that our current classification for three scales is relatively valid.

Four logistic regressions were performed taking the above-mentioned dichotomized dependent variables to conduct multivariable analyses. In the first logistic regression, knowledge was taken as the dependent variable and sociodemographic characteristics as the independent

variables. In the second logistic regression, attitude was taken as the dependent variable, and knowledge and sociodemographic characteristics as the independent variables. In the third logistic regression, practice was selected as the dependent variable, and knowledge and sociodemographic characteristics as the independent variables. The fourth model considered the practice score as the dependent variable and the knowledge and attitude as the independent variables. Variables that showed $p < 0.2$ in the bivariate analysis were included in the multivariable models to decrease potential confounders. Afterward, another set of three logistic regressions, taking the same dependent and independent variables, was conducted after stratification by sex. In all cases, models' equations for significant variables were presented.

3. Results

3.1. Sample description

The mean age was 28.38 ± 12.02 years, and most participants were female (79.8%) and single (68.1%). Only 10.1% had a family member who was infected by COVID-19, and only 27.9% had a family history of COVID-19. Table 1 summarizes all sociodemographic characteristics.

3.2. Principal component analyses of the KAP scales

Using the principal component analysis (PCA), the COVID-19 knowledge scale items produced eight factors that had an eigenvalue over 1. The first component (knowledge of preventive measures) explained the most variance by 15.89%, followed by the second component (knowledge of the transmission mode of the virus), 7.97%. The total variance was 58.38%. The Cronbach's alpha value of the COVID-19 knowledge scale was 0.626 (Table S1). The COVID-19 attitude scale items produced two factors that had an eigenvalue over 1. The total variance was 56.55%, with a Cronbach's alpha value of 0.615 (Table S2). Regarding the COVID-19 practice scale, it could yield four components with eigenvalues greater than one. The first component (protective measures) accounted for 37.77% of the total variance, while the second component (practice of preventive measures) contributed to 12.53%. The Cronbach's alpha value of the COVID-19 practice scale was 0.899 (Table S3). Cronbach's alpha values of the FCV-19S and CAS scales were 0.856 and 0.846, respectively.

3.3. Bivariate analyses

The mean scores of knowledge, attitudes, and practices were 16.29 ± 2.86 , 16.5 ± 1.8 , and 100.78 ± 12.11 , respectively. No significant association was found between the KAP scores and sex (Figure 1). Married status, university degree, Christian religion, older age, and direct or indirect contact

Table 1. Sociodemographic characteristics of the study sample

Sociodemographic characteristics	Frequency	Percentage (%)
Total	405	100.0
Age	405	28.38 (12.02) ^a
Sex		
Male	82	20.2
Female	323	79.8
Marital status		
Currently not married	276	68.1
Currently married	129	31.9
Education level		
Non-university level	42	10.4
University level	363	89.6
Employment status		
Employed, medical field	65	16.1
Employed, non-medical	114	28.1
Unemployed	226	55.8
Family member in the medical field		
Yes	114	28.1
No	291	71.9
Living place		
Rural	108	26.7
Urban	297	73.3
Religion		
Christian	71	17.5
Muslim	254	62.7
Other	80	19.7
Tested positive for COVID-19		
Yes	41	10.1
No	364	89.9
Ever tested for COVID-19		
Yes	164	40.5
No	241	59.5
Having a family member who has been infected with COVID-19		
Yes	113	27.9
No	277	68.4
I do not know	15	3.7
Household crowding index	405	1.14 (0.55) ^a

Note: ^aMean (SD) of age and household crowding index

with COVID-19 patients were significantly associated with higher knowledge scores (Table 2). However, a higher household crowding index and higher anxiety were related to lower knowledge scores. Older age, being married, being

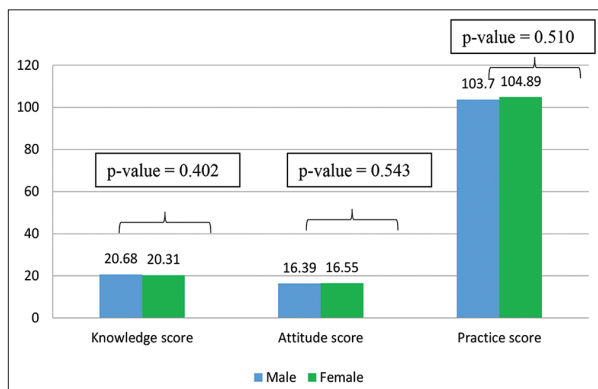


Figure 1. Mean difference of the knowledge, attitude, and practice scales between males and females

Christian, being a health care worker, having a university degree, having a family member working in the medical field, and scoring higher on the fear of COVID-19 scale were significantly associated with higher attitude scores. However, having tested positive for COVID-19, indirect contact with COVID-19 patients, higher household crowding index, and higher anxiety scores were related to lower attitude scores. Older age, being married, being Christian, having a university degree, not working in the medical field, and fearing COVID-19 were significantly associated with higher practice scores. Furthermore, spending more than 30 min/day on COVID-19 information, never having tested for COVID-19, never having tested positive for COVID-19, and having a family member working in the medical field were significantly associated with higher practice scores (Table 2).

3.4. Multivariable analyses

The first logistic regression taking knowledge (K) as the dependent variable in the whole sample showed that a university education level (adjusted odds ratio [aOR] = 3.90) was related to a better knowledge of COVID-19. A higher household crowding index (aOR = 0.41), a higher anxiety (aOR = 0.88), and do not know if there was an indirect contact with a COVID-19 patient (aOR = 0.44) were significantly associated with low knowledge of COVID-19 (Table 3, Model 1).

The second logistic regression taking acceptable attitude (A) as the dependent variable in the whole sample with knowledge score as a covariate showed that having a family member working in the medical field (aOR = 1.76) and higher COVID-19 fear scores (aOR = 1.04) were associated with a more acceptable attitude toward COVID-19 (Table 3, Model 2).

The third logistic regression, taking adequate practice (P) as the dependent variable in the whole sample and knowledge and attitude scores as covariates, showed that

higher knowledge scores (aOR = 1.14), higher attitude scores (aOR = 1.41), higher COVID-19 fear scores (aOR = 1.10), and more time spent on COVID-19 information (aOR = 1.91) were associated with good practice during the COVID-19 pandemic (Table 3, Model 3).

3.5. Stratification by sex

In both groups, the stratified results showed that a higher household crowding index was significantly associated with lower knowledge. When considering the acceptable attitude as the dependent variable, the results showed that no significant association was found between the variables and the attitude ($P > 0.05$ for all).

Among males, being married was significantly associated with higher knowledge (Table 4a, Model 1). Taking the practice scale as the dependent variable, the results showed that high attitude scores (aOR = 2.77) were significantly associated with higher practice scores while not knowing if they had been an indirect contact with a COVID-19 patient (aOR = 0.01) which was significantly associated with lower practice (Table 4a, Model 3).

Among females, not knowing if they had been in indirect contact with COVID-19 patients (aOR = 0.36) was significantly associated with lower knowledge, while having a university degree (aOR = 3.87) was significantly associated with better knowledge (Table 4b, Model 1). Taking the practice scale as the dependent variable, the results showed that high attitude scores (aOR = 1.24), better knowledge (aOR = 1.17), higher fear score (aOR = 1.09) and spending more than 30 min/day on COVID-19 information (aOR = 2.25) were significantly associated with higher practice scores (Table 4b, Model 3).

4. Discussion

The present study assessed knowledge, attitudes, and practices toward COVID-19 using scales validated in the Lebanese population. As this study was conducted while the pandemic was in full swing, people had access to a wealth of information on the topic through various social media platforms, thus increasing their knowledge. In addition, attitudes toward COVID-19 were vastly influenced by the level of disease control in the country, where adequate management of COVID-19 led respondents to have more acceptable attitudes and adopt better practices overall.

In this study, married participants working in the medical field or with a family member working in the medical field had high knowledge about COVID-19, while those with a high household crowding index had low knowledge about COVID-19. Furthermore, participants who had a family member working in the medical field and those with higher fear of COVID-19 scores had a more acceptable attitude

Table 2. Bivariate analyses of knowledge, attitude, and practice scores

	Knowledge score		Attitude score		Practice score	
	Median [IQR]	P-value ^a	Median [IQR]	P-value ^a	Median [IQR]	P-value ^a
Tested positive for COVID-19						
No	17 [15 – 18]	0.289	17 [16 – 18]	0.005	105 [96 – 110]	0.003
Yes	16 [13 – 18]		16 [13.5 – 18]		100 [90.5 – 105.5]	
Ever tested for COVID-19						
No	17[15 – 18]	0.293	17[16 – 18]	0.012	106 [95 – 111]	0.038
Yes	16[15 – 18]		17[16 – 18]		102 [96 – 108]	
Have a family member working in the medical field						
No	17 [15 – 18]	0.065	17 [16 – 18]	0.001	104 [95 – 108]	0.026
Yes	17 [16 – 18]		17.5 [16 – 18]		98 [106 – 112]	
Urban-rural settings						
Urban	17 [15 – 19]	0.391	17[16 – 18]	0.267	109[100;114]	0.596
Rural	17 [16 – 18]		17[16 – 18]		108[97;113]	
Marital status						
Single	17 [15 – 18]	0.012	17 [16 – 18]	<0.001	103.5 [94.2 – 108]	0.002
Married	17 [16 – 18]		17 [17 – 18]		107 [97 – 112]	
Education level						
Non-university degree	15.5 [11 – 17]	0.002	16.5 [14 – 18]	0.019	100 [86.5 – 106.25]	0.005
University degree	17 [15 – 18]		17 [16 – 18]		105 [96 – 110]	
Time spent on COVID-19 information/day						
0 – 30 min	17 [15 – 18]	0.370	17 [16 – 18]	0.196	103 [95 – 109]	0.017
>30 min	17 [15 – 18]		17 [16 – 18]		106 [100 – 110]	
Employment status						
Non-medical and unemployed	17 [16 – 18]	0.055	17 [16 – 18]	<0.001	107 [102 – 112]	0.001
Medical field	17 [16 – 18]		18 [17 – 18]		102.5 [95 – 108]	
Religion						
Christian	17 [16 – 18]	0.030	17 [16 – 18]	0.021	107 [101 – 112]	0.011
Muslim	17 [15 – 18]		17 [16 – 18]		104 [94.75 – 108.25]	
Others	17 [15 – 19]		17 [15.75 – 17]		103 [94 – 108]	
Had an indirect contact with COVID-19 a patient						
No	17 [15 – 18]	0.003	17 [16 – 18]	0.054	105 [97 – 109.75]	0.050
Do not know	16 [14 – 17]		17 [16 – 18]		100.5 [91 – 107.25]	
Yes	17 [16 – 18]		16.5 [15 – 18]		105 [95 – 108]	
Had a direct contact with a COVID-19 patient						
No	17 [15 – 18]	0.024	17 [16 – 18]	0.399	105 [97 – 109]	0.068
Do not know	16 [12.5 – 17]		17 [16 – 18]		99 [90.5 – 106.5]	
Yes	17 [16 – 18]		16 [16 – 18]		106 [94 – 110]	
Having a family member who has been infected with COVID-19						
No	17 [15 – 18]	0.223	17 [16 – 18]	0.016	105 [97 – 110]	0.161
I do not know	16 [12 – 18]		17 [16 – 18]		96 [90 – 107]	
Yes	16 [15 – 18]		16 [15 – 17]		104 [95.5 – 108]	

(Cont'd...)

Table 2. (Continued)

	Knowledge score		Attitude score		Practice score	
	Median [IQR]	P-value ^a	Median [IQR]	P-value ^a	Median [IQR]	P-value ^a
	r ^b	P-value	r ^b	P-value	r ^b	P-value
Age	0.150	0.002	0.201	<0.001	0.186	<0.001
Household crowding index	-0.244	<0.001	-0.085	0.087	-0.074	0.136
Fear score	0.010	0.834	0.108	0.030	0.279	<0.001
Anxiety score	-0.188	<0.001	-0.099	0.047	-0.012	0.816

Note: P-values marked in bold are significant ($P < 0.05$); ^aThe Mann–Whitney U-test was used to compare two groups; the Kruskal–Wallis test was used to compare three groups; ^bSpearman correlation test was used

toward COVID-19; however, being of other religions versus Christian was significantly associated with more negative attitudes. Furthermore, more appropriate practice during the COVID-19 pandemic was associated with high scores on knowledge, attitude, and fear of COVID-19, in addition to spending more time on COVID-19 information per day. Stratification by sex showed different correlates for COVID-19 KAP; most importantly, males with higher attitude scores had better practice (but not knowledge), while females with better knowledge and more acceptable attitudes had better practices.

The present study validated scales of KAP toward COVID-19 by examining their reliability and validity in the Lebanese population, as, to date, few studies have validated such type of scales in Lebanon (Abounoori *et al.*, 2021; Wake, 2020). The principal component analysis results showed that the constructed and validated KAP scales could tackle all aspects of knowledge, attitude, and practice over a broad range of factors. The KAP scales in this study had an adequate internal consistency (reliability), similar to the previous findings from Korea (Park, 2021). The knowledge scale showed a moderate internal reliability value (Cronbach's alpha = 0.615), similar to the results of a Spanish study (Aguilar-Latorre *et al.*, 2021), which evaluated participant knowledge in different areas, including sanitizing methods and techniques, symptoms related to COVID-19, diseases due to coronavirus, and transmission modes. Consistent with the previous findings among the Iranian population, the practice scale had excellent internal reliability (Cronbach's alpha = 0.899) (Abounoori *et al.*, 2021; Wake, 2020).

Regarding knowledge correlates, participants working in the medical field or with family members working in the medical field had high knowledge about COVID-19, in line with recent findings from China and Lebanon (Domiaty *et al.*, 2020; Huynh *et al.*, 2020). A possible explanation could be that, usually, health-care professionals are well-positioned to get information from reliable sources, integrate it, comprehend it, and explain it to their families,

thus increasing their awareness of diseases and other ailments. Participants with a family member working in the medical field also had a more acceptable attitude toward COVID-19, suggesting that better health education could increase knowledge, change attitudes and behaviors, and prevent infectious illnesses (Verelst *et al.*, 2016).

In this study, the high household crowding index was associated with lower knowledge about COVID-19, explained by the fact that respondents with a high household crowding index have low income and low education levels and thus lack knowledge about COVID-19 (Chai *et al.*, 2022). The previous literature revealed that high household crowding index is associated with disease transmission, which is related to several factors, such as poor socioeconomic status (Chipeta *et al.*, 2022) and poor knowledge about the disease progression and transmission. In the same line, participants who did not know whether they had indirect or direct contact with COVID-19 patients had lower knowledge in both males and females, explained by the fact that those with higher knowledge and awareness of transmission modes avoid contact with COVID-19 cases/suspected cases. Increased awareness and better attitudes among individuals who were in contact with previous COVID-19 patients can promote health-seeking behaviors to obtain more information from reliable sources and avoid getting the infection.

Similar to the previous findings, an increase in age was also linked to lower awareness of COVID-19 (Adhena & Hidru, 2020; Akalu *et al.*, 2020; Wolf *et al.*, 2020; Zhong *et al.*, 2020). Older adults use technology and social media less frequently, which could explain their poorer knowledge. Another reason might be the decline in cognition, hearing, and vision, making it difficult to read or comprehend medical instructions. Our results showed that participants of other religions had negative attitudes toward COVID-19 compared to Christians, consistent with the previous findings (Defar *et al.*, 2021). A possible explanation is that participants of other religions are susceptible populations/groups highly bound to cultural

Table 3. Adjusted odds ratios of knowledge, attitudes, and practices toward COVID-19 from multivariable analyses

	Knowledge	Attitudes	Practice 1
	Model 1	Model 2	Model 3
Independent variables			
Knowledge score	--	1.04	1.14**
Attitude score	--	--	1.41***
Having a family member working in the medical field			
Yes (no)	1.40	1.76*	0.93
Indirect contact with a COVID-19 patient			
Yes (no)	1.17	0.85	0.67
Do not know (no)	0.44*	0.53	0.63
Having a family member who has been infected with COVID-19			
Yes (no)	0.64	0.91	1.52
Do not know (no)	0.99	0.41	0.70
Direct contact with a COVID-19 patient			
Yes (no)	0.93	1.42	1.71
Do not know (no)	0.79	1.45	0.73
Diagnosed with COVID-19 (no)	1.45	0.72	0.41+
Tested with COVID-19 (no)	0.67	0.73	0.57+
Fear of COVID-19 score	1.00	1.04*	1.10***
Time spent on COVID-19 information/day			
30+min (<30)	1.37	1.38	1.91**
Covariates			
Age	0.99	1.00	1.02+
Males (females)	0.87	0.74	0.80
Urban (rural)	0.85	0.64+	1.13
Currently married (no)	1.69	0.98	0.56
College education (no)	3.90**	1.52	1.65
Currently employed (no)	0.83	0.88	0.99
Household crowding index	0.41***	1.02	1.33
Muslim (Christian)	0.65	0.91	0.73
Other religions (Christian)	0.76	0.63	0.59
Anxiety score	0.88*	0.89+	1.02
df	20	21	22
Wald Chi-square	7.71	25.18	3.19
N	405	405	405

Note: The category in the parentheses is the reference group. Knowledge dichotomized variable: Low (values less than 17.00) versus high knowledge (values greater than or equal to 17.01). Attitude dichotomized variable: Fearful (values less than 17.00) versus acceptable attitude (values greater than or equal to 17.01). Practice dichotomized variable: Flawed (values less than 104.00) versus good practice (values greater than or equal to 104.01). + $P < 0.1$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 4a. Adjusted odds ratios of knowledge, attitudes, and practices toward COVID-19 from multivariable analyses, males

	Knowledge	Attitudes	Practice 1
	Model 1	Model 2	Model 3
Independent variables			
Knowledge score	--	0.92	0.92
Attitude score	--	--	2.77*
Having a family member working in the medical field			
Yes (no)	0.31	1.91	0.61
Indirect contact with a COVID-19 patient			
Yes (no)	2.03	0.79	3.11
Do not know (no)	0.19	0.08	0.01*
Having a family member who has been infected with COVID-19			
Yes (no)	1.46	0.56	0.32
Do not know (no)	0.006	0.001	0.003
Tested with COVID-19 (no)	0.43	0.41	0.04+
Fear of COVID-19 score	0.85	1.15	1.15
Time spent on COVID-19 information/day			
30+min (< 30)	1.99	0.22+	2.10
Covariates			
Age	0.88	1.06	0.85
Urban (rural)	9.59+	0.71	5.22
Currently married (no)	3241.10*	11.53	223.54+
College education (no)	21.08	0.54	0.29
Currently employed (no)	0.07	0.15	0.56
Household crowding index	0.01*	0.26	1.14
Muslim (Christian)	0.98	4.61	3.10
Other religions (Christian)	3.56	0.43	0.62
Anxiety score	0.32	0.59	0.30+
df	16	17	18
Wald Chi-square	0.19	0.43	0.04
N	82	82	82

Note: The category in the parentheses is the reference group. Knowledge dichotomized variable: Low (values less than 17.00) versus high knowledge (values greater than or equal to 17.01). Attitude dichotomized variable: Fearful (values less than 17.00) versus acceptable attitude (values greater than or equal to 17.01). Practice dichotomized variable: Flawed (values less than 104.00) versus good practice (values greater than or equal to 104.01). + $P < 0.1$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

traditions, such as eating together (usually from the same plate) and sharing utensils, and private social acts like kissing older family members' hands or heads (Hassan *et al.*, 2021; Hussain, 2020). Therefore, social distancing and self-isolation during COVID-19 were hard to follow

Table 4b. Adjusted odds ratios of knowledge, attitudes, and practices toward COVID-19 from multivariable analyses, females

	Knowledge	Attitudes	Practice 1
	Model 1	Model 2	Model 3
Independent variables			
Knowledge score	--	1.04	1.17***
Attitude score	--	--	1.24*
Having a family member working in the medical field			
Yes (no)	1.49	1.49	0.84
Indirect contact with a COVID-19 patient			
Yes (no)	0.96	0.87	0.61
Do not know (no)	0.36*	0.69	0.67
Having a family member who has been infected with COVID-19			
Yes (no)	0.61	0.88	1.79+
Do not know (no)	1.00	0.49	1.06
Tested with COVID-19 (no)	0.92	1.04	0.58
Fear of COVID-19 score	1.01	1.03	1.09**
Time spent on COVID-19 information/day			
30+min (< 30)	1.17	1.53	2.25**
Covariates			
Age	0.97	0.97	1.03
Urban (rural)	0.66	0.66	1.15
Currently married (no)	1.53	1.02	0.52+
College education (no)	3.87**	2.02	2.60+
Currently employed (no)	0.91	1.08	1.20
Household crowding index	0.44**	0.94	1.26
Muslim (Christian)	0.60	1.36	1.04
Other religions (Christian)	0.56	1.04	1.05
Anxiety score	0.88+	0.94	1.08
df	16	17	18
Wald Chi-square	11.04	27.73	3.57
N	323	323	323

Note: The category in the parentheses is the reference group. Knowledge dichotomized variable: Low (values less than 17.00) versus high knowledge (values greater than or equal to 17.01). Attitude dichotomized variable: Fearful (values less than 17.00) versus acceptable attitude (values greater than or equal to 17.01). Practice dichotomized variable: Flawed (values less than 104.00) versus good practice (values greater than or equal to 104.01). + $P < 0.1$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

because of these traditions (Hassan *et al.*, 2021). This result deserves more thorough research since it shows the association between religious practices and beliefs and different elements of health, including the capacity to manage diseases, but is contradictory to the acceptable attitude shown in challenging medical conditions (Albers *et al.*, 2010, Kowalczyk *et al.*, 2020).

Our study found an association between good practice during the COVID-19 pandemic and higher knowledge and fear levels. This result is consistent with a recent analysis that found that knowledge and attitude are strongly associated with better practice (Wake, 2020). Participants with high fear scores had a more acceptable attitude toward COVID-19, in line with findings in Saudi Arabia (Al-Hanawi *et al.*, 2020). The acceptable attitude toward COVID-19 among individuals who exhibit anxiety and panic can be explained by their complete adherence to government actions and stringent measures against COVID-19, including lockdowns, national curfew, and closure of schools, universities, praying places, and other public spaces. Other studies conducted among the general population and health care workers also support these kinds of associations (Abdelhafiz *et al.*, 2020; Bekele *et al.*, 2020; Clements, 2020; Hossain *et al.*, 2020; Karim *et al.*, 2020; Roy *et al.*, 2020; Zhong *et al.*, 2020).

Our findings showed that spending more time on COVID-19 information and having higher knowledge and attitude scores were associated with good practice during the COVID-19 pandemic, similar to other studies (Clements, 2020; Zhong *et al.*, 2020). Improving knowledge through raising awareness could have a positive effect on addressing factors associated with disease transmission. Thus, increased knowledge about COVID-19 favors the application of the required preventive measures needed to halt and regulate virus transmission (Aravindhan *et al.*, 2021).

In this study, knowledge, attitude, or practice did not significantly differ among males and females. Nevertheless, knowledge affected practice among females but not among males, although the attitude score was associated with higher practice scores in both groups. Except for a Lebanese study, where male youth perceived the risk of COVID-19 infection to be much higher and exhibited more appropriate COVID-19 practices than female participants (Sakr *et al.*, 2021), the previous studies reported conflicting data, with males often showing less knowledge, worse attitudes, and less cautious behaviors than females (Zhong *et al.*, 2020, Haque *et al.*, 2020, Maheshwari *et al.*, 2020). Furthermore, this study is the first to show that, even if knowledgeable, men would not have a better practice, contrary to women. The appropriate practice of males during COVID-19 was related to age, profession, attitude, and anxiety, while it was associated with knowledge and education in females. According to a German study among 3245 participants, women could use social media and information platforms more frequently than men and might make more efforts to educate themselves about COVID-19 (Lemenager *et al.*, 2021), which could partially explain our result. Risk-taking behaviors, known to be higher among males, could also explain this worthwhile finding, but more research would be necessary to understand its underlying reasons.

4.1. Limitations and strengths

This study has a few limitations. First, it was web-based and employed an online questionnaire to gather data, which explains the high participation rate of young, female, single, unemployed, and educated participants. The sample might not be representative of the entire population as it was recruited by the snowball technique, which does not allow for the generalization of the findings. This non-random method could also generate a selection bias since participants are nominated by people who know them. As in all KAP studies, a social desirability bias may exist, which could lead participants to underreport practices/behaviors related to the disease. Furthermore, a recall bias cannot be excluded since the results were self-reported and depended on the participant's memory. Finally, although our study provided valuable information on KAP and associated factors among the Lebanese population, the validity of the scales should be confirmed in future research, particularly for the knowledge and attitude scales where the variance explained was less than 60% and since the reliability analysis was only acceptable. Thus, studies that override the identified limitations are suggested to confirm our results.

Despite above limitations, our study has several strengths. First and the foremost, the questions used to evaluate KAP toward COVID-19 were adapted from the previous studies conducted among health practitioners and the general population and validated in our sample, thus reflecting the Lebanese context regarding these concepts; the practice scale was particularly shown to have good properties. Furthermore, our findings would help assess the protective measures in Lebanon, knowledge, and risk perception among Lebanese adults and contribute to the national efforts addressed to control the COVID-19 pandemic in Lebanon.

4.2. Clinical implications

This study aimed to assess the knowledge, attitude, and practice during the COVID-19 outbreak. The study has considerable implications for future actions, such as improving self-care by increasing COVID-19 prevention and control guidelines. Our results could also serve to better identify vulnerable groups and target them in future public health awareness campaigns.

5. Conclusions

This study validated three tools to highlight the knowledge, attitudes, and practices among the general population during the COVID-19 outbreak in Lebanon. It showed that working in the medical field, education level, and a previous history of COVID-19 were significant factors of KAP toward COVID-19. Furthermore, better knowledge and attitudes toward COVID-19 were associated with better preventive

practices. Nevertheless, our findings suggested the need for health education programs tailored differentially according to sex, taking into account education, age, and socioeconomic status to raise awareness of COVID-19 and promote more acceptable attitudes and sustained safe practices among the general Lebanese population.

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Conflict of interest

The authors declare no conflicts of interest.

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Ethics approval and consent to participate

The ethics committee at the Psychiatric Hospital of the Cross approved the study protocol (HPC-038-2020). Online consent was obtained from all participants on the first page of the questionnaire.

Consent for publication

Not applicable.

Availability of data

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

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