Premature Mortality during the Covid-19 Pandemic in Bangladesh

Ahbab Mohammad Fazle Rabbi*[1]

[1]*Department of Population Sciences, University of Dhaka, Dhaka, Bangladesh*

Abstract

The impact of sudden epidemics is often reflected across different stages of the lifespan, leading to increased mortality rates in affected populations. The COVID-19 pandemic, a major global health crisis, has significantly disrupted the ongoing trend of global mortality reduction. Although COVID-19 fatality rates increase with age, the pandemic has affected all age groups, leading to an increase in premature mortality on a global scale. This study aimed to assess the impact of COVID-19 on premature mortality specifically in Bangladesh during the years 2020 and 2021. Using data from the 2022 revision of the World Population Prospects, we analyzed both absolute and relative measures of premature mortality to evaluate the effects of excess mortality. Our analysis revealed a decrease in premature mortality for Bangladeshi males in 2020, which continued the trend of mortality transition, followed by an increase in 2021. In contrast, premature mortality increased for Bangladeshi females during both years. The findings suggest that relative measures of premature mortality were more sensitive to changes in excess mortality compared to absolute measures. Additionally, the cut-off age remained a critical factor in accurately estimating absolute premature mortality.

Keywords: Premature mortality; PYLL; Threshold ages; Covid-19 pandemic, Bangladesh

1 Introduction

Human mortality has declined globally over the past centuries (Oeppen & Vaupel 2002) and continued to do so until the beginning of 2020. The Coronavirus Disease 2019 (COVID-19), caused by the SARS-CoV-2 virus, developed into a global pandemic at the start of 2020 (Velavan & Meyer 2021). As of May 29, 2024, the World Health Organization (WHO) reported over 775 million confirmed cases of COVID-19 worldwide, resulting in 7 million deaths (World Health Organization and others 2022). Cause-specific mortality due to COVID-19 varied by age and sex globally (United Nations 2022), and estimates of excess mortality were inconsistent across different waves of the pandemic (Schöley et al. 2022). The total number of excess deaths due to COVID-19 may be potentially confounded by the age structure of a population as well as the health system of the country. Clinical evidence has clearly indicated that the risk of dying from COVID-19 is associated with age (Zhou et al. 2020). COVID-19 fatality increases steadily with age, and while infants and older adults are at higher risk for other respiratory diseases (Raoult et al. 2020), the effect of excess mortality in older age groups has received more focus compared to younger age groups (Ugarte et al. 2022). From a demographic perspective, the majority of severe cases involve older populations, particularly those aged 70 years and over (Marois et al. 2020). However, the pandemic not only affects the elderly but also contributes to premature mortality globally (Islam et al. 2021; Marois et al. 2020).

*Corresponding: `fazlerabbi@du.ac.bd`

The concept of premature mortality is now a widely used indicator of population health (Ugarte et al. 2022; OECD 2009). According to Martinez et al. (2020), a premature death is defined as a death occurring before the potential maximum life expectancy for the age of the deceased. The standard expected years of life lost method is used to measure the duration of time lost due to premature mortality. A particularly high level or an increasing trend in premature mortality may signal to policymakers an underlying health problem within the population. Measuring premature mortality helps explain both international and country-level assessments of unnecessary or avoidable mortality burdens (Mazzuco et al. 2021). Additionally, premature mortality is strongly associated with health inequalities; thus, a reduction in early mortality contributes to greater longevity and increased equality among individuals (Mazzuco et al. 2021).

Several methods have been proposed to quantify premature mortality, which can be broadly classified into two categories: absolute and relative measures. Absolute measures use a fixed age threshold to differentiate between premature and older age mortality. In contrast, relative measures determine premature mortality based on the distribution of age-at-death (Mazzuco et al. 2021). One of the most commonly utilized metrics in the literature is the Potential Years of Life Lost (PYLL), which is considered a reliable measure of premature mortality (Romeder & McWhinnie 1977). PYLL is an absolute measure and can be calculated using various threshold ages. For instance, the Organisation for Economic Co-operation and Development (OECD) defines premature mortality in terms of PYLL before the age of 70 (OECD 2009). On the other hand, organizations like the World Health Organization (WHO) and Eurostat use different operational definitions for calculating premature mortality (Mazzuco et al. 2021). These variations in thresholds and definitions reflect the diversity in methodologies used to assess the burden of premature mortality, which can influence the interpretation and comparison of mortality data across different contexts and studies.

Since the onset of the COVID-19 pandemic, numerous studies have been conducted to assess changes in premature mortality. Due to the availability of high-quality mortality data, many of these studies have focused on low-mortality countries (see, Ugarte et al. 2022, for an example). These studies have often highlighted various approaches to defining the threshold between premature and senescent mortality, with differing criteria observed across the pandemic period (Mitra et al. 2020). However, there is a notable gap in the existing literature regarding the impact of excess mortality—specifically due to the pandemic—in populations experiencing higher mortality regimes. While some studies have attempted to analyze life years lost due to the pandemic in a multi-country comparison, these studies have not specifically focused on premature mortality (Pifarré i Arolas et al. 2021). Bangladesh, a developing country in South Asia, serves as an illustrative example of mortality transition in this context. Prior to the pandemic, Bangladesh was undergoing a demographic transition characterized by a stabilization of fertility rates near replacement levels and a steady decline in mortality rates, resulting in a significant increase in life expectancy (Rabbi & Mazzuco 2017). Although Bangladesh was less severely impacted by the pandemic compared to its neighboring countries, the presence of excess mortality was notably observed among younger age groups due to its relatively young population.

This paper aims to examine the changes in premature mortality levels in Bangladesh during the COVID-19 pandemic. For absolute measures of premature mortality, we utilized Potential Years of Life Lost (PYLL). For relative measures, we considered two different thresholds for age. These relative measures of threshold age also delineate the points at which lifespan inequality increases or decreases. Given that Bangladesh has experienced an increasing trend in life expectancy for both sexes, this analysis will help elucidate the extent of inequality associated with this rise in life expectancy. By integrating these findings with other available measures of longevity, we aim to provide demographers with deeper insights into the impact of excess mortality due to the COVID-19 pandemic in Bangladesh. This comprehensive approach will enhance our understanding of how the pandemic has affected premature mortality and contribute to a more nuanced assessment of its implications for public health and demographic trends.

2 Data and methods

The following subsection provides details on data used in this study and different methods to measure premature mortality.

Data

Due to lack of detailed mortality data from vital registration systems, we considered alternative data sources for the current study. The data used in this study is derived from the 2022 revision of the World Population Prospects (WPP 2022) (United Nations 2022). For Bangladesh, WPP 2022 provides estimated life tables in single years which are constructed up to age 100 years. However, due to the presence of zero mortality rates in the upper ages for most of the years for Bangladesh, we reconstructed these life tables up to age 85 years (or less where needed) for our analysis. Detailed information regarding the data sources, estimation procedures is discussed elsewhere (United Nations 2022). Instead of analyzing all available data in the WPP 2022, we considered the data from 1972 to 2021 for current study.

Methods

Standard life-table notations are used all over the paper. Age-specific mortality rates for a period life-table is defined as,

$$m(x) = \frac{D(x)}{P(x)};$$

where $D(x)$ is the observed death counts in a calendar year and $P(x)$ is the mid-year population of that year for age group x.

Absolute measures of premature mortality

Period expected years of life lost (PEYLL)

We estimated the period expected years of life lost (PEYLL) to measure the overall change in mortality during pandemic rather than the premature mortality only. The PEYLL demonstrates the mortality gap between the current period of life expectancy at a given age and the actual age at the time of death. Symbolically,

$$PEYLL = \sum_{x=0}^{\omega} d_x e_x; \tag{1}$$

where, d_x is the number of deaths at each age x, e_x is the remaining life expectancy at each age x and ω is the maximum attainable age in the life table.

Potential years of life lost (PYLL)

We considered the potential years of life lost (PYLL) as the main indicator of premature deaths (Romeder & McWhinnie 1977). PYLL provides more conservative estimates than other indicators and it focuses on the premature mortality of those who die (Ugarte et al. 2022). Symbolically,

$$PYLL = \sum_{x=0}^{\tau}(\tau - x)d_x; \tag{2}$$

where τ is the potential limit of life (cut-off point in lifespan). Following OECD (2009), we considered 70 years as the cut-off age for premature mortality. This choice of upper limit (70 years) ensures that deaths happening over 70 years of age contribute zero PYLL to the calculation. Another benefit of this methodology is that it also assumes uniform distribution of deaths within the age groups (Romeder & McWhinnie 1977; Ugarte et al. 2022). PYLL are calculated per person death and as rates (per 100,000 population) using the following equation.

$$Crude\ PYLL\ rate = \frac{PYLL}{Population\ under\ age\ 70\ years} \times 100,000. \tag{3}$$

Relative measures of premature mortality

Two different definition of threshold ages are considered in this study. Both of them are defined as an specific age which divide premature deaths from the late deaths.

Threshold age based on lifespan disparity

The first measure of the threshold age was proposed by Zhang & Vaupel (2009) and this measures is based on lifespan disparity. To measure lifespan disparity, we utilize the definition of Vaupel & Romo (2003) and Zhang & Vaupel (2009) where it is defined as the average number of life years lost at birth (as a result of death). Symbolically,

$$e_0^\dagger = \frac{\int_0^\omega e(x)d(x)\ dx}{l(0)}. \tag{4}$$

Here ω is the maximum attainable age, d_x is the distribution of death and l_x is the number of people alive at age x (l_0 is the life table radix). It should be noted that, despite of several other alternative formulations of $e^\dagger$ (see Vaupel & Romo 2003, for an example), the difference between these measures are negligible in terms of outcomes and sensitivity analysis (Van Raalte & Caswell 2013). Hence, the threshold age proposed by Zhang & Vaupel (2009) is denoted by $a^\dagger$ is the age at which,

$$e^\dagger(a) = e(a)(1 - H(a)). \tag{5}$$

Here, $e(a)$ is the life expectancy for threshold age a and $H(a) = \int_0^a \mu(x)dx$ is the cumulative hazard to age a. This estimation is based on the assumption that the life table entropy (defined in the next subsection) should be less than one. $a^\dagger$ can be estimated using interpolation routines in most of the widely used statistical software.

Threshold age based on life table entropy

The second measure of threshold age between premature deaths and late deaths is based on life table entropy (Aburto et al. 2019). Life table entropy is defined as a measure of elasticity of life expectancy to a change in mortality (Aburto et al. 2019). Symbolically,

$$\mathcal{H} = -\frac{\int_0^\omega l(a)\ln l(a)\ da}{\int_0^\omega l(a)da} = \int_0^\omega c(a)H(a)\ da = \frac{e_0^\dagger}{e(0)}; \tag{6}$$

where $c(a) = l(a)/\int_0^\omega l(x)dx$ is the population age structure; $H(a) = \int_0^a \mu(x)dx$ is the cumulative hazard to age a; $\mu(x)$ is the force of mortality at age x and $\int_0^\omega l(a)\ln l(a)\ da$ is the lifespan disparity, $e^\dagger$ (Vaupel & Romo 2003). Later, Aburto et al. (2019) defined a measure of threshold age between premature deaths and later deaths as a relative change in $\mathcal{H}$. To compute this measure, Aburto et al. (2019) defined entropy of life table at age x as a conditional measure (on surviving to age x). Symbolically,

$$\bar{\mathcal{H}}(x) = \frac{\int_x^\omega l(a) \ln l(a) \; da}{\int_x^\omega l(a) da} = \frac{e^\dagger(x)}{e(x)}. \tag{7}$$

Assuming an improvement in mortality over all ages, the threshold age defined by Aburto et al. (2019) separates positive from negative contributions to $\mathcal{H}$ resulting from mortality improvements. Since mortality improvement over time occurs at all ages, there exists a unique threshold age a^H that separates positive from negative contributions to the lifetable entropy $\mathcal{H}$. This threshold age a^H is reached when

$$H(a^H) + \bar{\mathcal{H}}(a^H) = 1 + \mathcal{H}. \tag{8}$$

3 Results

3.1 Absolute measures of premature mortality

In this subsection, we present the findings from the absolute measure of premature mortality only. All results are provided separately for males and females throughout this section to facilitate age- and sex-specific comparisons. Figure 1 illustrates the relative increase in the number of premature deaths in Bangladesh during 2020 and 2021 compared to 2019. Before analyzing changes in premature mortality, we first examined the period expected years of life lost (PEYLL) for Bangladesh. For Bangladeshi males, PEYLL decreased consistently until 2020 but increased in 2021. In 2019, the PEYLL for Bangladeshi males was 13.59 years. This measure dropped to 12.91 years in 2020 but rose to 13.94 years in 2021. For Bangladeshi females, PEYLL was 13.43 years in 2019 and increased steadily to 14.15 years by 2021.

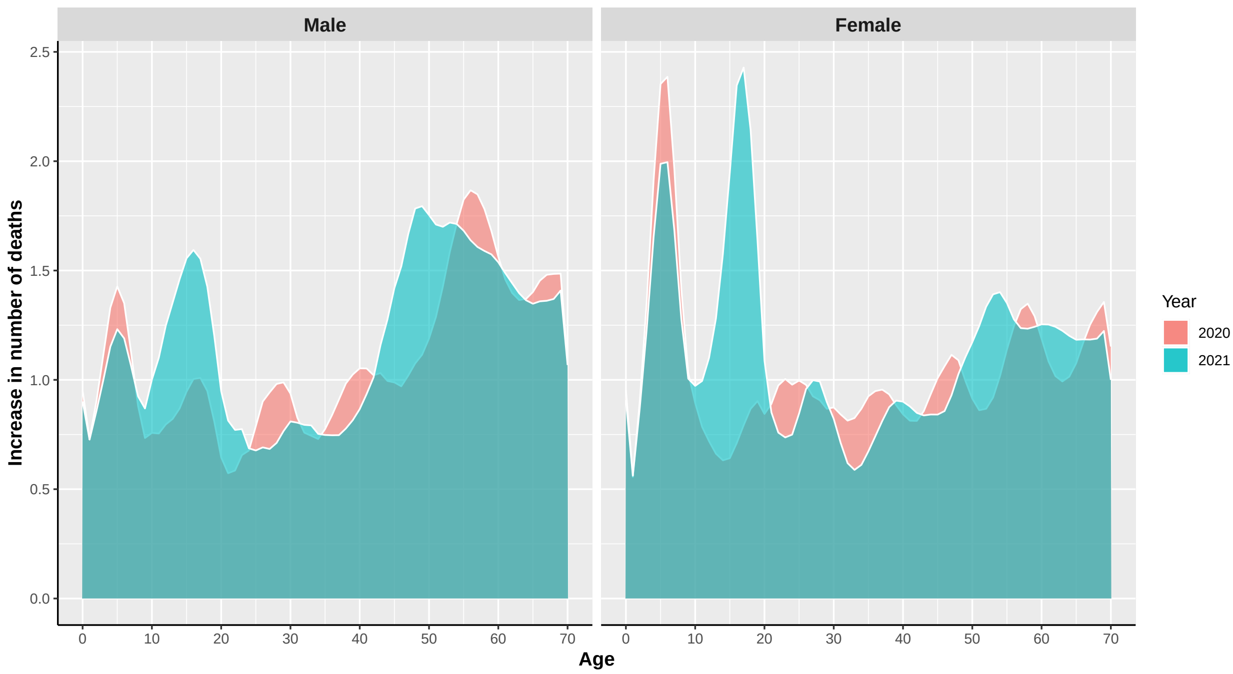

Figure 1: Relative increase in number of deaths during 2020 and 2021 compared to 2019 in Bangladesh for premature mortality. *Source:* Author's analysis of data from World Population Prospect-2022 (WPP 2022).

The Potential Years of Life Lost (PYLL) for males in Bangladesh declined in 2020, continuing a previous trend, but increased again in 2021. In 2019, the PYLL for Bangladeshi males was 7.33 years. This figure decreased slightly to 7.32 years in 2020 but then rose to 7.38 years in 2021. Similar to the trends observed in the period expected years of life lost (PEYLL), the PYLL for Bangladeshi females also exhibited a steady increase. Specifically, the PYLL for females in Bangladesh was 5.82 years in 2019, rose to 6.02 years in 2020, and further increased to 6.13 years in 2021. Figure 9 illustrates the crude rate of PYLL, with the year 2019, the last year before the pandemic, highlighted using a bold-dashed line. This visual representation emphasizes the changes in PYLL during the pandemic years.

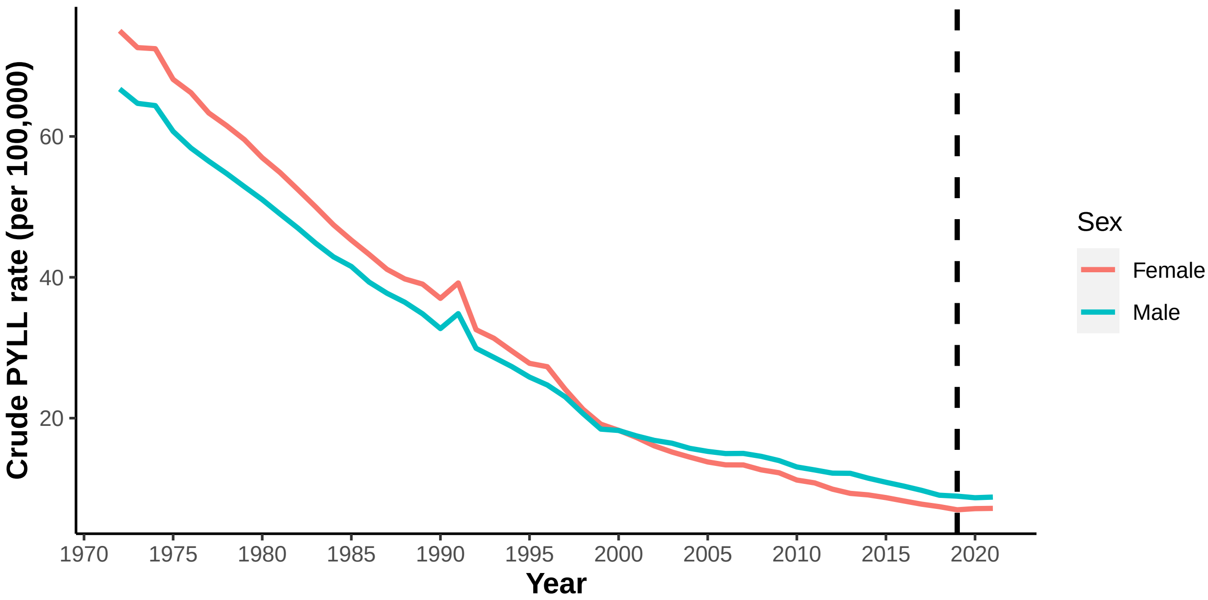

Figure 2: Trend of potential years of life lost (PYLL) in Bangladesh for both sexes (1972:2021).

A similar trend is observed for the crude Potential Years of Life Lost (PYLL) rate. At the beginning of the period analyzed, the crude PYLL rate was high for both sexes in Bangladesh, but it subsequently declined over the years. In 2019, the crude PYLL rate was 8.93 years for males and 6.99 years for females. For Bangladeshi males, this declining trend continued into 2020; however, there was a slight increase in 2021, with rates of 8.70 years and 8.79 years, respectively. For females, the crude PYLL rate increased during both pandemic years, reflecting a rise in premature mortality during these years.

3.2 Relative measures of premature mortality

This subsection presents the findings from the relative measures of premature mortality. We calculated two different threshold ages as relative measures of premature mortality. These measures are illustrated in Figures 3 and 4. The first measure is based on lifespan disparity, denoted as ($a^{\dagger}$). This measure assesses the variability in age at death across a population, providing insights into how inequality in lifespan contributes to premature mortality. The second measure is based on life table entropy, denoted as (a^{H}). Life table entropy captures the uncertainty or dispersion in the distribution of age at death, offering another perspective on lifespan inequality. The detailed estimation procedures and calculations for these relative measures are provided in the appendix. These calculations include the methods for determining the threshold ages and interpreting the results within the context of premature mortality. Figures 3 and 4 visually represent the trends and changes in these relative measures over time, providing a comprehensive view of how premature mortality has evolved in relation to lifespan disparity and life table entropy.

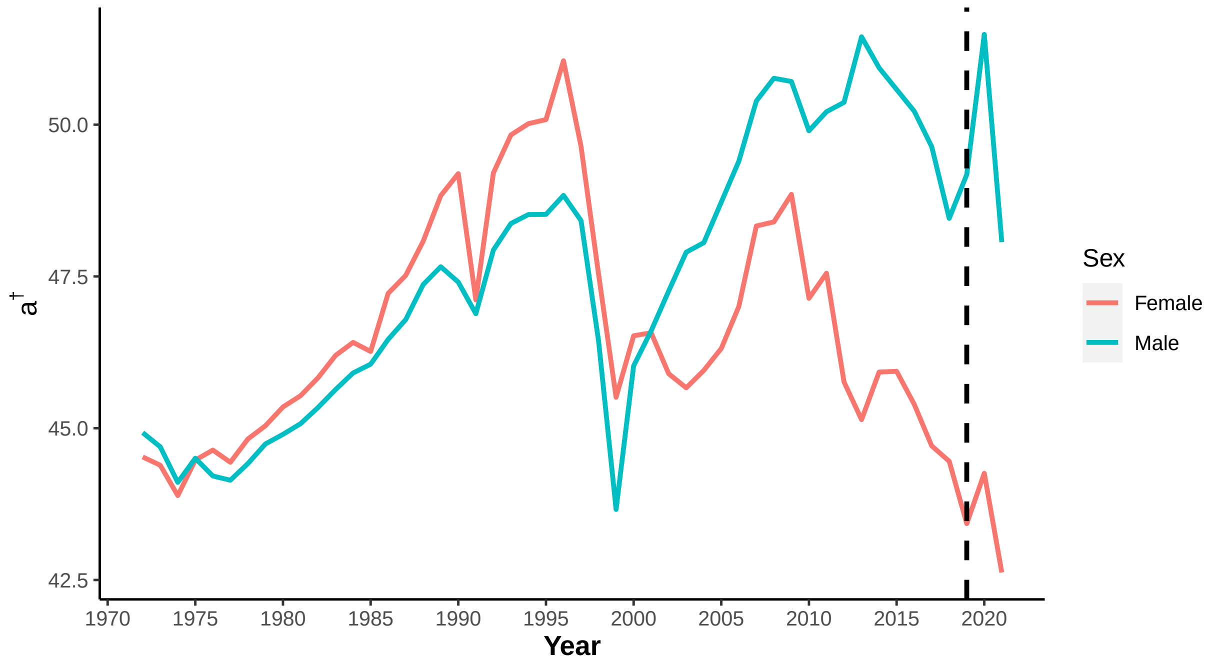

Figure 3: Trend of threshold age based on lifespan disparity ($a^\dagger$) in Bangladesh for both sexes (1972:2021).

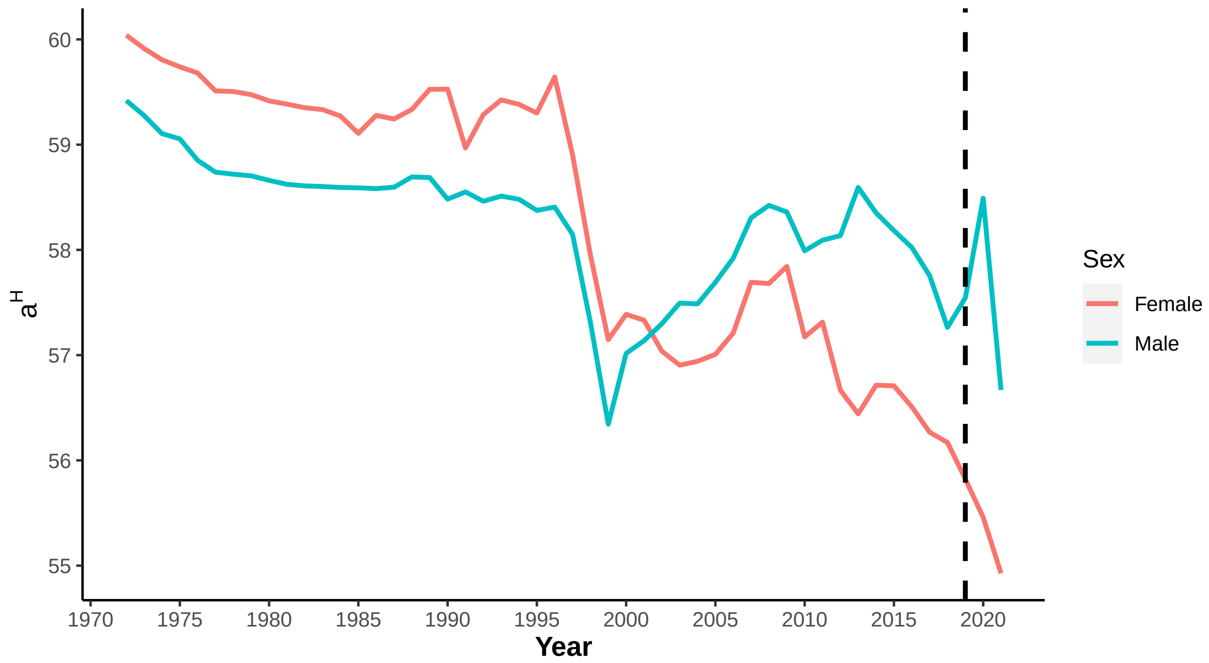

Figure 4: Trend of threshold age based on life table entropy (a^H) in Bangladesh for both sexes (1972:2021).

Both relative measures exhibited an irregular trend over the years. However, the threshold age

Table 1: Changes in life expectancy and measures of premature mortality in Bangladesh during pandemic (2019:2021).

	Years	e_0	PEYLL	PYLL	Crude PYLL rate (Per 100,000)	$a^{\dagger}$	a^H
Male	2019	70.75	13.60	7.33	8.92	49.17	57.54
	2020	70.19	12.91	7.22	8.70	51.48	58.49
	2021	70.66	13.94	7.38	8.79	48.07	56.49
Female	2019	75.22	13.45	5.83	6.99	43.43	55.82
	2020	74.07	13.69	6.03	7.15	44.26	55.46
	2021	74.43	14.15	6.13	7.19	42.62	54.92

based on lifespan disparity showed more irregularity compared to the threshold age based on life table entropy. The trends in lifespan disparity and life table entropy are detailed in the appendix for both sexes. In the first year of the pandemic, the threshold age based on lifespan disparity increased from 49.18 years in 2019 to 51.49 years for Bangladeshi males, but then declined to 48.07 years in 2021. For females, the change was less pronounced compared to males. In 2019, $a^{\dagger}$ was 43.43 years, which rose to 44.26 years in 2020 before falling to 42.62 years in 2021. A similar irregular pattern was observed for the threshold age based on life table entropy and lifespan disparity among Bangladeshi males. In 2019, the threshold age a^H was 57.54 years for Bangladeshi males, which increased to 58.49 years in the first year of the pandemic, but then declined to 56.67 years in 2021. In contrast, the threshold age based on life table entropy showed a steady decline among Bangladeshi females during the pandemic period. In 2019, a^H was 55.83 years for Bangladeshi females, which decreased to 55.49 years in 2020 and further to 54.92 years in 2021. A summary of changes in all these measures (both absolute and relative) and life expectancy at birth (e_0) for the years 2019 to 2021 is provided in Table 1.

4 Discussion

Attempts to precisely estimate premature mortality are not new in epidemiology (Martinez et al. 2020). Impact of sudden epidemic are often reflected on different part of the lifespan with increased mortality, and the COVID-19 pandemic was one of the such disasters which alter ongoing global mortality reduction significantly. The aim of this study was to assess COVID-19 impact on premature mortality for Bangladesh during 2020 and 2021. Different measures of premature mortality was estimated for Bangladesh and the results showed effect of the pandemic on premature mortality.

Our estimated trend of potential years of life lost (PYLL) showed an increase in 2021 for males and an increase in both 2020 and 2021 for the females. This findings can be interpreted from higher level of observed mortality in 2021 than that of 2020 (Figure 1). Increased number of deaths are observed for both sexes in 2021. The effect of the pandemic was more severe in 2021 after the Delta variant spread in the country. The delta version was responsible for the second wave of the pandemic in India and neighbor country and was the most deadly wave during the entire pandemic (Verma et al. 2023).

We further estimated the crude Potential Years of Life Lost (PYLL) rate as an absolute measure of premature mortality. Unlike PYLL, the crude rate of PYLL considers the age- and sex-specific population structure while summarizing premature mortality. The trend in the crude PYLL rate showed a similar pattern to that of PYLL for Bangladesh, with an increase observed in both 2020 and 2021 for females, diverging from previous trends. A previous study also reported an increase in 2020 compared to the trend observed over the last five years for many countries (Ugarte et al. 2022). The change in the crude PYLL rate was lower compared to PYLL for both sexes during the pandemic. However, our results may differ from those reported in other studies. For instance, Kozierkiewicz et al. (2016) highlighted a problem related to the definition of the cut-off age for old-age mortality and premature mortality. In our analysis, we used the most commonly accepted definition of premature mortality (OECD 2009), while some studies have employed the average life expectancy at birth for a specific period (Mitra et al. 2020). Additionally, Mazzuco et al. (2021) noted that a major drawback of the absolute approach is the need to select a unique, arbitrary threshold for different mortality patterns. Exploring different thresholds for absolute measures may thus provide deeper insights into the issue.

In relative measures of premature mortality, the share of premature deaths depends on the entire distribution of deaths by age (Mazzuco et al. 2021). The exact operationalization of premature mortality also depends on the pattern of senescent mortality, and each country has its own pattern of senescent and premature death distributions. Such a definition addresses the challenge of identifying a generalized threshold age, which was a significant issue when estimating absolute measures of premature mortality (Mazzuco et al. 2021). This approach also helps avoid defining a universal threshold that might be problematic for some countries in specific situations, such as the impact of a pandemic.

In this regard, we used two different threshold ages based on lifespan disparity and life table entropy. A major advantage of these measures is that both provide a clear reflection of the age-at-death distribution (Zhang & Vaupel 2009; Aburto et al. 2019). Unlike absolute measures, the threshold ages based on lifespan disparity ($a^{\dagger}$) were found to be more sensitive to changes in mortality over time and during the pandemic when excess mortality occurred in Bangladesh. Moreover, unlike absolute measures of premature mortality, $a^{\dagger}$ did not show a consistent decreasing trend for Bangladeshi females. In contrast, a^{H} showed a decreasing trend for Bangladeshi females during the pandemic years. For Bangladeshi males, a^{H} increased in 2020 and then decreased in 2021. The observed trend in lifespan disparity was more irregular compared to that of life table entropy for Bangladesh, which may affect the indices as well (see appendix for detailed trends).

The underlying idea behind developing both threshold ages is to identify an age in the human lifespan that hypothetically separates the negative from the positive contributions of age-specific mortality improvements (Aburto et al. 2019). Empirical analysis using data from low-mortality countries has shown that $a^{\dagger}$ tends to fall below the life expectancy at birth (Van Raalte & Caswell 2013). Additionally, Aburto et al. (2019) observed that a^{H} tends to be higher than $a^{\dagger}$ based on empirical data. Our findings were consistent with both of these studies. However, the trends for $a^{\dagger}$ and life expectancy at birth were similar for historical populations (during mortality transitions) in empirical findings, which was not the case for the trend observed in Bangladesh. The relative approaches to premature mortality implicitly acknowledge that a death can be considered premature—and thus to be avoided—in one population but not necessarily in another (Mazzuco et al. 2021). Further studies could provide more insight into this.

5 Strength and limitations

Our study provides several valuable insights compared to other published research on this topic. It is one of the few studies that attempts to evaluate the burden of COVID-19 on premature mortality using both absolute and relative approaches. Additionally, this study explored relative measures of premature mortality by considering threshold ages based on demographic measures of lifespan variation, rather than relying solely on statistical measurements. Unlike many other studies focusing on countries undergoing mortality transitions, the data used in this study is more nationally representative. This characteristic makes the study more reliable compared to publicly available or regional-level data often used in similar studies for high-mortality countries.

However, this study is not without its data and methodological limitations. Due to the availability of detailed national-level mortality data, we used data from the 2022 revision of the World Population Prospects (United Nations 2022). To estimate life tables for high-mortality countries, various statistical modeling techniques have been applied extensively (United Nations 2022). As a result, the trends in our indices may appear overly smoothed because the mortality rates themselves were already smoothed (see appendix). Consequently, this may offer only a partial view of the actual scenario. In contrast to previous studies, we focused less on the age-specific contributions of premature mortality to overall indices (Ugarte et al. 2022). We chose to omit this aspect because it has already been extensively covered in other research. Moreover, our study is limited by the methodological constraints related to the definition of premature mortality. While using the OECD definition (OECD 2009) made our results comparable to those of other countries, employing different cut-off ages for premature mortality could potentially yield more robust results. For instance, the life expectancy at birth is higher for both sexes in Bangladesh compared to the OECD cut-off age, which could produce more accurate findings. However, this would also reduce the comparability of our study with other countries.

6 Conclusion

This paper presents a comparative analysis of changes in premature mortality in Bangladesh during the pandemic, quantifying its effects on age- and sex-specific mortality through two different measures of premature mortality. Most of the methods indicated a decrease in premature mortality in 2020, reflecting the continuation of the ongoing mortality transition for Bangladeshi males, followed by an increase in 2021. In contrast, increased premature mortality was observed for both years among Bangladeshi females. These findings suggest a modest elevation in premature mortality levels in Bangladesh during the pandemic.

One of the major challenges in this area of research is that premature mortality is an inherently latent concept, which means it cannot be precisely estimated. The operationalization of this concept can significantly influence the results obtained. In the study of premature mortality, it is common for one population to appear to have a more favorable scenario compared to another population based on one measure of premature mortality, while appearing worse according to another measure. This discrepancy is often due to the fact that the population under study may still be undergoing a mortality transition or may be in a high mortality regime. Consequently, such comparisons can be problematic and should be interpreted with caution. The variability in how premature mortality is measured and reported underscores the importance of carefully considering the methodological approaches and contextual factors when interpreting findings in this field.

While this study provides valuable insights into the impact of the COVID-19 pandemic on premature mortality in Bangladesh, there are still areas that warrant further exploration. A more comprehensive analysis that incorporates age-specific decomposition for all measures during the pandemic would offer a clearer understanding of the true scenario. Additionally, considering cause-specific mortality could provide a deeper insight into the effects of excess mortality on longevity in Bangladesh. The reliance on data from the World Population Prospects was necessitated by the absence of fully functional registration systems in Bangladesh. Applying these methods to nationally representative data would yield more nuanced insights. Furthermore, the study did not include a comparison of premature mortality during the pandemic period across neighboring countries, which could have offered a more detailed explanation of the observed relative changes in mortality improvement. To address some of the limitations of existing approaches in both classes of measures, a hybrid method that combines features of both approaches may offer more comprehensive insights into premature mortality. Such estimates could become more comparable across populations with similar characteristics. Addressing these aspects would significantly contribute to a broader understanding of the pandemic's impact on premature mortality and longevity in Bangladesh, potentially guiding more effective public health policies and interventions in future health crises.

References

Aburto, J. M., Alvarez, J.-A., Villavicencio, F., & Vaupel, J. W. (2019). The threshold age of the lifetable entropy. *Demographic Research*, *41*, 83–102.

Islam, N., Jdanov, D. A., Shkolnikov, V. M., Khunti, K., Kawachi, I., White, M., ... Lacey, B. (2021). Effects of covid-19 pandemic on life expectancy and premature mortality in 2020: time series analysis in 37 countries. *bmj*, *375*.

Kozierkiewicz, A., Megas, B., Natkaniec, M., Topór-Mądry, R., Kissimova-Skarbek, E., Śliwczyński, A., & Gajda, K. (2016). Years of life lost due to deaths in poland measured with potential years of life lost (pyll) and period expected years of life lost (peyll) indicators in years 2000-2014.

Marois, G., Muttarak, R., & Scherbov, S. (2020). Assessing the potential impact of covid-19 on life expectancy. *Plos one*, *15*(9), e0238678.

Martinez, R., Lloyd-Sherlock, P., Soliz, P., Ebrahim, S., Vega, E., Ordunez, P., & McKee, M. (2020). Trends in premature avertable mortality from non-communicable diseases for 195 countries and territories, 1990–2017: a population-based study. *The Lancet Global Health*, *8*(4), e511–e523.

Mazzuco, S. S., Suhrcke, M. M., & Zanotto, L. L. (2021). How to measure premature mortality? a proposal combining "relative" and "absolute" approaches. *Population health metrics*, *19*, 1–14.

Mitra, A. K., Payton, M., Kabir, N., Whitehead, A., Ragland, K. N., & Brown, A. (2020). Potential years of life lost due to covid-19 in the united states, italy, and germany: an old formula with newer ideas. *International journal of environmental research and public health*, *17*(12), 4392.

OECD. (2009). Premature mortality. *Health at a Glance 2009: OECD Indicators*.

Oeppen, J., & Vaupel, J. W. (2002). Broken limits to life expectancy. *Science*, *296*(5570), 1029–1031.

Pifarré i Arolas, H., Acosta, E., López-Casasnovas, G., Lo, A., Nicodemo, C., Riffe, T., & Myrskylä, M. (2021). Years of life lost to covid-19 in 81 countries. *Scientific reports*, *11*(1), 3504.

Rabbi, A. M. F., & Mazzuco, S. (2017). Mortality decline in bangladesh: Age-sex specific differences. In *Giornate di studio sulla popolazione 2017*.

Raoult, D., Zumla, A., Locatelli, F., Ippolito, G., & Kroemer, G. (2020). Coronavirus infections: Epidemiological, clinical and immunological features and hypotheses. *Cell stress*, *4*(4), 66.

Romeder, J.-M., & McWhinnie, J. R. (1977). Potential years of life lost between ages 1 and 70: an indicator of premature mortality for health planning. *International journal of epidemiology*, *6*(2), 143–151.

Schöley, J., Aburto, J. M., Kashnitsky, I., Kniffka, M. S., Zhang, L., Jaadla, H., … Kashyap, R. (2022). Life expectancy changes since covid-19. *Nature human behaviour*, *6*(12), 1649–1659.

Ugarte, M. P., Achilleos, S., Quattrocchi, A., Gabel, J., Kolokotroni, O., Constantinou, C., … others (2022). Premature mortality attributable to covid-19: potential years of life lost in 17 countries around the world, january–august 2020. *BMC Public Health*, *22*, 1–13.

United Nations. (2022). *World population prospects 2022 – population division – united nations.* Population Division – United Nations.

Van Raalte, A. A., & Caswell, H. (2013). Perturbation analysis of indices of lifespan variability. *Demography*, *50*(5), 1615–1640.

Vaupel, J. W., & Romo, V. C. (2003). Decomposing change in life expectancy: A bouquet of formulas in honor of nathan keyfitz's 90th birthday. *Demography*, *40*, 201–216.

Velavan, T. P., & Meyer, C. G. (2021). Covid-19: a pcr-defined pandemic. *International Journal of Infectious Diseases*, *103*, 278–279.

Verma, V., Nath, D. C., & Khan, H. T. (2023). Evaluation of concordance in estimation of excess mortality due to covid-19 pandemic. *Journal of Evaluation in Clinical Practice*.

World Health Organization and others. (2022). World health organization coronavirus (covid-19) dashboard. *World Health Organization, Geneva, Switzerland. https://covid19. who. int*.

Zhang, Z., & Vaupel, J. W. (2009). The age separating early deaths from late deaths. *Demographic Research*, *20*, 721–730.

Zhou, F., Yu, T., Du, R., Fan, G., Liu, Y., Liu, Z., … others (2020). Clinical course and risk factors for mortality of adult inpatients with covid-19 in wuhan, china: a retrospective cohort study. *The lancet*, *395*(10229), 1054–1062.

Appendix

Trend of mortality rates in Bangladesh

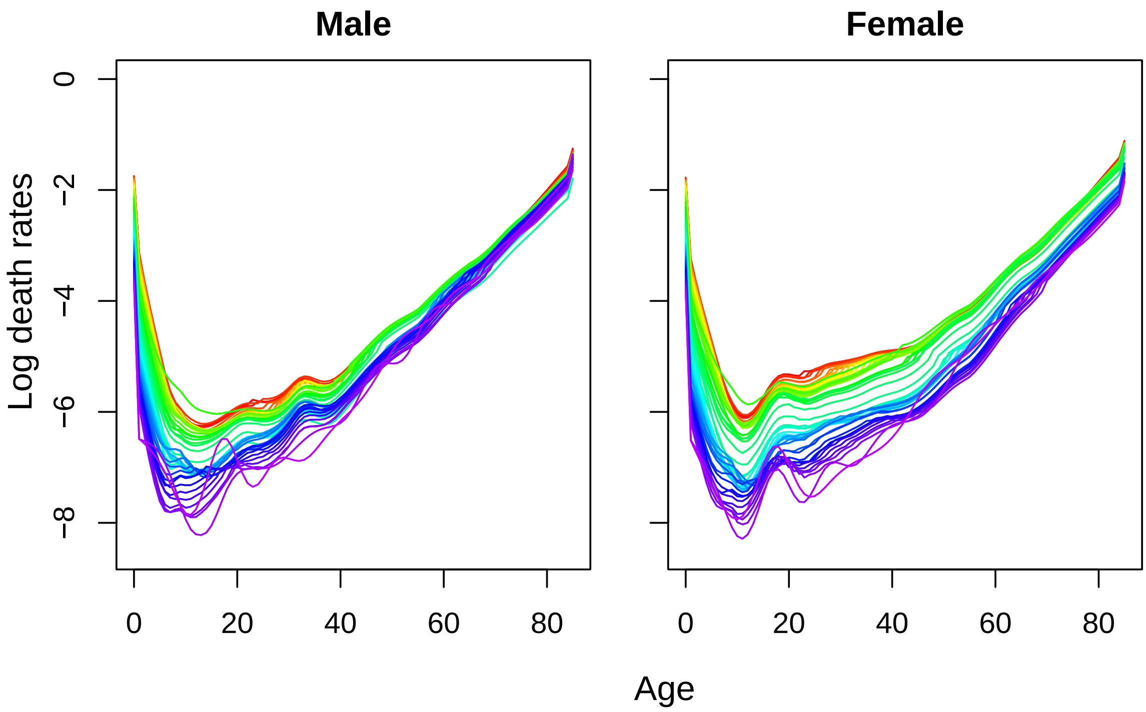

Figure 5: Trend of mortality rates in Bangladesh for both sexes (1972:2021). The years are plotted using a rainbow color scheme, where the earlier years are shown in red, followed by orange, yellow, green, blue and indigo and the most recent years are marked in violet. The last two years showed clear deviation from the ongoing mortality transition for both sexes (violet lines).

Trend of PEYLL in Bangladesh

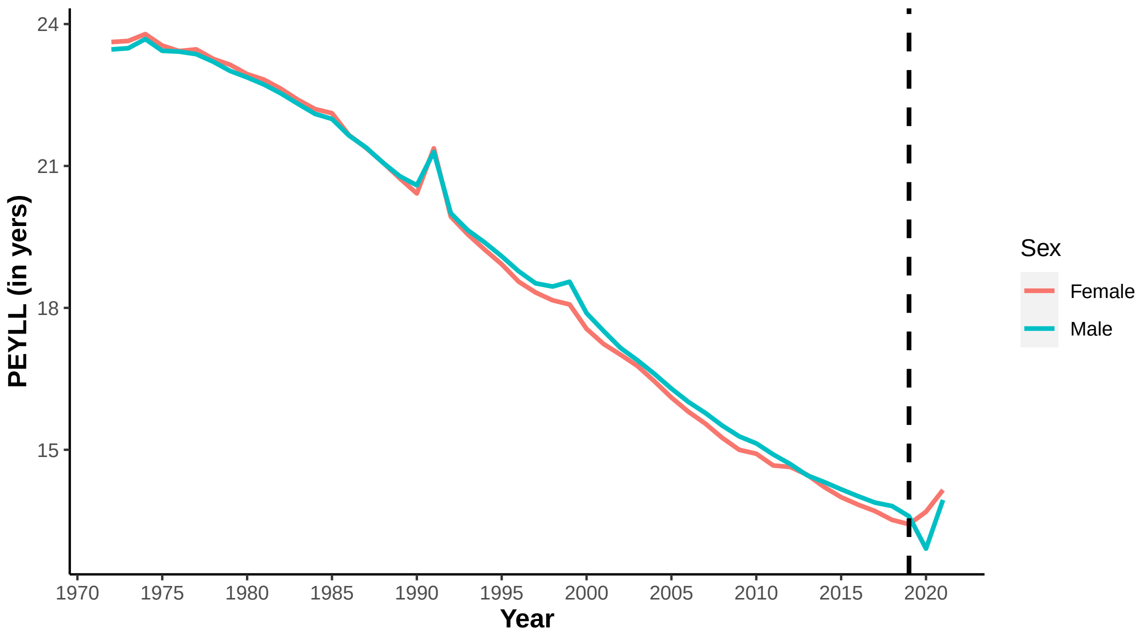

Figure 6: Trend of potential expected years of life lost (PEYLL) in Bangladesh for both sexes (1972:2021).

Illustration of the estimation procedure of different threshold ages for Bangladesh

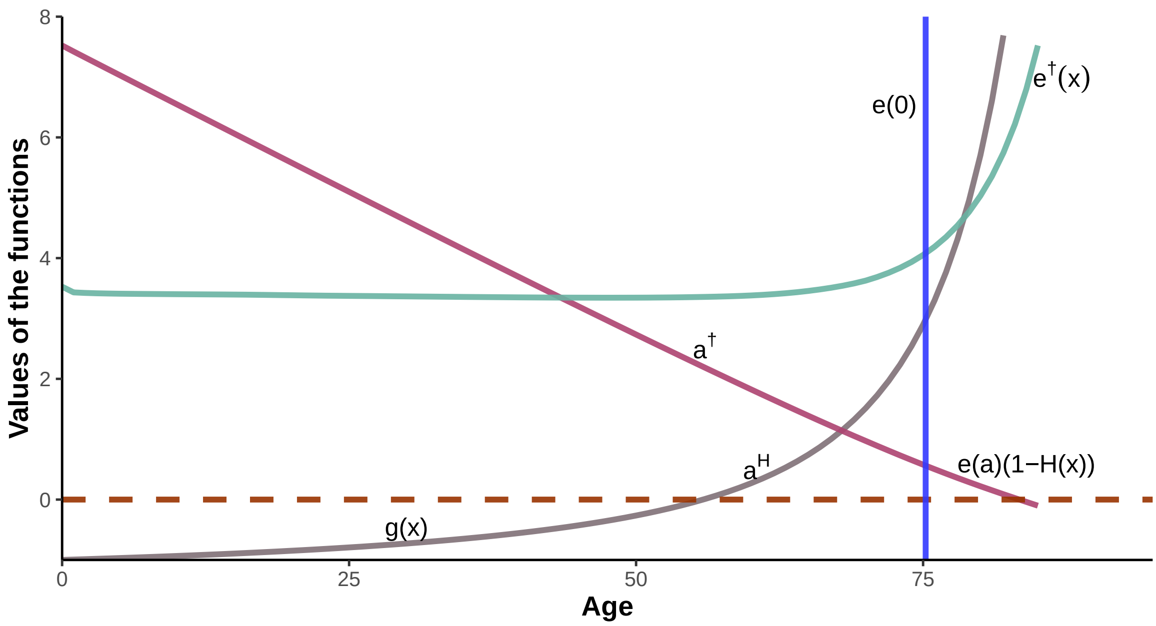

Figure 7: Estimation procedure of different threshold ages for Bangladeshi females in the year 2019 as an example.

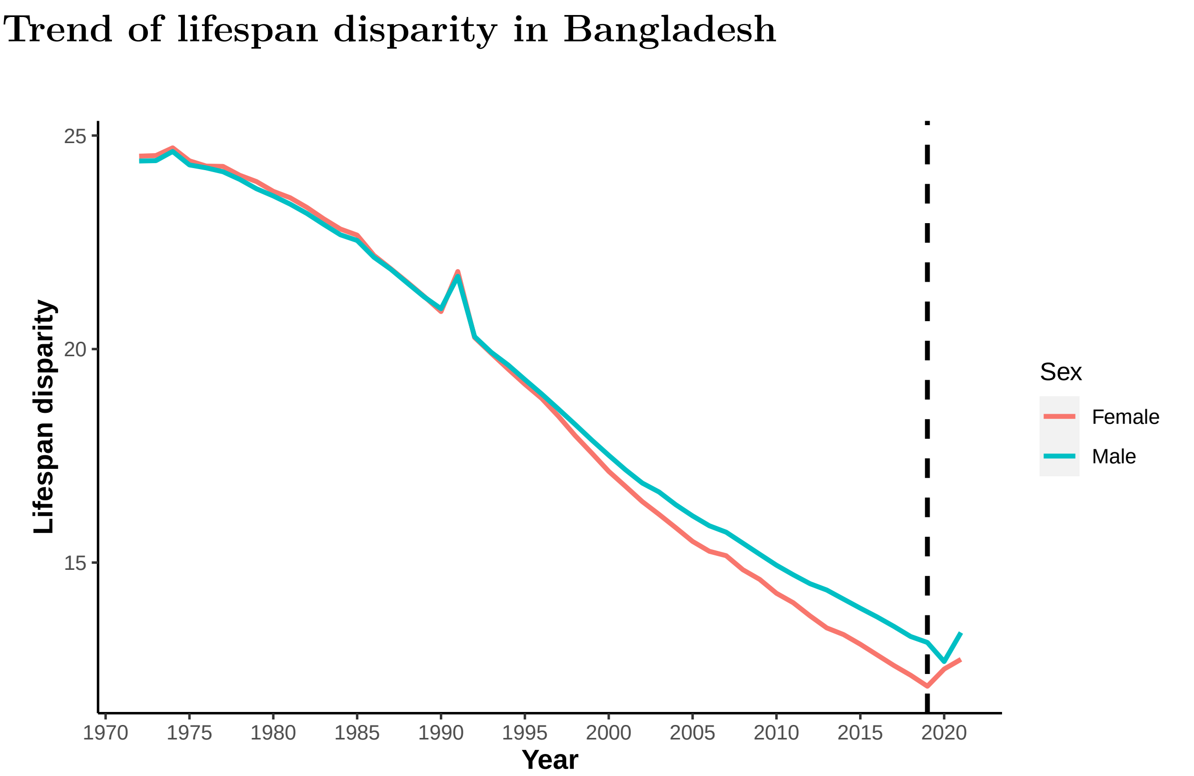

Figure 8: Trend of lifespan disparity in Bangladesh for both sexes (1972:2021).

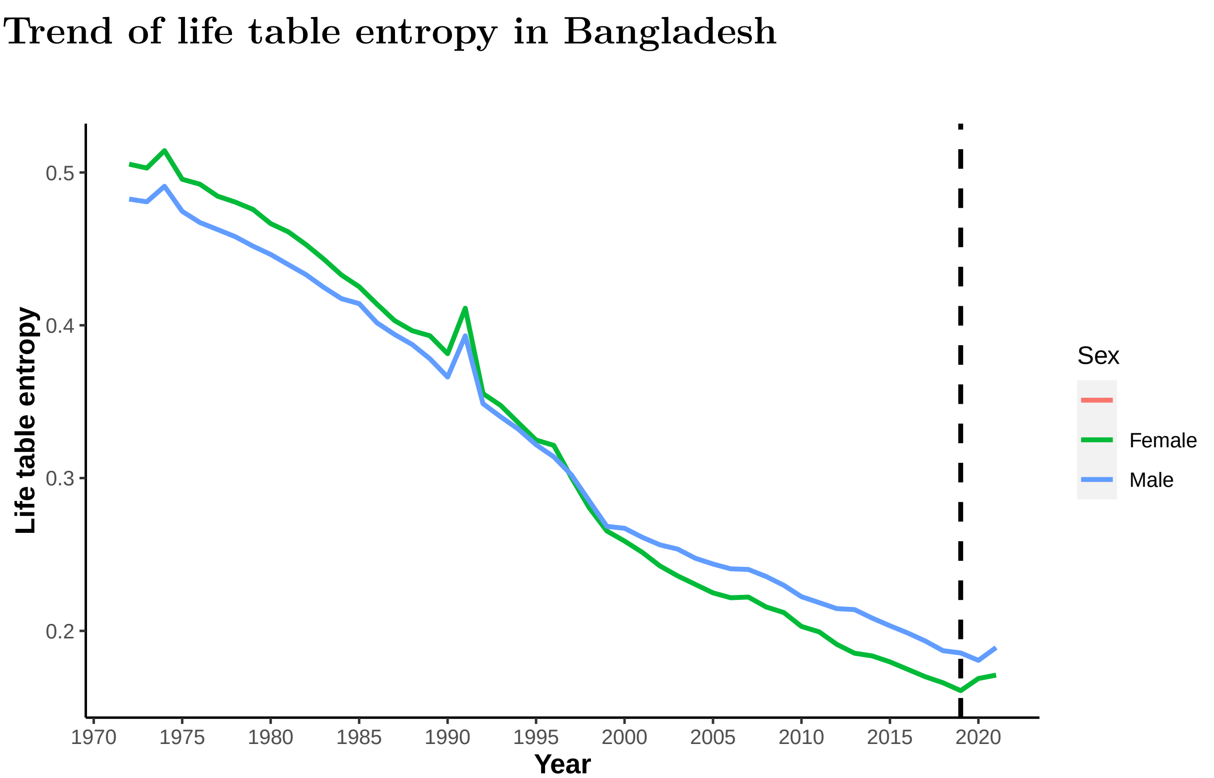

Figure 9: Trend of life table entropy in Bangladesh for both sexes (1972:2021).