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RESEARCH ARTICLE

Child trafficking in China: Evidence from sentencing documents

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Abstract: Child trafficking has long been internationally recognized as a serious crime. However, due to data scarcity and inconsistent definitions, the scope and the nature of such criminal activity are not well understood in China. To fill this gap, this study aims to provide new evidence by digitizing and analyzing sentencing documents on child trafficking in China during 2014–2016. Taking advantage of web-scraping techniques, all child trafficking cases were downloaded from the China Judgments Online website. Through geographic mapping and network analysis, we identified four geographic hotspots for trafficking - the Central East (Shandong, Henan, and Hebei Provinces), the East (Jiangsu and Zhejiang Provinces), the Southeast (Guangdong and Fujian Provinces), and the Southwest (Sichuan, Guizhou, and Yunnan Provinces) and explored the connection between the hotspots and the gender of victims. We further examined the association of provincial socioeconomic characteristics with the frequency of trafficking cases and found that the sex ratio at birth and the number of legal adoptions per thousand population were positively correlated to the frequency of buying and selling children.

Keywords: child trafficking; China; gender difference; illegal adoption

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1. Introduction

Child trafficking, a serious and grave crime against vulnerable children, has attracted global attention for decades (Gozdziak and Collett, 2005; Kangaspunta, 2003; Lee, 2005; Staiger, 2005). Scholars in this area have spent a tremendous amount of time on issues of international trafficking, yet domestic trafficking has largely been ignored, possibly due to the inconsistency in definitions of human trafficking that most researchers have adopted (Larsen, 2011; Rafferty, 2007; Shen, Antonopoulos, and Papanicolaou, 2013; Weitzer, 2014). For example, according to the United Nations (UN) Protocol on trafficking document, human trafficking is defined as "the recruitment, transportation, transfer, harboring, or receipt of persons by improper means (such as force, abduction, fraud, or coercion) for an improper purpose including forced labor or sexual exploitation." The definition emphasizes three specific elements: The act, the means, and the purpose of exploitation (UN, 2000). When studying domestic trafficking, however, researchers might find that the exploitation-oriented framework does not fit a country's legal system. For instance, in the Chinese legal system, the definition of child trafficking focuses on the abduction or trafficking of a child for the purpose of selling, while forced labor or sex exploitation is only considered an aggravating factor during the whole trafficking process (Shen, 2016). Therefore, such an inconsistency may hinder the effort to understand the severity of domestic trafficking in the Mainland China (hereafter China).

Ren (2004) reported that, from 1980 to 2000, there were 10,768 children trafficked nationwide, meaning that thousands of families lost their young children and most of whom had little chance of ever finding them again (Shen, Antonopoulos, and Papanicolaou, 2013). Although forced labor or sex exploitation might not be the main purpose of child trafficking - some victims were voluntarily sold by their own parents - the negative consequences are certainly not negligible; the victims live with their buyers who are not monitored by official institutions, and the chances of a child being abused, resold, or abandoned are quite high if their buyers become incapacitated in any way (Rafferty, 2007). Some scholars argue that the Chinese legal definition of child trafficking can be categorized as an illegal adoption (Shen, 2013). Regardless of what officially constitutes as child trafficking in different countries, the consequences of such crimes cannot be overlooked, and understanding the pattern and related issues of child trafficking is still of great urgency.

Unfortunately, empirical studies on child trafficking in China are rare (Li, Tan, Wang *et al*., 2018; Shen, 2016; Wang, 2015; Xing, Chen, and Xu, 2017). One possible reason is the lack of empirical data. Previous work has either been entirely based on official statistics released by governmental agencies (Ren, 2004) or mixed with interviews of individual victims conducted by NGOs (Chu, 2011; Jiang and Sánchez-Barricarte, 2013), which offer little insight to the problem besides aggregated numbers and unsupported speculations on general patterns. In recent years, new empirical studies have emerged using information garnered from Regional Police records or websites that help people to find their missing children to investigate child trafficking (Wang, 2015; Li, Tan, Wang, *et al*., 2018; Wang, Wei, Peng *et al*., 2018). For instance, Wang (2015) utilized Provincial Police records that contained information on the origins of victim(s), locations of buyer(s), purposes of purchasing, and means of transportation to explore the pattern, size, and potential causes of child trafficking in Fujian Province from 2009 to 2014. Moreover, based on self-reported information scraped from missing children websites, both Li *et al*. (2018) and Wang *et al*. (2018) identified regional hotspots and critical bridges of child trafficking. Even though studies such as these improved the current understanding of child trafficking in China, the applicability and implications of their results are potentially limited by regional relevance (e.g., Fujian Province) or self-reported bias (e.g., abducted or missing cases only).

As part of the effort to improve Judicial Transparency, beginning on January 1, 2014, the Supreme People's Court of China (SPC) required the People's Courts at all levels to upload their sentencing documents, except for those cases that may contain classified information (e.g. cases related to national security) and pose a threat to individual privacy (e.g. cases related to juveniles) or those deemed "inappropriate" to publicize. The publicized sentencing documents provide a unique opportunity to investigate child trafficking, as the documents include information on defendants and trafficking routes (Tao, 2017; Xing, Chen, and Xu, 2017).

Previous findings on the magnitude of child trafficking in China are mixed, especially when different sources of data are compared. Due to the limited sources of data regarding these crimes, most of the prior studies have either used official statistics from government reports and police records or cited self-reported information while evaluating the extent of child trafficking. For example, using released government reports, Ren (2004) reported that, from 1980 to 2000, there were 10,768 children trafficked nationwide, approximately 500 cases per year, which is consistent with the data released from the National Bureau of Statistics of China that documented the total number of detected child trafficking cases as 618 in 2016 (National Bureau of Statistics of China, 2017). According to the information obtained from missing children websites, Li *et al*. (2018) found that the number of trafficked children increased from <50 in the early 1980s to nearly 400 in the year 1994; the number of children trafficked then decreased to a stable level of around 250 after the year 2002. These differences might be due to selective reporting. For instance, the cases reported by the missing child websites are exclusive to children who are either missing or abducted; however, many victims of child trafficking are sold by their parents (Li, Ren and Zhang, 2013). As such, those cases are included in the governmental reports but are not reported to the missing child websites. While utilizing police records in the Fujian Province, Wang (2015) reported that, between the years of 2010 and 2013, the police in Fujian Province detected more than 11,000 child trafficking cases, which is equivalent to more than 3000 cases per year in one province. Although both Ren (2014) and Wang (2015) employed data from official sources, the huge discrepancy is still difficult to explain.

Despite the disparity in the magnitude of child trafficking cases across different data sources, researchers have suggested a consistent pattern of geographical hotspots for child trafficking. For example, victims were trafficked from the Inland Northern and Southwest regions (e.g., Sichuan, Yunnan, and Guizhou Provinces) to the Central East (e.g., Shandong, Henan, and Hebei Provinces) and Southeastern coastal regions (e.g., Fujian and Guangdong Provinces) (Li, Tan, Wang *et al*., 2018; Ren, 2004; Tao, 2017; Wang, 2017; Wu, 2017).

Generally speaking, younger boys were more marketable than girls in the black market. Existing literature has shown that male victims comprised 53–66% of the total number of children trafficked (Li, Tan, Wang *et al*., 2018; Ren, 2004; Xing, Chen, and Xu, 2017), and the price of boys ranged from 10,000 to 20,000 Chinese yuan (approximately USD $1,500–$3,000) in 2,000, which was nearly 2–3 times higher than the cost of girls (Ren, 2004). Wang (2015) reported that, in the Fujian Province, boys were bought at 70,000–80,000 yuan (approximately USD $10,300–$11,800), and the price of girls was only about half (Wang, 2015). In terms of age distribution, the majority of victims were under 7 years old, while older girls were more frequently sold into the sex industry or bridal trade (Ren, 2004).

Scholars have linked some trafficking patterns, for example, the frequency and probability of selling or buying for economic and cultural reasons (Wang, 2017; Wu, 2017). For instance, studies have suggested that the large income gap, low level of education, and high illiteracy rate are positively correlated to the probability of selling victims; similarly, a high sex ratio at birth (SRB), which is considered a consequence of the restrictive practice of the family planning policy and traditional culture, is associated with the high probability of buying victims (Wang, 2017). In addition to the profit- or culture-motivated hypothesis (Jiang Q and Sánchez-Barricarte, 2013; Shen, 2013), some scholars have argued that the black market for child trafficking in China was triggered by the demand for illegal adoption, a result of the unique combination of the one-child policy, the traditional culture of male-preference, and the barriers to legal adoption (Ren, 2004; Shen, Antonopoulos, and Papanicolaou, 2013; Tao, 2017; Wang, 2015; Xing, Chen, and Xu, 2017). Given that many children were voluntarily sold by their parents or relatives, people who lived in poor rural areas with relatively loose family planning policies were more likely to sell their own children (Wu, 2017; Wang, 2017), given their own gender preference (Rafferty, 2007). In addition, the high profit, low risk, and lenient punishment for parental sellers in child trafficking businesses elevated the supply (Jiang and Sánchez-Barricarte, 2013; Shen, Antonopoulos, and Papanicolaou, 2013; Zhang, 2006).

Although previous studies have examined the child trafficking issue in China, due to limited information provided by official records and the unreliable nature of self-reported cases, much of the research suffers from inconsistent results or a lack of empirical evidence. Moreover, to understand the extent of child trafficking, legal adoption has to be considered because adopters and buyers share the same “market” in China. To fill this gap, the current study aims to provide a more substantial basis for empirical research on child trafficking through the analysis of official sentencing documents. Although a single source of information cannot provide a complete picture of the extent of child trafficking in China, the sentencing documents provide useful information on both the victims and offenders. Furthermore, by taking the advantage of geographic information system technology, we are able to map trafficking networks and summarize trafficking patterns, thus contributing to a better understanding of the nature of child trafficking in China.

Taking advantage of the released sentencing documents from 2014 to 2016, the current study seeks to explore the patterns of child trafficking in China, focusing on the characteristics of the victim, geographic distribution of trafficking routes, and the related socioeconomic factors. This article is organized as follows: First, we begin by summarizing previous findings. Next, a description of the data and methods used is presented, followed by our results and discussion. We conclude with a summary of our findings and suggestions for future studies.

2. Data and Methods

2.1. Data

In this study, we utilized web-scraping techniques to retrieve all available sentencing documents during the period of 2014–2016 citing Article 240 of the Chinese Criminal Law that criminalizes the trafficking of females or children. Sentencing documents were obtained directly from the China Judgments online (CJO) website, which is the official archiving platform for the national judicial documents. The process of webpage data collection is to automatically browse the website through client-server communication, store the contents of webpage, and to structuralize them into analyzable data. The contents of interest, for example, the sentencing documents, are stored on server and can be located and visited by a global address - Uniform Resource Locator (URL). Theoretically, once the URL of each of webpages is known, the contents could be retrieved and transported using HTTP protocol (Fielding, Gettys, Mogul *et al*., 1996). However, due to the lack of well-developed software and individually customized structure of the CJO website, the whole process of data collection was done by specialized programming in Python. According to Article 240, any individual who is involved in “any act of abducting, kidnapping, buying, trafficking in, fetching or sending, or transferring a woman or a child for the purposes of selling the victim” faces a penalty of not <5 years or life imprisonment and a fine or confiscation of property. Since the mandatory uploading started from January 01, 2014, and there is no regulation to urge the People’s Courts to upload the cases sentenced before that, the number of cases sentenced before the year of 2014 is very limited. While the project was started in 2017, only three full years of data were available. Therefore, the analytical sample consists of 536 first trial cases sentenced from 2014 to 2016 with 1,074 defendants and 859 victims.

For a criminal case, usually there are three steps involving investigation, prosecution, and trial. The process of each of cases might be different. Among the total of 536 cases sentenced between 2014 and 2016, more than 90% of victims were sold at the same year of the case being trafficked. Although there were no official data sources showing the number of prosecuted child trafficking cases in the legal system, according to the official emergency response system - *Tuanyuan* which is led by the Ministry of Public Security of China, there were totally 3,053 reported missing children, and 97.6%

of them were found between May 2016 and May 2018. Among all the solved cases, the top four categories were running away from home (55.9%, 1,705 cases), getting lost (13.9%, 424 cases), accidental death (4.6%, 140 cases), and being trafficked (1.6%, 48 cases) (Mo, 2018). Roughly <30% of total reported cases, 250 per year were child trafficking even if we assume the worst case scenario that all the rest were child trafficking cases.

Based on the number of cases uploaded to the websites of CJO and Open Law and the official gazettes of the SPC, the percentage of the uploaded among sentenced cases for crimes of infringing on the rights of the person and the democratic rights of citizens including murder, homicide, rape, and human trafficking was about 60%. If there is no substantial discrepancy on the pattern of selective uploading across provinces, the number of cases that we have was about one-third to half of total number of cases.

In contrast to the international definition of trafficking that focuses on the purpose of exploitation, child trafficking in the Chinese Judicial System emphasizes the illegal trafficking process and the purpose of profit making. Therefore, we acknowledge that a direct comparison of findings between the international child trafficking studies and those using data from the Chinese Judicial System might not be suitable. Furthermore, we acknowledge that sentencing data acquired from the CJO may be incomplete due to the interpretations of the SPC (2013; 2016), which states that all sentencing documents are required to be uploaded, except for cases with classified information, individual privacy concerns, defendants under 18 years old, those closed for mediation, and other "unpublishable" situations, thus leading to suspicions that the uploaded sentencing documents might be subjective to selection or purposeful deletion (Liebman, Roberts, Stern *et al*., 2017). Unfortunately, there are no available sources (e.g. official gazettes, news reports, and research articles) that could be used to cross-reference and evaluate the pattern and extent of uploading or deleting case information so far. In addition to the possible selective uploading or deleting of documents, it should be cautioned that not all incidents of trafficking have been identified by the police, and of those offenders who have been caught, not all have gone through the legal system. Still, despite the limited access to child trafficking data, the information garnered from the CJO sentencing documents may add some much-needed insight into the current trafficking issues in China.

2.2. Measurements

As a structured document, each of the sentencing reports has three distinct parts: A caption, main body, and conclusion. The caption contains the parties, the court, and the case number. The main body gives a description of acknowledged facts by the court, for example, information about the offender(s) and the victim(s), characteristics of the offense, such as time and location, and court processes (e.g. legal representation and appeal). The dispositional decisions, such as articles cited and sentences, are listed in the conclusion. We manually coded all the information on offenders, victims, offenses, and victim-offender relationships. For example, gender of victim (male), age of victim in years, whether the victim is sold by guardian(s), final price paid by the buyer in thousand Chinese *yuan*, whether the case is reported to police, whether the purpose of trafficking is adoption, the number of offenders involved, and the proportion of male offenders involved, were coded.

For each of the cases, geographic information on both the origin and destination of trafficking routes was also recorded at both the provincial and city levels, which were used to match local socioeconomic indices, such as the urban–rural average income ratio (URAIR), the SRB, the rate of illiteracy, and the level of legal adoption. For provincial socioeconomic characteristics, the URAIR and the percentage of rural illiteracy were chosen as the measures of socioeconomic development. The ratio of the summed number of adoptions over 2013-2016 versus the average total population was used to access the level of legal adoption, and the SRB was used as the level of son preference.

Except for the level of adoption that were from the Statistical Yearbook of the China Civil Affairs (Ministry of Civil Affairs, 2013; 2014; 2015; 2016), all other measures were from the latest census. Regional hotspots, as identified by the heat maps, were also controlled using dummy variables for regions: Central East (Shandong, Henan, and Hebei Provinces), East (Jiangsu and Zhejiang Provinces), Southeast (Guangdong and Fujian Provinces), and Southwest (Sichuan, Guizhou, and Yunan Provinces).

2.3. Analytical methods

We provided regular descriptive analyses to explore the link between socioeconomic factors and characteristics of child trafficking, such as the gender of the victim. To examine the geographic pattern of child trafficking, heat maps were generated to see the areas where trafficking origins and destinations were mostly concentrated, and trafficking networks were plotted using R packages such as recharts (Xie, 2017) and igraph (Csardi and Nepusz, 2006). We also estimated a series of zero-truncated Poisson models to explore the link between the socioeconomic characteristics at the province level and the frequency of child trafficking.

3. Results

3.1. Descriptive analyses and gender differences

Table 1 provides the descriptive statistics for the victims by gender. Among the victims, 61% were boys. The average age of the victims was 1.38-year-old, and girls were slightly older by approximately two months ($p < 0.10$). About 80% of the victims were sold by their guardian(s) with little difference by gender. Except for the cases that were detected during the transaction or transport period, almost all children were adopted by their buyers. In terms of price, boys were sold at an average of 46,430 *yuan* (approximately USD $6,800), which is 18,390 *yuan* (USD $2,650) higher than that of girls. The highly significant difference ($p < 0.001$) underlines the high market value of boys, which coincides with the son preference in China. However, it is worth mentioning that, due to substantial discrepancies on the level of socioeconomic development across provinces, price might not be comparable and the inference may not be applicable to a broader population. Among all cases, slightly more than half of the children (55%) were trafficked across provincial borders, only 23% of victims were found by the help of informants, and the rest were found by police investigation or connections to other trafficking cases. Apparently, boy victims were 8% more likely to be reported or identified by informants ($p < 0.01$). For each of the victims, there were multiple offenders. For example, on average, five offenders were involved in a single trafficking case, with two or three of them being female.

It is worth noting that the majority of children were sold by their guardians (parents, grandparents, or other relatives), and nearly all of the victims were adopted. This phenomenon is rooted in the unique legal regulations and practice of adoption, in which private adoption agreements are not formally recognized. Although the law does not exclude private parties, most of accepted adoption cases are from state-run orphanages. In practice, it is not easy to fulfill the legal requirements for private adoptions, which fosters a market of selling and legalizing victims of child trafficking. For

Table 1. Descriptive analysis and gender difference between male and female victims

Variables	Both sexes		Females		Males		Sex difference
	n	Mean (SD) or %	*n*	Mean (SD) or %	*n*	Mean (SD) or %	
Male children	851	61%	330	--	521	--	--
Age (years)	846	1.38 (1.38)	320	1.50 (1.89)	518	1.31 (0.94)	0.19+
Guardian	496	80%	152	80%	339	81%	–1%
Adoption purpose	676	99%	256	97%	416	100%	–3%
Price (RMB *yuan*) (*1,000)	801	39.34 (34.73)	302	28.04 (20.80)	494	46.43 (39.49)	–18.39***
Reported to police	859	23%	330	18%	521	26%	–8%**
Average # of offenders	859	4.93 (3.60)	330	5.06 (3.56)	521	4.86 (0.365)	0.20
Male offenders	810	56%	309	54%	493	57%	3%
Inter-provincial cases	565	55%	198	57%	363	54%	3%

Note: The p value is based on z/t test. SD: Standard deviation, +p<0.10; *p<0.05; **p<0.01; ***p<0.001.

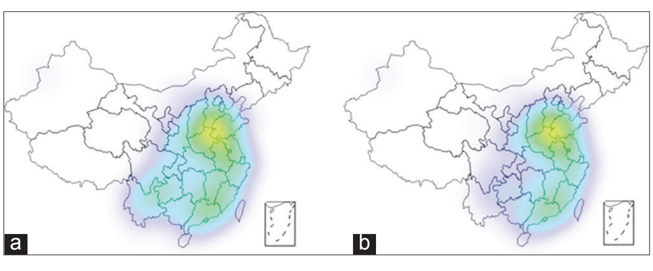

Figure 1. Heat maps of origins and destinations of trafficking victims. (a) Origins of child trafficking. (b) Destinations of child trafficking

example, after adopters' pay for victims, they usually need to purchase a falsified birth certificate to legitimize their "children" (Shen, 2013; Wang, 2015).

3.2 Geographic pattern of child trafficking

Using the brightness to represent the frequency, panels (a) and (b) in Figure 1 show the concentrated areas of trafficking origin and destination of victims, respectively. Consistent with the previous findings on child trafficking patterns in China, the Central East (Shandong, Henan, and Hebei Provinces) and the Coastal (Jiangsu, Zhejiang, Fujian, and Guangdong Provinces) regions were the most frequent destinations of child trafficking in the past few years, though victims were also trafficked from Sichuan, Yunnan, and Guizhou Provinces besides the areas overlapped with destinations. Figure 2 maps the origin and destination with the known route information. It is clear that the trafficking routes could be classified into two types: Intra- and inter-province. Among the origin and destination overlapped areas, most of the routes share the same origin and destination at the provincial level, while the Southwestern region (Sichuan, Yunnan, and Guizhou provinces) dominates at the inter-province level, serving as the main supplier to the Central East and Coastal provinces. Possible reasons for these patterns may include the large demand for adoptions in the Central East and coastal regions, and the profit-driven trafficking in the regions where the implementation of the one-child policy is relatively less restricted (Xing, Chen, and Xu, 2017; Wang, Wei, Peng *et al*., 2018).

To further explore whether the pattern of child trafficking differs by gender, Figure 3 shows the heat maps of male and female victims in relation to their origins and destinations. Compared with the destinations of the female victims, one distinct pattern of male victims is that more boys were brought to the Southeastern coastal areas, especially for Fujian and Guangdong Provinces where the son preference is high (Wang, 2015). Similarly, for the origins, the Southeast region, for example, Fujian and Guangdong Provinces, contributed to substantial numbers of boy victims, while the demand and supply of the Central East region, such as Shandong, Henan, and Hebei, tended to be less gender selective. Scholars have linked gender-selective trafficking to the combination of patrilineal family structures and practices in certain regions, as well as the high level of economic development that makes illegal adoption affordable (Shen, 2013; Wu, 2017; Zhang, 2006).

3.3. Provincial characteristics and child trafficking

To evaluate the effects of provincial socioeconomic characteristics, we estimated a series of zero-truncated Poisson models against the number of cases by gender and location of victims, and the results are summarized in Table 2. After controlling for regional hotspots, the level of adoptions was positively associated with the expected log count of child trafficking for both male and female victims at origins and destinations, which could be an indication that the frequency of child trafficking is triggered by the demand of adoptions. Another interesting finding is that the SRB was correlated to the expected log count of male victims at the destinations, which means that a higher SRB is linked to more boys being purchased in the destinations.

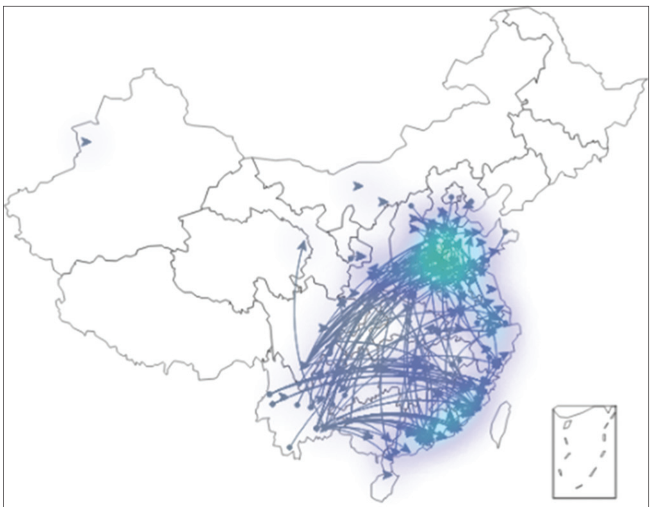

Figure 2. Routes of child trafficking in China from 2014 to 2016

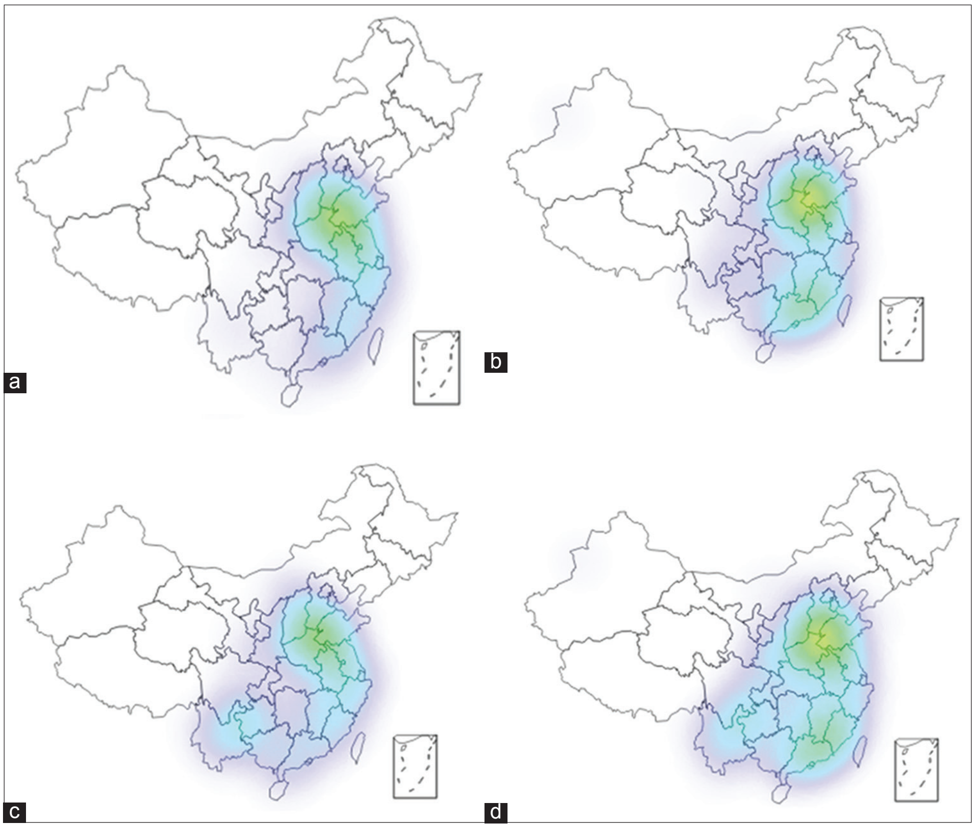

Figure 3. Heat maps of origions and destinations by gender of victims. (a) Destinations of female victims. (b) Destinations of male victims. (c) Origions of female victims. (d) Origions of male victims

Consistent to the geographic hotspots revealed in the heat maps, Table 2 also reinforces the geographic patterns. For instance, compared to other areas, the Southwest region (Sichuan, Guizhou, and Yunnan Provinces) has much fewer female victims bought (1-exp(-1.655))=80.8%, but a considerably higher amount of selling cases for both boys (exp(1.849)-1=535% and girls (exp(1.949)-1=602% more), while the East region (Jiangsu and Zhejiang Provinces) was only associated with a high frequency as a destination for both boys and girls but not as a point of origin. The Southeast region (Guangdong and Fujian Provinces) has very high levels of buying both male and female victims and selling boys but a slightly higher level of selling girls; the Central East region (Shandong, Henan, and Hebei Provinces) showed high concentrations of both selling and buying for both boys and girls.

4. Discussion

The current study explores the characteristics, patterns, and related factors for child trafficking in China using the CJO sentencing documents. By quantifying the sentencing documents citing Article 240 of the Chinese Criminal Law from the years 2014 to 2016, we provide some new evidence of child trafficking in China. Our results indicated that there were two major categories of child trafficking: Intraprovincial (45%) and interprovincial trafficking (55%). The Central East provinces of Shandong, Henan, and Hebei, as well as the Coastal provinces of Jiangsu, Zhejiang, Guangdong, and Fujian, are among the top trafficking destinations for all types of trafficking, with more than half of intraprovincial trafficking occurring in these regions. Interprovincial trafficking was more frequently observed in routes originating from the Southwest regions, such as Sichuan, Guizhou, and Yunnan provinces, to the Central East and Coastal regions.

Our results indicated that the majority of the trafficked victims were under 3 years old and were sold by their guardians and that almost all of the victims were adopted by their buyers. The findings implied that illegal adoption might be one of the major driving forces behind child trafficking in recent years. In contrast to earlier findings that highlight the connection of child trafficking and the tradition of child-brides in certain regions such as the Fujian province (Chen, Ebenstein, Edlund *et al*., 2015; Lid, Larsen, and Wyshak, 2004), we only found six victims intended for the role of a child bride, which may suggest

Table 2. Results of zero truncated Poisson regression model by location and gender

Parameter	Destination models				Origin models			
	Females		Males		Females		Males	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Coefficient (beta)								
Level of adoption (*1,000)	1.53 (0.09)***	0.28 (0.13)*	1.45 (0.08)***	0.66 (0.11)***	0.95 (0.13)***	0.53 (0.18)**	0.85 (0.10)***	0.54 (0.14)***
Sex ratio at birth	0.06 (0.01)***	−0.02 (0.02)	0.13 (0.01)***	0.07 (0.02)***	−0.01 (0.01)	0.04 (0.02)*	0.01 (0.01)	0.00 (0.01)
% of rural illiteracy	0.00 (0.03)	0.20 (0.05)***	−0.16 (0.02)***	−0.02 (0.04)	0.01 (0.02)	−0.11 (0.04)**	−0.03 (0.02)*	−0.06 (0.03)*
URAIG	−0.69 (0.20)***	0.96 (0.42)*	−0.52 (0.18)**	−0.40 (0.34)	0.57 (0.14)***	0.37 (0.20)+	0.56 (0.11)***	0.25 (0.15)
Region: CT		3.40 (0.35)***		2.26 (0.22)***		1.20 (0.25)***		1.34 (0.21)***
EA		2.35 (0.41)***		1.45 (0.29)***		1.10 (0.31)***		0.98 (0.25)***
SE		2.51 (0.47)***		2.30 (0.28)***		0.18 (0.34)		1.62 (0.25)***
SW		−1.66 (0.61)**		0.58 (0.45)		1.95 (0.30)***		1.85 (0.20)***
Other statistics								
Intercept	−3.58 (1.50)*	−1.15 (2.63)	−10.88 (1.39)***	−5.80 (2.19)**	1.63 (1.37)	−3.39 (2.09)	−0.12 (0.95)	1.47 (1.50)
−2LL	271.57	90.13	288.32	125.70	263.03	183.23	425.60	229.20
AIC	281.57	108.13	298.32	143.70	273.03	201.23	435.60	247.20
BIC	287.25	118.35	304.00	153.92	278.92	211.83	441.28	257.42
N	23	23	23	23	23	23	23	23

Note: URAIG: urban–rural average income ratio. CE: Central East; EA: East; SE: Southeast; SW: Southwest; LL: loglikelihood, AIC: Akaike information criterion, BIC: Bayesian information criterion, N: Sample size, SE: Standard error. +p<0.10; *p<0.05; **p<0.01 ; ***p<0.001.

that the tradition is diminishing. In line with the previous findings (Shen, 2016), child trafficking often involved multiple offenders (4.93 on average) whom were loosely organized as a group in which nearly half (44%) of them were female.

Our analysis has identified geographic patterns of trafficking that related to the gender of victims. The Southwest region (Sichuan, Guizhou, and Yunnan Provinces) served as a supplier to the rest of the hotspots for both male and female victims, while the East region (Jiangsu and Zhejiang Provinces) showed a high frequency of child purchases. The Southeast region (Guangdong and Fujian Provinces) has high levels of buying both male and female victims and selling boys; and the Central East region (Shandong, Henan, and Hebei Provinces) tended to be less gender selective for both selling and buying.

Our research also found that the frequency of trafficking was related to the provincial socioeconomic characteristics, such as the SRB, and the number of adoptions per thousand. Although the previous studies have called attention to the link between high SRB and the trafficking of women (Wu, 2017), the current understanding of the role of SRB on child trafficking is still very limited. Our results indicated that a high SRB might also be a contributing factor of child trafficking. Furthermore, the strong link between the number of adoptions per thousand, the frequency of child trafficking, and the high proportion of victims sold by their guardians should bring much-needed attention to the problem of child trafficking from a different angle. As noticed by others (Chen, Ebenstein, Edlund *et al*., 2015; Johnson, 2002; Johnson, Banghan, and Liyao, 1998; Lid, Larsen, and Wyshak, 2004), the current market of child trafficking is built on the current legal regulations and practices of adoption. When the demand of adoption cannot be satisfied or is encumbered by the lengthy adoption process, prospective parents may turn to the black market to fulfill their needs, which may reinforce the son preference and gender stereotypes.

The current research is limited in the following respects: First, we retrieved all the sentencing documents from the official CJO website where the court documents, above all, only represent a small proportion of child trafficking activities in China. For instance, as the final outcomes of a complicated legal process, the sentencing documents may represent only a small fraction of all the cases initiated by the Criminal Justice Agencies. Furthermore, the definition of child trafficking we adopted from Article 240 of the Chinese Criminal Law restrains our analysis to a narrow scope. It also bears repeating that, although it is required by the SPC that courts from all levels upload their sentencing documents, certain types of files are exempted, especially those deemed “inappropriate” to publicize. As we mentioned above, the number of cases we have might only be one-third to half of totally number of cases. Second, we are lacking the necessary information to evaluate the effects of possible selective uploading or purposeful deletion of cases on our study. In addition, since many measures included in the regression model were considered as indirect and crude, for example, regional dummies and SRB as indirect control of cultural difference on son preference, the findings must be interpreted with caution. Finally, but not least, the origins of some of the victims were not mentioned in the sentencing documents, leaving a substantial proportion of information missing. Hopefully, in the future, the Chinese Court will adopt a more streamlined format when recording court cases. Until then, cautions should be taken when making further inferences based on our analysis.

5. Conclusions

Neither child trafficking nor infant purchase has been widely studied; Given the lack of reliable data in China, it is hardly to obtain the accurate annual number of children trafficked. Nevertheless, our analysis represents an attempt to broaden the current understanding of child trafficking in China. Our research may promote evidence-based strategies for fighting against child trafficking in China. For instance, data from our research can be used to inform location-based policing tactics that would concentrate additional law enforcement in the identified hotspots and high-frequency routes, which would be a both efficient and straightforward method to catch traffickers.

Authors’ Contributions

Both XIN and CAI contributed to the design and implementation of the research, analysis of the results, and writing of the manuscript.

Ethics

No ethics approval was required for this study.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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RESEARCH ARTICLE

Gender difference in trends in healthy life expectancy in 2005–2012 for adults aged 50 years and older in South Africa

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Abstract: Data characterizing older people's life expectancy by good or poor health is important for policy and fiscal planning. This study aims to examine trends and investigate gender differences in healthy life expectancy (HLE) for older people in South Africa for the period 2005–2012. Using data from three repeated cross-sectional surveys conducted in 2005, 2008, and 2012, we applied a self-rated health measure to estimating HLE. The Sullivan method was used in the calculations. We found that unhealthy life expectancy decreased over the period, while HLE and the proportion of life spent in good health increased more than total life expectancy in the same period. Gender disparities were evident: Women had higher life expectancy than men, yet they spent a greater proportion of their lifetime in poor health. We concluded that HLE of older people in South Africa has improved over the period under investigation.

Keywords: *gender difference; health expectancies; healthy life expectancy; older adults; self-rated health; South Africa; Sullivan method*

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1. Introduction

Populations are rapidly growing older across the globe. The proportion of people aged 60 years and over is growing at a faster rate than any other age group (United Nations, 2017). Coupled with this, the length of life has also increased dramatically in most parts of the world. Initially, this demographic transition was experienced in developed countries, but of late, it has become a global phenomenon experienced by less developed regions as well. In South Africa, life expectancy at birth in the period of 2002–2014 increased from 51.1 years to 59.1 years for males and from 55.7 years to 63.1 years for females (Statistics South Africa, 2014). However, between 2002 and 2005, life expectancy declined due to the HIV epidemic. Nevertheless, there has since been an upward trend partly due to the successful roll-out of antiretroviral treatment (ART) (Bor, Herbst, Newell *et al*., 2013; Mayosi and Benatar, 2014; Statistics South Africa, 2014). According to the United Nations, the proportion of South Africans aged 60 years and over increased from 6.7% in 2005 to 8.0% in 2017 and is projected to double to 15.9% in 2050 due to gains in improved longevity (United Nations, 2017). Against this background, one interesting question is whether the gains in longer life are being accompanied by healthy and productive lives or by periods of illness, frailty, and more dependency. In other words, is the number of years gained being matched by quality in terms of health and well-being?

To answer the question about trends in mortality and morbidity, there is a need to develop a population health measure that combines the two components together into a single measure (Mathers and Robine, 1997). This means that conventional measures solely based on mortality, such as life expectancy, are not sufficient to summarize population health. Progress has been made over the past decades in developing new summary measures of population health which is called health expectancies (Jagger, Cox, Le Roy *et al*., 2006; Saito, Robine, and Crimmins, 2014). Health expectancies can be defined as the average number of years an individual at a given age can be expected to live in good health based on the prevailing age-specific mortality and morbidity status (Jagger, Cox, Le Roy *et al*., 2006). Health expectancies can be derived from various health measures that vary from objective ones, for example, disability, to subjective ones, such as self-rated health, and well-being. As such, different conclusions can be reached depending on the health measure used (Alves and Arruda, 2017; Christensen, Doblhammer, Rau *et al*., 2009; Doblhammer and Kytir, 2001; Zimmer, Hidajat, and Saito, 2015). Therefore, the first critical issue in health expectancy research is to define clearly the operational definition of health used (Saito, Robine, and Crimmins, 2014).

In this present study, a self-rated health measure was used to calculate healthy life expectancies (HLE). Self-rated health measures, albeit their subjectivity, have been widely accepted as reasonable measures of population health status (Doblhammer and Kytir, 2001). In fact, their use, initially in sociology (Suchman, Phillips, and Streib, 1958) and later in medical and epidemiological research (Kaplan and Camacho, 1983), dates back >50 years. Furthermore, self-rated health measures have been found to be a good predictor of mortality by longitudinal studies (Ardington and Gasealahwe, 2014; Feng, Zhu, Zheng *et al*., 2016; Idler and Benyamini, 1997; Mossey and Shapiro, 1982) and a good predictor of health care expenditures (De Salvo *et al*., 2009). There are some perceptions, though, that self-rated health measures are too subjective (Jagger, Gillies, Cambois *et al*., 2010), and questions have been raised about their reliability in developing areas where people have low awareness of health (Sabatini, 2014). This is due to "health illusions," a scenario whereby people "normalize" health deficits due to their low health expectations (Sen, 2002), which is likely the case in low-income settings. As a result, people may rate their health as good even if they are in a poor disease condition and without basic health-care facilities. Another view is that older adults can underrate the level of their disability and health challenges because they may subconsciously rate themselves better compared to their elderly peers (Jagger, Gillies, Cambois *et al*., 2010). On the other hand, Jylha's theoretical framework for self-rated health (Jylhä, 2009) suggests that a cognitive process is involved in an individual's rating of their own health status. According to this theory, the cognitive process is essentially subjective and is influenced by one's contextual environment (Jylhä, 2009). Therefore, despite its limitations, self-rated health is a useful global health indicator that can summarize all specific domains into a single health measure (Crimmins, 2004). The applicability of self-rated health in low-income settings has been established (Burström, 2012), and its construct validity has been confirmed through its association with socioeconomic status (Subramanian, Subramanyam, Selvaraj *et al*., 2009). Such a simple and single measure becomes even more efficient in resource-limited settings, where it can substitute for detailed composite measures that are more expensive.

Among researchers and policymakers mainly from European countries and the United States, the major interest has developed over the past years in using health expectancies to monitor population health over time (Jagger, Cox, Le Roy *et al*., 2006). Policymakers in these countries have shifted their focus to using health expectancy instead of life expectancy as a policy tool and primary measure of population health and to monitor health outcomes (Robine, Romieu, and Cambois, 1999). Furthermore, the indicator is also used for assessing inequalities, planning health care and social services, and allocating resources (European Health Expectancy Monitoring Unit, 2007). Unfortunately, in Africa, including South Africa, there is not much awareness of the usefulness of health expectancies for monitoring processes and policymaking. That is, in spite of the rapid aging processes mentioned above, which call for immediate attention on the well-being of older people, all that we know is that people are living longer, but we do not know how healthy older people are in South Africa.

The gender paradox in health is widely well known, that is, women tend to have a longer life yet poorer health than men. The root causes of the gender paradox are generally attributed to differences in socioeconomic status, genetic and acquired risks, immune-system responses, hormones, disease patterns and prevention, and health-reporting behaviors (Crimmins and Saito, 2000; Oksuzyan, Juel, Vaupel, *et al*., 2008). Nevertheless, a number of studies in Western countries and in China have persistently showed that the improvement in self-rated health and HLE between older men and older women largely depends on classification of self-rated health (Doblhammer and Kytir, 2001; Zack, Moriaarty, Ford *et al*., 2004; Gu, Dupre, Warner *et al*., 2009). For example, in Austria, older men and older women witnessed similar improvements in very good, good, and fair self-rated health and HLE in the 1990s, whereas older women showed greater improvements if the healthy condition was defined by very good and good (Doblhammer and Kytir, 2001). A study from the United States demonstrated similar improvements in self-rated health among older men and older women when good health was categorized as excellent, very good, and good (Zack, Moriaarty, Ford *et al*., 2004). Using three categories of self-rated health (good, fair, and not good), data from the United Kingdom showed that HLE among older men increased more than older women from 1981 to 2001 (UK National Statistics, 2006). In China, improvements in self-rated health based on two or three categories were comparable for men and women in the late 1980s (Saito, Qiao, and Jitapunkul, 2003) and the 1992–2002 (Gu, Dupre, Warner *et al*., 2009). No studies on gender difference have been conducted in South Africa so far, which implies a need to examine the difference in self-rated health and HLE.

This study intends to explore the health state of older people in South Africa using a national HIV household dataset collected by the Human Sciences Research Council of South Africa. To the best of our knowledge, this is the first study to estimate health expectancies for South Africa using repeated cross-sectional surveys. The objective of this paper is to examine trends and investigate gender differences in HLE for older people in South Africa for the period 2005–2012. The research questions posed by this study are: Has the recent increase in total life expectancy (TLE) observed in South Africa been accompanied by an increase or decrease in health status among older people? Is there any difference between women and men? In answering these two questions, and based on the data on the elderly population of South Africa, we will also be simultaneously testing the hypotheses of compression or expansion of morbidity.

2. Methods

2.1. Data sources

The study was based on 2005, 2008, and 2012 waves of the South African National HIV Incidence, Prevalence, Behaviour and Communication Survey (SABSSM) conducted in South Africa by the Human Sciences Research Council (HSRC). These are repeated cross-sectional surveys aiming at surveillance of HIV incidence and prevalence in South Africa. The individual response rates for each survey were 96.0% in 2005 (Shisana, Rehle, Simbayi *et al*., 2005), 89.5% in 2008 (Shisana, Rehle, Simbayi *et al*., 2009), and 89.1% in 2012 (Shisana, Rehle, Simbayi *et al*., 2014). All three surveys included persons residing in community dwellings and aged 2 years and above. Institutionalized individuals (i.e., those in educational institutions, military barracks, old-age homes, or hospitals) were not included in the three surveys, and hence as a result they were also excluded from this study. The surveys included a multistage cluster sample stratified by province and settlement geography (genotype) with the predominant population group in each area used. In our analysis, the design characteristics of the three surveys were adjusted using the weighted prevalence rates. Further details about the sampling procedures were presented elsewhere for 2005 (Shisana, Rehle, Simbayi *et al*., 2005), 2008 (Shisana, Rehle, Simbayi *et al* 2009), and 2012 (Shisana, Rehle, Simbayi *et al*., 2014). A questionnaire was administered through face-to-face interviews conducted by trained fieldworkers. Sociodemographic and behavioral information were collected from consenting individuals. The surveys were approved by the HSRC Research Ethics Committee (REC). We restrict our analysis to older adults aged 50 years and older with a total valid sample of 14,344 respondents, consisting of 5333 men and 9011 women, 3795 from the 2005 wave, 2702 from the 2008 wave, and 7847 from the 2012 wave.

2.2. Analysis

HLE were calculated using the Sullivan method (Sullivan, 1971). This method utilizes the age-specific prevalence of different health states in a population at a certain point in time to calculate the person-years lived in the respective health states among life table stable population. The next step is to derive the total person-years lived by summing up the person-years lived from age x upward until the last age group in the life table. The total number of person-years lived is then divided by the number of survivors to obtain the HLE at a given age.

In the present study, the HLE is calculated based on a self-rated health measure obtained from the 2005, 2008, and 2012 waves of the SABSSM described above. In the three SABSSM waves, self-rated health was measured by self-assessed global health condition using a question *"In general, would you say that your health is excellent, good, fair or poor?"* The same wording of the question was used in the 2005, 2008, and 2012 surveys, which makes it feasible to evaluate trends in population health. Following the common practice in the field (Idler and Benyamini, 1997), a binary variable was created by categorizing; excellent and good as "good health" and fair and poor as "poor health." Multiplying the age-sex-specific prevalence of "good health" to the corresponding number of person-years lived with the given age range in the life table to obtain person-years in good health, and then accumulated them from a given age onward and divide by total survivors at a given age to obtain its HLE.

As previous research evidenced that the categorization of self-rated health may yield different outcomes for HLE (Doblhammer and Kytir, 2001; Gu, Dupre, Warner *et al*., 2009). A sensitivity analysis was performed by treating outcomes as excellent/good/fair as a group, which produced a comparable result. The estimates of life expectancy used in this study were based on the mid-year sex-specific complete life tables that were interpolated and smoothed from the abridged life tables published by the United Nations (United Nations, 2017). We presented life tables in 10-year age intervals for each gender, beginning with age 50 and having an open interval for age 80 and above. The reason for collapsing the ages was to obtain more stable prevalence estimates. The United Nations life tables were available for the years - 2000–2005, 2005–2010, and 2010–2015. We used linear interpolation following a Lexis diagram approach to obtain life tables to correspond with the survey years (i.e., 2005, 2008, and 2012). Standard errors were calculated from the formulae suggested by the International Network on Health Expectancy (Jagger, Cox, and Le Roy, 2006). We calculated the age-sex-specific HLE and the proportion of HLE to TLE over the period 2005–2012 to establish if there was an absolute or relative expansion or compression of morbidity (European Health Expectancy Monitoring Unit, 2009) for the period.

3. Results

Table 1 summarizes the background characteristics of the sample aged 50 years and older who participated in the 2005, 2008, and 2012 national HIV household surveys. In all the surveys, the majority of the respondents was women and was in the 50–59 age category; most respondents rated their own health as "good" or "fair." Africans accounted for about 45–50% in the sample across years with a proportion of Africans mildly higher in women.

Table 2 shows that TLE was higher for women than men across all ages and time periods (2005, 2008, and 2012). For example, in 2012, a 50-year-old woman could expect to live 24.1 years, while a man of the same age could expect to live 19.1 years. Furthermore, in terms of absolute figures, women had higher expected lifetimes in good health across all ages and time periods. For example, the expected lifetime in good health for a 50-year-old woman was 15.0 years. The equivalent for a man of the same age was 13.1 years. However, women also had greater expected lifetimes in bad health across all ages. For example, in 2012, the expected lifetime in bad health at ages 50 and 80 for women was 9.1 and 3.5 years, respectively, while for men it was 6.0 and 2.1 years, respectively. As expected, both TLE and HLE decreased with age for both men and women in all the time periods.

Table 2 also shows the absolute difference in total, healthy, and unhealthy life expectancies between 2005, 2008, and 2012. The results show that TLE increased at all ages over the whole study period. This was accompanied by increases in HLE (good health) and remarkable declines in unhealthy life expectancy (poor health). This implies that older people in South Africa not only lived longer but also the absolute number of years lived in good health increased. Figure 1a clearly shows that the increases in HLE were greater than the increases in TLE across all ages with one exception for men at age 50. This is even more evident when looking at the figure for women [Figure 1b]. There was an absolute reduction in unhealthy years (years spent in bad health) for both men and women across all ages for the whole time period 2005–2012. However, for men, there appear to have been marginal gains in unhealthy years at age 50. The improvements in healthy years for the period 2005–2012 were statistically significant across all ages for women, while for men, the difference was significant at the oldest ages. However, for men of age 60, the change in HLE was significant for the period 2008–2012. The change in healthy years from 2005 to 2012 at age 80 was the same for both genders, i.e., a gain of 1.3 years.

Table 1. Descriptive characteristics of the sample aged 50 years and older by gender, 2005, 2008, and 2012 national HIV household surveys.

Variables	2005		2008		2012	
	Men (*n*=1291)	Women (*n*=2504)	Men (*n*=946)	Women (*n*=1756)	Men (*n*=3096)	Women (*n*=4751)
Self-rated health						
Excellent	9.06	6.71	17.44	12.81	15.60	11.26
Good	55.46	48.84	46.62	47.04	51.49	51.11
Fair	28.66	37.34	25.48	30.24	26.61	31.36
Poor	5.11	5.19	6.24	5.69	4.65	4.86
Age groups (in years)						
50–59	50.58	48.80	50.85	47.04	47.80	46.35
60–69	33.93	31.27	31.29	31.15	32.40	31.17
70–79	11.93	15.38	12.58	16.29	15.05	15.89
80+	3.56	4.55	5.29	5.52	4.65	6.52

Table 2. Total life expectancy, expected lifetime in self-rated good health and bad health for men and women in South Africa in 2005, 2008, and 2012.

Age	Life years	Men						Women					
		2005	2008	2012	Changes			2005	2008	2012	Changes		
					2005–2008	2008–2012	2005–2012				2005–2008	2008–2012	2005–2012
50	Total LE	18.4	18.4	19.1	−0.1	0.7	0.7	23.0	23.0	24.1	−0.1	1.2	1.1
	Unhealthy LE	5.9	6.1	6.0	0.2	−0.1	0.1	10.8	8.9	9.1	−1.8	0.2	−1.6*
	Healthy LE	12.6	12.3	13.1	−0.3	0.9	0.6	12.3	14.1	15.0	1.8*	1.0*	2.7*
60	Total LE	13.1	12.9	13.3	−0.2	0.5	0.3	17.5	17.3	17.9	−0.2	0.6	0.4
	Unhealthy LE	4.7	5.2	4.4	0.6	−0.9	−0.3	8.7	7.4	7.3	−1.3*	−0.1	−1.4*
	Healthy LE	8.4	7.6	9.0	−0.8	1.3*	0.6	8.8	9.9	10.6	1.1*	0.7	1.8*
70	Total LE	8.6	8.4	8.7	−0.3	0.3	0.1	11.9	11.6	11.9	−0.3	0.4	0.0
	Unhealthy LE	3.8	3.5	3.4	−0.3	−0.1	−0.4	6.5	6.1	5.2	−0.4	−0.9	−1.3*
	Healthy LE	4.9	4.9	5.3	0.0	0.4	0.4	5.4	5.5	6.8	0.0	1.3*	1.3*
80	Total LE	5.5	5.2	5.5	−0.3	0.2	−0.1	7.5	7.0	7.3	−0.4	0.2	−0.2
	Unhealthy LE	3.5	3.1	2.1	−0.4	−1.0*	−1.4*	5.0	4.0	3.5	−1.0	−0.5	−1.5*
	Healthy LE	2.0	2.1	3.4	0.1	1.2*	1.3*	2.4	3.0	3.7	0.6	0.8	1.3*

Level of significance for a two-tailed test. Test for statistical significance done for healthy LE and unhealthy LE. *Significantly different at 5% level from the previous time period. The sum of LE in health states might not add up to Total LE because of rounding, LE: Life expectancy

It is important to note that not only the absolute numbers of life expectancy and HLE increased over the period 2005–2012 for both men and women of all ages but also the proportions of life in good health did so. In 2005, an 80-year-old South African woman could expect to live about a third of her remaining lifetime in good health. By 2012, she could expect to live approximately half of her remaining lifetime in good health [Table 3]. On the other hand, a man of the same age could expect to live more than a third (36.8%) of his remaining lifetime in good health in 2005 and by 2012 approximately two-thirds (61.5%) [Table 3]. It is also evident that although women lived longer than men, they spent much of their lifetime in poor health. The standard errors of the proportions get larger with age due to the relatively smaller sample sizes at the oldest ages.

However, the changes in TLE and HLE over the period 2005–2008 and over the period 2008–2012 were different. Our results show that the TLE at all ages declined from 2005 to 2008 for both men and women with a reduction from 0.1 to 0.4 years and a greater reduction found at older ages, although such a decline is not statistically significant [Table 2]. Our results further show that male HLE at ages 50 and 60 declined in the period 2005–2008, while female HLE at these ages did not decline in the same period. The reduction in male HLE caused a decrease in the proportion of life in good health from 2005 to 2008 for age 50 by 1.4 percentage points (=66.8–68.2%) and age 60 by 4.9 percentage points (=59.3–64.2%). However, from 2008 to 2012, no reduction in TLE, HLE, and the proportion of life in good health was observed, and men at age 60 witnessed a more pronounced increase (by 1.3 years) in HLE, or 7.9% in 2012 than in 2008.

4. Discussion

Our focus in this study was to use a single global domain (self-rated health) from three waves of a nationally representative cross-sectional survey in South Africa from 2005 to 2012 to investigate changes in population health in relation to increases in TLE and to investigate the gender difference in such changes. Overall, the findings showed that the health of older people in South Africa improved over the period under investigation with a greater improvement in women. Our findings provide additional evidence to support the compression of morbidity (European Health Expectancy Monitoring Unit, 2009).

The improvement in HLE in South Africa over the period 2005–2012 that we observed in this study may be partially explained by contextual factors related to the hosting of the Federation of International Football Association (FIFA) World Cup in 2010. The success of hosting the 2010 World Cup brought a "feel good" sensation, happiness, national pride, and enhanced social cohesion across the country (Gibson, Walker, Thapa *et al*., 2014; Møller, 2014). We speculate that this could have translated into positive responses on self-rated health and, hence, a positive trend in HLE during the period

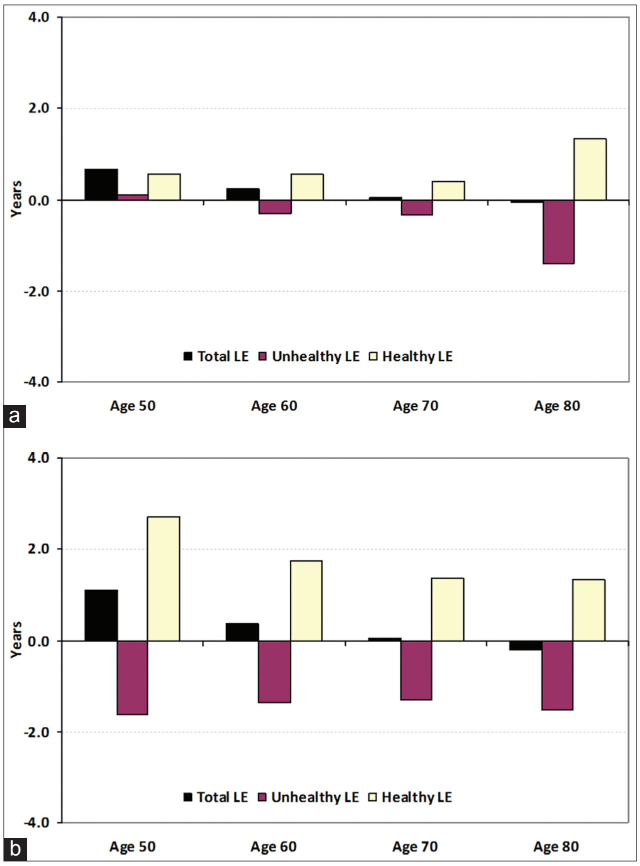

Figure 1. Changes in total life expectancy and life expectancy in good and bad health for (a) men and (b) women, South Africa, 2005–2012

Table 3. The proportion of expected lifetime in self-rated good health and bad health for men and women at ages 50, 60, 70, and 80 in South Africa in 2005, 2008, and 2012.

Age	Life years	Men			Women		
		2005	2008	2012	2005	2008	2012
50	Unhealthy LE	31.8	33.2	31.3	46.7	38.8	37.8
	Healthy LE	68.2	66.8	68.7	53.3	61.2	62.2
	SE for HLE/TLE	(2.1)	(2.2)	(1.4)	(1.6)	(1.9)	(1.3)
60	Unhealthy LE	35.8	40.7	32.8	49.6	42.7	40.9
	Healthy LE	64.2	59.3	67.2	50.4	57.3	59.1
	SE for HLE/TLE*	(3.3)	(3.3)	(1.9)	(2.1)	(2.6)	(1.7)
70	Unhealthy LE	43.6	41.9	39.2	54.5	52.9	43.4
	Healthy LE	56.4	58.1	60.8	45.5	47.1	56.6
	SE for HLE/TLE*	(5.3)	(5.2)	(3.2)	(3.2)	(4.5)	(2.7)
80	Unhealthy LE	63.2	59.3	38.5	67.7	57.6	48.6
	Healthy LE	36.8	40.7	61.5	32.3	42.4	51.4
	SE for HLE/TLE*	(10.0)	(9.3)	(7.1)	(6.3)	(7.3)	(5.5)

The sum of LE in health states might not add up to 100% because of rounding. *SE: Standard error for proportion Healthy LE/Total LE. LE: Life expectancy, HLE: Healthy life expectancy, TLE: Total life expectancy

2008–2012. Similar feel-good effects from hosting such a mega sports event were previously reported in France and Germany (Dutch National Committee for International Cooperation and Sustainable Development, 2008). A study from

Japan also observed the effect of contextual factors, i.e., the "Golden plan" during the period of 1986–2004 (Yong and Saito, 2009). During this period, several policy reforms were implemented which improved the health and well-being of older people in Japan. As a result, a positive trend in HLE was observed (Yong and Saito, 2009). Another possibility for improvement in HLE may be related to decrements in retirement age for men from age 65 down to age 60 in 2008–2010 as the receiving pension increases well-being (Schatz, Gomez-Olive, Ralston *et al*., 2012).

The finding that a greater improvement in HLE observed in women is accordance with a study from Austria (Doblhammer and Kytir, 2001). It is possibly due to better access to health and social services over the study period by women. The General Household Survey (Lehohla, 2013) showed that a higher proportion of women had better health-seeking behaviors compared to men, which included consulting a health worker when they were ill or injured. Another possible reason could be resilience in older women (Kinsel, 2005). There is evidence showing that older women are more resilient than their male counterparts in dealing with daily difficulties because women tend to have a better social supporting network than men (Depp and Jeste, 2006). Furthermore, as we reviewed above, self-rated health involves a process of self-perceptions and subjective judgments about various health domains (Feng, Zhu, Zheng *et al*., 2016; Jylhä, 2009); it is possible, during the study period, some health outcomes of women in South Africa improved greater than those of men. Unfortunately, this study did not analyze and isolate the independent effects of possible predictors of poor health. More research is clearly warranted to shed light on the root causes on the gender differential in the improvement of HLE.

One interesting finding of the present study is a decline in life expectancy for both women and men and a decline in HLE for men from 2005 to 2008, although these declines were not statistically significant. The declines in life expectancy and HLE in the period of 2005–2008 were probably linked to the financial crisis in South Africa. As the 2008 survey was conducted from May 2008 to March 2009 (Shisana, Rehle, Simbayi *et al*., 2009), it is thus possible that a sizeable portion of the sample provided the responses during the financial crisis in South Africa and across the global. There is evidence that the global financial crisis had a severe impact on South Africa, and consequently, the country's economy went into recession between 2008 and 2009 for the 1st time in 19 years (Rena and Msoni, 2014). During this period, the unemployment rate and poverty levels increased dramatically (Padayachee, 2010). We speculate that this could have a negative impact on HLE in South Africa, especially for men. Such a global and local economic crisis should also have reshaped people's daily life and behaviors and produced a negative impact on health-care access and health outcomes in South Africa, and such an impact might be more fatal to the older adults than the younger adults as the former needs more medical treatment and is more vulnerable. Fortunately, South African Government implemented a policy related to retirement age decrement from age 65 to age 60 for men in 2008–2010, which may partially offset the negative impact of financial crisis, especially for those aged 65 or younger.

Notwithstanding, although there were improvements over time in women, our results show that the proportion of women reporting "fair'/'poor" health [Table 1] was higher than men, and the proportion of life spent in poor health [Table 3] was higher for women than men in the study period. Studies are needed to investigate contextual determinants to which the health gaps between older men and women can be attributed in the South African setting, including gender roles. Health interventions need to be gender sensitive to address the health differences between the sexes.

One strength of this study is to use a nationally representative sample to investigate the trend of HLE among South Africans aged 50 or older for the 1st time. The consistencies in survey design, data collection methods, and same wording of questions across three waves in 2005, 2008, and 2012 make it possible to evaluate trends in the health of older people over the period. The study period is unique, not only covering the global financial crisis but, also covering the major events such as nation's pension reform and hosting the 2010 FIFA World Cup. All these events could largely influence people's assessment of their emotion, spirit, psychological well-being, and eventually self-rated health. We recommend studies that can disentangle this complexity tempo change of self-rated health in referring to contextual environments.

Several caveats are worthy of mentioning when interpreting the results. First, it is possible to have concluded otherwise had we used other measures, for example, disability. Such a measure is, however, not included in the SABSSM surveys' questionnaires used in this analysis. A study on HLE in Thailand found stagnation when using self-rated health and improvements in health status when using disability measures based on activities of daily living (ADLs) limitations (Karcharnubarn and Rees, 2009). It has been acknowledged that self-rated health and disability can actually follow different trends (Crimmins, 1996; Robine and Michel, 2004; Gu, Dupre, Warner *et al*., 2009; Spiers, Jagger, and Clarke, 1996). Furthermore, the cross-national and cross-cultural comparison of healthy expectancy based on self-rated health should be caution due to its subjectivity of self-rated health. Nevertheless, our results are in line with findings from the Rapid mortality surveillance (Dorrington, Bradshaw and Laubscher, 2014) which, based on mortality indicators over the same period as this present study, also concluded that the country was progressing well toward the improvement of the population's health status.

Second, although we did not specifically analyze HIV and ART data, our results likely lend support to recent findings that people living with HIV are living longer and healthier lives than their past cohorts partly due to the successful roll-out of ART (Bor, Herbst, Newell *et al*., 2013; Shisana, Rehle, Simbayi *et al*., 2014). Nevertheless, more research on the separation of analysis of HIV and non-HIV populations is needed to validate our speculation.

Third, we only stratified the analyses by gender. This can be expanded to include other differentials such as education and race that have been also frequently studied in the existing literature (Feng, Zhu, Zheng *et al*., 2016; Gu, Dupre, Warner *et al*., 2009). The only drawback would be the unavailability of mortality data disaggregated by these variables, which would be required to apply the method used in this study. Related to this, due to the relatively small sample size of at oldest-old ages in the SABSSM surveys, we had an open interval at 80 years and above to have reliable estimates.

Fourth, the exclusion of institutionalized individuals from the SABSSM surveys can bias the prevalence of self-rated health and HLE estimates upward. It is important to include this segment of the elderly population, since they are likely to be different in terms of health from those residing in the community. Unfortunately, there are no comparable surveys that collect information on health among institutionalized elderly populations in South Africa. Fortunately, the effect of excluding the institutionalized population in the current study is negligible because the number of institutionalized older adults in South Africa is relatively small (Phillips and Noumbissi, 2004).

Fifth, as the sample size for single-age is not sufficiently large to calculate the prevalence of self-rated health, we used prevalence in 10-year age group to assume that the prevalence of self-rated health within the age group is the same for each of single year of age. Such a practice may introduce some bias than that based on the single-age rate if it would be available. However, the bias should not be substantial since such a practice is similar to the construction of abridged life tables.

Six, no covariate was included in the analysis. Given that self-rated health is closely linked to some major demographics and psychosocial factors (Feng, Zhu, Zheng *et al*., 2016), it is possible that the improvement in HLE in South Africa over the period of 2005–2012 may be attributable to differences in covariates even if disease condition, physical and cognitive functions, and reporting pattern had no change over time. Studies incorporating major covariates into modeling would shed light on investigating the possible root causes or underlying associates linked to the change of HLE.

Seven, we relied on the life tables produced by the United Nations as a basis to estimate the healthy expectancy. Although the data quality in South Africa is still a concern, as in most developing countries, we are confident that the United Nations life tables in the World Population Prospects are relatively robust given that these estimates are obtained from multiple sources under systematic examinations (United Nations, 2017).

5. Conclusions

Based on self-rated overall health in the South African National HIV Incidence, Prevalence, Behaviour and Communication Survey in 2005, 2008, and 2012, we concluded that the health condition of older adults in South Africa was improved over the period of 2005–2012. Gender differences were evident with women having a longer life expectancy, HLE, and unhealthy life expectancy, but lower proportions of life spent in healthy years. Our findings highlight the need for gender-sensitive health interventions among older adults. We also observed an increase in the proportion of HLE in 2012 for both men and women compared to those in 2005. This suggests some evidence of compression of morbidity in terms of self-rated health for South African older adults in the period of 2005–2012.

Authors' Contributions

W. Chirinda and Y. Saito designed the study, and W. Chirinda performed the analysis and drafted. W. Chirinda, Y. Saito, D. Gu and N. Zungu revised the manuscript and interpreted the results.

Ethics

Not applicable as the dataset used in this study is a publicly available source.

Conflicts of Interest

No conflict of interest was reported by the authors.

Disclaimer

Views expressed in the study are solely those of the authors and do not reflect those of the South African Medical Research Council, Nihon University, the United Nations, Human Sciences Research Council of Pretoria (South Africa), and the University of Pretoria.

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RESEARCH ARTICLE

Living longer: For better or worse? Changes in life expectancy with and without mobility limitation among older persons in India between 1995–1996 and 2004

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Abstract: This study estimates changes in life expectancy with and without mobility limitation to test whether older persons in India experienced compression or expansion of morbidity from the period 1995–1996 to 2004. Age-specific death rates and the prevalence of mobility limitation were obtained from the Sample Registration System and two rounds (1995–1996/2004) of the National Sample Survey. Sullivan's method was employed to compute life expectancy with and without mobility limitation by gender and by place of residence. From 1995–1996 to 2004, at ages 60, 70, and 80, older men and older rural persons in India experienced a significant increase in life expectancy without mobility limitation and a significant reduction in the proportion of remaining life with mobility limitation, suggesting a compression of morbidity. However, over this same period, older women and older urban persons seem to have experienced an expansion of morbidity with an increase in life expectancy with mobility limitation and an increase in the proportion of remaining life with mobility limitation. These results call for the promotion and maintenance of physical mobility among all older persons in India, with special attention to older women and older urban persons.

Keywords: *health expectancy; India: life expectancy; mobility limitation; morbidity*

1. Introduction

According to the 2011 census, nearly one in 10 persons (8.6%) in India were aged 60 and above (hereafter older persons) (Census of India, 2011). This proportion translates to 104 million individuals in India's burgeoning population (Census of India, 2011), making India home to the world's second largest population of older persons. Moreover, by 2051, the number of older persons is expected to reach 298 million, nearly 20% of India's total projected population (Rajan, Risseeuw, and Perera, 2008). A key contributor to the large and increasing population of older persons in India is the rise in life expectancy at older ages; while in 1990 an Indian aged 60 was expected to live another 15 years, in 2013 an Indian aged 60 was expected to live another 17 years (World Health Organization, 2015). The increase in life expectancy at older ages is a significant development and public health achievement for India. However, whether this increase in life expectancy is associated with a better or worse state of health during the additional years of life has received little attention.

This important yet unanswered question can be addressed by assessing changes over time in the health expectancy of older persons in India. Health expectancy refers to the average number of remaining years of life a person at a given age is expected to spend in various states of health. Calculating health expectancy allows the decomposition of total remaining years of life, at a given age, into those lived in a state of good health (healthy life expectancy) and those lived in one or more states of ill health (unhealthy life expectancy) (Saito, Robine, and Crimmins, 2014). While the concept of health expectancy is unique, different measures have been used to define "health." Commonly used measures are the absence or presence (or the extent therein) of mobility limitation, disability, activities of daily living (ADL) limitations, instrumental ADL limitations, any non-communicable disease (NCD), or specific NCDs (Saito, Robine, and Crimmins, 2014). Health expectancy combines information about mortality and morbidity. Thus, a comparison of changes in health expectancy over time directly addresses whether the duration of remaining life spent with morbidity or disability is shortening or lengthening relative to changes in life expectancy.

The extant literature provides two main hypotheses for the relationship of longer life with changes in health. The first hypothesis argues that improvements in life expectancy evolve from a delay in the onset and progression of diseases and disability, and morbidity is generally reduced (Fries, 1980). This hypothesis is called compression of morbidity, as it proposes that an increase in life expectancy is accompanied by a decrease in the proportion of remaining life lived with morbidity and disability. In other words, it posits a decrease in relative unhealthy life expectancy (the ratio of unhealthy life expectancy to life expectancy) over time. Conversely, the expansion of morbidity hypothesis states that as mortality declines through improved medical care, an increase in life expectancy is accompanied by an increase in the proportion of remaining life lived with morbidity and disability. That is, there is improved survival among frail individuals who have higher expected incidence rates of disability (Gruenberg, 1977; Kramer, 1980). In other words, it suggests an increase in relative unhealthy life expectancy over time.

Studies from several countries support the presence of both hypotheses (Doblhammer and Kytir, 2001, Graham, Blakely, Davis *et al.*, 2004, Crimmins and Beltrán-Sánchez, 2011, Fries, Bruce, and Chakravarty, 2011). However, to the best of our knowledge, only one recent study, operationalizing "health" as self-reported absence (or presence) of NCDs, assesses NCDs among older persons in India (Arokiasamy and Yadav, 2014). This 2014 study supports the expansion of morbidity hypothesis.

While informative, the said study has its limitations. First, the use of self-reported disease status to define "health" is sensitive to changes in awareness or literacy about diseases and to changes in health-care accessibility over time. Thus, a change in health expectancy may simply reflect a change in awareness, or it may reflect a change in awareness and/or access to health care. Over time, this can lead to a change in the diagnosis of diseases in otherwise undiagnosed individuals. Alternatively, changes in health expectancy may reflect a change over time in the criteria used for diagnosing diseases (Crimmins and Saito, 2000). Second, the list of NCDs and the referent time period varied across the rounds of National Sample Surveys (NSS) considered for health expectancy calculations in the study. Thus, any observed change in health expectancy, rather than real, could have been due to this variation in NCD criterion across the rounds. Third, it has been shown in studies, though not from India, that while the prevalence of diseases among older persons has consistently increased over the past few decades, the prevalence of functional or activity limitations consistently declined in the 1980s and 1990s (Freedman, Crimmins, Schoeni *et al.*, 2004) and remained stable in the 2000s (Freedman, Spillman, Andreski *et al.*, 2013). Thus, it is of interest to see if the expansion of morbidity observed for NCDs in India holds in the context of functional or activity limitations.

In this paper, we use mobility limitation to define health, such that the absence of mobility limitation is considered healthy (and its presence, unhealthy). A mobility limitation is a functional impairment which limits a person's ability to move her- or him-self independently and safely. Mobility limitation leads to social isolation, depression, and other adverse mental health outcomes (Lampinen and Heikkinen, 2003), contributes to poor quality of life (Netuveli, Wiggins, Hildon *et al*., 2006), and is associated with a higher risk of health service use (Penninx, Ferrucci, Leveille *et al*., 2000), institutionalization (von Bonsdorff, Rantanen, Laukkanen *et al.*, 2006), and mortality (Rolland, Lauwers-Cances, Cesari *et al*., 2006). Further, mobility limitation may lead to dependency, a need for assistance, and an increased risk for disability (Lawrence and Jette, 1996; Stuck, Walthert, Nikolaus *et al*., 1999). Given the pivotal role of mobility for older persons, we thus utilize changes over time in life expectancy with and without mobility limitation among the population of older persons in India to assess whether increases in total life expectancy at older ages are associated with better or worse states of "health" during the years of life added. In other words, are increases in total life expectancy at older ages associated with the compression or expansion of morbidity?

In a largely patriarchal society like India with sharp gender disparities, across age groups, in access to nutrition, health, education, and economic resources (Agarwal, 1994; Singh, 2012; Saha, 2013; Maharana and Ladusingh, 2014), older women become disproportionately vulnerable to disability (Sengupta and Agree, 2003, Sreerupa and Rajan, 2010), and disease and poor health-care utilization (Sreerupa and Rajan, 2010). In a similar vein, older rural persons face a disproportionately higher prevalence of disease and disability and lower access to and availability of health care, relative to their urban counterparts (Alam, 2000). It is important to keep in mind that nearly three-fourths of older people in India live in rural areas. Therefore, it is of interest to assess how changes over time in life expectancy with and without mobility limitation differ among older Indian men and women and among older persons residing in rural and urban areas of India.

Thus, utilizing data from two cross-sectional national surveys conducted in 1995–1996 and 2004, we test for the presence of expansion or compression of morbidity among older men and women and among older rural and urban persons in India. We do so by estimating changes over a decade in absolute and relative life expectancy with and without mobility limitation by gender and by place of residence.

2. Data and Methods

2.1. Data sources

Information on age-specific death rates (ASDR) from the Sample Registration System (Office of the Registrar General) was used to construct abridged life tables. The average values of ASDR from 1995 to 1998 and 2002 to 2005 were used as the ASDR of 1995–1996 and 2004, respectively, to avoid inconsistencies. Information on the age-specific prevalence of mobility limitation, by gender, and by place of residence, was obtained from publically available de-identified data of two survey rounds: The NSS on Morbidity and Treatment of Ailments, 52nd Round (National Sample Survey Organization, 1998), conducted from July 1995 to June 1996, and the NSS on Morbidity, Health Care, and the Conditions of the Aged, 60th Round (National Sample Survey Organisation, 2006), conducted from January to June 2004. The prevalence estimates were weighted using appropriate round-specific survey weights. The NSS are nationally representative cross-sectional household surveys conducted by the National Sample Survey Organization (NSSO), a branch of the Department of Statistics of the Government of India.

The sample for either round was selected using a two-stage stratified design, with census villages and urban blocks as the first-stage units for the rural and urban areas, respectively, and households as the second-stage units. The surveys had a sample of 34,084 older persons from 120,942 households in the 52nd NSS Round and 34,831 older persons from 73,868 households in the 60th NSS Round. Data were collected using structured questionnaires in face-to-face interviews at the homes of the respondents.

2.2. Mobility limitation

The physical mobility statuses of the respondents of both NSS rounds were recorded, with the options being (1) physically immobile and confined to bed (persons unable to move around the house and, in particular, to use the washroom on their own), (2) physically immobile and confined to their homes (persons able to move within the house but unable to move outside the house), and (3) physically mobile (National Sample Survey Organization, 1998, National Sample Survey Organization, 2006). The proportion of individuals categorized in option (1) was $<2\%$ in either round. Thus, for our analysis, those categorized in options (1) and (2) were combined so as to dichotomize physical mobility status into “with mobility limitation” and “without mobility limitation.”

Our decision to focus on mobility limitation as the measure of health and not on other variables such as disability or NCDs, was in part due to comparability issues of such variables between the two NSS rounds. While questions and/or response options relating to disability or NCDs varied, the question on physical mobility status and its response categories remained unchanged between the rounds.

2.3. Statistical analysis

Using the method devised by Sullivan (1971), data on the prevalence of mobility limitation were combined with abridged life table data to compute life expectancy with and without mobility limitation for older persons in India, by gender and by place of residence. With this method, it is possible to see the current mobility health structure of a population adjusted for mortality by partitioning life expectancy at a given age into two mobility states: Expected years lived without mobility limitation (~healthy) and with mobility limitation (~unhealthy). Weighted age-specific prevalence rates were used to divide the life table stable population for each age group into specific mobility states. The total stable population above age x by mobility states was divided by survivors at age x to compute life expectancy with and without mobility limitation. Differences, by gender and by place of residence, in absolute and relative estimates of life expectancy with and without mobility limitation were tested using the approach described by Jagger *et al.* (2014).

3. Results

From 1995–1996 to 2004, the prevalence of mobility limitation decreased by 0.2–3.0% points among older men, older women, and older rural and urban persons [Table 1]. At both time points, the prevalence was higher among women, and the gender-gap widened over time (1.7% points [1995–1996] to 2.4% points [2004]). While in 1995–1996 the prevalence of mobility limitation was higher (by 2.1% points) among older rural persons, in 2004 it was higher (by 0.7% points) among older urban persons.

Table 1. Weighted prevalence (%) of mobility limitation among older persons in India, by gender and by place of residence, 1995–1996 and 2004.

Year	Gender		Place of residence	
	Men	Women	Rural	Urban
1995–1996	9.6	11.3	10.9	8.8
N	(16514)	(16148)	(20141)	(12521)
2004	6.9	9.3	7.9	8.6
N	(17750)	(17081)	(22265)	(12566)
Change from 1995–1996 to 2004	−2.7	−2.0	−3.0	−0.2

Note: N refers to the unweighted sample size.

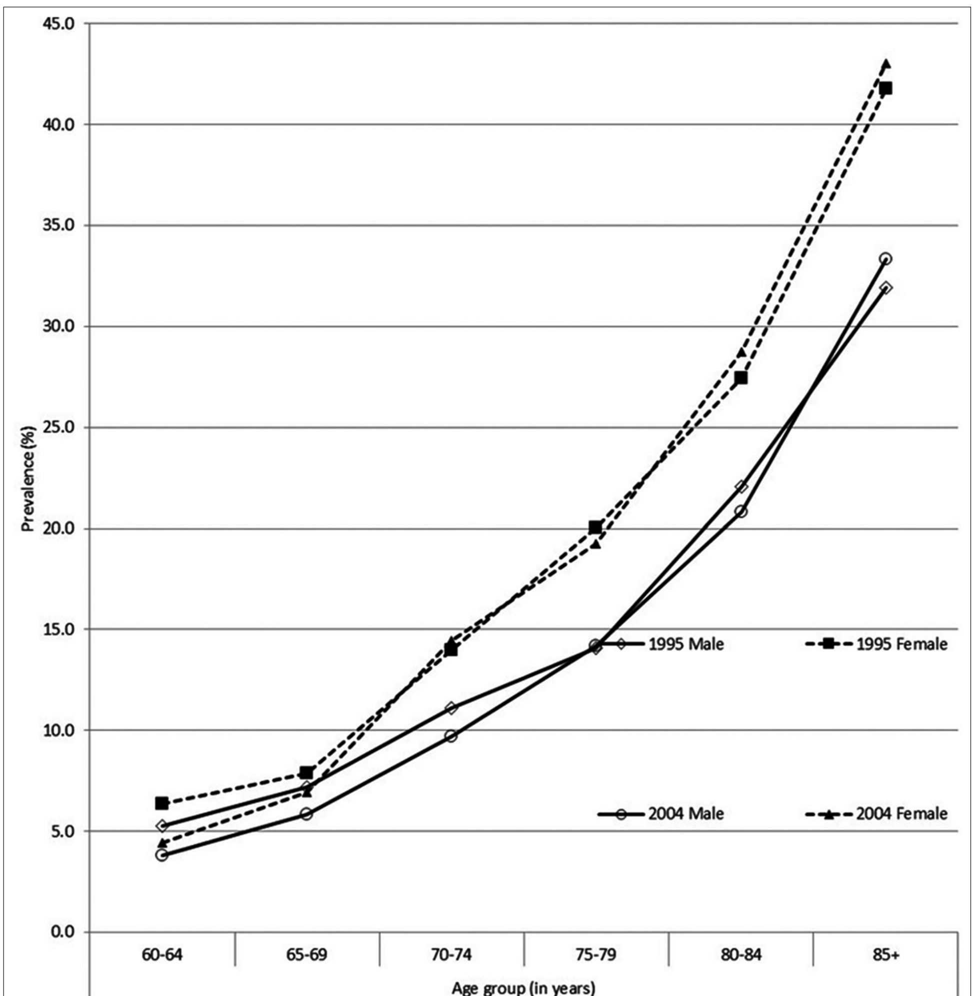

Figure 1. Prevalence of mobility limitation by 5-year age groups and gender, 1995–1996 and 2004.

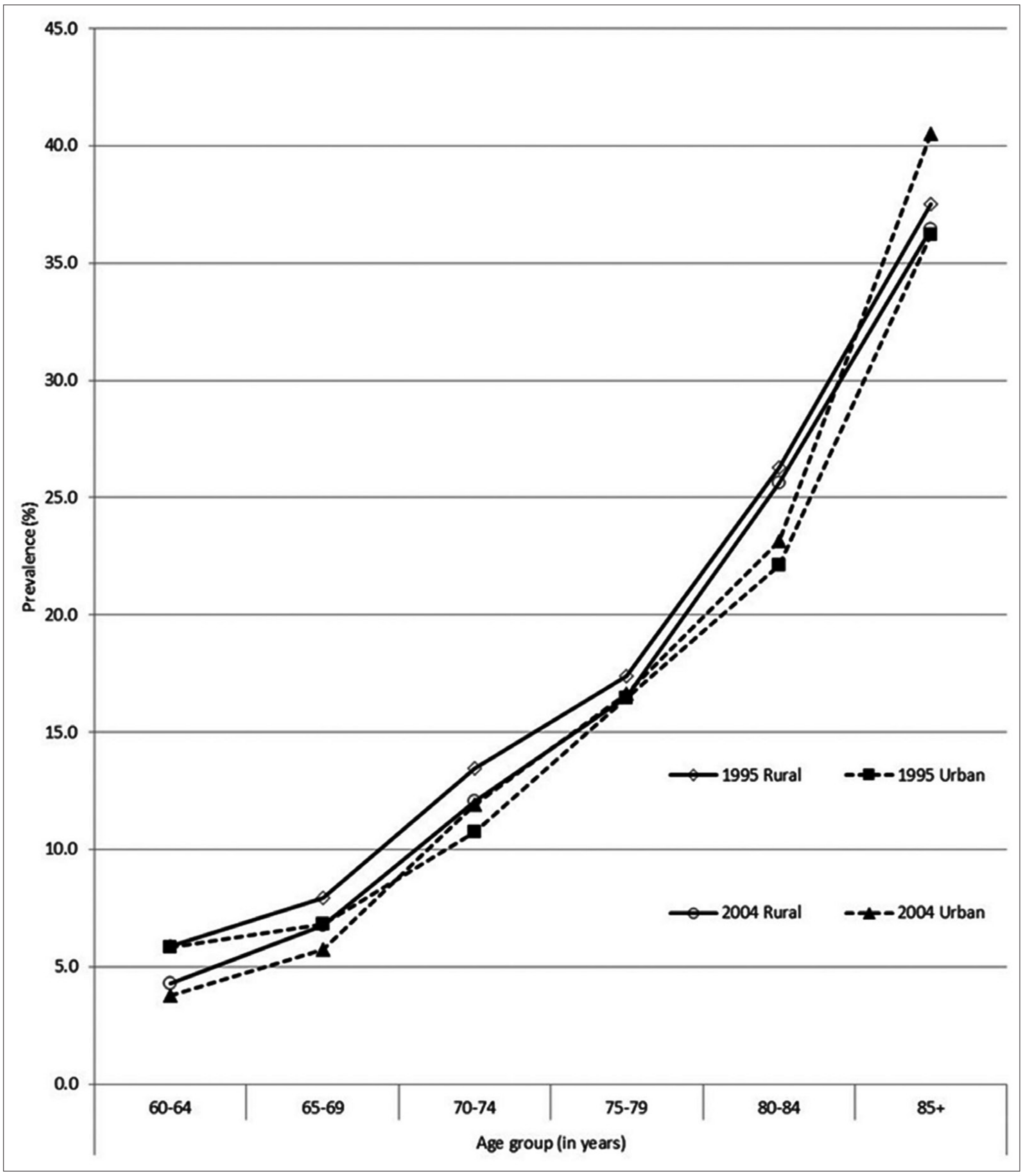

Figure 2. Prevalence of mobility limitation by 5-year age groups and place of residence, 1995–1996 and 2004

For both genders, in 1995–1996 and 2004, the prevalence of mobility limitation increased with age [Figure 1]. Further, at both time points, the prevalence was higher among women than men, particularly so after the age of 65–69 years. Among men, over the course of 10 years, the prevalence decreased slightly, especially for those aged 60–74. Among women, over the decade, the prevalence remained largely unchanged. There was a slight decrease in the prevalence for those aged 60–64, but then the prevalence marginally increased for those aged 80 and above.

Irrespective of the place of residence [Figure 2], there was an increase in the prevalence of mobility limitation with age in 1995–1996 as well as 2004. In 1995–1996, the rural-urban difference in prevalence varied by age group; the prevalence was higher for those residing in rural rather than urban areas, especially for respondents aged 65–84. However, in 2004, while there was a convergence in the prevalence for those aged <80, it was slightly higher for those aged 80–84 in rural areas and in urban areas for those aged 85 and above in urban areas. Among older rural persons, over the course of 10 years, the prevalence of mobility limitation decreased for all age groups, though it was only marginally for those aged 75 and above. However, among older urban persons, over the course of the decade, the prevalence increased for those aged 70–74 and those aged 80 and above.

Table 2. Life expectancy (in years), total and with and without mobility limitation, by age and gender, 1995–1996 and 2004.

Age	Life expectancy	Men			Women		
		1995–1996	2004	Change from 1995–1996 to 2004	1995–1996	2004	Change from 1995–1996 to 2004
60	Total	15.6	16.7	1.1	17.5	18.7	1.2
	Without mobility limitation	13.9	15.3	1.3**	15.0	16.2	1.1**
	With mobility limitation	1.7	1.5	-0.2*	2.4	2.5	0.1
70	Total	10.2	11.0	0.8	11.3	12.2	0.9
	Without mobility limitation	8.5	9.4	1.0**	8.8	9.5	0.7**
	With mobility limitation	1.7	1.6	-0.2	2.5	2.7	0.2
80	Total	6.5	7.0	0.6	7.1	7.7	0.6
	Without mobility limitation	4.7	5.3	0.6**	4.7	5.0	0.2
	With mobility limitation	1.8	1.7	0.0	2.3	2.7	0.4*

Note: Sum of life expectancy with and without mobility limitation may not add to total life expectancy due to rounding; Values under "Change from 1995–1996 to 2004" may not match exactly those obtained by subtracting 1995–1996 values from 2004 values listed above due to rounding. Differences in total life expectancy with and without mobility limitation were tested using the approach described by Jagger *et al*. (2014). *Significant at $p<0.05$ level; **Significant at $p<0.01$ level.

Table 3. The proportion of life expectancy with mobility limitation by age and gender, 1995–2004.

Age	Life expectancy with mobility limitation					
	Men			Women		
	1995–1996 (%)	2004 (%)	Change from 1995–1996 to 2004 (% points)	1995–1996 (%)	2004 (%)	Change from 1995–1996 to 2004 (% points)
60	10.6	8.8	−1.9**	13.9	13.5	−0.4
70	16.9	14.2	−2.6**	21.9	22.0	0.1
80	27.2	24.3	−2.9	33.0	35.1	2.1

Note: Values under "Change from 1995–1996 to 2004" may not match exactly those obtained by subtracting 1995–1996 values from 2004 values listed above due to rounding. Differences in the proportion of life expectancy with and without mobility limitation were tested using the approach described by Jagger *et al*. (2014). **Significant at 0.01 level.

Table 4. Life expectancy (in years), total and with and without mobility limitation, by age and place of residence, 1995–1996 and 2004.

Age	Life expectancy	Rural			Urban		
		1995-1996	2004	Change from 1995-1996 to 2004	1995-1996	2004	Change from 1995-1996 to 2004
60	Total	16.3	17.5	1.2	17.1	18.2	1.1
	Without mobility limitation	14.3	15.6	1.3**	15.3	16.2	0.8**
	With mobility limitation	2.1	1.9	−0.2*	1.8	2.0	0.2*
70	Total	10.6	11.5	0.9	11.1	11.9	0.8
	Without mobility limitation	8.5	9.4	0.9**	9.4	9.8	0.4**
	With mobility limitation	2.2	2.1	−0.1	1.8	2.1	0.4**
80	Total	6.7	7.4	0.7	7.1	7.3	0.3
	Without mobility limitation	4.6	5.2	0.6**	5.2	5.1	−0.1
	With mobility limitation	2.1	2.2	0.1	1.8	2.2	0.3

Note: Sum of life expectancy with and without mobility limitation may not add to total life expectancy due to rounding; Values under "Change from 1995–1996 to 2004" may not match exactly those obtained by subtracting 1995–1996 values from 2004 values listed above due to rounding. Differences in total life expectancy with and without mobility limitation were tested using the approach described by Jagger *et al*. (2014). *Significant at 0.05 level. **Significant at 0.01 level.

Table 5. The proportion of life expectancy with mobility limitation by age and place of residence, 1995–2004.

Age	Life expectancy with mobility limitation					
	Rural			Urban		
	1995–1996 (%)	2004 (%)	Change from 1995–1996 to 2004 (% points)	1995-1996 (%)	2004 (%)	Change from 1995–1996 to 2004 (% points)
60	12.7	10.9	−1.8**	10.5	11.2	0.7
70	20.3	17.9	−2.3**	15.9	17.9	2.0
80	31.2	29.4	−1.8	25.9	29.5	3.6

Note: Values under "Change from 1995–1996 to 2004" may not match exactly those obtained by subtracting 1995–1996 values from 2004 values listed above due to rounding. Differences in the proportion of life expectancy with and without mobility limitation were tested using the approach described by Jagger *et al*. (2014). **Significant at 0.01 level.

Table 2 shows total life expectancy and estimates of life expectancy with and without mobility limitation at selected ages by gender in 1995—1996 and 2004. From 1995–1996 to 2004, total life expectancy and life expectancy without mobility limitation increased for both older men and women in each age group, although more slowly in older age groups. The increase in life expectancy without mobility limitation was statistically significant, except for women aged 80. While life expectancy with mobility limitation fell slightly or remained unchanged from 1995–1996 to 2004 for men, it increased for women over this period; the change was significant only among men aged 60 and women aged 80. For men, over the decade, the gains made in total life expectancy at the considered ages were due to a significant increase in life expectancy without mobility limitation, balanced by a marginal reduction in life expectancy with mobility limitation. On the other hand, for women, over the decade, the gains in total life expectancy were due to an increase in life expectancy both with and without mobility limitation, their relative contributions varying across the considered ages. For women aged 60 and 70, the predominant increase was in life expectancy without mobility limitation, whereas for women aged 80, the increase in life expectancy with mobility limitation prevailed.

Examination of the proportion of life expectancy with mobility limitation is central for determining whether expansion or compression of morbidity was operational from 1995–1996 to 2004 among older Indian men and women [Table 3]. For men, over the decade, the proportion of life expectancy with mobility limitation fell for all the considered ages, suggesting a compression of morbidity. The drop was highest (−2.9% points), though not statically significant, among men aged 80. A 0.4% point reduction in this proportion was also observed for women aged 60. However, for women aged 70 and 80, from 1995–1996 to 2004, the proportion of life expectancy with mobility limitation increased, marginally for those aged 70 (+0.1% point) and more for those aged 80 (+2.1% points), indicating an expansion of morbidity. However, none of the changes for women were statically significant.

The various life expectancy estimates for 1995–1996 and 2004 by place of residence are shown in Table 4. From 1995–1996 to 2004, the total life expectancy increased at the considered ages for both older rural and urban persons, the increase tempering with age. For those residing in rural areas, over the decade, the gains in the total life expectancy at the considered ages were entirely or predominantly due to a significant increase in expected years of life without mobility limitation, with relatively minor contributions from a slight decrease (for those aged 60 and 70) or increase (for those aged 80) in expected years of life with mobility limitation. For those residing in urban areas, from 1995–1996 to 2004, the gains in total life expectancy at the considered ages were due to an increase in expected years of life both with and without mobility limitation, their contributions varying across the considered ages. For older urban persons aged 60, there was a significant and predominant increase in expected years of life without mobility limitation, whereas, for those aged 70, there were similar and significant increases in expected years of life with and without mobility limitation, and for those aged 80, a non-significant increase in expected years of life with mobility limitation predominated.

Table 5 shows that from 1995–1996 to 2004 the proportion of life with mobility limitation decreased for older rural persons, and significantly so for those aged 60 and 70, suggesting a compression of morbidity. For older urban persons, there was an increase, though non-significant, in this proportion over time, pointing to an expansion of morbidity.

4. Discussion

The current paper, to the best of our knowledge, is among the few to examine changes in health expectancy over time among older persons in India. Moreover, utilizing nationally representative data, it is the first in India to examine compression or expansion of morbidity in the context of mobility limitation. In the decade spanning 1995–1996 to

2004, older men and older rural persons in India experienced increases in life expectancy without mobility limitation, a reduction or no change in life expectancy with mobility limitation, as well as a reduction in the proportion of remaining life with mobility limitation. These changes were mostly statistically significant, thus strongly suggesting a compression of morbidity among these sub-groups of older persons. From 1995–1996 to 2004, older women and older urban persons likewise experienced increases in life expectancy without mobility limitation. However, they also experienced increases in life expectancy with mobility limitation and in the proportion of remaining life with mobility limitation. It is important to point out that these changes, especially those for the proportion of remaining life with mobility limitation, were not consistently statistically significant. Thus, while they are suggestive, they are not conclusive of, an expansion of morbidity among older women and older urban persons in India.

There could be several reasons for the observed urban-rural difference. One reason could be that Indian urban areas, driven by developmental and industrial objectives, have been expanding in an unplanned manner. This has resulted in unhealthy residential areas (Bentinck and Chikara, 2001) and restricted opportunities for older persons to move freely outside their homes. In a recent study from India (United Nations Population Fund, 2012), concern for safety was an important reason for older people not leaving their homes; and the proportion of older people citing this reason was higher in urban than rural areas. Another possible reason is that from the 1990s to 2000s there has been a greater increase in the concentration of sicker, less mobile older persons in urban areas than in rural areas, and there has been an increase in the movement of such older persons from rural to urban areas in search of health and medical care. While there is no direct data to support this conjecture, there is some indirect support through numbers portraying a greater increase in the older population and in medical care infrastructure in urban, versus rural, India. The increase in India, from 1991 to 2001, in the proportion of older persons in the urban population (5.8–6.7%) was marginally higher than that in the rural population (7.1–7.8%) (Chakrabarti and Sarkar, 2011). Concurrently, there was an increase in the population residing in urban slums (Prakash, 1999), and older people residing in urban slums are more vulnerable to chronic diseases than their counterparts in other urban areas (Anand, Shah, Yadav *et al.*, 2007). Greater availability of medical services, especially specialist services, in urban areas may be contributing to the growth in the older urban population (Chakrabarti and Sarkar, 2011). While there was a considerable expansion in medical care infrastructure in India from 1991 to 2001, the expansion was greater in urban than in rural areas. For example, growth from 1991 to 2001 in hospitals, hospital beds, and doctors per 100,000 people, was 43%, 28%, and 27%, respectively, in urban areas compared to 37%, 19%, and 23%, respectively, in rural areas (Bhatia, 2013). The greater availability in urban versus rural areas of advanced medical care may have led to sicker, less mobile older people remaining alive for longer in urban than in rural areas, contributing to the observed increase in absolute and relative life expectancy with mobility limitation in older urban persons.

At the same time, it appears that in rural India the increase in medical care infrastructure (as stated above) as well as in primary health-care facilities (the number of functioning sub-centers and primary health centers, specific to rural India, increased by 6.6% and 1%, respectively, from 1991 to 2001) (Ministry of Health and Family Welfare, 2005) has been beneficial, as indicated by the compression of morbidity seen among older rural persons in our study.

Similar to our study, previous studies, though not from India, have also documented the expansion of morbidity (using different "health" indicators) among older women (Tu and Chen, 1994, Gu, Dupre, Wamer *et al*., 2009). It has been suggested that with the progression of the epidemiologic transition, life span increases and the survival gap favoring women over men have led to women being at a higher risk of becoming disabled at older ages and of spending a greater time of their remaining life with disability (Myers, Lamb, and Agree, 2003). This may very well explain our finding. The potential reasons for the gender differences in life expectancy and life expectancy with a disability could be that women tend to have more non-life-threatening but disabling conditions, whereas men have a higher prevalence of life-threatening conditions (Case and Paxson, 2005). Previous studies have also found that women are more likely to experience a decline in functional status and are less likely to recover than men (Becket, Brock, Lemke *et al*., 1996). Thereby, women may simply accumulate more disability throughout the life course (Laditka and Laditka, 2002).

In India, it is well known that gender disparities in health (in infancy, childhood, and adulthood) favor men (Pande and Yazbeck, 2003, Tiwari, 2013). Our study points to the continuation of the gender disparity well into old age, as reflected in the gender disparity in absolute and relative life expectancy without mobility limitation favoring older men. Our study confirms the existence of the gender gap in health and mortality, generally termed "the male-female health-survival paradox," as observed elsewhere (Oksuzyan, Brønnum-Hansen, Jeune *et al*., 2010; Van Oyen, Nusselder, Jagger *et al*., 2013), wherein women live longer than men but spend a larger proportion of their life with a disability.

Certain limitations of this study must be acknowledged. First, our study focuses on the decade from 1995–1996 to 2004, and not thereafter. Other than the data available through the NSS, there is a lack of national-level data on older Indians collected through either repeated cross-sectional or longitudinal/panel surveys. Recent data collection efforts, such as the Longitudinal Study of Ageing in India (LASI), will be useful in addressing this lack; we plan to use data from LASI in future analyses on health expectancy when they are available. Second, this study employs a vital yet a single measure of health, that is, mobility status. This, as mentioned before, was due to the lack of comparability of other measures of disease and disability between the two NSS rounds. Going forward, the NSSO, and other organizations and researchers conducting repeated cross-sectional and/or longitudinal surveys, should be mindful of maintaining consistency in all aspects (such as wording, referent time period, and response options) of included questions over time. Utilization of additional indicators of "health" over a longer period of time in future analyses using data, when available, from studies like the LASI, will be useful in determining whether there is a compression or expansion of morbidity among older persons in India. Third, health expectancy computed with the Sullivan method does not take into account the expected life cycle events of individuals exposed to current morbidity conditions (Saito, Robine, and Crimmins, 2014). Thus, it may underestimate (or overestimate) healthy life expectancy because it produces estimates based on past (as opposed to current) probabilities of becoming unhealthy. Finally, the NSS does not capture information on the environmental characteristics of older persons. Environmental characteristics play a role in defining functional ability (World Health Organization, 2015). We cannot, therefore, categorically comment on the role played by environmental characteristics in enabling or restricting mobility for older persons in our sample and thereby in the observed compression or expansion of morbidity. Having said that, mobility is less likely to be affected by environmental changes than other measures like instrumental ADL used to define "health" (Crimmins and Beltrán-Sánchez, 2011).

5. Conclusions

While the prevalence of mobility limitation fell among older men, older women, and older urban and rural persons from 1995–1996 to 2004, this did not translate into an absolute and relative reduction in the duration of remaining life without mobility limitation for all older people in India. Older men and older rural persons did experience a compression of morbidity, whereas older women and older urban persons seem to have experienced an expansion of morbidity over this decade. This suggests that current national programs in India, such as the National Health Mission and the National Program for Health Care of the Elderly, which aim to address health issues in general or, specifically, among older persons, need to focus on addressing mobility limitation among older women and older urban persons. At the same time, one cannot ignore the high absolute numbers of older persons (6.2 million, comprising 2.6 million older men and 3.6 million older women, or 4.5 million older rural persons and 1.7 million older urban persons [based on the observed prevalence estimates in 2004 and the 2001 India population census]) who are confined either to their beds or their homes and who need assistance with mobility. Clearly, there is a need for a policy focus on promoting and maintaining mobility and functional capacity among all older persons in India, concurrently with development and support for formal and informal long-term care services.

Authors' Contributions

Sreerupa, S Irudaya Rajan, and Yasuhiko Saito conceptualized and conducted the data analyses, interpreted the results of the analyses, and contributed in drafting the manuscript. Shweta Ajay and Rahul Malhotra interpreted the results of the analyses and contributed to drafting the manuscript.

Ethics

Secondary analysis of the available de-identified data was done. The de-identified data are publicly available. Therefore, we did not seek any ethical approval.

Availability of Supporting Data

Secondary analysis of the available de-identified data was done. The de-identified data are publicly available, i.e., ASDR from the Sample Registration System and two rounds of the NSS on Morbidity and Treatment of Ailments, 52nd Round (National Sample Survey Organisation, 1998), conducted from July 1995 to June 1996, and on Morbidity, Health Care, and the Conditions of the Aged, 60th Round (National Sample Survey Organisation, 2006), conducted from January to June 2004.

Conflicts of Interest

No conflicts of interest were reported by the authors.

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None.

Appendix

None.

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RESEARCH ARTICLE

Adolescent obesity by different growth charts and its efficacy with central adiposity among school-age children in Mumbai

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Abstract: Adolescent obesity can be defined using various age- and sex-specific growth charts. In addition to general obesity, central adiposity is also crucially important. This paper aims to study the efficacy of central adiposity with general obesity using different growth charts recommendations. A cross-sectional study was conducted among school-age children in Mumbai. Anthropometric data were obtained from 1349 adolescents aged 9–15 years. Growth charts of Indian Academy of Pediatrics (IAP), International Obesity Task Force (IOTF), and World Health Organization (WHO) were used to classify overweight and obese status among each of the participants. Central obesity indices such as the waist circumference (WC), the waist to height ratio (WHtR), and the waist to hip ratio (WHR) were calculated. The efficacy of each of central obesity indices was checked with overweight and obesity status. The receivers operating characteristics curves were drawn to check the efficacy of central obesity indices. According to IAP, IOTF, and WHO chart, the prevalence rates of overweight and obese among the sampled adolescents were 35.9%, 27.0%, and 25.0%, respectively, while, 26.5%, 26.3%, and 31% were found to be centrally obese as per WC, WHtR, and WHR, respectively. The values of area under curve for WC and WHtR were found between 0.857 and 0.942 for all three methods, while the corresponding values were between 0.611 and 0.689, indicating that WHR is a less robust indicator. We conclude that the central obesity status appears to be an efficient measure to identify the general obesity status irrespective of growth chart recommendations. WHtR and WC are found to be more robust indicators of general obesity.

Keywords: *adolescent obesity; central adiposity; growth chart; India; Mumbai; obesity; overweight; school-age children*

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1. Introduction

Childhood obesity has become one of the alarming public health concerns in 21st century. The severity of this issue is widespread across the globe, steadily affecting not only high-income countries but also low- and lower middle-income countries (World Health Organization [WHO], 2016). Overweight and obese children are likely to stay obese into their adulthood and more likely to develop non-communicable diseases such as diabetes and cardiovascular diseases at a younger age (WHO, 2016). Abdominal obesity is one of the strong predictors of high blood pressure, cardiovascular, and metabolic risk factors (Goran and Gower, 1999; Casonatto, Ohara, Giuliano, *et al.*, 2011; Jagadesan, Harish, Miranda, *et al.*, 2014; Patil, Shejul, Bhandarkar, *et al.*, 2018). Similarly, general and abdominal fat measures are also associated with cardiovascular risk factors, independent of body mass index (BMI) (Gishti, Gaillard, Durmus, *et al.*, 2015). BMI does not distinguish lean mass from fat mass; furthermore, it significantly underestimates adiposity. Prevention of obesity in early life may be important to reduce the risk of coronary heart disease in later life (Lurbe, Alvarez, Liao, *et al.*, 1998). Subcutaneous and visceral adipose tissue (VAT) are correlated with metabolic risk factors, while VAT remains strongly associated with an adverse metabolic risk profile (Pou, Massaro, Hoffmann, *et al.*, 2007).

India with 19.6% adolescent population is one of the youngest nations in the world (Office of the Registrar General and Census Commissioner, 2011). Obesity status has been evidenced to be influenced by rapid changes in lifestyle and diet (Goyal, Shah, Saboo, *et al.*, 2014). Obesity and overweight status of any child in India are revealed using the BMI percentile chart. BMI requires a calculation of anthropometric measures. In busy clinics, it is often difficult to assess obesity status using BMI percentile charts because for every adolescent referring age-sex specific percentile table and decide the cutoff points is quite difficult and time-consuming (August, Caprio, Fennoy, *et al.*, 2008). As a result, a simple calculation of physical growth parameters, representative of general obesity may of immense importance and interest to the practitioners and researchers. Considering variability in general adiposity, regional as well as global growth charts are available (World Health Organization, 2009; de Onis, and Lobstein, 2010; Khadilkar and Khadilkar, 2015). Adiposity depends on an anthropometric indicator, a reference population and cutoff points that best identify individuals as overweight/obese (Shah and Braverman, 2012). Further, central adiposity indices are related to general adiposity. Important indicators of central adiposity include waist circumference (WC), waist to height ratio (WHtR), and waist-to-hip ratio (WHR) (Nyamdorj, Qiao, Lam, *et al.*, 2008).

In sum, because adolescent obesity and adiposity are associated with various cardiometabolic risk factors (Weiss, Dziura, Burgert, *et al.*, 2004; Jagadesan, Harish, Miranda, *et al.*, 2014; Patil, Shejul, Bhandarkar, *et al.*, 2018; Pillai, 2018) and because the early prevention of childhood obesity could reduce morbidity and mortality in adulthood and further reduce global socioeconomic burden of cardiovascular disease and Type II diabetes (Zimmet, Alberti, Kaufman, *et al.*, 2007), studying obesity and adiposity among school-age children has a far-reaching significance. It is important to validate the available methods of obesity estimation in accessing the adolescent obesity status in busy clinics. With the use of junk food, sugar additive drinks, and restricted outdoor activities, Indian urban kids are most vulnerable to lifestyle and obesity-related disease, which makes the high levels of the prevalence of obesity among adolescents (Yadav, Yadav, Gautam, *et al.*, 2015). By 2025 India with more than 17 million obese children will stand second in the world (Sen, 2013). Many studies have discussed adolescent obesity in numerous sets of populations and with the basis of growth estimation using regional, national, and international registry standards, yet studies focusing on the city of Mumbai are rare. As one of the most populous cities in the world (United Nations, 2018), Mumbai not only comprises the representative population of India but also has its unique value for studying obesity of adolescents. This study aims to check the relationship between BMI and central adiposity among the adolescent population. Specifically, we aim to estimate the general obesity for school-age children in Mumbai using Indian Academy of Pediatrics (IAP), International Obesity Task Force (IOTF), and the World Health Organization (WHO) growth charts and also to evaluate the central adiposity.

2. Data and Methods

The study is based on a cross-sectional survey conducted at five schools in Mumbai from December 2016 to June 2017. Data were collected by trained medical professionals at Atomic Energy Central Schools (AECS) in Mumbai. One division from each standard across all the schools was randomly selected. All the healthy adolescents aged 9-15 years were included, while those who were having a known case of chronic illness and were not able to stand erect at the time of the survey were excluded from this study.

Selected adolescents were interviewed, and their anthropometry measurements such as height, weight, and waist and hip circumference were taken. Standard equipment and procedures were followed in measurements. On digital scale weight were measured after calibration to zero and with the least count of 0.1 kg. Similarly, for height wall-mounted stadiometer (Ishnee Stature Meter) was used for least count of 0.1 cm. While measuring the height of children, it is ensured that children were standing upright, barefoot on ground with heels, buttocks, upper back and head making firm contact with the wall, chin tucked-in slightly and the head held erect. Waist was measured at mid-point of the lower border of tenth rib and the superior border of the iliac crest. Hip circumference measured below the waist, where maximum reading was observed.

BMI was calculated as a ratio of weight in kilogram to the square of height in meter. Further, the adolescents in the study population were classified as overweight and obese according to the IAP (Khadilkar and Khadilkar, 2015), IOTF

(Cole, 2000), and WHO growth charts (World Health Organization, 2000).

To calculate central adiposity, the WC was used along with two indices, WHtR and WHR. In consistent with common practice in the existing literature, for WHtR, 0.5 was used as a universal cutoff to identify centrally obese, and WHR cutoff for boys and girls were 0.90 and 0.85, respectively (World Health Organization, 1999; Chung, Park, Park, *et al*., 2016). WC was categorized using age-and sex-specific percentile. WC between the 75th and 90th percentiles was classified as centrally overweight while above the 90th percentile as a centrally obese (Weiss, Dziura, Burgert, *et al*., 2004; Zimmet, Alberti, Kaufman, *et al*., 2007; Lee, Davis, Woolford, *et al*., 2009; Khadilkar, Ekbote, Chiplonkar, *et al*., 2014).

Data were analyzed using Microsoft Excel 2013 and R Studio for Windows (version 3.5). Descriptive statistic across study variables was presented as frequency as well as percentage. $p < 0.05$ was considered as statistically significant. Receiver operating characteristics (ROC) curves were drawn among IAP, IOTF, and WHO charts with central adiposity indices WHtR, WHR, and WC. Values of the corresponding area under the curve (AUC) from ROC were used to draw an inference.

2.1. Consent

An informed consent was obtained from each of children participated in the survey.

3. Results

Among 1486 adolescents interviewed, 1349 with the valid records of all the variables under consideration were included for the study, with 702 (52%) boys and 647 (48%) girls [Table 1]. The proportion of overweight and obese was found as 36% by IAP growth charts, 27 % by IOTF, and 25% by the WHO growth charts. Gender had no statistically significant difference in all categories ($p > 0.05$) [Table 2].

The prevalence of central adiposity was 26%, and 31% by WC percentile, WHtR, and WHR, respectively. The age- and sex-specific WC percentile showed the centrally overweight as 15% and the centrally obese as 11%. For WC and WHtR, no statistically significant difference was found in both boys and girls ($p > 0.05$). However, there was a gender difference in WHR [Table 3].

In the ROC curve, the general adiposity shows a better efficacy for WC and WHtR but a poor efficacy for WHR [Figure 1]. WC and WHtR were found to be excellent indicators of adiposity as compared to WHR. The values of AUC for WC and WHtR were in the range of 0.857–0.927, while the corresponding values for WHR were in the range of 0.610–0.675 for all three percentile charts referred [Table 4].

4. Discussion

The BMI percentile charts referred in the present study revealed that the prevalence rates of general obesity were in the range of 25%–35%, whereas the prevalence rates of central obesity were found in the range of 24%–31%. The higher values of AUC in the respective ROC curve indicate that WHtR and WC are robust indicators of adiposity in the present study population. According to the IAP growth chart, a relatively higher proportion of overweight and obese adolescents was found. However, a higher value of the proportion of centrally obese adolescents was found in WC. WHtR seemed to have the highest efficacy with the WHO growth charts (AUC = 0.927), whereas the poorest efficacy was seen for WHR associated with the IOTF growth chart (AUC = 0.610). The efficacy of WHtR and its usefulness in the identification of

Table 1. Characteristics of the study population.

Variable	Median (IQR)	
	Girls	Boys
Age (Years)	12.0 (13.0–10.0)	12.0 (13.0–11.0)
Height (cm)	148.0 (154.5–141.0)	148.5 (160.0–139.0)
Weight (kg)	40.6 (48.9–33.4)	41.0 (51.1–32.0)
BMI (Kg/m^2)	18.5 (21.5–16.1)	17.9 (21.1–15.9)
WC (cm)	67.0 (74.0–62.0)	67.0 (75.0–61.0)
WHR	0.83 (0.87–0.79)	0.85 (0.89–0.81)
WHtR	0.46 (0.50–0.43)	0.45 (0.50–0.42)

BMI: Body mass index, WC: Waist circumference, WHR: Waist-to-hip ratio, WHtR: Waist-to-height ratio.

Table 2. Prevalence of overweight and obesity based on IAP, IOTF, and WHO BMI growth charts.

Narration	Normal-weight (%)	Over-weight (%)	Obesity (%)
IAP			
Girl	406 (62.8)	138 (21.3)	103 (15.9)
Boy	459 (65.4)	145 (20.6)	98 (14.0)
IAP total	865 (64.1)	283 (21.0)	201 (14.9)
IOTF			
Girl	471 (72.8)	111 (17.2)	65 (14.0)
Boy	514 (73.2)	114 (16.2)	74 (10.5)
IOTF total	985 (73.0)	225 (16.7)	139 (10.3)
WHO			
Girl	495 (76.5)	86 (13.3)	66 (10.2)
Boy	517 (73.6)	88 (12.5)	97 (13.8)
WHO total	1012 (75.0)	174 (12.9)	163 (12.1)

IAP: Indian academy of pediatrics, IOTF: International obesity task force, WHO: World Health Organization.

Table 3. Central adiposity using WC, WHtR, and WHR.

Central adiposity	Girls	Boys	Total (%)
Waist circumference (age- and sex-adjusted)			
<75th percentile	473	518	991 (73)
75–90th percentile	97	106	203 (15)
90th percentile	77	78	155 (11)
WHtR			
< 0.5	473	521	994 (74)
≥0.5	174	181	355 (26)
WHR			
<0.85–girl, <0.90–boy	375	558	933 (69)
≥0.85–girl, ≥0.90–boy	272	144	416 (31)

WC: Waist circumference, WHR: Waist-to-hip ratio, WHtR: Waist-to-height ratio.

Table 4. Values of the AUC in ROC curve for the efficacy evaluation of central adiposity by IAP, IOTF, and WHO reference tables.

Narration	WC	WHtR	WHR
IAP	0.908	0.925	0.644
IOTF	0.857	0.869	0.610
WHO	0.891	0.927	0.675

AUC: Area under curve, ROC: Receiver operating characteristics, IAP: Indian academy of pediatrics, IOTF: International obesity task force, WHO: World Health Organization, WC: Waist circumference.

increased morbidity risk related to central obesity was discussed in various studies (Yoo, 2016). Our findings support to its robustness.

WHtR in present study appeared as a more predictive indicator than WC, which is consistent with the previous studies that found that WHtR is superior to BMI in predicting cardiometabolic risk (Šimundić, 2009; Yoo, 2016). In a similar

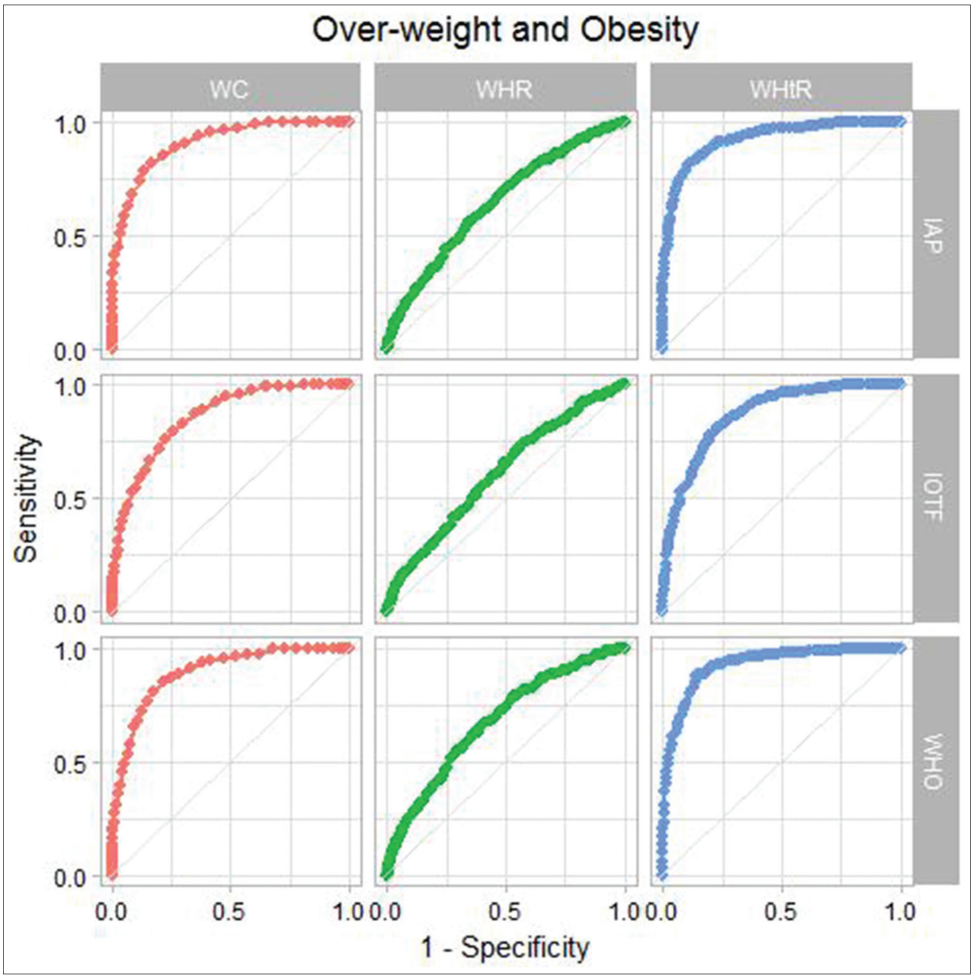

Figure 1. Receiver operating characteristic curve for the waist circumference, the waist-to-hip ratio, and the waist-to-height ratio for Indian academy of pediatrics, International obesity task force, and World Health Organization growth charts.

study on Nigerian adolescents, WC also performed better than WHR (Okafor, Ofoegbu, Fasanmade, *et al.*, 2011). The WC percentile might be an interesting tool to calculate central adiposity because it is the most widely accepted method; it is also noninvasive and easy to use. For children and adolescents, age-sex-specific separate cutoffs are required to measure obesity and adiposity due to their physiologically changing body shape.

Among three indices of central obesity, WHtR, and WC appeared useful to identify high central obesity, while WHR failed to highlight. Visceral adiposity carries a high metabolic risk compared to general adiposity. BMI cannot specify about central obesity; hence, specific indices such as WHtR and WC were found a representative in the study population. Furthermore, central obesity indicators are relatively easy to use during busy clinics in the Indian as well as in low- and middle-income countries setups.

The findings of this present study add weight to the consideration of the central adiposity irrespective of children's gender or age group. It could be simply mentioned as "keep your WC to less than half your height" (McCarthy and Ashwell, 2006). Simply, by considering the WHtR and WC indices for general obesity status is possible to be predicted. Public health message should be propagated toward the prevention of obesity throughout childhood and adolescence.

When interpreting the results, the following limitations should be taken into account. First, the present study is based on children belonging to urban middle-class communities. They may not be representative of the entire city of Mumbai. Variability across school types such as rural and urban-slum would have different results and would have added values to such research. More research based on samples of a representative of entire schools in Mumbai or entire India urban areas is clearly warranted to have a fuller spectrum of our understanding the validity of WHtR and WC in school-age adolescents. Second, as there have been no other similar surveys in Mumbai to compare with, whether the prevalence of central obesity truly represents this population are unknown.

In our study, 89% of obese adolescents were found to be centrally obese. A Bangladesh study in Dhaka area reported a prevalence of 54% central obesity among adolescent girls (Zabeen, Tayyeb, Naz, *et al.*, 2015). The reason why our study has a much higher prevalence of central obesity is unknown. This may be due to sampling bias of the population or maybe due to the accuracy of measurement and data quality. More research is needed to compare the possible causes. Third, we did not perform advanced analysis to take different covariates into account. More research projects have been put forward, and we will release more robust findings.

5. Conclusions

The present study documents the efficacy of central obesity indicators with general obesity in adolescents. WC and WHtR appear to be more robust indicators of general obesity and they can be used to determine the obesity status of adolescents.

Authors Contributions

AP, PB, and PP planned and designed the study and drafted the discussion. AP prepared the draft and PP did the analysis and visualization. PB and PP worked on data analysis. The manuscript was written and approved by all the authors.

Ethics Clearances

This study was approved by Institutional Ethics as well as Scientific Committee of Bhabha Atomic Research Center Hospital, Mumbai, through their letter no BHMEC/NP/13/16 dated January 24, 2017.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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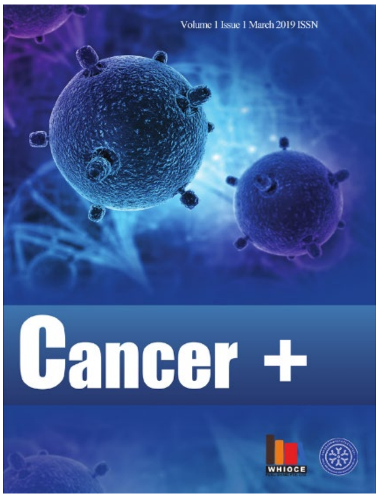

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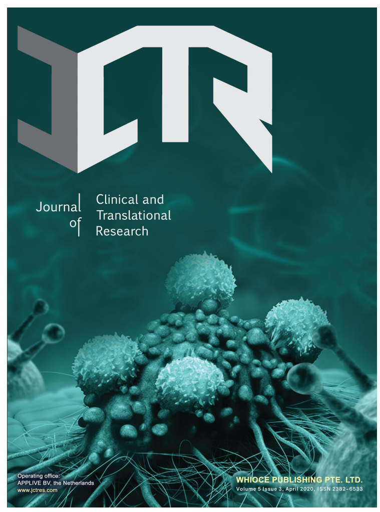

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