Mortality transition in Bangladesh

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Abstract

Transition in life expectancy is well understood in terms of the underlying changes in age-specific mortality; fall in mortality level at any age or age groups of life span increases life expectancy. Bangladesh has shown remarkable rise in life expectancy since the last few decades. This paper incorporates the change in age and sex specific mortality patterns over time for Bangladesh to determine the dominating factors behind this ongoing mortality transition. The analysis of different dimensions of mortality and measures of longevity indicates that mortality is continuously declining in Bangladesh since the 1970s. This mortality decline is strongest among infants, children and young women but is visible across the whole age spectrum for both sexes which indicates the presence of mortality selection in Bangladesh. Analysis of modal age at death justified the shifting mortality hypothesis for Bangladesh, which indicates imminent aging in near future.

Keywords: Bangladesh, Mortality transition, Modal age at death, Age-sex specific mortality.

Introduction

Bangladesh, a developing country of South Asia, is passing demographic transition with sharp decline in fertility followed by decline in mortality. The decline in mortality level is subject to analyze because as a result of public health policies mortality level declined in the whole life span (Blue and Espenshade, 2011). Along with remarkable decline in early aged mortality, senescence mortality also declined in the last decade. This transition is consequently followed by sharp rise in life expectancies; life expectancy at birth increased from 46 years at 1974 to around 70 years in the end of 2013 (Matlab HDSS, 2013). The trend of mortality in different age groups and life expectancy at birth for Bangladesh is presented in the following figures (Figure 1&2). Instead of single year, several time periods is considered to show the trend in mortality using smoothed logarithmic central death rates (Figure-1). Two unique characteristics of this transition are visible in these trend lines; rapid fall in infant and child mortality over the time (for both sexes) and rapid decline in adult female mortality (especially around age 20 years). Bangladesh showed notable success in millennium development goals in term of reducing infant mortality and maternal mortality, which is also reflected in these trends (Blue and Espenshade, 2011). This change in mortality pattern is not identical for all age groups. Sex differential is present in this mortality transition; pace of decline in male adult mortality is slower than that of females. Another important feature of this transition is the slow decline in senescence mortality, the pace of decline is almost same for both sexes. Still, the decline in early-aged mortality remained as main determinant for rise in life expectancy. The trend of life expectancy at birth is presented in Figure-2.

Figure 1: Mortality trend of Bangladesh (Matlab HDSS-1975-2009).

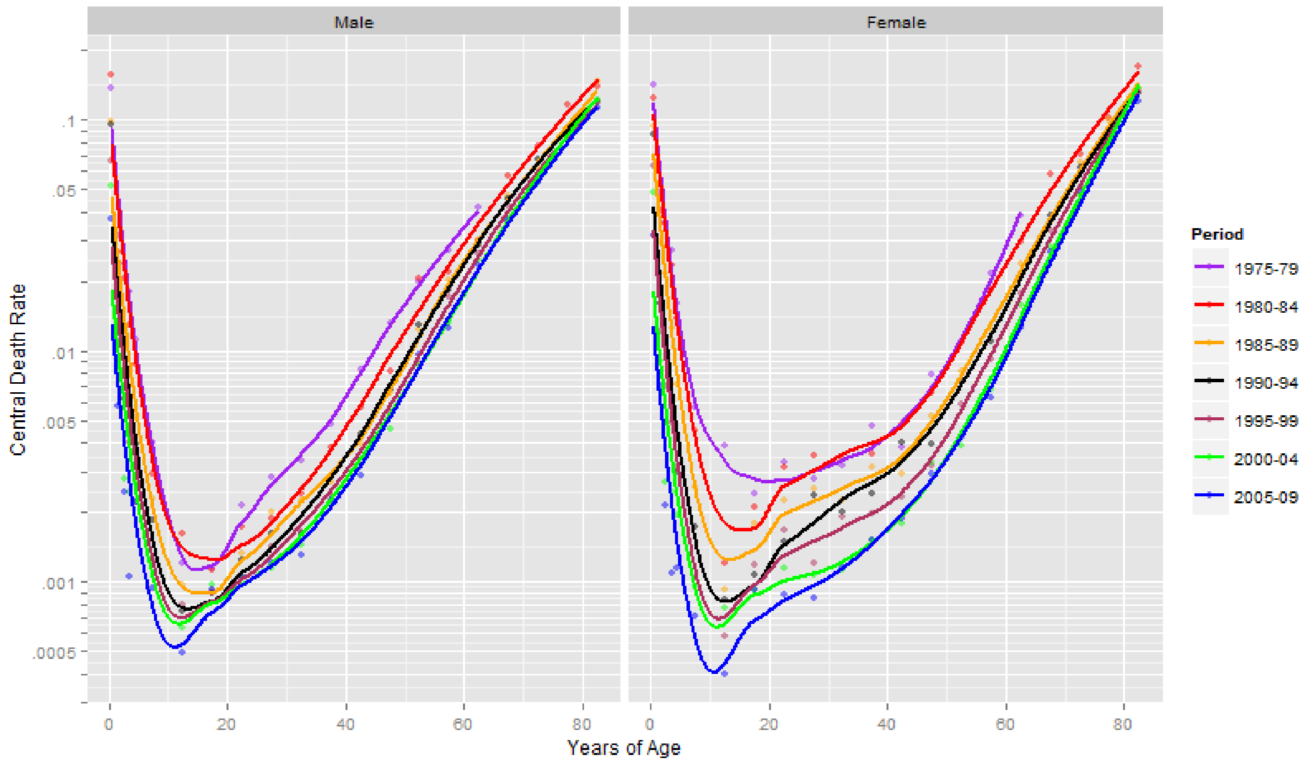
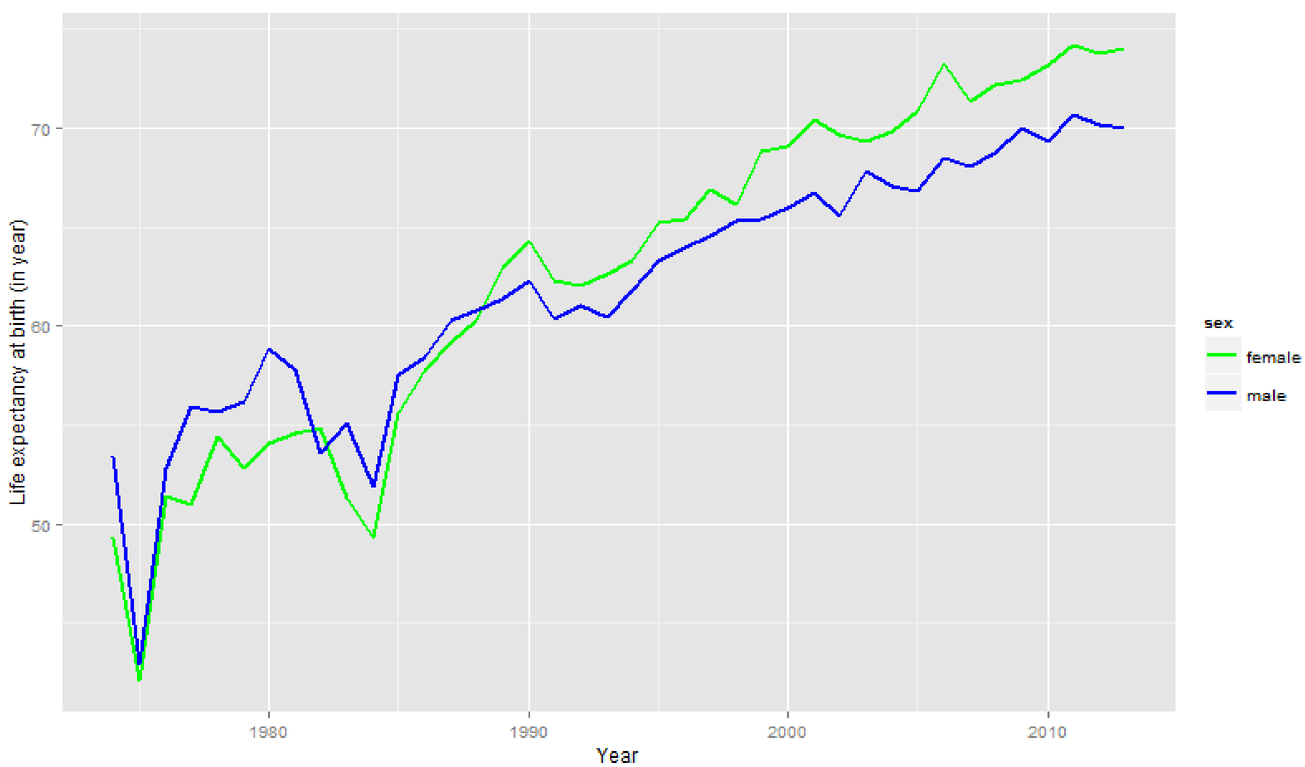


Figure 2: Trend of life expectancy at birth for Bangladesh (Matlab HDSS-1974-2013).



Like all other developed countries (which already passed demographic transition), the life expectancy for female is higher in Bangladesh now; although it was lower than male till let 1980s. Sharp rise in the life expectancy implies upcoming aging for Bangladesh; although due to high fertility till 2000 the effect in change of population structure will not create notable problem in labor market (Blue and Espenshade, 2011).

Form the observation of change in age-specific mortality and life expectancies over time it is clear that this mortality transition in Bangladesh may be attributable to several sources, like epidemiological transition or natural selection in mortality **(**; Kannisto, 2001; Keyfitz, 1991**).** Like many other countries that had passed demographic transition, the pattern of mortality decline is not symmetrical for Bangladesh. This asymmetric nature of mortality pattern over age groups may cause heterogeneity in mortality distribution, which is subject to analyze for Bangladesh. These sorts of dissimilarities have been observed for most of the under developed and developing countries; industrialized countries also faced this circumstances before a certain era (Economos, 1982). Empirically, analysis of human mortality pattern always indicate almost stable mortality pattern in adult age (till a threshold age); and hence a sharp rise in mortality level in old age. This mortality pattern can be well explained by Gompertz mortality law, which is appropriate for most of the observed human population (Gompertz, 1825). With increase in age, mortality risk increases exponentially for human and most of the species. The empirical evidence for the law of mortality suggests a connection between its slope parameter and the underlying biological aging processes (Keyfitz, 1991; Economos, 1982). The slope of the increase of adult mortality rates is generally known as the demographic rate of aging. This rate is not same for every population due to difference in demographic transition and epidemiologic transition **(**Kannisto, 2001; Keyfitz, 1991**)**. However, this rate is usually higher for females than for males in the same population (Jacobsen et al, 2013; Bongaarts, 2005). Since this estimation depends on whole life span, clearly this different pattern of mortality in different age groups may be a consequence of heterogeneity in mortality distribution. Although Gompertz mortality law gives good fit for adult mortality, still it does fit well for different causes of death, like accidental death, maternal deaths, or infant mortality **(**Pollard, 1991**)**. Different parameters were suggested in different approaches to discuss the whole life span, which also estimates the variation in mortality level also in particular age group; namely Gompertz-Makeham model or Gamma-Gompertz model and so on (Bongaarts, 2005; Pollard and Valkovics, 1992; Heligman and Pollard, 1980).

However, all of these studies analyzed the pattern of longevity for developed and industrial countries only; less concern is given for developing countries where much asymmetry may be observed in mortality distribution. Still researches needed to analyze life expectancies at older ages with analysis of trend and pattern of longevity for Bangladesh and many other developing countries (Blue and Espenshade, 2011). Moreover, other indicators of longevity (for example, modal age at death) are remained to estimate for Bangladesh. The modal age at death is commonly used for analyzing shift in mortality scenario experienced by low mortality countries and is a nice indicator of aging as mortality is concentrated at older ages in most of these countries (Canudas-Romo, 2008). Thus, studying the modal age at death provides an opportunity to have a different perspective of the changes in the distribution of deaths and to explain the change in mortality at older ages (Canudas-Romo, 2008; Pollard and Valkovics, 1992). Analysis of modal age at death for a developing country will provide more insight in presence of irregular, asymmetric pace of decline in age-specific mortality pattern (Vallin and Meslé, 2001).

This paper aims to analyze the change in age and sex specific mortality patterns over time for Bangladesh. Furthermore, as a lifespan indicator in the Era of longevity extension (aging), modal age of death will be estimated for Bangladesh and transition of modal age at death will be illustrated. Considering these findings in conjunction with other available measures of longevity will allow Demographers to gain further insight into the progress of mortality reductions at specific ages over time.

Materials and methods

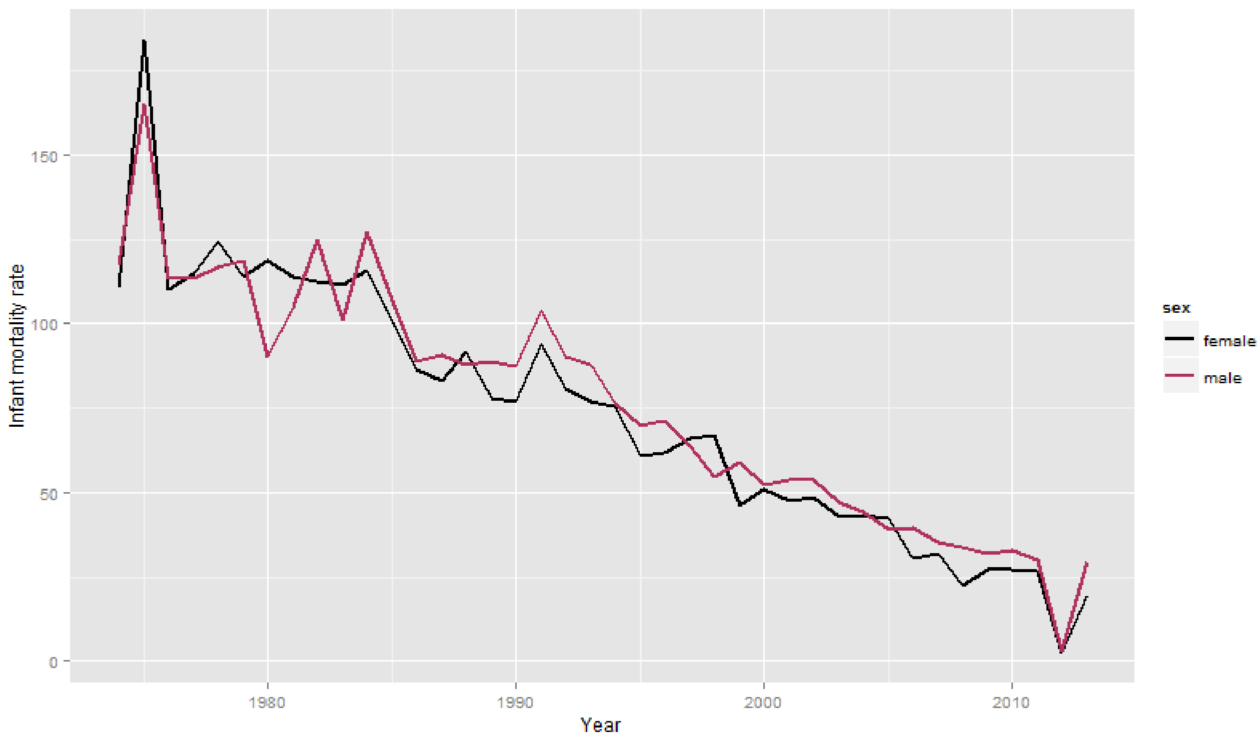
Bangladesh has not started complete vital registration yet. The vital registration and maternal and child health data gathered from Matlab Health and Demographic Surveillance System (HDSS), Bangladesh is utilized for current study (Matlab HDSS, 2013) as proxy. Matlab HDSS is recognized worldwide as one of the long-term demographic surveillance sites for a developing country. Since 1966, the Health and Demographic Surveillance System (HDSS) has maintained the registration of births, deaths, and migrations, in addition to carrying out periodical censuses in Matlab. Details of about the HDSS may be found elsewhere (Matlab HDSS, 2013). Bangladesh became independent in 1971, so the life tables of 1974 to 2013 are considered for current study. These life tables are also available in the Human Life-Table database. The illustration is done all over the paper considering life tables separately for male and female. It should be noted that, these life tables are period life tables, cohort life tables may produce different results than this. For estimating modal age at death, Gompertz (1825) mortality curve is fitted and modal age at death is obtained by maximization of the distribution function of deaths (see appendix for details).

Results and Discussion

The shift in age-specific mortality pattern for Bangladesh is already discussed in the first section. In this section, characteristics of this transition will be analyzed from some key point of view. In the past century, the rise of life expectancy due to mortality declines at almost all ages is one of the most remarkable achievements in the world. From a theoretical point of view, rising life expectancy means improved survival which is the result of decline in mortality level of a population in different and particular age groups (Vallin and Meslé, 2001; Horiuchi and

Wilmoth, 1998). Sharp fall in infant and child mortality causes the rapid increases in life expectancy for most of the historical populations, the other ages also have the impact but infant and child mortality always have the highest impact. For empirical populations, the mortality transitions begin with the fall in infant and child mortality levels (Vallin and Meslé, 2001). From figure-1, the fast decline in infant and child mortality is also observed for Matlab HDSS. It is already mentioned before that the pace of decline in infant mortality is higher compare to other age groups. The following figure presents the infant mortality rate for both sexes in Matlab HDSS (Figure-3).

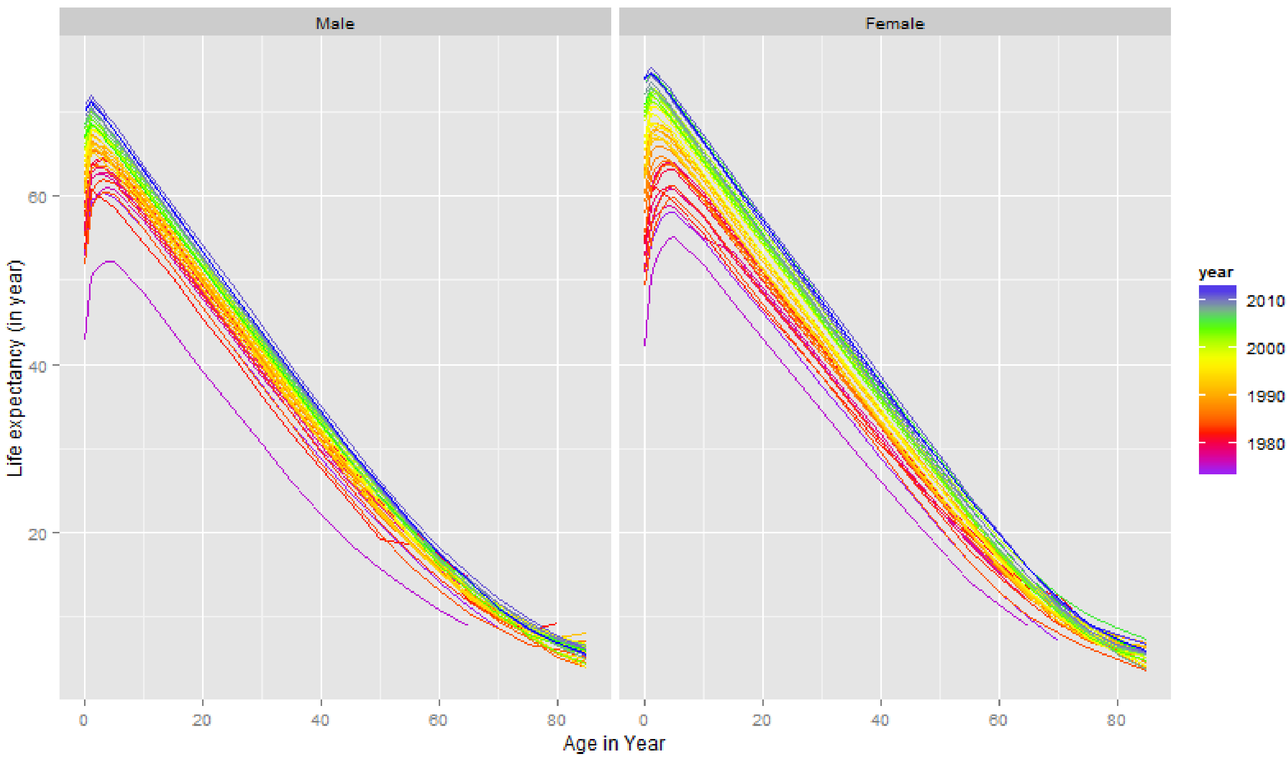
Figure 3: Trend of infant mortality rates for Bangladesh (Matlab HDSS-1974-2013).



Sex differential is present in case of infant mortality; infant mortality is lower in case of female since late 1990s. Infant mortality rate (IMR) was 29.5 per 1,000 live births for males and 19.6 for females at 2013 while it was 165 and 184 respectively for male and female in 1975. Since beginning of the observation period, the IMR decline sharply except one notable pick at 1975. It should be noted that, in the earlier period infant and child mortality was higher in Bangladesh; there are two picks in mortality and life expectancy pattern which were observed in 1975 and 1984 (see Figure 2&5). The reason for high infant and child mortality is the result of shortage of foods as a consequence of flood in 1974 (Matlab HDSS, 1975). Epidemic of diarrhea (or dysentery) in 1984 is responsible for this unusual mortality rise in all age groups which didn't affect specifically on earlier age groups (Matlab HDSS, 1984). These two rises in mortality levels affect the life expectancy as well. Nevertheless, these massive reductions of infant and child mortality have resulted in a remarkable improvement in life expectancy at birth over the last 40 years (Matlab HDSS, 2013).

To visualize the impact of other sources of mortality, the life expectancies over complete life span for the Matlab HDSS are presented below for both sexes (Figure-4). Except 1975, the life expectancies at different ages showed transition significantly. The reason behind lower life expectancy is due to high mortality in 1975 in all age groups due to food shortage due to flood in preceding year. Mortality selection is visible as the deaths occurred higher in male population compare to females; female life expectancies deviated less than the usual pattern.

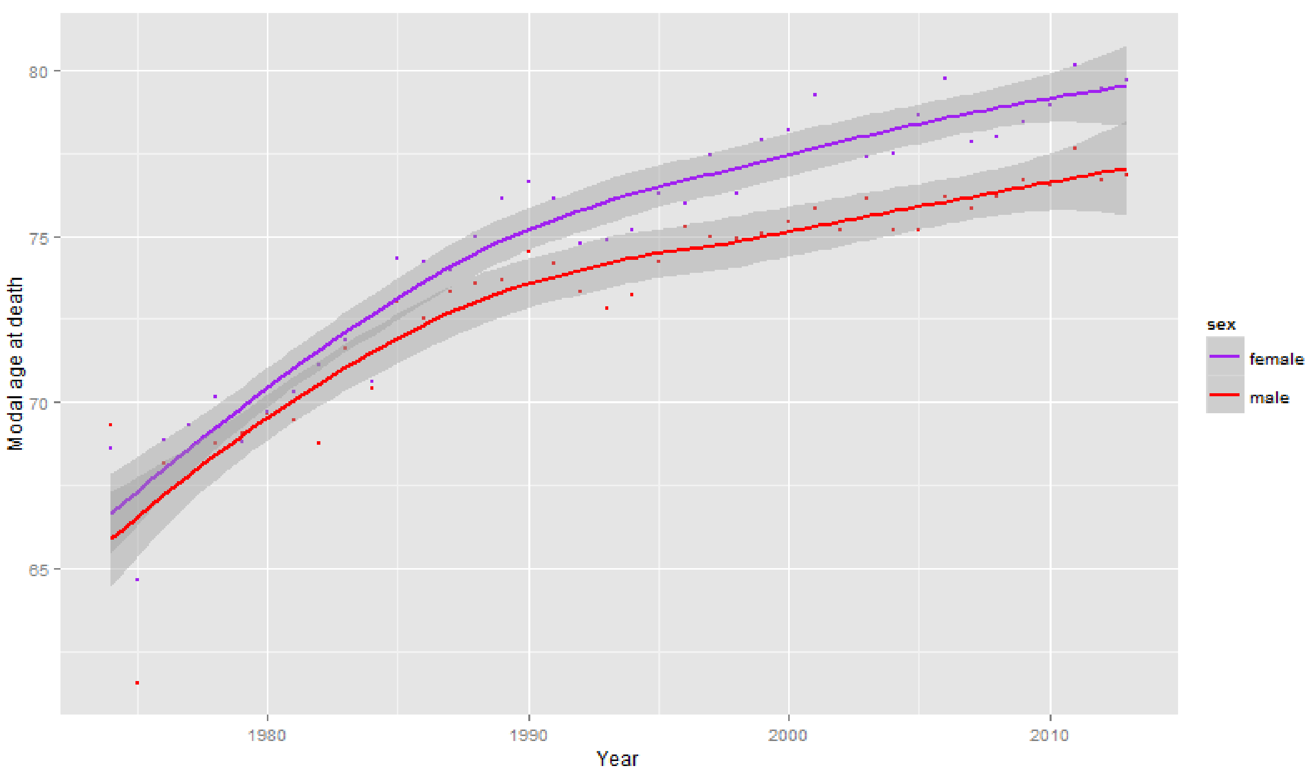
Figure 4: Trend of life expectancies of Bangladesh (Matlab HDSS 1974-2013).



This is one of the unique characteristic for any population which is in transition; life expectancy at birth is lower than other ages. In earlier period, highest life expectancy is observed even at age 15. Due to reduction in infant and child mortality, highest life expectancy is now observed at age 1; moreover, the gap between life expectancy at birth and age 1 is getting closer every year. For female, the difference is 0.5 year at 2013. Notable increase in observed in all age groups in the observation period, remaining life expectancy in the last age group also increased simultaneously. Thus, even in presence of early aged mortality, maximum attainable longevity increased sharply over time. Sex differential is present in this case also as well; maximum attainable life expectancy is higher in case of female in recent time than that of male. Except the rise at age 1 or higher ages (earlier period), the trend of life expectancy is usual for Matlab HDSS, decreasing linear function over ages. For all of the age groups, the transition of life expectancies indicate mortality selection, female life expectancies are higher than male since the last two decades. This setting is common for almost all of the developed countries which have passed mortality transition. It's already discussed in previous section about faster decline in female mortality in all age groups than that of male. Hoverer, due to lack of cause-specific life tables, it's hard to state anything about healthy life expectancy for Matlab HDSS. Most of the developed countries faced the health-survival paradox, i.e., female live longer but they suffer most (Jacobsen et al, 2013). Lack of cause-specific life tables for Bangladesh unable to illustrate the impact of other sources of mortality on lifespan trajectories. This is important because most of the sources of adult mortality is due to accidental mortality or maternal mortality. Analysis of cause specific life tables will be also better for explaining the pattern of senescence mortality.

As high mortality level in particular age groups has greater impact on life expectancy at birth, in a regime with a high level of infant mortality, life expectancy will be within the age range of premature deaths, even when most deaths occur around ages zero and the modal age at death (Kannisto, 2001). This shifting mortality hypothesis is getting popular since the last decade as shift in the mortality concentration to the right indicates shift in longevity whereas the pace of increase in life expectancy is slower now than past century (Pollard, 1991). The modal age at death for Matlab HDSS is presented in the following figure (Figure-5).

Figure 5: Trend of modal age at death of Bangladesh (Matlab HDSS 1974-2013).



Trend of modal age at death showed significant improvement of mortality scenario in Bangladesh. Modal age at death increased from around 69 years in 1974 (for both sexes) to 77 year and 79 year respectively for male and female of Matlab HDSS. It should be noted that modal age at death is always higher than life expectancy at birth and increase (shift to the right) in the late modal age at death over the twentieth century has been observed in several countries (Canudas-Romo, 2008; Kannisto, 2001; Vallin and Meslé, 2001; Pollard and Valkovics, 1992; Pollard, 1991). The values of slope parameter of fitted model indicate that aging is approaching in Bangladesh (see appendix for details). Also from the findings of current analysis, the modal age at death is strongly dependent on the observed force of mortality and its rate of change over age prevailing at older ages. Moreover, changes in infant mortality affects less in pattern of modal age at death (Canudas-Romo, 2008), although an effect in the modal number of deaths is may be observed in the findings.

Previous studies revealed that the increasing modal age at death illustrates changes from a dominance of child mortality reductions to a dominance of adult mortality reductions. This process has been expressed as shifting mortality process where the deaths of a population clusters around the modal age at death move toward the older ages; which is the ultimate aging scenario (Canudas-Romo, 2008; Horiuchi and Wilmoth, 1998; Pollard, 1991). This hypothesis is true for Bangladesh, remarkable decline in observed in adult mortality followed by the decline in infant mortality (see Figure-1). Previous approaches on shifting mortality models (Bongaarts and Feeney, 2002) showed many implications for the survival function and the distribution of deaths. Further advanced implications for this type of shift in mortality were suggested; for instance, the need to find alternative summary measures of mortality that takes this shift into account (Bongaarts and Feeney, 2002). This is also a case for Bangladesh; here the pace of mortality shift is faster than many other historical populations (Blue and Espenshade, 2011). Clearly application of others mortality models will describe the mortality scenario more elaborately, especially for adult and senescence mortality. For the recent years, Siler model gives better fit for adult and senescence mortality for Bangladesh (see appendix for details).

Conclusion

The aim of this article is to study the mortality transition in Bangladesh by assessing change in age specific mortality patterns change over time along with analysis of possible selection (mainly sex differences) and dominating factor behind this transition. The analysis over different measures of mortality and longevity indicates that mortality is continuously declining in Matlab since the 1970s. This mortality decline is strongest among infants, children and young women but is visible across the whole age spectrum for both sexes. Like many other existing and historical populations, female survival is higher in Bangladesh (Matlab HDSS), in terms of mortality and life expectancies as well. However, contribution of decline in senescence mortality seemed to have least impact on this sharp rise in life expectancy (at birth).

There are some scopes of further studies in this topic. Cause-specific life table will allow further insight of this mortality transition, which was not possible in current study due to lack of data. The data used in this paper came from vital registration system of a surveillance site (of INDEPTH network) which ensures highest quality ensuring protocols (Matlab HDSS, 2013). Nevertheless, instead of regional data with comparatively better mortality and morbidity scenario, national data from vital registration system will be more effective for policy making purposes. The mortality model used for analyzing modal age at death (Gompertz mortality law) work well without negligible infant and child mortality; which is not the case for Bangladesh. Application of mortality models by taking into account the other key sources of mortality (accidental, maternal, senescence and so on) will provide more insight for the policy makers. For the recent years, Siler model gives better fit for the mortality scenario of Bangladesh as infant and child mortality declined notably. The fit for adult and senescence mortality is better in Siler model than that of Gompertz model in recent years (see appendix for details). However, most of the mortality and life expectancy models were proposed for industrialized countries which may cause some difficulties for those analyses for Bangladesh which still has high mortality regime. Impact of reduced maternal mortality on life expectancy is also subject to analyze.

The findings of the paper have importance for policy makers as well with existing information regarding mortality. Huge literature exists on importance of reducing infant mortality and adult mortality on longevity (for instance, Kannisto, 2001; Vallin and Meslé, 2001). Existing public health policies may be needed to be upgraded from the experience of other aging population to be prepared for the consequences of aging. Further information regarding accidental mortality and old age mortality is required for policy implication to increase longevity in Bangladesh.

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Appendix

A1. Modal age at death

Let, the life table survival function *l(x)* and death density function $d(x) = -\mathrm{d}lx/\mathrm{d}x$*;* such that *d(x)* ≥ 0 for any age *x* in [0, *v*] and *d(x)* = 0 for any *x* > *v*. Suppose, *d(x)* is differentiable on the open interval (0, *v*). If *d(x)* has a local maximum or minimum at age *y*, then *μ(y) = k(y);* where *μ(x) = d(x)/l(x)* and *k(x)* = d*ln μ(x)/*dx. This may be obtained by differentiating *d(x) = l(x)μ(x)* with respect to *x*, setting *x = y*, and putting the derivative of *d(x)* at *y* as zero. Thus, the force of mortality, *μ(x)* and the life table aging rate, *k(x)*, are identical at *M*, i.e., *μ(x) = k(M).*

This equation indicates that as far as adult mortality increases with age monotonically, smoothly and gradually, the distribution of death is unimodal at adult ages. In this context, d *μ(x)/*dx *≥0* for any adult age *x*.

For Gomeprtz Mortality law:

Nature of modal age at death *M* in the Gompertz model was investigated in previous studies (Pollard 1991; Pollard and Valkovics 1992). For Gompertz model we have,

$$d(x) = l(x)\,\mu(x)$$

Where the force of mortality *μ(x)* satisfies,

$$\mu(x) = e^{A+Bx}$$

And the survival function satisfied,

$$l(x) = e^{-\int_o^x \mu(y)dy}$$

Then we have, $d'(x) = \mu'(x)l(x) + \mu(x)l'(x)$

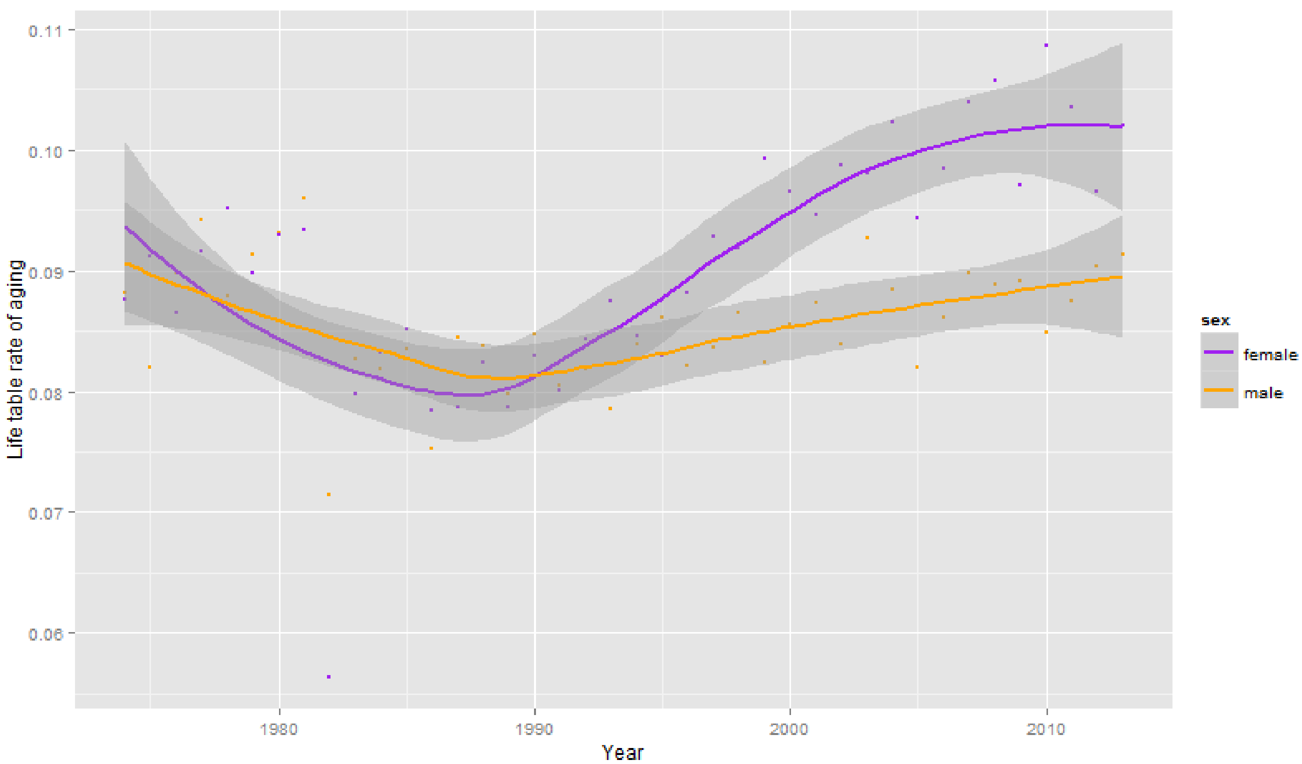
So that, $d'(M) = 0 \Leftrightarrow [B - \mu(M)] = 0 \Leftrightarrow M = \frac{ln(B)-A}{B}$

A2. Life Table rate of aging for Bangladesh

For Gompertz mortality law, the life table rate of aging is $k(x) = B$.

For the data of Matlab HDSS, the model gives best fit for $x \geq 20$.

Figure A 2. Life table rate of aging for Bangladesh (Matlab HDSS 1974-2013).



A3. Application of Siler model for shifting mortality hypothesis

In presence of early aged mortality, Siler model gives better fit for mortality scenario. For Matlab HDSS-2013, Siler model gives better explanation for infant and senescence mortality. However, reason for earlier (later) shift in male (female) adult mortality may be caused from accidental mortality which is subject to analyze with cause-specific mortality data.

Figure A 3.1. Fitted Siler model for male of Matlab HDSS-2013.

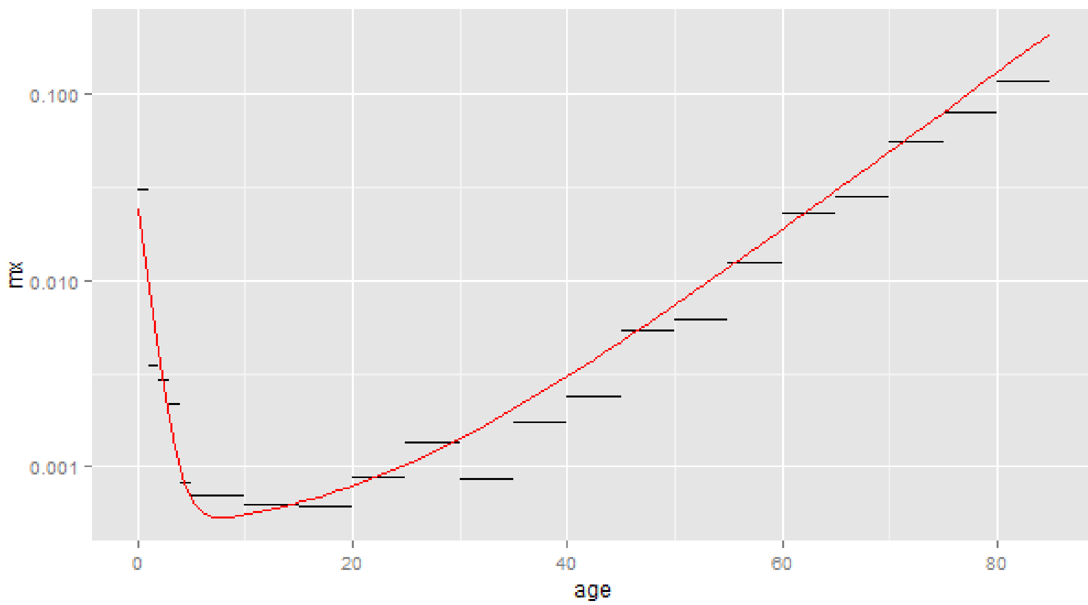


Figure A 3.2. Fitted Siler model for female of Matlab HDSS-2013.