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Decomposition of Life Expectancy at Birth for India and Some of its Selected States

N. Saikia[1]

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[1]Nabanita Saikia, Research Scholar, Department of Statistics, Gauhati University, Guwahati-781014, Assam, India. Email id:nabanitasaikia@gmail.com

ABSTRACT

Objective: This study aims to assess the contributions of various factors towards the change in life expectancy at birth in India and some of its selected states from various zones during 1970 and 2010 by age, sex and place of residents.

Methods: Arriaga (1984) decomposition method is used to estimate the age specific contribution of the difference in life expectancy at birth. Abridged life tables of the Sample Registration System in India from 1970–1975 and 2006–2010 were used to fulfil the research goals.

Results: In India under age 1,males contribute 5.32 years of life to the total gain of 10.93 years and females contribute 5.83 years of life to the total gain in life expectancy of 15.02 years. These indicate the improvement of infant mortality rates for both sexes during 1970 and 2010. Orissa achieved highest gain in life expectancy at birth in both sexes. Contributions of older ages (up to 65 ages) increased for both urban and rural residents of India and its selected states for 1970 and 2010 regardless of sex.

Conclusion: The study highlights that the highest contribution to change in life expectancy at birth came from reduction in infant and under-5 mortality rates in both sex and residents.

Keywords: Arriaga, decomposition, infant mortality, life expectancy at birth, India, under-5 mortality.

INTRODUCTION

Life expectancy is one of the most widely used measures in demographic and health analysis. It gives the average number of years a new born is expected to survive, on average, given the prevailing age schedule of mortality (Pollard, 1982). Life expectancy at birth is usually considered as an important indicator of the mortality level of a population (Choudhury & Sarma, 2011). In India, life expectancy has increased notably over the past century, reflecting the significant falls in mortality rates. Though the life expectancy has increased, the increase is not consistent across the different states of India. It is found that average life expectancy

which used to be around 49.3 years during the periods 1970 steadily climbed to 66.5 years in 2010 (Arjun *et.al.* 2014). The infant mortality rate, which is an important indicator of health status of a country, has also registered a significant decline from 129 per one thousand live births in 1971 to 40 in 2013 (SRS, 2014). Although, both genders have experienced a continuous rise in life expectancy since 1970's still female enjoy longer life expectancy at birth than their man counterpart. Increase in the life expectancy at birth was more rapid in rural than in urban areas (Singh & Ladusingh, 2016). The changes in economic, social, and sanitary conditions first triggered an important decline in infant, child, and early adult mortality, which contributed to the reduction in lifespan disparities (Boucher, *et.al.* 2015).

The changes of life expectancy over time serve as an interesting public health indicator for medical, social and economic developments within populations (Klenk, *et.al.* 2016). When analyzing changes in life expectancy between two populations, it is useful to estimate mortality differences in a specific age group contribute to the total difference in life expectancy (Preston, *et.al.* 2001). While comparing the changes in life expectancy at birth, it is necessary to understand the contributions of types of mortality change towards the change in life expectancy at birth and for this one can use the method of decomposition of life expectancy at birth. In demography, decomposition means to split a demographic variable in to its basic parts or elements and this method are used to compare the demographic variables that belong to different population or variable of same population over time (Romo 2003). Decomposing the changes in life expectancy could provide a clear picture of the age patterns in mortality change. Perhaps, in the field of demography no other methods have attracted as much attention as that of decomposing the difference between life expectancy (Ponnapalli, 2008). The decomposition analysis would help to estimate the age-specific contribution of increase in life expectancy at birth.

Decomposition techniques in demography were formalized and generalized by Kitagawa (1955) and elaborated by Das Gupta (1978, 1989, 1991, and 1993) (Sanchez & Preston, 2007). A number of methods were suggested by a several researchers on decomposing a difference between two life expectancies over time or place (Gu, *et.al.* 2007). Among those that have contributed to these studies are Keyfitz (1985), Mitra (1978), United Nation report (1982), Pollard (1982;1988), Andreev (1982), Arriaga (1984), Pressat (1985), Vaupel (1986), Goldman and Lord (1986), Valkovics (2002). There are two main approaches to decompose the difference in life expectancies: a continuous approach proposed by Pollard in 1982 and a discrete approach initiated by Arriaga in 1984 (Gu, *et.al.* 2007). Arriaga distinguishes three different effects of mortality changes on life expectancy: a direct effect

(DE), an indirect effect (IE) and an interaction effect (I) (EHEMU Technical report 2010). The direct effect is the change in the number of person years lived within a particular age group as a result of a mortality change in that age group. The indirect effect and interaction effect account for the addition of person years to be added at and after that age interval (Gu, *et.al.* 2007) and addition of direct, indirect and interaction effect gives the total effect of the difference in life expectancy.

The need for analysis through the use of the decomposition method of change in life expectancy at birth is important for India and some of its major states as to paint a more accurate picture of the contributions made by the various factors. To have an idea about the contributions towards the change in life expectancy at birth, mortality data from different states were selected from the North, South, East, West, Central and Northeast zones of India. For the present study, this includes Assam from North-East, Madhya Pradesh from Central, Kerala from South, Punjab from North, Maharashtra from West and Orissa from East. In order to know the factors which help to rise in life expectancy at birth in India during the 40 years from 1970-75 through 2005-10, decomposition of differences in life expectancy was undertaken using the decomposition method developed by Arriaga (1984). In this paper, we try to assess the male–female difference between life expectancy at birth and place of residence (rural and urban) to capture the possible existent of heterogeneity in the country. By examining contribution of various ages towards the change in life expectancy at birth, one can identify the population which faces risks of early mortality or, alternatively, enjoy greater longevity and also obtain a more detailed understanding of differences among gender and place of resident. The decomposition results reveal that recent improvements in life expectancy in India are mainly due to steeper mortality changes at the younger ages (Singh, *et.al*. 2017). It is believed that, this study would be very helpful to understand which factors have the greatest impact on change in life expectancy at birth across India and its selected states by place of resident (rural and urban) and also examine the sex differentials in change in life expectancy at birth.

DATA AND METHODOLOGY:

The required data for this study were obtained from Sample Registration System (SRS) based on abridged life table for the period 1970-75 and 2006-10. The SRS is a large scale demographic sample survey based on the dual record system with the objective of providing reliable estimates of fertility and mortality indicators at state and national levels for both rural and urban areas separately.

Based on the available life tables, we perform the method of decomposition by using Arriaga's (1984) discrete decomposition method.

Let us consider the age group x to x+n, the total effect ($_n\Delta_x$) of a difference in mortality rates between ages x and x+n on the life expectancy at birth can be expressed as:

$$_n\Delta_x = \frac{l_x^1}{l_0}\left(\frac{nL_x^2}{l_x^2} - \frac{nL_x^1}{l_x^1}\right) + \frac{T_{x+n}^2}{l_0}\left(\frac{l_x^1}{l_x^2} - \frac{l_{x+n}^1}{l_{x+n}^2}\right) \qquad (1)$$

Where,

l_x^1 = number of person alive at exact age x, in the initial time period '1'.

l_x^2 = number of person alive at exact age x, in the latter time period '2'.

$_nL_x^1$ = number of person year lived between ages x and x+n, in the initial time Period'1'.

$_nL_x^2$ =number of person year lived between ages x and x+n, in the latter time Period '2'.

T_x^1 = number of person year lived above exact age x, in the initial time Period '1'

T_x^2 = number of person year lived above exact age x, in the latter time Period '2'

l_0 = 1, 00,000

The first right hand side of the above formulae

$$\frac{l_x^1}{l_0^1}\left(\frac{nL_x^2}{l_x^2} - \frac{nL_x^1}{l_x^1}\right) \qquad (2)$$

Corresponds to the direct effect of a change in mortality rates between ages x and x+n, i.e., the effect that a change a number of years lived between x to x+n produces on the life expectancy at birth.

Second term of the above formulae,

$$\frac{T_{x+n}^1}{l_0}\left(\frac{l_x^1}{l_x^2} - \frac{l_{x+n}^1}{l_{x+n}^2}\right) \qquad (3)$$

Corresponds to the sum of the indirect and interaction effects, i.e., the contribution resulting from the person years to be added because additional survivors at age x+n are exposed to new mortality condition (Preston, *et.al.* 2001). We can say that the total contributions of an age

group to the life expectancy gap (in years) is the sum of two mathematical terms, first corresponds to the direct effect and seconds to indirect and interactions effects.

RESULTS AND DISCUSSIONS:

Our results and discussion are divided into two sections. In section 1, decomposition of life expectancy at birth are evaluated at the national and state level for the period 1970 and 2011 by age and sex whereas section 2 by place of resident.

Section 1: Age and gender pattern of contribution to gain in life expectancy at birth

Decomposition of life expectancy at birth (LEB) up to 70 years of age for the period 1970-75 and 2006- 2010 have been presented for India and all the selected states in Tables 1 and 2 for both males and females, respectively. Figure 1 provides the decomposition of gain in life expectancy at various age groups by sex (1970-75 and 2006-10) for India and all its selected states.

From tables 1 and 2 we have seen that the total gain in life expectancy at birth for India and its states under consideration are mainly resulted from the decline in infant mortality rate (IMR) and under-5 child mortality rate (U5MR) for both sexes, which can also be viewed from Figure 1. We can say that more than half of the total increase in life expectancy at birth in each state along with India is due to the improvement of infant and child mortality. Infant and child mortality in India have declined substantially over the past years where infant mortality declined by 35% over the past 15 years and under-five mortality by 25% between 1978–83 and 1988–93 (Claeson, *et.al.* 2000). An important factor for the increase in life expectancy in any country is still the contribution of infant and child mortality (Singh & Ladusingh, 2013). Early childhood mortality is a major contributor to the change in life expectancy at birth as compared to the higher age in India.

At the all India level, the mortality decline in the age group 0–1 year contributes to 5.32 years of the gain of 10.93 years for men. Furthermore, the mortality decline in the age group 1–4 contributes towards the gain in life expectancy at birth by 32%. For women, the mortality decline in the age group 0–1 year contributed to 5.83 years of the gain of 15.02 years. The mortality decline in the age group 1–4 further contributes to the gain in life expectancy at birth by 38%. These indicate the improvement of infant and child mortality rates for both sexes during the period 1970 and 2010. The health care issues addressed by the government which resulted in increased life expectancy in India are malnutrition, high infant mortality rate, diseases like hepatitis, poor sanitation, unavailability of safe drinking water, female health issues, (Panigrahi, 2014). However different ages contribute different shares to

life expectancy at birth over time for both sexes. While considering the age group 0-1, we have seen that Gujarat achieved the highest positive contribution to the gain in life expectancy i.e. 6.29 years for females and 6.15 years for males. We can say that Gujarat has the highest improvement in infant mortality rates among all the states including India for both sexes during the period under consideration.

Table 1 depicts that age 0-1 contribute the majority of increase in life expectancy at birth during the 40 years period for all selected states including India except Madhya Pradesh for which large decline in death rates from age 1-5 contribute 4.94 years of life to the total gain of 10.93 years. In Punjab males, contribution of the improvement in adulthood mortality (i.e. ages 25 and beyond) towards the gain in life expectancy at birth is more remarkable than other selected states including India. In Punjab, both the direct and indirect contributions of ages 25 and beyond are all negative for males, but are generally positive in all the other states for the same ages.

Table 1: Age and sex decomposition of life expectancy at birth for India and its selected states, 1970-75 to 2006-10, Males

States Age	India	Assam	Gujarat	Kerala	Madhya Pradesh	Orissa	Punjab
0-1	5.32	5.88	6.15	3.45	4.56	4.64	4.25
1-5	3.55	2.99	4.6	2.28	4.94	4.08	2.5
5-10	0.83	1.07	0.57	0.65	0.63	0.95	0.25
10-15	0.25	0.31	0.21	0.18	0.25	0.45	0.17
15-20	0.18	0.09	0.18	0.14	0.15	0.3	0.11
20-25	0.15	0.17	0.14	0.16	0.16	0.19	0.02
25-30	0.12	0.08	0.11	0.11	0.14	0.03	-0.04
30-35	0.15	0.12	0.19	0.28	0.11	0.45	-0.03
35-40	0.2	0.19	0.17	0.26	0.1	0.60	-0.04
40-45	0.34	0.48	0.40	0.33	0.26	0.51	-0.02
45-50	0.30	0.49	0.34	0.28	0.18	0.56	-0.05
50-55	0.46	0.66	0.50	0.28	0.43	0.51	-0.1
55-60	0.57	0.63	0.65	0.40	0.53	0.71	-0.04
60-65	0.53	0.82	0.51	0.41	0.62	0.49	-0.03
65-70	-0.71	-0.53	-0.59	-1.07	-0.83	-0.37	-1.26
70+	-1.36	-0.69	-1.04	-2.26	-1.33	-0.58	-2.80
Total difference	10.93	12.82	13.12	5.95	10.93	13.59	2.86

Moreover we have also seen that total gain in life expectancy at birth of Punjab seems to be lowest among all the selected states. Along with the decline in general mortality, there appears to be a change in the mortality of elderly population in India (Yamunai & Sulaja, 2016). From table 1 we have seen that the contribution to life expectancy at birth by ages 50

to 60 tend to grow in all the selected states including India but contributions of ages 65 and beyond are all negatives for males. We can say that the life expectancy at old ages (50-60) was improving but after the ages 60 it seems to be gradually decreasing. The growth of elderly population is due to the longevity of life achieved because of economic well being, better medicines and medical facilities and reduction in fertility rates (MOSPI, 2016).

We have also seen from Table 2 that the increase in female life expectancy at birth in Kerala, Madhya Pradesh and Gujarat is mainly due to the improvement in survivorship of children aged 1-4 whereas in case of Assam, Punjab and Orissa the improvement of infant mortality rates contributes more towards the gain in life expectancy at birth during these periods. We have also seen that the contribution of life expectancy at birth by older ages from ages 50 to 65 tend to grow in all the selected states along with India but age 65 and beyond witness a negative contribution to life expectancy at birth for all selected states and India.

Table 2: Age and sex decomposition of life expectancy at birth for India and its selected states, 1970-75 to 2006-10, Females

States Age	India	Assam	Madhya Pradesh	Kerala	Gujarat	Punjab	Orissa
0-1	5.83	4.46	5.09	3.22	6.29	5.22	4.94
1-5	5.05	3.79	6.25	3.23	6.58	4.21	4.49
5-10	1.01	1.18	0.81	0.67	0.84	0.41	1.07
10-15	0.31	0.57	0.37	0.17	0.23	0.12	0.31
15-20	0.41	0.66	0.46	0.48	0.29	0.001	0.56
20-25	0.49	0.61	0.32	0.24	0.44	0.34	0.64
25-30	0.45	0.61	0.49	0.29	0.42	0.31	0.49
30-35	0.47	0.76	0.39	0.34	0.45	0.38	0.46
35-40	0.42	0.62	0.42	0.26	0.37	0.33	0.37
40-45	0.44	0.63	0.40	0.34	0.40	0.23	0.58
45-50	0.42	0.51	0.42	0.38	0.49	0.08	0.38
50-55	0.59	0.61	0.56	0.53	0.39	0.23	0.73
55-60	0.59	1.37	0.37	0.50	0.46	-0.06	0.88
60-65	0.68	0.77	0.41	0.70	0.73	0.14	1.02
65-70	-0.64	-0.48	-0.76	-0.79	-0.76	-1.39	-0.23
70+	-1.56	-0.69	-1.67	-3.12	-1.65	-2.06	-0.64
Total difference	15.02	16.03	14.39	7.50	16.04	8.52	16.10

In Assam, the contribution of female age group 55-60 years is remarkably high in life expectancy i.e. 1.37 years to the gain of 16.03 years and in Punjab, ages 60-65 contribute 1.02 years to the total gain of 16.10 years during the periods 1970 and 2010.

In general, the sex pattern of the gain in life expectancy at birth was more or less similar across different age groups as shown in the figure 1. In India, the total gain in life expectancy at birth is 10.93 years for males and 15.02 years for females, which indicates that the females have highest gain in life expectancy than males during 1970 and 2010. 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 (Singh & Ladusingh, 2016). In Assam the contribution of improvement of infant mortality rates for males (5.88 years) was higher than females (4.46 years) and also in Kerala the males had higher improvement of infant mortality rates i.e. (3.45 years) than females (3.22 years). On the other hand females population of Madhya Pradesh, Gujarat, Orissa and Punjab achieved the highest contribution of mortality change before age 1 than males which indicates the improvement of infant mortality rates during these above mentioned periods.We have also seen from figure 1 that females have the higher improvement of increased in life expectancy at birth than males among all states and India. The gender difference in the gain in life expectancy at birth is mainly due to improvement of reproductive health for women (Gu, *et.al.* 2007) or we can say that the effect of declined mortality rates at reproduction prime ages of females.

We have also seen that, Orissa achieved highest gain in life expectancy at birth among all the selected states for both sexes as Orissa shows the sign of progress in improving maternal health and childbirth. On the other hand male population of Punjab has the lowest gain in life expectancy at birth in 1970 and 2010 as females in the state benefited more than males from the increase in life expectancy. Overall we can say that there has been an improvement in the mortality situation in India and all its selected states for both males and females. The change in life expectancy at birth in this period can be largely attributed to the improvement in survivorship at young ages as India witnessed a declining trend in the Infant and child mortality rate over the years. During these periods under study, the gains in life expectancy are accompanied by high contributions from the older age groups, an important factor in aging of the population. Due to improvement in health care services and constant effort by the Indian Government, under-5 mortality in India has shown a considerable decline (Singh, Shukla, *et.al*. 2017). Among men, under-5 mortality has declined from 297 deaths per 1000 live births in 1981 to 53 deaths per 1000 live births in 2011. Similarly, among women, it has decreased from 180 deaths per 1000 live births in 1981 to 61 deaths per 1000 live births

in 2011 (RGI 1985, 2013).The contributions of mortality reductions at adult ages were generally smaller

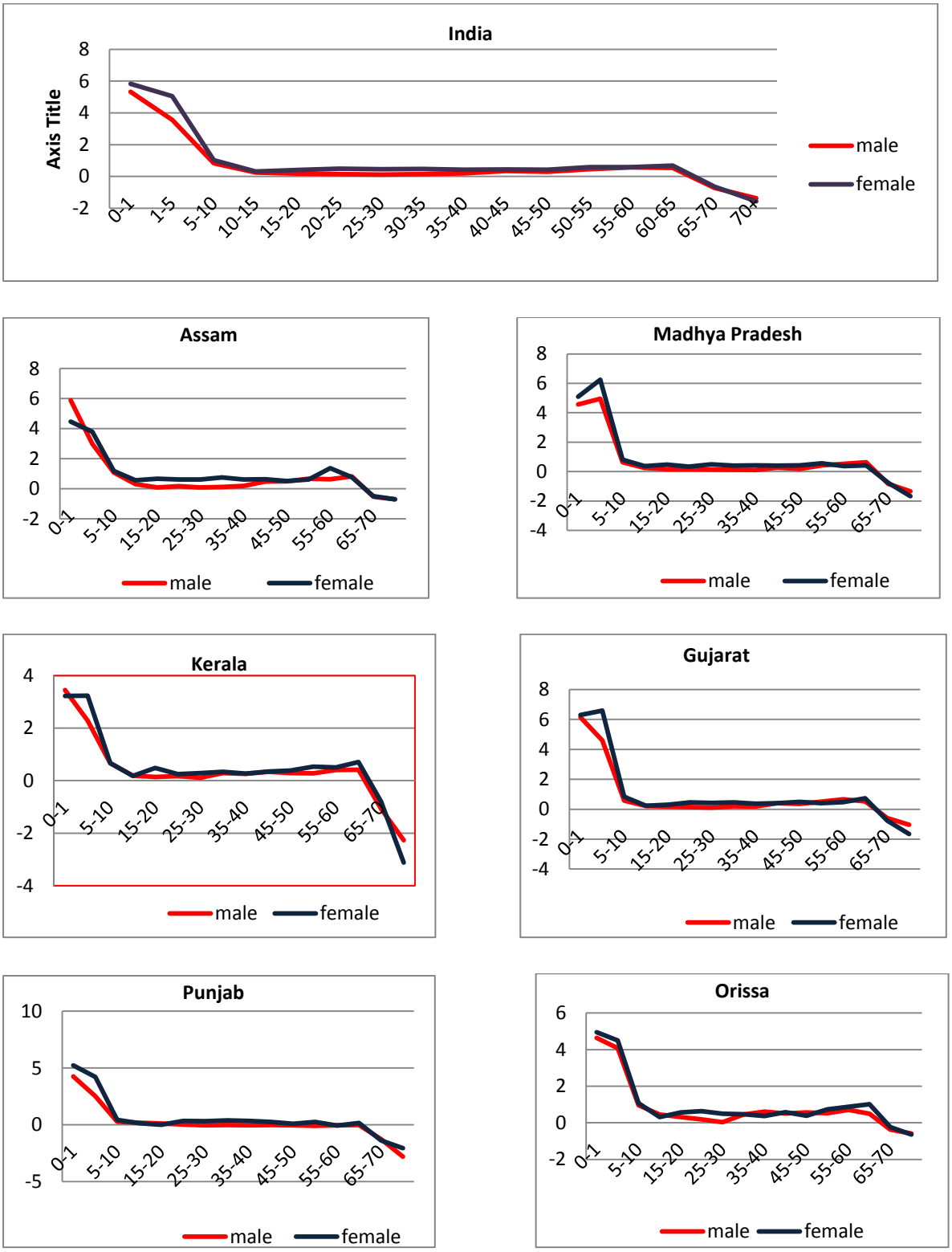

Figure 1: Decomposing the Gain LEAB by Age and Sex, for 1970-75 to 2006-10

Section 2: Rural / Urban difference

Tables 3 and 4 represent the decomposition of life expectancy at birth by rural and urban resident of India and its selected states. We have considered the age groups 0-1, 1-5, 10-15, 20-25, 35-40, 50-55, 60-65, and above 70. Here we found that the contribution of older ages (up to 65 ages) increased for both urban and rural residents of India and its selected states for the periods 1970 and 2010 regardless of sex.

Table 3: Decomposition of life expectancy at birth by rural residents in India and some of its selected states 1970 and 2010

States	Age / Sex	0-1	1-5	10-15	20-25	35-40	50-55	60-65	70+	Total Difference
India	Male	5.62	3.81	0.3	0.24	0.6	1.82	2.69	-1.16	23.03
	Female	5.91	5.31	0.38	0.7	0.77	1.64	2.85	-1.36	25.66
Assam	Male	5.72	2.97	0.38	0.26	0.38	2.05	3.47	-0.6	21.54
	Female	4.31	3.68	0.67	0.84	1.1	1.62	3.31	-0.77	26.54
Madhya Pradesh	Male	4.31	5.07	0.32	0.27	0.17	1.17	1.3	-1.32	15.18
	Female	4.85	6.2	0.45	0.43	0.72	1.65	2.4	-1.49	22.01
Kerala	Male	3.52	2.48	0.21	0.22	0.59	0.66	1.41	-2.27	13.27
	Female	3.4	3.52	0.2	0.4	0.5	1.41	2.86	-2.92	19.84
Gujarat	Male	5.97	4.56	0.21	0.13	0.1	1.17	1.67	-0.96	19.97
	Female	5.86	6.61	0.27	0.58	0.58	0.95	2.55	-1.49	24.03
Punjab	Male	4.32	2.51	0.22	-0.02	-0.14	-0.61	-0.28	-2.82	3.51
	Female	4.8	4.39	0.35	0.82	0.68	2.01	4.12	-0.55	28.75
Orissa	Male	4.45	4.01	0.53	0.03	1.24	1.39	1.97	-0.52	23.65
	Female	5.43	4.2	0.16	0.4	0.62	0.36	0.3	-1.97	11.66

We have seen from Table 3 that the rural resident of Punjab males contribute negatively from ages 20 towards the change in life expectancy at birth. In India we have found that the total gain in life expectancy at birth was higher among rural residents than among urban residents across ages and sexes during these above mentioned periods. Among rural residents (table 3), Orissa males and Punjab females achieved the highest gain in life expectancy at birth whereas among urban residents (table 4) Kerala males and Assam females achieved the highest gain in life expectancy at birth.

In urban resident except Kerala and Orissa, contribution towards the change in life expectancy at birth seems to be higher among females than among males and also in rural

resident female population achieved the higher contribution towards the gain in life expectancy at birth than males. We can say that females enjoyed longer life expectancy at birth than males in both the residents during the periods of 1970 and 2010.

Table 4: Decomposition of life expectancy at birth by urban residents of India and some of its selected states 1970 and 2010.

States	Age / Sex	0-1	1-5	10-15	20-25	35-40	50-55	60-65	70+	Total difference
India	Male	3.43	1.34	0.26	0.07	0.29	1.42	2.99	-2.4	14.08
	Female	3.43	2.7	0.21	0.44	0.72	1.57	2.81	-3	17.29
Assam	Male	4.45	2.34	0.02	-0.02	0.23	1.29	4.11	-1.79	18.22
	Female	3.14	2.93	0.16	0.46	1.31	2.94	3.66	-1.99	24.13
Madhya Pradesh	Male	3.23	2.14	0.05	-0.01	0.2	1.54	2.91	-1.64	15.48
	Female	3.6	3.57	0.11	0.28	0.8	1.02	2.24	-3.43	16.03
Kerala	Male	2.92	2.03	0.28	0.29	0.11	1.89	4	-2.23	21.56
	Female	2.11	2.68	0.22	0.12	0.48	2.02	3.65	-3.93	17.06
Gujarat	Male	4.78	4.09	0.27	0.2	0.87	2.2	3.98	-2.75	20.5
	Female	5.58	5.6	0.2	0.59	0.95	1.48	2.31	-3.77	21.7
Punjab	Male	2.87	2.61	0.08	0.043	-0.11	0.69	1.01	-3.16	8.2
	Female	2.91	3.71	0.08	0.48	0.56	1.55	1.23	-3.17	12.95
Orissa	Male	2.91	3.05	0.16	0.22	-0.03	2.96	3.21	-1.61	18.5
	Female	2.58	3.13	0.22	0.41	0.42	2.22	3.74	-1.79	17.23

The lower contribution in life expectancy for the male may be due to excess mortality resulting from occupational and lifestyle factors. The increase in the expectation of life at birth in females has also been faster than that in males in both rural and urban areas. From Tables 3 and 4 we can say that the total gain in life expectancy at birth in both the residents mainly resulted from the decline in infant mortality rates and under-5 mortality for both the sexes. In both the residents, change in life expectancy at birth above the ages 70 decreases, leading to a negative contribution from the period 1970.

CONCLUSIONS:

The study demonstrated the contribution of different age groups to the differences between the male and female life expectancy at birth, and their variation over time. Almost all the selected states of India have registered declining infant and under-5 mortality rates over the period 1970 to 2010 by place of residence and also by sex. The contributions of mortality reductions at adult ages towards the gain in life expectancy at birth were generally smaller. At older ages, the gain in life expectancy is much higher among females than that of males in

India and its selected states for both the residents during these periods. We also say that the health advantage for Indian females compared to males has been growing since the 1970s.

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