

RESEARCH ARTICLE

Life expectancy at birth and life disparity: an assessment of sex differentials in mortality in India

Akansha Singh* and Laishram Ladusingh

International Institute for Population Sciences, Govandi Station Road, Deonar, Opposite Sanjona Chamber, Mumbai, Maharashtra 400088, India

Abstract: This study aims to examine the sex differentials in life expectancy at birth and life disparity, and to estimate the age-specific contribution of the differences for India and its major states. Life disparity measures the variation in the distribution of deaths, and life expectancy at birth measures the average length of life. Complete life tables generated from death rates and abridged life tables of the Sample Registration System in India from 1970–1975 to 2006–2010 were used to fulfill the research goals. Stepwise replacement algorithm was used for the decomposition of sex differences in life expectancy at birth and in life disparity. The results indicate that the increase in life expectancy at birth and decline in life disparity was higher for females. The sex differential was more prominent in urban areas than in rural areas. A majority of the states in India experienced changes in the direction and magnitude of sex differentials in life expectancy at birth and life disparity from 1970–1975 to 2006–2010. The sex differentials in life expectancy at birth and life disparity in 1970–1975 were primarily attributed to child mortality, whereas the sex differentials in recent decades were attributed to adult mortality.

Keywords: adult mortality, child mortality, decomposition, India, life expectancy at birth, life disparity, life table, sex differential

*Correspondence to: Akansha Singh, International Institute for Population Sciences, Govandi Station Road, Deonar, Opposite Sanjona Chamber, Mumbai, Maharashtra 400088, India; Email: akanshasinghiips@gmail.com

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1. Introduction

1.1 Rationale

Life expectancy at birth is not only a summary measure of mortality, but also an accepted indicator for the development of a country (UN/DESA, UNICEF, and WHO, 2016). The sex differential in life expectancy at birth has been the focus of research in both developed and developing countries. Mortality gains in men and women have not been uniform (Edwards and Tuljapurkar, 2005), with males having higher death rates at all ages in developed nations like Denmark, Japan, and the United States (Oksuzyan, Crimmins, Saito *et al.*, 2010), and in most developing countries (United Nations, Department of Economic and Social Affairs, and Population Division, 2015). In recent decades, the male–female gap in life expectancy at birth in some developed nations, like the United States, rapidly widened and then stabilized (Edwards and Tuljapurkar, 2005).

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Mortality research in several developed nations has not been restricted to differentials in life expectancy. The differentials in the distributions of deaths at different ages and dispersion measures of mortality have also been analyzed in recent studies. Various dispersion measures have been proposed and examined along with the life expectancy to show the sex, socio-economic, and educational differences (Edwards and Tuljapurkar, 2005; Shkolnikov, Andreev, Zhang *et al.*, 2011). As with the declining mortality and improvement in life expectancy, deaths are postponed and concentrated at advanced ages. Studies indicate that there is a substantial negative correlation in life expectancy and dispersion measures across time in most countries (Shkolnikov, Andreev, Zhang *et al.*, 2011; Singh and Ladusingh, 2013). The correlation is strong, but there are inconsistencies. Some countries, notably the United States, have a greater lifespan disparity than expected, even after achieving higher levels of life expectancy (Edwards and Tuljapurkar, 2005). At a similar level of remaining life expectancy, some population subgroups are experiencing lower levels of lifespan variation than others.

The sex differentials in dispersion measures of mortality have been observed in several countries. Most studies suggested that the female advantage is vigilant in the mean length of life and also observed in dispersion measures of age at death. The dispersion measure, standard deviation of age at death for ages 10 or older (S_{10}) among females is lower than that among males, which indicates a smaller uncertainty in female's life span (Edwards and Tuljapurkar, 2005). Female populations in developed countries, like France and the United States, have a higher mean and modal age at death, the age where most of the deaths are occurring (Kannisto, 2001). The measure of life disparity (e^{\dagger}) is also a dispersion measure based on the distribution of deaths at different ages and is defined as the average life years lost due to death. Females often have a lower life disparity than males in developed countries (Shkolnikov, Andreev, Zhang *et al.*, 2011).

However, until now, studies focused on the difference in lifespan variation have been limited to cross-sectional analyses (Vaupel, Zhang, and van Raalte, 2011) or changes over time (Shkolnikov, Andreev, and Begun, 2003), as evident from the studies in the developed countries. These studies provide evidence that females from the developed countries usually have a higher life expectancy and a lower level of death dispersion than males, with some exceptions. No such studies are from developing countries, including India, either to support or negate the phenomenon of death dispersion found in the developed countries. The mortality differentials by sex, in India, are mostly analyzed for life expectancy at birth. Furthermore, the sex differentials in life expectancy at birth are often examined by mainly observing their time trends (Chaurasia, 2010). It is quite evident that the sex differentials in life expectancy at birth are widening over the period in India, with significant differentials by age as well (Canudas-Romo, Saikia, and Diamond-Smith, 2015).

With significant mortality decline in the past four decades, there is a need for a comprehensive study that looks into the sex differentials in life expectancy at birth and death dispersion in India. This study is an attempt to enrich research on the implication of enhancement in life expectancy on the dispersion of deaths over time, in India. This study would also examine the sex differentials in life expectancy at birth and dispersion measures of mortality for states of India to discover regional differentials in dispersion measures of mortality in India. Studies on dispersion of deaths are confined to examining the differences between countries and less focused on variations within the country (van Raalte, Martikainen, and Myrskylä, 2014). Hence, this study would provide an important contribution to understand the sex differentials in the dispersion of deaths for subpopulations within the country.

Before we describe our data sources, we first provide some brief information about India's life expectancy and distribution of deaths since the 1970s, relevant to this study.

1.2 Brief Background about Life Expectancy in India

The life expectancy at birth in India increased from 49.7 years in 1970–1975 (RGI, 1984) to 66.1 years in 2006–2010 (RGI, 2012). The increase was smaller for males than for females. The female life expectancy at birth was higher during the late 1990s to mid-2000s in all the states of India, whe-

reas the male life expectancy at birth was higher in the 1970s and 1980s (Dyson, 1984). However, in recent decades, in spite of higher child and maternal mortality, life expectancy at birth of females has surpassed that of males. The increase in life expectancy at birth was more rapid in rural than in urban areas. The increase in life expectancy at birth also varied across Indian states. There was a strong North-South gradient across the states, with great variations in the level and the pace of mortality reduction over time (Bhat, 1987; Saikia, Jasilionis, Ram *et al.*, 2011). The pace of mortality decline was faster than international standard for males in Kerala and Tamil Nadu, and for females in Kerala, Tamil Nadu, Himachal Pradesh, and Uttar Pradesh (Chaurasia, 2010).

The sex differentials in mortality indicators also vary by age, in India. Research on infant and child mortality in India showed significant sex differentials (Subramanian, Nandy, Irving *et al.*, 2006; Claeson, Bos, Mawji *et al.*, 2000). Although the sex differential in adult mortality was not very high, it has been increasing continuously since the declining female mortality outpaced male mortality (Saikia and Ram, 2010). At older ages, the probability of survival is much higher among females than males in India in the recent decades (Chaurasia, 2010).

The distribution of deaths in 2013 by age showed that child (aged 0–4) deaths constituted 3% of the total deaths in Kerala compared with 25% in Uttar Pradesh, whereas adult (aged 15–59) deaths constituted almost 30% to 35% of the total deaths in all the major states of India (RGI, 2014). Saikia *et al.* (2013) further demonstrated that there was a substantial rural–urban difference in infant mortality at both national and state levels. Such a rural-urban difference in infant mortality was found in both socio-economically advanced states (e.g., Goa, Kerala) and disadvantaged states (e.g., Madhya Pradesh, Assam, and Orissa).

2. Data and Methods

2.1 Data

The Sample Registration System (SRS), under the auspices of the Office of the Registrar General of India (RGI), is the major source of mortality data and life tables in India (RGI, 2014). SRS is a dual record system with the continuous registration of birth and deaths in a nationally representative sample of villages and urban blocks in addition to a half-yearly survey for an independent count of events to update the demographics of the sample population. Events recorded in both the operations are matched to identify the unmatched and partially matched events, which can be referred to the field for verification. SRS provides information on age-specific death rates in different age groups and the abridged life tables starting 1970–1975. The data on death rates along with the abridged life tables from 1970–1975 till the recent time period (ORG 1984, 1985, 1989; RGI 1994, 1996–2010, 1998) were used in this study.

The quality of death statistics, in particular, uneven completeness of death registration by age, and systematic age misreporting can have an adverse impact on the accuracy of a life table and estimated life expectancy and life disparity. Nevertheless, SRS data are considered the most reliable of all death statistics in India (Roy and Lahiri, 1988; National Commission on Population, 2001; Mathers, Fat, Inoue *et al.*, 2005). Definition of terms, administrative guidelines, and data collection methods of SRS are consistent over time, allowing for comparisons across time periods. An SRS representative character allows for estimation of vital statistics for India and the major states. The death registration completeness was about 95% for both males and females during 1971–1980. Evaluation for the recent time period 1990–1997 suggested no substantial changes in the completeness of reporting of either deaths or births in SRS (Bhat, 2002). With exceptions at the older ages, the registration of deaths at both childhood and adult ages was considered to be reliable because they were consistent with the SRS data (Saikia, Jasilionis, Ram *et al.*, 2011).

2.2 Complete Life Table Construction

${}_nq_x$ (the probability of dying from age x to $x+n$) was segregated into ${}_1q_x$ (the probability of dying

from age x to $x+1$) using the parametric technique of Heligman and Pollard (1980) with the help of Mortpak developed by United Nations Population Division (2003), which provides smoothed values of ${}_1q_x$. The parametric model provides a smoothed curve, which reaches the whole age interval and provides flexible solutions in a set of parameters. This facilitates comparisons between and across time periods and spaces (Kostaki and Panousis, 2001). The procedure for constructing a life table in Mortpak from ${}_nm_x$ or ${}_nq_x$ is based on a method developed by Greville (1943). To construct a life table with the open age group at 100+, the ${}_nq_x$ values are extrapolated until no survivors remain, by fitting a Makeham function through the last six ${}_nq_x/(1 - {}_nq_x)$ values available (United Nations Population Division, 2003).

The conversion of age-specific death rates into age-specific probabilities of dying was consistent with the RGI abridged life tables from 1970–1975 to 1991–1995. However, previous studies reported problems in the conversion of age-specific death rates into age-specific probabilities of dying at early ages in the recent SRS abridged life tables from 1996–2000 to 2002–2006 (e.g., Saikia, Singh, and Ram, 2010). This conversion error further affects the estimates of infant, child mortality, and the life expectancy at birth. The purpose of our new life tables from 1996–2000 to 2006–2010 is to correct these errors. The ${}_nq_x$ values of the newly constructed abridged life tables from 1996–2000 to 2006–2010 were used as inputs in the Heligman–Pollard equation. The complete life tables were constructed according to ${}_1q_x$ values from age 0 to terminal age ω (100+).

2.3 Life Disparity

To measure dispersion of death, several measures such as S_{10} , interquartile range (Wilmoth and Horiuchi, 1999), the Gini coefficient (Shkolnikov, Andreev, and Begun, 2003), the Theil index of inequality (Smits and Monden, 2009), and average interindividual difference and the related measures of absolute inequality (Moser, Shkolnikov, and Leon, 2005; Shkolnikov, Andreev, and Begun, 2003) are often used extensively. S_{10} is defined as the standard deviation of the age at death for ages 10 or older (Edwards and Tuljapurkar, 2005). The distance between the lower and the upper quartile of the distribution of ages at death in a life table is called as interquartile range (Wilmoth and Horiuchi, 1999). The Gini coefficient is defined as the average of absolute differences in individual ages at death relative to the average length of life (Shkolnikov, Andreev, and Begun, 2003). The inequality in the distribution of age at death can be measured using the Theil index of inequality (Smits and Monden, 2009). Some formal properties of these measures are different from each other and the degree of their aversion to inequality. In this study, life disparity based on the distribution of death at different ages was used to measure the dispersion of deaths. The convergence of death rates in a narrow age interval can be observed from the decline in life disparity. The life disparity declines when saving lives occur at early ages, which compresses the distribution of deaths. The distribution of death expands when saving lives occur at late ages, which leads to increase in the average remaining life expectancy. Unlike life expectancy at birth, life disparity combines the age pattern of mortality and average mortality in a single measure (Singh and Ladusingh, 2013). The concept of this measure is in line with Keyfitz's idea that everybody dies prematurely, that is, every death deprives the individual concerned of his or her remaining life expectation (Keyfitz, 1977). Hence, life disparity occurs because of deprivation from death and inequality in the length of life. The measure of life disparity e_x^\dagger , appeared in several previous studies (Mitra, 1978; Zhang and Vaupel, 2009; Shkolnikov, Andreev, Zhang, *et al.*, 2011).

Life expectancy at age x is measured using the following formula:

$$e_x^0 = \frac{T_x}{l_x} \quad (1)$$

Life disparity at age x is estimated using the following formula:

$$e_x^\dagger = \frac{1}{l_x} \sum_{y=x}^{\omega-1} [d_y (e_{y+1} + 1 - a_y)] + \frac{1}{l_\omega} d_\omega \left(\frac{1}{2} e_\omega \right) \quad (2)$$

where

l_x = Number of survivors at age x

d_y = Expected number of deaths in age interval $[y, y+1)$

T_x = Total number of person-years lived above age x

e_{y+1} = Life expectancy at age $y+1$

a_y = Average number of years lived in age interval $[y, y+1)$

ω = 100+

2.4 Decomposition of Sex Differences in Life Expectancy and Life Disparity

The purpose of the decomposition is to estimate the contribution at each level of the underlying factor which can be added to the overall difference between values of the aggregated measure. A stepwise algorithm was developed for decomposing differences between aggregated demographic measures and applied it to analyzing the change in life expectancies, healthy life expectancies, parity-progression ratios, and total fertility rates (Andreev, Shkolnikov, and Begun, 2002). Using a stepwise algorithm programmed with VBA/Excel, Shkolnikov and Andreev (2010) generated a spreadsheet to decompose the age-specific difference in any life table indicator between two populations. With the help of a general stepwise replacement algorithm, age decompositions for different types of life-table based quantities can be executed. This Excel spreadsheet was used in this study to decompose the sex difference in life expectancy at birth or life disparity, that is, the difference between male and female life expectancy at birth or the life disparity. Decomposition was performed for all periods, yet we only presented the results for two periods (1970–1975 and 2006–2010) to show the transition in age-specific contributions of sex difference in both periods. Because the life tables for Bihar and West Bengal were available only from 1981–1985 onward, the figures for these two states are for the time period of 1981–1985, not 1970–1975.

3. Results

3.1 Male-female Differences in Life Expectancy and Life Disparity

Figure 1 shows that there was not much difference between the observed and fitted values of abridged $\ln({}_nq_x)$ for males and females in both periods. The $\ln({}_nq_x)$ values from the Heligman-Pollard model are also compared with the $\ln({}_nq_x)$ values of United Nations life tables and shown in Appendix 1. It is evident from the figures that there are no major differences in the values from the two sources in both periods, except some differences in the adult age group during 1970–1975. These comparisons indicate that the complete life table estimates based on the fitted ${}_nq_x$ values are good enough to be used for further comparison and decomposition analyses.

Figure 2 shows that over time, larger numbers of survivors (the l_x column of the complete life tables) had reached the older ages. Deaths are shifting to the older age, which leads to a compression of deaths. The difference in male and female survivors is evident in both 1970–1975 and 2006–2010 periods. In 1970–1975, as compared to that of females, a higher proportion of male survivors reached at age 50 from age 5. No significant sex difference was found in the older ages. In 2006–2010, the number of survivors in the initial ages was almost the same between males and females, but the gap became noticeable after age 40. The curves for males and females did not converge at any point after this age. The graph clearly shows a major transition in mortality in India: females, who were lagging behind males in the earlier decades, have outpaced males in survival in the recent years.

Figure 3A clearly shows that the sex difference in life expectancy at birth increased over the period. The male advantage in life expectancy at birth was mainly observed until 1981–1985. There is an apparent increasing trend in sex difference in life expectancy at birth in India, with females at the higher end. The female life expectancy at birth was 3.0 years higher than the male life expectancy

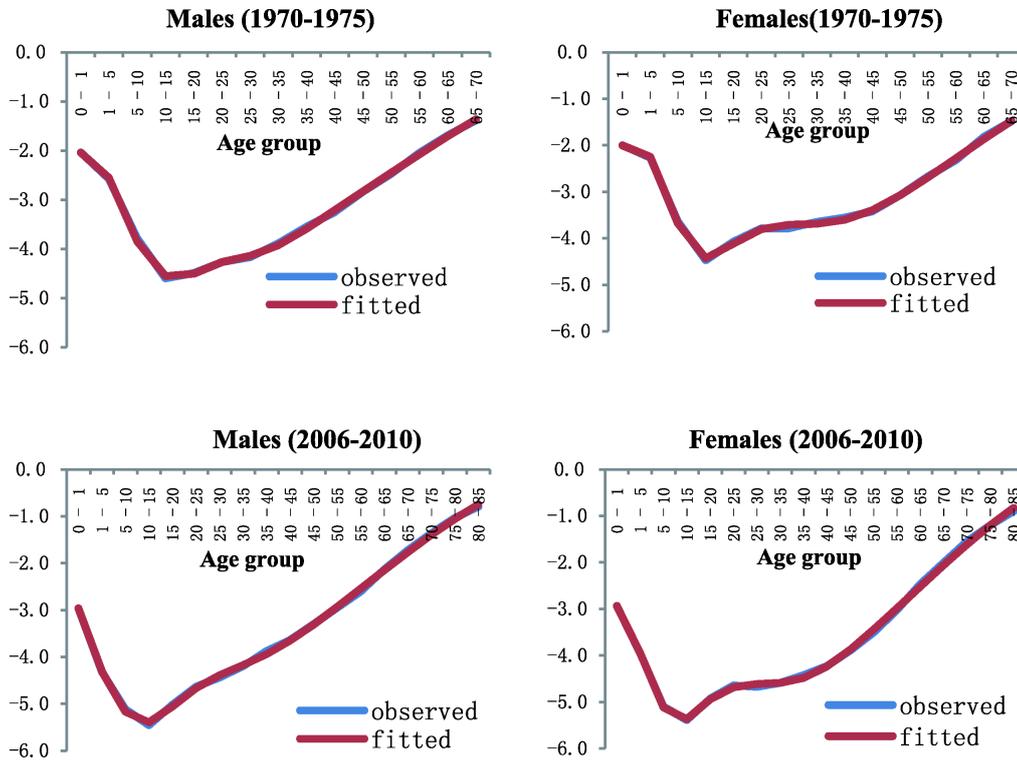


Figure 1. Fitting of $\ln(q_x)$ values using the Heligman–Pollard equation on SRS Data for males and females in India, at two time periods.

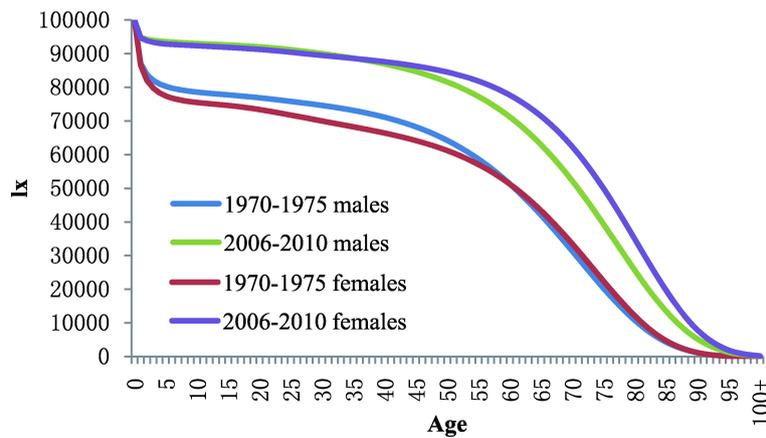


Figure 2. l_x values of the complete life tables at two time periods for males and females in India.

at birth in 2006–2010. The male–female difference in life expectancy at birth significantly varied by the place of residence. In the rural areas, because the female life expectancy at birth increased at a faster pace than the male life expectancy at birth, male advantage in the earlier periods was faded out in the recent period. In the urban areas, females were already in advantage in 1970–1975 and the gap has enlarged in the recent period.

Figure 3B reveals that over time, the male–female difference in life disparity was diminishing, from –1.5 years in 1970–1975 to 0.4 years in 2006–2010. Contrary to the male–female gap in life expectancy at birth by the place of residence, the male–female gap in life disparity has shown diverging trends by the place of residence. The urban–rural difference in the male–female gap of life disparity has increased significantly. The male–female gap in life disparity for urban areas was almost twice of that in the rural areas in 2006–2010.

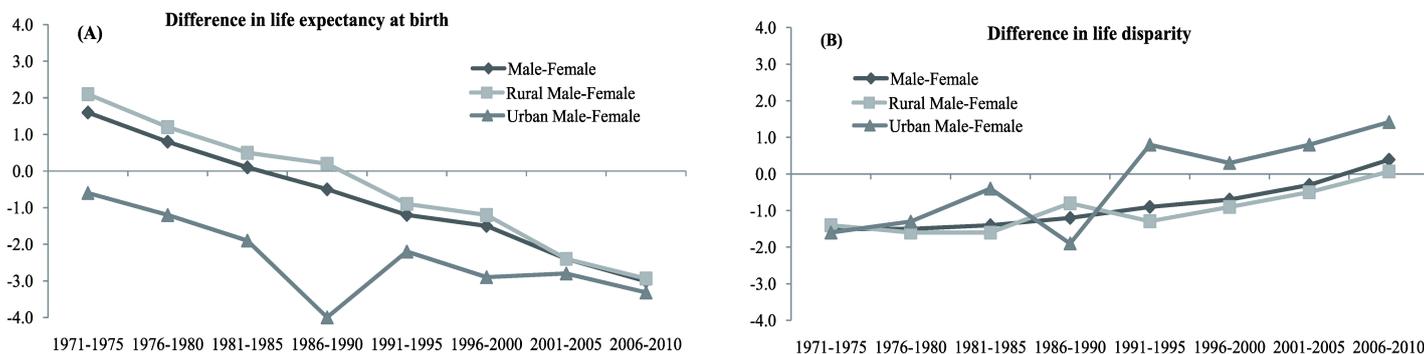


Figure 3. Sex difference in life expectancy at birth (A) and life disparity (B) by the place of residence, 1970–2010

3.2 Decomposition of Male–Female Difference in Life Expectancy and Life Disparity by the Place of Residence

Figures 4A and 4B present the age-specific contribution (in years) of the male–female difference in life expectancy at birth and life disparity in the two time periods by the place of residence. In 1970–1975, the male–female difference in life expectancy at birth was positive, and life disparity was negative. The decomposition result shows that in 1970–1975, a significant portion of the observed sex difference in life disparity and life expectancy at birth was explained by the higher female mortality under age 30 years, with infant (<1 year) and child age group (1–14 years) contributing most. In 2006–2010, the adult age group (30–59 years) contribution served to the widened female advantage in life expectancy by almost 2 years. The same age group contributed to the enlarged male life disparity by 1 year in 2006–2010. In the rural areas, the male advantage in both indicators of mortality was explained by the large contribution of child age group (1–14 years) in 1970–1975. The contribution of infant (<1 year) and child (1–14 years) age group in the rural areas was higher than in the urban areas. On the other hand, in 2006–2010, the negative sex difference in life expectancy was mainly attributed to the contribution of the age group 30–59 years (–2.0) and older age group 60+ (–1.4). The contributions of adult age group (30–59 years) and older age group (60+ years) increased over time. The sex difference in life expectancy at birth was negative in the urban areas for both time periods, with an increased intensity in 2006–2010. The negative difference in life disparity in 1970–1975 was mainly because of the higher female mortality in children (0–14 years) and the early adult age group (15–29 years). Higher male life disparity in 2006–2010 was because of the large contribution of the adult age group (30–59 years). The contribution of the adult age group (30–59 years) was higher in the urban (life expectancy at birth: –2.2 years; life disparity: 1.1 years) than in the rural areas (life expectancy at birth: –2.0 years; life disparity: 0.8 years).

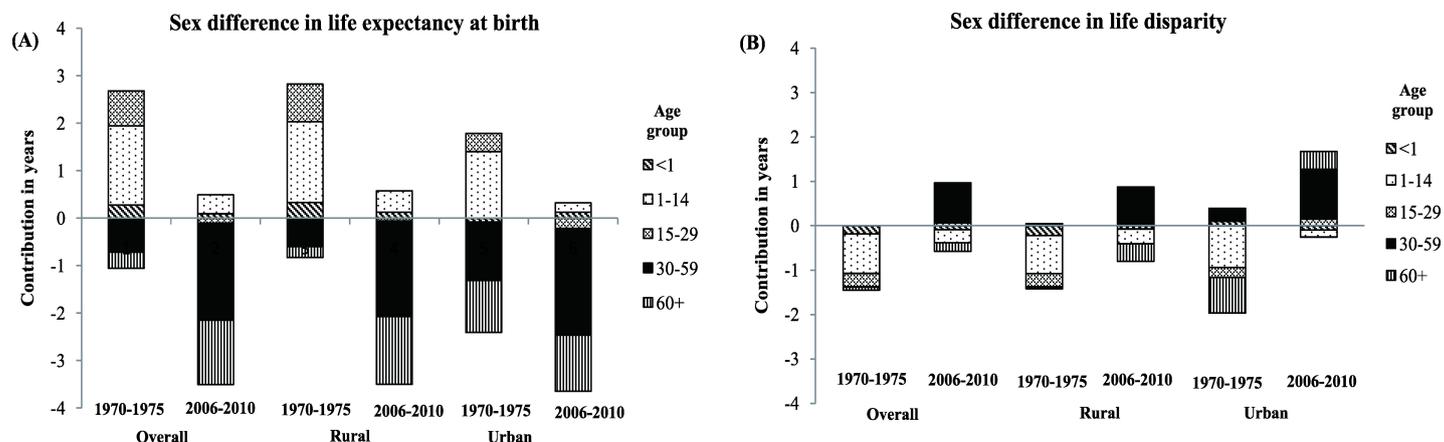


Figure 4. Age-specific contribution to sex differences in life expectancy at birth and life disparity in India at two time periods.

3.3 Male-Female Difference in Life Expectancy and Life Disparity by State Group

Figures 5A and 5B show the geographical pattern of the male–female difference in life expectancy and life disparity in 1970–1975 and 2006–2010. The increase in life expectancy at birth and the decline in life disparity were higher among females in the majority of the Indian states. The male–female difference in life expectancy at birth changed from positive to negative, whereas it was just opposite for life disparity. The change in terms of the number of years was more prominent for life expectancy at birth than for life disparity. The female life expectancy at birth in 2006–2010 was higher than the male life expectancy at birth in every major state of India. The female life expectancy at birth was more than 4 years higher than males for demographically advanced south Indian states such as Kerala, Karnataka, and Andhra Pradesh, and north Indian states such as Punjab, Haryana, and Himachal Pradesh. Along with life expectancy at birth, life disparity in Himachal Pradesh and Kerala was in favor of females in 1970–1975. Most of the states had higher female’s life disparity in 1970–1975, that is, negative sex difference, with the maximum gap found in Uttar Pradesh and West Bengal. This negative sex difference in life disparity changed to positive in two-thirds of Indian states in 2006–2010. The female life disparity in 2006–2010 was higher than the male life disparity in states such as Assam, Bihar, and Uttar Pradesh.

The states are classified into two groups based on the transition of sex differentials in life expectancy, as observed in Figure 5A and 5B. This approach was adopted to present the decomposition results for the major states in Figures 6 and 7 more systematically. Group 1 includes the states where the male–female difference in life expectancy or life disparity changed the sign either from positive to negative or from negative to positive, and Group 2 includes the states that have not undergone a

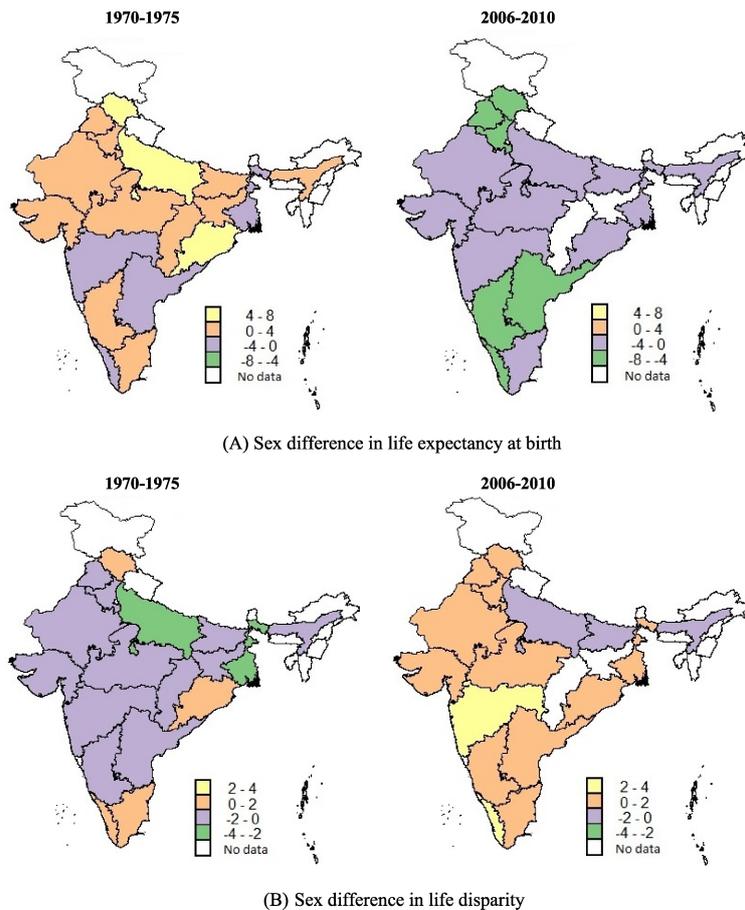


Figure 5. Sex difference in life expectancy at birth and life disparity in major states of India at two time periods 1970–1975 and 2006–2010.

transition, that is, the male–female difference in life expectancy or life disparity did not change the sign over the periods.

3.4 Decomposition of Male–Female Difference in Life Expectancy and Life Disparity by State

Figure 6 shows the decomposition of sex difference in life expectancy at birth results for each major state in India during 1970–1975 and 2006–2010. The states in Group 1 of life expectancy analysis comprise states with a positive sex differential in life expectancy at birth in 1970–1975 and a negative one in 2006–2010. Group 2 consists of four states (Andhra Pradesh, Kerala, Maharashtra, and West Bengal), which had negative male–female difference in life expectancy in both periods. In 1970–1975, all the states had higher male life expectancy at birth and only a few states with higher female life expectancy. The sex differentials in mortality were largely influenced by the difference in death rate under the age of 15 in 1970–1975. A major shift in age-specific contribution toward these sex differentials was observed in 2006–2010. The contribution of the two age groups 0 and 1–14 years was replaced by the age groups of 30–59 years and 60+ years. The contributions of age groups of 30–59 years and 60+ years in 1970–1975 were already higher in the Group 2 states, which were further enlarged in 2006–2010, leading to a larger negative male–female difference. The maximum contributions of adult and old age mortality toward the sex differential in life expectancy at birth were observed in Himachal Pradesh in Group 1 and Kerala in Group 2. In Bihar, the positive contribution of child age group (1–14 years) was negated by the negative contribution of the adult age group (30–59 years) in 2006–2010. The states in Group 2 had a negative male–female difference in life expectancy at birth in 1970–1975, which suggests that females in these states were in a much better situation at that time period than those in the other states.

Figure 7 presents the decomposition of sex differentials in life disparity in the major states in India. Compared to life expectancy at birth, transition in sex differences in life disparity occurred in a lesser number of states. Nearly half of the states fell in Group 1 and the remaining were in Group 2. Group 1 states had a negative male–female difference in life disparity in 1970–1975 and a positive value in 2006–2010; while in Group 2 states such as Assam, Bihar, and Uttar Pradesh had a negative

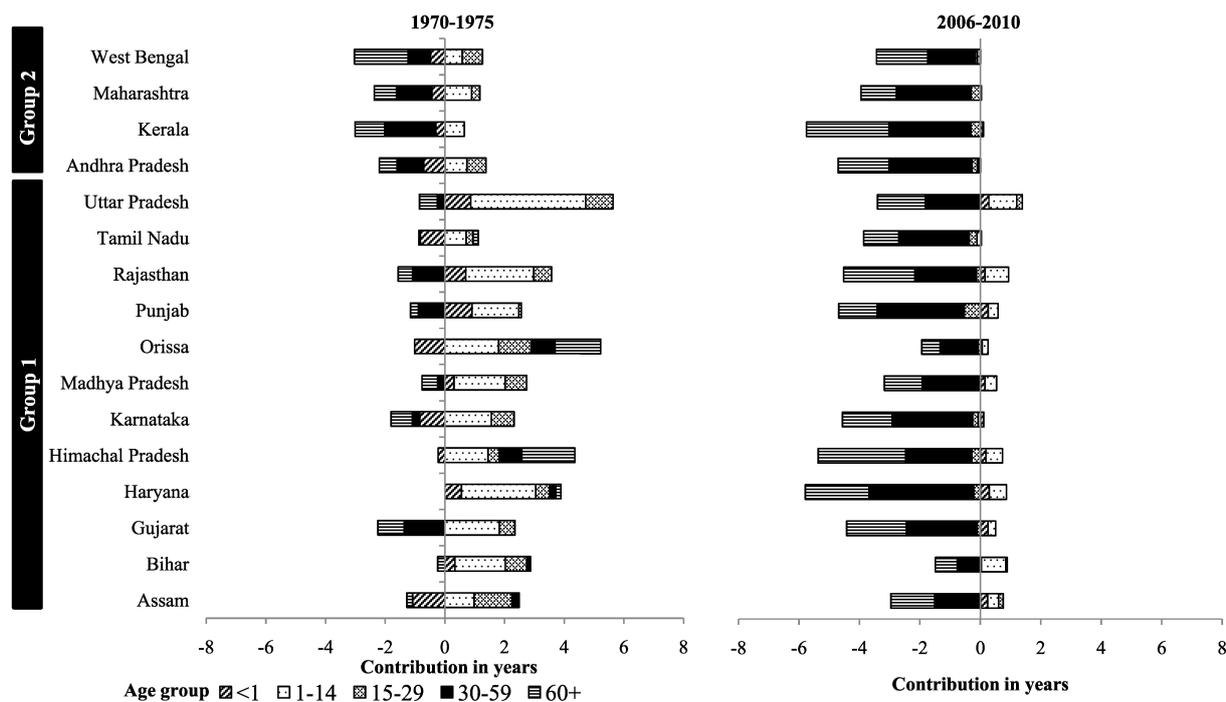


Figure 6. Age-specific contribution to sex differences in life expectancy at birth at two time periods, in major states of India.

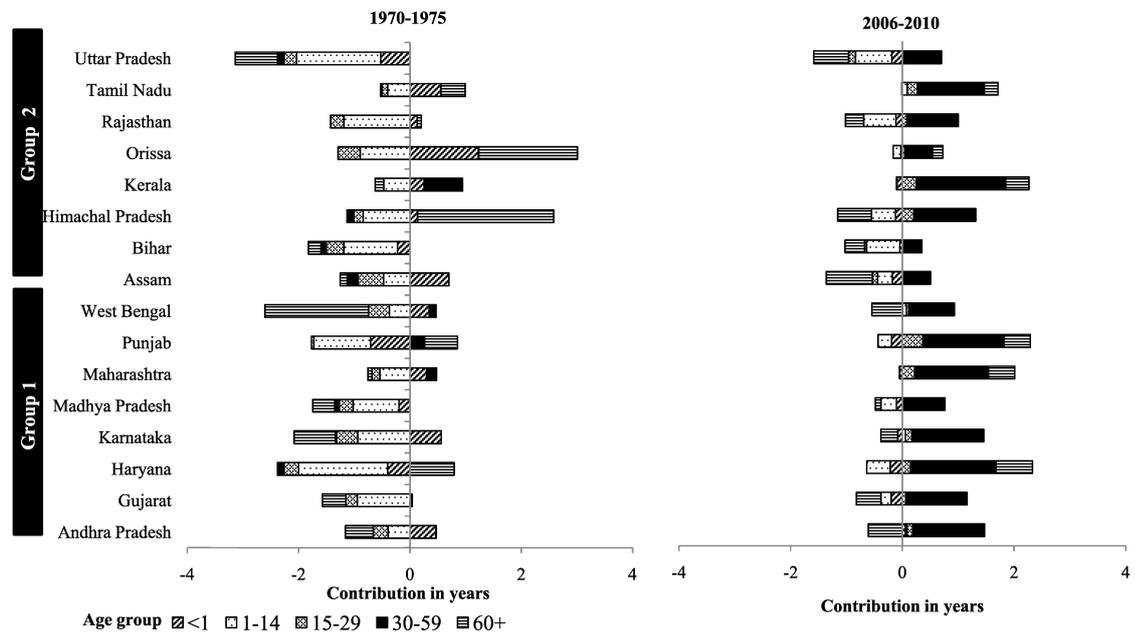


Figure 7. Age-specific contribution to sex differences in life disparity at two time periods, in major states of India.

male–female difference in life disparity in both 1970–1975 and 2006–2010, and states such as Himachal Pradesh, Kerala, Orissa, and Tamil Nadu had a positive difference for both the time periods. In 1970–1975, the sex differential in life disparity was negative for most of the states, suggesting a higher female life disparity than male. In 1970–1975, in states with poor mortality indicators like Uttar Pradesh, Rajasthan and Bihar as well as states with better mortality indicators like Punjab, Haryana and Karnataka, the negative difference in life disparity was largely due to higher female mortality at or below 14 years. The female life disparity in Kerala was lower than males in both periods, with increasing contribution of adult and older age groups to this gap in 2006–2010. The transition in the role of age-specific mortality toward sex difference in both periods is evident in the Group 1 states. The analysis shows that in all the states, the positive sex difference in life disparity in 2006–2010 was mainly attributed to the higher male mortality in the adult age group (30–59 years) and the older age group (60+ years). This contribution was larger in states like Maharashtra and Punjab, which are in the advanced stages of mortality transition in India. The states in Group 2 also experienced a similar change. However, the contributions of child age group (0–14 years) and younger adult age group (15–29 years) was also significant for the states in Group 2.

4. Discussion and Conclusions

Essentially, life disparity measures the dispersion of deaths, whereas life expectancy is a measure of the average length of life. An important factor in increased life expectancy in India is the contribution of infant and child mortality (Singh and Ladusingh, 2016). While trends in infant mortality are important, a small change in early ages of mortality would have a significant effect on the momentum of age distribution at death (Edwards and Tuljapurkar, 2005). Unlike S_{10} , life disparity covers the child, adult and old age group and holds an important public health interpretation. For a developing country like India, where the infant and child mortality are still high as compared with those in developed countries, using life disparity to study the dispersion of deaths is most suitable. Life disparity at specific age can be easily compared to the life expectancy at specific ages.

This study is distinctive in the sense that it analyzed the sex differentials in life expectancy at birth and life disparity at the same time. Furthermore, the study demonstrated the changing dynamics of different age groups and their contribution to the differences between the male and female life ex-

pectancy and life disparity, and their variation over time. The sex differentials in life expectancy at birth and life disparity were measured at the state and urban–rural level. Such dispersion measures have not been in much use in developing countries like India. In this study, we made such an attempt using the most reliable data source of mortality – from the SRS.

Our results showed that the sex gap in life expectancy at birth and life disparity widened over time, in India. The study suggested a shift in the role of age-specific mortality to the sex differentials in life expectancy and disparity, with adult ages contributing more significantly unlike in the past, younger ages contributing more to the differentials. The female advantage in life expectancy in 2006–2010 was mainly attributable to the low level of female adult and older age mortality than males in India, and the low life disparity is because of the contribution at the adult ages. This finding indicates that the female advantage in life expectancy and life disparity is occurring in India as what have been found in the developed countries (Shkolnikov, Andreev, Zhang, *et al.*, 2011; Edwards and Tuljapurkar, 2005). However, in comparison to the international levels, there is a scope for further reduction, especially in the rural areas and high mortality states. Large decline in adult mortality among females is because of a significant decline in maternal mortality. Under the Reproductive and Child Health Programme started in 1997 and the National Rural Health Mission started in 2005, the government has started several new initiatives to address the problem of maternal deaths and to speed up the rate of decline of maternal mortality across all states (RGI, 2006, 2013).

In India, it has been observed that sex of the person is one of the important and significant determinants of adult mortality in India (Saikia and Ram, 2010). The mortality risk in middle-aged female people in India is lower than males (Subramanian, Nandy, Irving *et al.*, 2006). Adult mortality in the age group 15–59 has declined to a large extent among females from 358 per 1000 in 1970 to 145 per 1000 in 2010 (Rajaratnam, Marcus, Levin-Rector *et al.*, 2010). The decline among males has not been at the same rate as it has been for females. Studies in developed countries mostly attribute such differences to the behavioral risk factors (Edwards and Tuljapurkar, 2005). The grandness of health risk and behavioral factors is increasing in India due to the changing pattern in the cause of death (Krishnan, Nawi, Kapoor, *et al.*, 2012). In India, the level of risk factors among the males is more marked than among the females (Wu, Guo, Chatterji *et al.*, 2015). Behavioral risk factors, such as smoking, little physical activity, poor diet, and other unhealthy practices, have a significant role to play in adult mortality in India (Jha, Gajalakshmi, Gupta *et al.*, 2006).

This study also showed that sex differential in life expectancy and life disparity existed in the rural and urban areas, with larger gap in the urban areas. The major reason of this large gap in the urban areas is the significant contribution of both older age group 60+ years and adult age group 30–59 years. The older age mortality decline for females was more pronounced than males in the urban areas (Yamunadevi and Sulaja, 2016). The difference in health behavior of older males and females can be associated with the significant decline in female older age mortality (RGI and CGHR, 2015). Furthermore, higher infant and child mortality among females in the rural areas (RGI, 2014) negated the advantage females gain from the mortality decline in the adult age group, and resulted in a higher life disparity. Discriminatory treatment of females over males with respect to food allocation and healthcare is associated with the excess female mortality (Arokiasamy, 2004).

This study found significant regional differentials in sex gap for both life expectancy and life disparity. Many studies have found that Maharashtra, Punjab, Haryana, and Kerala have much better mortality measures than the national level (Chaurasia, 2010; Saikia, Jasilionis, Ram *et al.*, 2011), but the sex gap in life expectancy and life disparity is increasing over time because of the increasing contribution of adult age group. This suggests that the sex differences in mortality rates for the adult age group is widening over time. In Kerala, females were in an advantageous position from the 1970s onward. The slow reduction in the mortality rates among adults and elderly males in Kerala was related with the ongoing epidemiological transition and misalliances in health policies (Thomas and James, 2014).

Compared to the life expectancy at birth, the transition in sex differentials in life disparity has oc-

curred in a lesser number of states. Even though the life expectancy at birth of females was higher than that of males in Assam, Bihar, and Uttar Pradesh, the life disparity of females was higher than that of males. This indicates that a strong negative correlation between the life expectancy and life disparity does not assure that higher life expectancy population would also have a lower life disparity. A higher female life disparity in these states was mainly because of the higher female child mortality (RGI, 2012), and negated the large gain of females in the adult age group.

Analyzing differentials in life disparity and life expectancy at birth simultaneously by sex in this study has provided a new perspective on mortality differentials. This study has shown that with the rapid increase in the average length of life of females, life disparity is also converging faster for females than for males in India, leading to enlarged sex differentials for the life expectancy and disparity, with the highest differences in low mortality states. To diminish the lifespan variability among males in India, among its states, and ultimately, to close the sex gap in lifespan variability, policies should focus on averting premature and young adult deaths among males in India. This aversion would simultaneously increase life expectancy and decrease life disparity, whereas strategies aiming at extending the length of life among the oldest-old would increase life expectancy of a population, but at the expense of increasing lifespan variability (Kannisto, 2001). As adult deaths have severe economic and social consequences, more and effective health policy interventions in India are clearly needed to prevent such deaths.

Conflict of Interest and Funding

No conflict of interest was reported by all authors.

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Ethics Statement

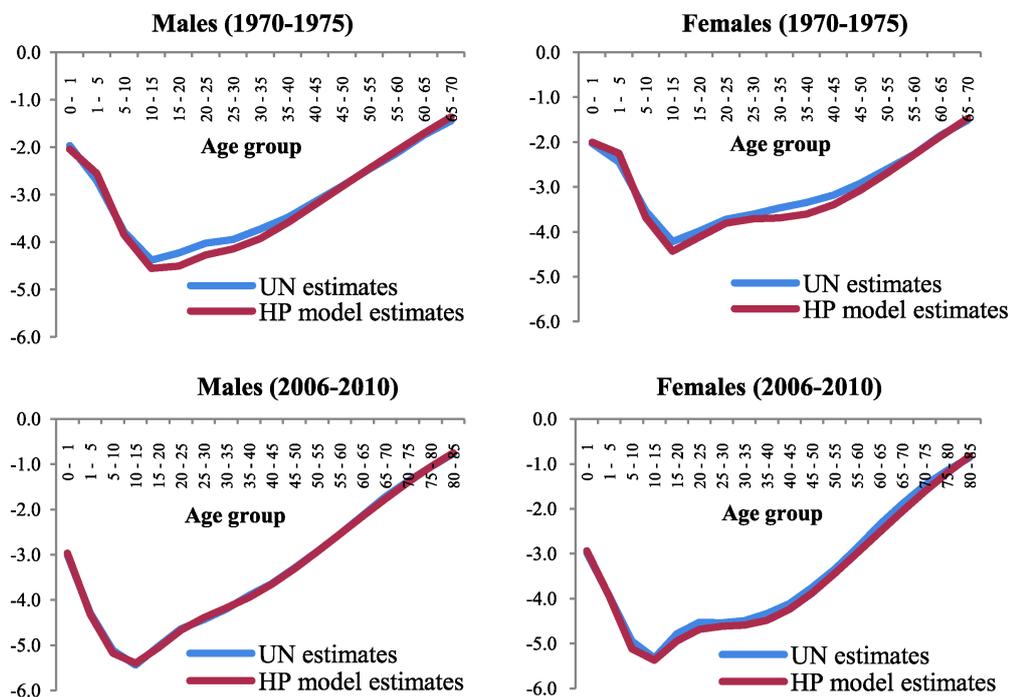
The analysis described in this paper was performed using secondary data obtained from publicly available sources as outlined in the Data and Methods section.

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Appendix 1. Comparison of $\ln(nq_x)$ values of United Nations (UN) and Heligman–Pollard (HP) model estimates.