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No. 22-02

Seventy Years of Mortality in India
1950-2021

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Seventy Years of Mortality Transition in India: 1950-2021

Abstract

Mortality in India remains high by international standards. This paper analyses mortality transition in India during the 70 years since 1950 based on the annual estimates of age-specific probabilities of death prepared by the United Nations Population Division for the period 1950-2021. The analysis reveals that characterisation of mortality transition is sensitive to the summary index of mortality used. Mortality transition in India based on the geometric mean of the age-specific probabilities of death is found to be different from that based on the life expectancy at birth. The transition in mortality based on the geometric mean of age-specific probabilities of death accelerated during 2008-2019 but decelerated when based on the life expectancy at birth. The reason is that mortality transition in younger ages has been faster than mortality transition in older ages. The analysis also reveals that there were around 4.3 excess deaths associated with the COVID-19 epidemic in the country leading to a loss of around 3.7 years in the life expectancy at birth between 2019 and 2021.

Key Words

India, Mortality, Transition, Life Expectancy at Birth, Joinpoint Regression

Introduction

Mortality in India remains high by international standards. Latest estimates prepared by the United Nations Population Division suggest that the life expectancy at birth in India was 67.2 years in 2021 which implies that India ranks 178 among the 236 countries or territories for which estimates have been prepared by the United Nations Population Division (United Nations, 2022). The estimates prepared by the United Nations Population Division also reveal that the rank of India vis-à-vis 236 countries of the world in terms of life expectancy at birth has never been above 160 during the period 1950 through 2021. The rank of India has been the highest (163) across the 236 countries during the period 2015 through 2018 but the lowest (196) in 1966. Between 2018 and 2021, the rank of the country decreased rapidly from 163 in 2018 to 178 in 2021, an indication that mortality transition in India slowed down considerably during the period 2018-2021 compared to mortality transition in other countries of the world. Between 2018 and 2021, the life expectancy at birth in India decreased by almost 3.7 years, from 70.9 years in 2019 to 67.2 years in 2022 (United Nations, 2022). This decrease in the life expectancy at birth in India may be attributed to the increase in mortality due to the COVID19 pandemic. India is one of the only 23 countries of the 236 countries of the world where life expectancy at birth decreased by more than 3 years between 2018 and 2021.

According to the official life tables prepared by the Registrar General and Census Commissioner of India, based on the age-specific death rates derived from the sample registration system, the life expectancy at birth in the country was 70.0 years during the period 2016-2020 or around the year 2018 (Government of India, 2022). The life expectancy at birth

varies widely within the country, across states. Among the 22 states of the country for which life tables are prepared by the Registrar General and Census Commissioner of India, the life expectancy at birth is the highest in Delhi (75.8 years) but the lowest (65.1 years) in Chhattisgarh for the period 2016-2020 (Government of India, 2022). Besides Delhi, Kerala is the only other state where the life expectancy at birth is at least 75 years according to the official sample registration system of the country. On the other hand, in 9 states of the country, the life expectancy at birth is still less than 70 years.

Although, life expectancy at birth is universally used as a single summary measure of mortality, it has limitations in analysing mortality transition. A recent study has highlighted these limitations (Modig et al, 2020). The relationship between mortality and life expectancy is essentially reciprocal but the exact connection is complicated, and becomes important when life expectancy at birth is used for analysing mortality transition (Pollard, 1982). The change in the life expectancy at birth is a weighted function of the changes in mortality at individual ages plus the interaction effects of mortality changes (Pollard, 1982). The difference in life expectancies cannot be directly translated into the difference in the relative risk of mortality because both level of mortality and the distribution of mortality over age play a role (Keyfitz, 1977; Vaupel, 1986). The implicit age standardisation in the calculation of the life expectancy at birth is construed in such a way that it raises concern about the standardisation of age and, therefore, life expectancy at birth should not be used as the measure of choice to identify risk factors of death. (Modig et al, 2020). Moreover, the life expectancy at birth reflects the mortality experience of a hypothetical population and not the mortality experience of the actual population.

There are measures other than life expectancy at birth that have been suggested as the summary index of mortality but there is disagreement on the most appropriate index to analyse mortality transition. There are advantages and drawbacks of different indexes (Spiegelman, 1955; Kitagawa, 1964). Age standardised death rate is commonly used but choosing an appropriate standard population is quite difficult. Standardisation does not eliminate the effect of the differences between the age distribution of the two populations but only held it constant (Schoen, 1970). Standardisation also gives disproportionately higher weights to older ages (Yerushalmy, 1951).

Schoen (1970) has recommended that the geometric mean of the age-specific death rates, termed as ∇ , should be used as the summary index of the prevailing mortality. The rationale for opting the geometric mean to construct a summary index of prevailing mortality and important properties of the index ∇ have been discussed by Schoen (1970). However, to the best of our knowledge, geometric mean of either age-specific death rates (∇) or age-specific probabilities of death which we term as index Γ has not been used for analysing mortality transition. Unlike the life expectancy at birth which depicts mortality situation of a hypothetical population, the index ∇ or the index Γ summarises currently prevailing mortality situation.

In this paper, we analyse mortality transition in India since independence or, during 1950-2021 in terms of the trend in both life expectancy at birth and geometric mean of the age-specific probabilities of death (Γ). The paper also analyses the impact of COVID-19 pandemic on mortality transition and estimates excess deaths associated with the pandemic. The paper reveals that mortality transition in India since independence has not been consistent, and there has been considerable slowdown in mortality transition because the transition in mortality has been different in different age groups. The analysis is relevant from the health policy perspective as mortality transition reflects improvements in the quality of life of the people through improvements in their health and nutritional status (United Nations, 1973). The analysis of mortality transition also contributes to understanding the evolution of the health policy. Ideally, there should be congruence between mortality transition and evolution of health policy as health policy has a direct reflection on the level and the transition

in mortality. At the same time, evolution of the health policy may be viewed as a response to the health status of the population as reflected in through the transition in mortality. It is well known that with the improvement in the health status of the population, the disease profile changes, there is a change in the pattern of causes of death and a shift in the age pattern of mortality. Evolution of the health policy, therefore, is a response to the transition in mortality resulting from the improved health status of the people (Chaurasia, 2009).

The paper is organised as follows. The next section analyses long-term trend in life expectancy at birth and in the geometric mean of age-specific probabilities of death (Γ). The analysis reveals that mortality transition in the country has not been consistent as the trend in the life expectancy at birth and in geometric mean of age-specific probabilities of death (Γ) changed at least five times. Section three analyses transition in the age-specific probabilities of death (Γ) using a polishing approach that is similar to median polish frequently used in exploratory data analysis. The analysis reveals that transition in the probabilities of death in younger ages has been different from the transition in the probabilities of death in the older ages and the slow transition in the probabilities of death at older ages appears to be the reason behind slowing the improvement in the life expectancy at birth. The fourth section of the paper estimates the number of excess deaths in the country that may be associated with the COVID-19 pandemic while the last section of the paper discusses policy and programme implications of the findings of the analysis in the context of demographic and health transition.

Long-term Trend in Life Expectancy at Birth

The United Nations Population Division has provided, for the first time, annual estimates of annual age-specific probabilities of death for the 70 years period from 1950 through 2021 for 236 countries of the world including India. These estimates permit analysis of mortality transition in each country. Using these estimates, we have analysed the trend in the life expectancy at birth during 1950-2021 to identify periods of acceleration or deceleration or even reversal in mortality transition. We have first examined whether there was a change in the trend in the life expectancy at birth or not. If there is a change in the trend, then we have identified the time point(s) or year(s) when the trend had changed so that the period 1950-2021 can be divided into different sub-periods. We have analysed mortality transition in different sub-periods by estimating annual per cent change in both life expectancy at birth and geometric mean of the age-specific probabilities of death in each sub-period assuming that the trend is linear on the log scale in each sub-period. A comparison of annual per cent change in the life expectancy at birth and in the geometric mean of age-specific probabilities of death in different sub-periods helps in identifying periods of acceleration or deceleration or reversal in mortality transition.

The joinpoint regression analysis (Kim et al, 2000) has been used for the analysis of the long-term trend as the long-term trend in mortality may not be assumed to be uniform but varies over time. There are three steps in joinpoint regression analysis. The first is to test whether there has been a change in the trend. If there is no change in the trend, then the trend analysis can be carried out by fitting a straight line (on the log scale) and the annual per cent change may be estimated from the slope of the regression line. However, if the trend has changed, then the second step involves identifying time point(s) or joinpoint(s) when the trend has changed. Finally, the last step involves estimating the regression function with identified joinpoint(s). If there are k joinpoints, then the entire reference period is divided into $k+1$ time-segments or sub-periods and annual per cent change (APC) in the different time segments is different. The APC in a time-segment characterises mortality transition in that time-segment. The weighted average of APC in different time-segments gives average annual per cent change (AAPC) for the entire trend period with weights proportional to the length of different time-segments. AAPC describes the long-term trend in a better way when compared to the commonly used approach in which a single regression line (on the log scale) is fitted for the

entire trend period and the average annual per cent change is calculated from the slope of the regression equation (Clegg et al., 2009). This approach best summarises the trend that varies over time (Marriot, 2010).

The number of times the trend has changed can be determined statistically. There are many methods that have been proposed for the purpose. These include permutation method (Kim et al, 2000); Bayesian Information Criterion (BIC) (Kim et al, 2009); BIC3 method (Kim and Kim, 2016); and modified BIC (Zhang and Siegmund, 2007). Determining the number of times, the trend has changed statistically is driven by the data and not by any a-priori assumption.

Let y_i denotes the life expectancy at birth or the geometric mean of the age-specific probabilities of death for the year t_i such that $t_1 < t_2 < \dots < t_n$ and $k_1 < k_2 < \dots < k_j$ are the jointpoints or years when the trend has changed. Then the long-term trend in y_i can be modelled as

$$\ln(y_i) = \alpha + \beta_1 t_1 + \delta_1 u_1 + \dots + \delta_j u_j + \epsilon_i$$

where

$$u_j = \begin{cases} (t_j - k_j), & \text{if } t_j > k_j \\ 0 & \text{otherwise} \end{cases}$$

Actual calculations have been carried out using the Joinpoint Regression Program version 4.8.0.1 developed by the National Cancer Institute of the United States of America (National Institute of Health, 2020). The software requires, in advance, specification of minimum (0) and a maximum number of jointpoints (>0). The Program starts with the minimum number of jointpoints (0, which is a straight line on the Log scale) and tests whether more jointpoints are statistically significant and must be added to the model (up to the pre-specified maximum number of jointpoints). The grid search method has been used to identify jointpoints (Lerman, 1980) which allows a jointpoint to occur exactly at time t . A grid is created for all possible positions of the jointpoint(s) or of the combination of jointpoint(s) and then the model is fitted for each possible position of the jointpoint(s). Finally, that position of jointpoint(s) is selected which minimises the sum of squared errors (SSE) of the model. It may, however, be pointed out that even if the final selected model has k jointpoint(s), the slopes of all of the regression functions of the $k + 1$ time segment may not be statistically significant which means that the APC may not be statistically significantly different from zero.

Joinpoint regression analysis has been frequently used in analysing the trend in cause-specific mortality and morbidity (Akinyede and Soyemi, 2016; Chatenoud et al, 2015; Doucet et al., 2016; John and Hanke, 2015; Mogos et al, 2016; Missikpode et al, 2015; Puzo et al, 2016; Qiu et al, 2008; Rea et al, 2017; Tyczynski and Berkel, 2005). It has also been applied for estimating population parameters under changing population structure (Gillis & Edwards, 2019). Chaurasia (2020) has used it for analysing long-term trend in infant mortality rate in India. Jointpoint regression analysis is one of the methods recommended for trend analysis of health-related measures when the trend is not linear (Ingram et al, 2018). The method provides an easily interpretable characterisation of non-linear trend.

The characterisation of mortality transition in India during 1950-2021 in terms of the trend in life expectancy at birth is presented in table 1. The life expectancy at birth in India increased at an average annual per cent change (AAPC) of almost 0.69 per cent per year during 1950-2021, but the trend changed five times so that APC in different time-segments has been different. The life expectancy at birth decreased, instead increased, during 1963-66 and 2019-21, and the decrease was very marked during 2019-2021. The increase in the life expectancy at birth was relatively the most rapid during 1966-1969 but the increase slowed down subsequently and, for more than 30 years (1986-2019), life expectancy at birth in India

increased at around 0.68 per cent per year. The increase in the female life expectancy at birth has been more rapid than that in the male life expectancy at birth. Moreover, the trend in male life expectancy at birth changed five times but the trend in female life expectancy at birth changed four times.

An assessment of mortality transition in India from the international perspective can be made by comparing the increase in the life expectancy at birth in India with the model mortality improvement trajectories developed by the United Nations (2004). These trajectories are expressed as annual increment in life expectancy at birth at a given level of life expectancy at birth but are presented as quinquennial increments. This comparison suggests that improvement in male life expectancy at birth in India has always been somewhere between medium and slow mortality trajectories (figure 1) whereas improvement in female life expectancy at birth has been close to medium trajectory (Figure 2). Mortality transition in India has always been slower than the global average.

Table 1: Long-term trend in life expectancy at birth in India, 1950-2021.

Segment	Endpoint		APC/ AAPC	Confidence interval		‘t’	P> t
	Lower	Upper		Lower	Upper		
	Combined population						
1	1950	1963	0.827	0.791	0.864	45.099	< 0.001
2	1963	1966	-0.787	-1.478	-0.092	-2.267	0.027
3	1966	1969	1.897	1.187	2.611	5.390	< 0.001
4	1969	1986	1.049	1.022	1.076	78.034	< 0.001
5	1986	2019	0.683	0.673	0.692	144.174	< 0.001
6	2019	2021	-2.687	-3.364	-2.005	-7.813	< 0.001
	1950	2021	0.689	0.642	0.735	29.085	< 0.001
	Male population						
1	1950	1963	0.773	0.724	0.822	31.685	< 0.001
2	1963	1966	-0.857	-1.774	0.068	-1.857	0.069
3	1966	1969	2.121	1.177	3.074	4.528	< 0.001
4	1969	1986	0.881	0.845	0.917	49.354	< 0.001
5	1986	2019	0.644	0.631	0.657	102.290	< 0.001
6	2019	2021	-2.612	-3.512	-1.703	-5.709	< 0.001
	1950	2021	0.629	0.567	0.691	19.991	< 0.001
	Female population						
1	1950	1962	0.918	0.841	0.995	24.013	< 0.001
2	1962	1966	-0.151	-0.792	0.494	-0.470	0.640
3	1966	1986	1.255	1.216	1.294	65.424	< 0.001
4	1986	2019	0.717	0.700	0.735	82.034	< 0.001
5	2019	2021	-2.662	-3.908	-1.400	-4.192	< 0.001
	1950	2021	0.756	0.702	0.81	27.623	< 0.001

Source: Author

Remarks: APC – Annual per cent change

AAPC – Average annual per cent change

The impact of the slowdown in the improvement in the life expectancy at birth in India after 1986 appears to have been quite substantial. If the APC in the life expectancy at birth observed during the period 1969-86 would have been sustained during the period 1986-2019, the life expectancy at birth in India would have increased to more than 80 years by the year in 2019. This means that the slowdown in the life expectancy at birth in the country during the period 1986-2019 is estimated to have resulted in a loss of almost 9 years in the life expectancy at birth between 1986 and 2019. The loss in the male life expectancy at birth because of the slowdown is estimated to be almost 10 years whereas the loss in the female life expectancy at birth is estimated to have been around 8 years during the post 1986 period.

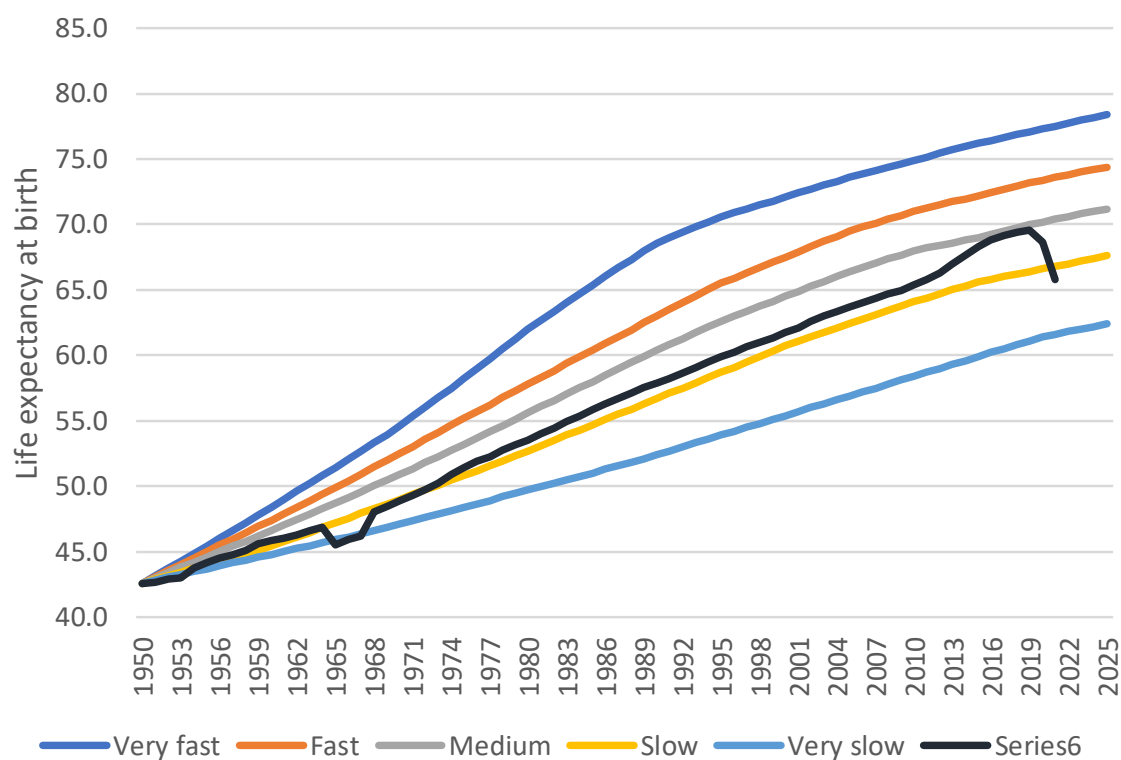


Figure 1: Improvement in male life expectancy at birth in India in relation to model mortality improvement schedules of United Nations

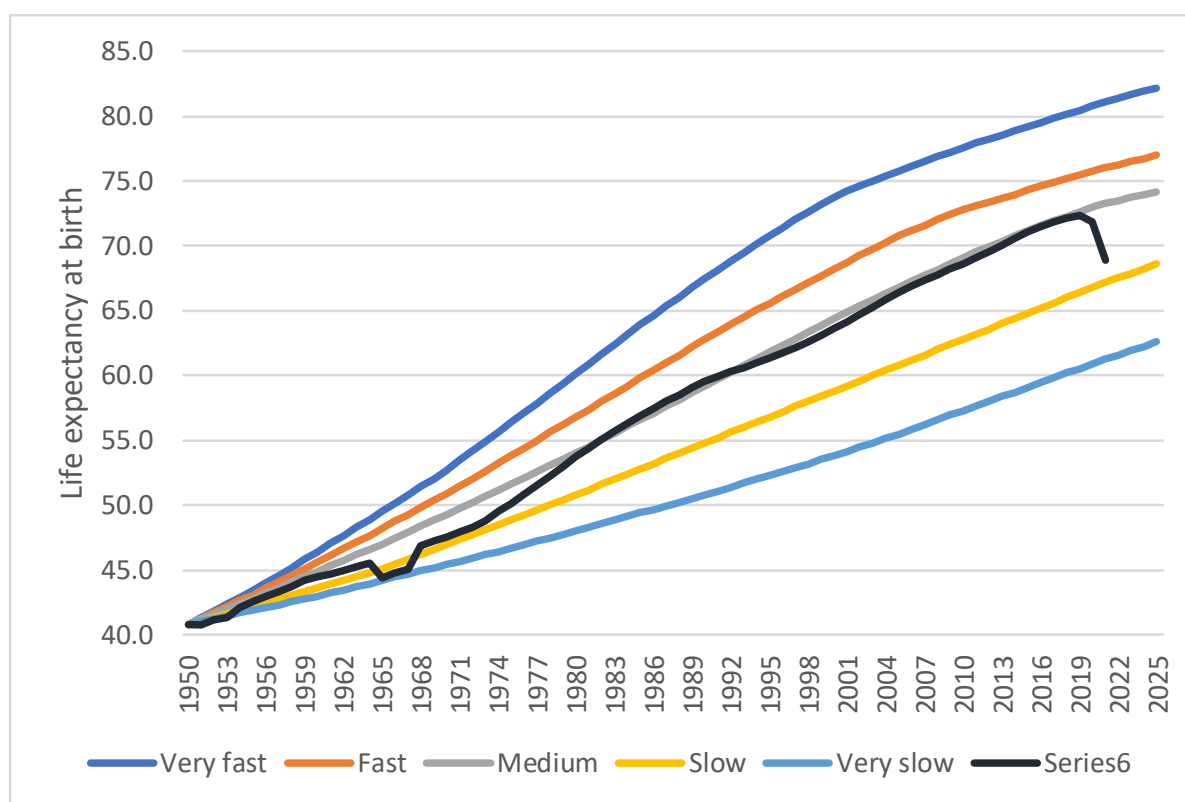


Figure 2: Improvement in female life expectancy at birth in India in relation to model mortality improvement schedules of United Nations

Table 2: Long-term trend in the geometric mean of age-specific probabilities of death (Γ) in India, 1950-2021.

Segment	Endpoint		APC/ AAPC	Confidence interval		‘t’	P> t
	Lower	Upper		Lower	Upper		
	Combined population						
1	1950	1962	-0.881	-1.021	-0.740	-12.505	< 0.001
2	1962	1965	0.859	-1.531	3.306	0.715	0.478
3	1965	1984	-1.985	-2.06	-1.909	-52.153	< 0.001
4	1984	2008	-1.528	-1.580	-1.476	-57.898	< 0.001
5	2008	2019	-3.026	-3.207	-2.845	-32.987	< 0.001
6	2019	2021	9.981	7.375	12.65	7.951	< 0.001
	1950	2021	-1.369	-1.495	-1.243	-21.194	< 0.001
	Male population						
1	1950	1963	-0.759	-0.869	-0.648	-13.72	< 0.001
2	1963	1966	0.987	-1.135	3.153	0.927	0.358
3	1966	1972	-2.807	-3.267	-2.345	-12.020	< 0.001
4	1972	2010	-1.365	-1.387	-1.342	-119.134	< 0.001
5	2010	2019	-3.331	-3.555	-3.107	-29.310	< 0.001
6	2019	2021	10.552	8.229	12.924	9.469	< 0.001
	1950	2021	-1.213	-1.33	-1.096	-20.206	< 0.001
	Female population						
1	1950	1963	-0.889	-0.997	-0.782	-16.528	< 0.001
2	1963	1966	1.101	-0.968	3.212	1.061	0.293
3	1966	1988	-2.317	-2.368	-2.266	-89.202	< 0.001
4	1988	2000	-1.405	-1.543	-1.268	-20.353	< 0.001
5	2000	2019	-2.650	-2.714	-2.585	-81.056	< 0.001
6	2019	2021	9.321	7.085	11.604	8.641	< 0.001
	1950	2021	-1.539	-1.646	-1.431	-27.741	< 0.001

Source: Author

Remarks: APC – Annual per cent change

AAPC – Average annual per cent change

The analysis of the long-term trend in the geometric mean of the age-specific probabilities of death (Γ), however, depicts a different picture of mortality transition in the country, especially, during the period 2008-2019 (Table 2). The trend in Γ suggests that mortality transition in India has accelerated during the period 2008-2019 whereas the trend in the life expectancy at birth suggests that mortality transition has slowed down during this period. On the other hand, the trend in the life expectancy at birth suggests that mortality increased more rapidly in females compared to males during the period 2019-2021, the period of COVID-19 pandemic but the trend in the Γ suggests that mortality increased more rapidly in males as compared to that in females during the period of pandemic. Tables 1 and 2 suggest that two different summary measures of mortality depict different perspective of mortality transition in the country. The possible reason is that the life expectancy at birth gives higher weight to the probability of death in older ages whereas the index Γ , or the geometric mean of age-specific probabilities of death gives equal weight to the probability of death in all ages. This means that if transition in the probability of death in older ages is slower than the transition in the probability of death in younger ages, mortality transition depicted by the trend in the life expectancy at birth will be slower than the mortality transition depicted by the trend in the index Γ which treats transition in the probability of death in different ages equally. On the other hand, if the transition in the probability of death in older ages is faster than the transition in the probability of death in the younger ages, the trend in the life expectancy of birth will depict more rapid transition in mortality compared to the transition in mortality depicted by the index Γ . The mortality transition depicted by the trend in the life expectancy at birth will be the same as mortality transition depicted by the index Γ only when transition in the probability of death is the same in all ages. The life expectancy at birth depicts the mortality

experience of a synthetic or hypothetical population whereas the index Γ depicts the mortality experience of the real population. Therefore, it is the trend in the index Γ or the geometric mean of the age-specific probabilities of death that depicts the true transition in mortality. This means that mortality transition in India has actually accelerated, not decelerated, during the period 2008-2019. Similarly, the increase in mortality during the pandemic period 2019-2021 has been more rapid in males as compared to the increase in mortality in females. Table 2 also indicates that, in the recent past, mortality transition has been faster in males as compared to the mortality transition in females.

The foregoing analysis suggests that the transition in the probability of death in the country has not been the same for all ages and it appears that transition in the probability of death in the younger ages has been faster than the transition in the probability of death in the older ages. In order to examine this hypothesis further, we have analysed the long-term trend in the age-specific probabilities of death during the period 1950-2021 under the assumption that the long-term trend in the age-specific probabilities of death has also not been linear on the Log scale during the period and the trend in the age-specific probabilities of death may have been changed at least once. The joinpoint regression analysis has therefore been carried out to analyse the long-term trend.

Transition in Age-specific Probabilities of Death

Let q_{ij} denotes the probability of death in the year i and age j , and $q_{..}$ denotes the measure of central tendency of q_{ij} over all i and all j . Then q_{ij} can be written as

$$q_{ij} = q_{..} \times \frac{q_{ij}}{q_{..}} \quad (1)$$

If q_i denotes the measure of central tendency for each i for all j and q_j denotes the measure of central tendency for each j for all i , then equation (1) can be expanded as

$$q_{ij} = q_{..} \times \frac{q_i}{q_{..}} \times \frac{q_j}{q_{..}} \times r_{ij} \quad (2)$$

where

$$r_{ij} = \frac{q_{ij} \times q_{..}}{q_i \times q_j} \quad (3)$$

Equation (3) suggests that q_{ij} can be decomposed into four components: 1) an overall average ($q_{..}$) across all i and all j ; 2) a row effect (q_i) which is common to all j of a given i and reflects how row average differs from the overall average; 3) a column effect (q_j) which is common to all i of a given j and reflects how column average differs from the overall average; and 4) a residual term (r_{ij}) which is independent of the grand overall average, row effect and column effect.

Equation (2) can be fitted by applying the polishing technique proposed by Tukey (1977) by choosing an appropriate polishing function. The polishing algorithm successively sweeps the polishing function out of rows (divides row values by the polishing function for the row), then sweeps the polishing function out of columns (divides column values by the polishing function for the column), then rows, then columns, and so on and accumulates them in rows, columns, and in 'all' registers to obtain q_i , q_j and $q_{..}$ and leaves behind the table of residuals (r_{ij}). When the entire variation in q_{ij} across all i and all j is explained by overall average $q_{..}$, row average q_i and column average q_j , all residuals (r_{ij}) are equal to 1. If this is not the case, then r_{ij} reflects that part of q_{ij} which is not explained by $q_{..}$, q_i , and q_j . Equation (2) suggests that transition in q_{ij} should be examined after separating the overall average, the row average which is common to all ages of a given row or year in the present case and the column average which is common to all rows of a given column or age, or in terms of residuals r_{ij} .

We have used Γ or the geometric mean of the age-specific probabilities of death as the polishing function because the age distribution of the probability of death is skewed. Results of the polishing exercise for the period 1950-2019 are presented in table 3 for the total population and in tables 4 and 5 for males and females respectively. The period 2020-2021 has not been included in the analysis because mortality levels during this period are biased by the COVID-19 pandemic. The overall average or $q_{..}$ for all i and all j is estimated to be 0.085 for the total population, 0.087 for male population and 0.083 for female population. The polishing exercise also suggests that, in the year 1950, q_i or the geometric mean of the age specific probabilities of death was almost 59 per cent higher than $q_{..}$ but, in the year 2019, q_i was almost 49 per cent lower than $q_{..}$. The age pattern of average mortality across the years or the variation in q_j by age is depicted in the figure 3 which shows that age pattern of average mortality in males is different from that in females.

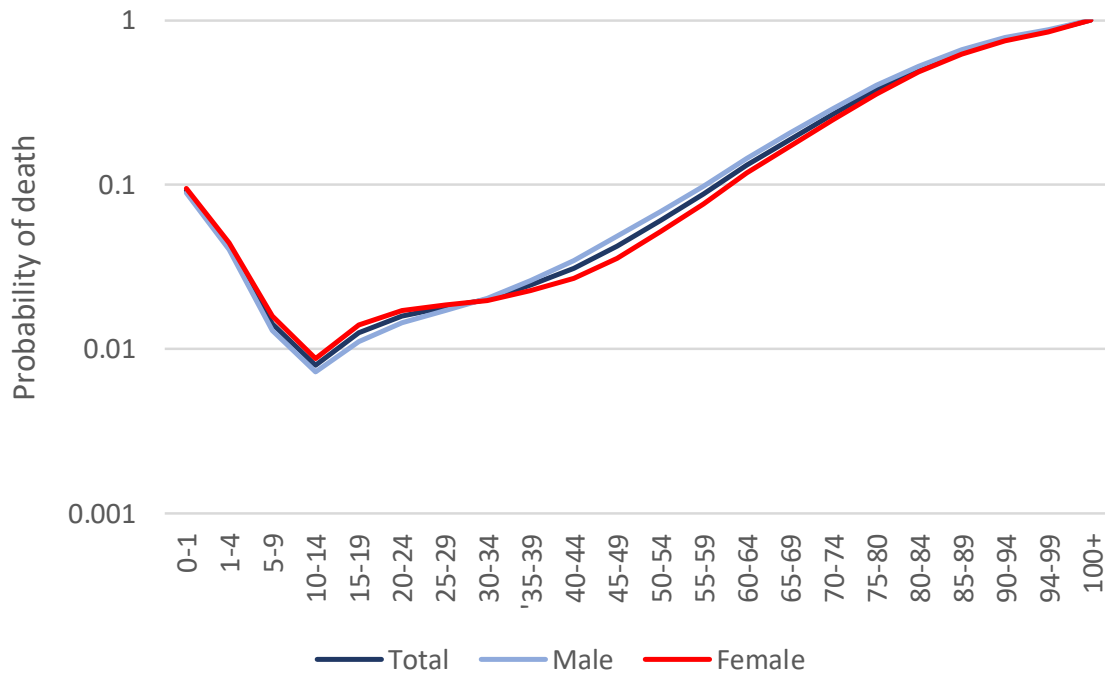


Figure 3: The age-pattern of average mortality during 1950-2019 in India

The residuals presented in tables 3, 4 and 5 are multipliers and their geometric mean=1. They decide whether probability of death in a particular year and age is higher or lower than the underlying probability of death determined by $q_{..}$, q_i , and q_j . If $r_{ij} > 1$, then the observed q_{ij} is higher than the underlying probability of death. If $r_{ij} < 1$, then the observed q_{ij} is lower than the underlying probability of death. Finally, if $r_{ij} = 1$, then the observed q_{ij} is the same as the underlying probability of death.

For example, the underlying probability of death in the age group 0-1 year determined by $q_{..}$, q_{2019} , and q_{0-1} was 0.0475 in 2019, but $r_{2019,0-1}$ was 0.5873 which means that $q_{2019,0-1}$ was more than 41 per cent lower than the underlying probability of death determined by $q_{..}$, q_{2019} , and q_{0-1} . Similarly, the underlying probability of death in the age-group 70-74 years determined by q_{1950} , and q_{70-74} was 0.4277, but $r_{1950,70-74}$ was 0.7685 so that $q_{1950,70-74}$ was about 23 per cent lower than the underlying probability of death determined by $q_{..}$, q_{1950} , and q_{70-74} . The underlying probability of death in the age group 80-84 years in 2015 determined by $q_{..}$, q_{2015} , and q_{80-84} was 0.212, but $r_{2015,80-84}$ was 1.3969 so that $q_{2015,80-84}$ was almost 40 per cent higher than the underlying probability of death determined by $q_{..}$, q_{2015} , and q_{80-84} .

Table 3: Results of the polishing of age-specific probabilities of death (q_{ij}) with geometric mean as the polishing function – total population.

Year	Geometric mean $q_{\cdot}$	Age																					
		0-1	1-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	
		q_j																					
		0.0854	0.0923	0.0423	0.0144	0.0080	0.0125	0.0159	0.0179	0.0202	0.0248	0.0309	0.0426	0.0609	0.0882	0.1315	0.1894	0.2697	0.3780	0.5049	0.6416	0.7676	0.8623
$q_{\cdot}$	r_{ij} (Multipliers)																						
2019	0.0440	0.587	0.305	0.421	0.612	0.653	0.664	0.744	0.844	0.981	1.083	1.097	1.254	1.360	1.273	1.324	1.389	1.422	1.459	1.526	1.616	1.714	
2018	0.0444	0.607	0.319	0.432	0.613	0.650	0.658	0.734	0.833	0.966	1.066	1.102	1.266	1.363	1.274	1.312	1.383	1.418	1.448	1.516	1.604	1.702	
2017	0.0451	0.632	0.341	0.451	0.618	0.652	0.660	0.730	0.825	0.953	1.048	1.104	1.269	1.352	1.266	1.293	1.368	1.404	1.428	1.495	1.580	1.676	
2016	0.0461	0.654	0.361	0.469	0.621	0.661	0.673	0.734	0.821	0.945	1.036	1.097	1.255	1.327	1.251	1.278	1.352	1.388	1.414	1.480	1.561	1.653	
2015	0.0476	0.670	0.379	0.489	0.625	0.676	0.697	0.748	0.822	0.943	1.031	1.079	1.222	1.288	1.229	1.270	1.334	1.370	1.405	1.469	1.546	1.629	
2014	0.0494	0.682	0.396	0.511	0.631	0.696	0.729	0.767	0.827	0.945	1.029	1.057	1.178	1.240	1.204	1.266	1.316	1.351	1.399	1.462	1.533	1.606	
2013	0.0514	0.692	0.415	0.535	0.640	0.720	0.765	0.788	0.835	0.946	1.023	1.035	1.130	1.188	1.178	1.260	1.299	1.330	1.393	1.454	1.518	1.580	
2012	0.0533	0.702	0.431	0.560	0.649	0.743	0.799	0.807	0.846	0.946	1.012	1.020	1.086	1.137	1.156	1.253	1.285	1.312	1.388	1.448	1.506	1.556	
2011	0.0551	0.716	0.451	0.589	0.664	0.765	0.825	0.820	0.859	0.941	0.988	1.014	1.050	1.090	1.139	1.240	1.273	1.294	1.380	1.439	1.489	1.530	
2010	0.0565	0.733	0.474	0.622	0.684	0.783	0.841	0.826	0.874	0.930	0.952	1.019	1.024	1.049	1.128	1.219	1.264	1.278	1.367	1.426	1.471	1.505	
2009	0.0578	0.754	0.500	0.658	0.707	0.798	0.850	0.828	0.890	0.917	0.914	1.030	1.006	1.015	1.121	1.196	1.255	1.261	1.351	1.410	1.450	1.481	
2008	0.0588	0.775	0.527	0.693	0.731	0.811	0.853	0.827	0.904	0.905	0.878	1.042	0.994	0.991	1.117	1.173	1.246	1.245	1.332	1.390	1.426	1.455	
2007	0.0598	0.796	0.555	0.727	0.756	0.823	0.855	0.829	0.916	0.896	0.852	1.048	0.988	0.977	1.113	1.153	1.233	1.227	1.309	1.365	1.398	1.427	
2006	0.0609	0.816	0.582	0.757	0.780	0.835	0.859	0.835	0.924	0.892	0.841	1.044	0.986	0.976	1.107	1.139	1.217	1.207	1.282	1.333	1.366	1.395	
2005	0.0621	0.833	0.608	0.782	0.801	0.848	0.867	0.849	0.928	0.896	0.847	1.027	0.988	0.987	1.099	1.133	1.195	1.185	1.252	1.295	1.328	1.359	
2004	0.0635	0.847	0.634	0.807	0.823	0.863	0.878	0.867	0.929	0.903	0.865	1.002	0.991	1.006	1.087	1.131	1.169	1.160	1.220	1.253	1.287	1.318	
2003	0.0646	0.863	0.658	0.821	0.829	0.872	0.888	0.885	0.924	0.911	0.889	0.975	0.998	1.032	1.080	1.136	1.149	1.142	1.193	1.218	1.252	1.284	
2002	0.0659	0.878	0.684	0.842	0.837	0.880	0.898	0.902	0.918	0.916	0.913	0.952	1.006	1.056	1.073	1.140	1.129	1.124	1.167	1.183	1.218	1.251	
2001	0.0674	0.891	0.710	0.869	0.850	0.887	0.909	0.918	0.912	0.917	0.932	0.936	1.011	1.072	1.069	1.139	1.113	1.109	1.142	1.153	1.186	1.217	
2000	0.0684	0.910	0.738	0.895	0.840	0.880	0.909	0.922	0.902	0.908	0.937	0.932	1.018	1.080	1.073	1.141	1.110	1.106	1.130	1.139	1.168	1.198	
1999	0.0695	0.927	0.769	0.933	0.843	0.875	0.907	0.922	0.893	0.893	0.932	0.935	1.021	1.076	1.079	1.136	1.109	1.104	1.119	1.128	1.152	1.180	
1998	0.0704	0.945	0.798	0.967	0.838	0.867	0.903	0.916	0.883	0.875	0.920	0.943	1.023	1.069	1.089	1.132	1.114	1.107	1.113	1.124	1.142	1.168	
1997	0.0713	0.963	0.828	1.001	0.837	0.861	0.896	0.907	0.874	0.857	0.905	0.953	1.023	1.059	1.098	1.127	1.120	1.112	1.111	1.123	1.136	1.158	
1996	0.0723	0.980	0.857	1.034	0.844	0.859	0.889	0.895	0.865	0.841	0.891	0.959	1.021	1.051	1.104	1.121	1.124	1.115	1.110	1.122	1.130	1.149	
1995	0.0732	0.994	0.884	1.059	0.856	0.864	0.881	0.882	0.856	0.829	0.879	0.960	1.017	1.047	1.107	1.117	1.125	1.118	1.110	1.121	1.126	1.141	
1994	0.0742	1.007	0.911	1.080	0.873	0.874	0.874	0.869	0.849	0.822	0.871	0.955	1.011	1.047	1.106	1.113	1.123	1.119	1.111	1.119	1.121	1.133	
1993	0.0753	1.018	0.935	1.100	0.897	0.889	0.869	0.858	0.843	0.818	0.867	0.948	1.003	1.048	1.102	1.109	1.118	1.116	1.109	1.114	1.114	1.123	
1992	0.0762	1.030	0.959	1.118	0.912	0.902	0.864	0.846	0.837	0.817	0.863	0.940	0.996	1.051	1.098	1.107	1.113	1.114	1.109	1.110	1.108	1.114	
1991	0.0773	1.040	0.983	1.145	0.931	0.915	0.862	0.837	0.832	0.817	0.862	0.934	0.990	1.051	1.093	1.104	1.106	1.109	1.105	1.103	1.099	1.103	
1990	0.0784	1.052	1.010	1.180	0.944	0.923	0.861	0.830	0.828	0.818	0.863	0.930	0.985	1.048	1.090	1.100	1.100	1.103	1.098	1.094	1.089	1.091	
1989	0.0795	1.064	1.037	1.223	0.951	0.927	0.862	0.824	0.825	0.820	0.864	0.930	0.982	1.042	1.089	1.097	1.094	1.095	1.089	1.084	1.076	1.078	
1988	0.0807	1.075	1.065	1.270	0.956	0.929	0.867	0.824	0.825	0.824	0.868	0.933	0.981	1.034	1.087	1.091	1.087	1.086	1.076	1.070	1.061	1.061	
1987	0.0820	1.086	1.092	1.315	0.960	0.930	0.874	0.827	0.826	0.829	0.874	0.937	0.981	1.027	1.086	1.085	1.079	1.075	1.062	1.055	1.045	1.044	
1986	0.0834	1.094	1.117	1.350	0.966	0.933	0.883	0.834	0.830	0.836	0.882	0.943	0.983	1.022	1.085	1.078	1.069	1.063	1.047	1.039	1.027	1.026	
1985	0.0850	1.099	1.140	1.371	0.976	0.937	0.895	0.847	0.837	0.845	0.893	0.948	0.987	1.021	1.083	1.069	1.056	1.051	1.031	1.022	1.009	1.007	
1984	0.0867	1.103	1.160	1.377	0.991	0.946	0.909	0.864	0.847	0.857	0.907	0.953	0.991	1.023	1.078	1.057	1.040	1.036	1.014	1.003	0.990	0.987	
1983	0.0885	1.106	1.181	1.372	1.010	0.958	0.926	0.886	0.860	0.870	0.921	0.957	0.995	1.027	1.072	1.044	1.022	1.020	0.995	0.983	0.970	0.966	
1982	0.0904	1.110	1.203	1.363	1.034	0.975	0.947	0.912	0.876	0.886	0.937	0.961	0.998	1.031	1.062	1.028	1.002	1.002	0.975	0.961	0.948	0.945	

Year	Geometric mean q_i	Age																					
		0-1	1-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	
		q_j																					
		0.0854	0.0923	0.0423	0.0144	0.0080	0.0125	0.0159	0.0179	0.0202	0.0248	0.0309	0.0426	0.0609	0.0882	0.1315	0.1894	0.2697	0.3780	0.5049	0.6416	0.7676	0.8623
q_i	r_{ij} (Multipliers)																						
1981	0.0923	1.116	1.229	1.353	1.060	0.998	0.973	0.942	0.895	0.904	0.953	0.965	0.999	1.031	1.049	1.009	0.979	0.981	0.953	0.937	0.925	0.923	
1980	0.0941	1.124	1.260	1.347	1.089	1.028	1.006	0.975	0.919	0.923	0.969	0.970	0.998	1.026	1.032	0.988	0.955	0.956	0.928	0.911	0.900	0.899	
1979	0.0958	1.135	1.294	1.346	1.119	1.063	1.045	1.011	0.946	0.945	0.985	0.975	0.995	1.017	1.012	0.964	0.931	0.930	0.902	0.883	0.874	0.876	
1978	0.0975	1.146	1.330	1.350	1.149	1.101	1.086	1.046	0.975	0.968	0.999	0.980	0.991	1.004	0.992	0.941	0.908	0.905	0.876	0.857	0.849	0.853	
1977	0.0992	1.155	1.364	1.359	1.180	1.135	1.122	1.078	1.004	0.990	1.011	0.986	0.986	0.991	0.972	0.921	0.888	0.882	0.852	0.833	0.826	0.832	
1976	0.1008	1.164	1.393	1.354	1.190	1.158	1.149	1.103	1.029	1.009	1.021	0.991	0.984	0.981	0.958	0.908	0.877	0.868	0.837	0.818	0.812	0.818	
1975	0.1028	1.168	1.417	1.353	1.198	1.167	1.160	1.116	1.049	1.026	1.027	0.996	0.983	0.974	0.948	0.901	0.872	0.860	0.829	0.810	0.803	0.807	
1974	0.1049	1.167	1.434	1.347	1.194	1.157	1.152	1.117	1.062	1.037	1.031	1.000	0.984	0.972	0.946	0.903	0.877	0.862	0.830	0.811	0.802	0.803	
1973	0.1077	1.163	1.453	1.345	1.196	1.140	1.135	1.111	1.073	1.047	1.034	1.004	0.987	0.972	0.945	0.908	0.884	0.867	0.833	0.814	0.802	0.798	
1972	0.1099	1.157	1.459	1.325	1.185	1.120	1.116	1.105	1.083	1.057	1.037	1.007	0.989	0.972	0.945	0.915	0.894	0.875	0.843	0.824	0.808	0.798	
1971	0.1119	1.148	1.456	1.292	1.174	1.109	1.106	1.107	1.098	1.072	1.045	1.010	0.989	0.969	0.942	0.917	0.900	0.882	0.851	0.833	0.815	0.799	
1970	0.1138	1.142	1.459	1.248	1.173	1.111	1.109	1.121	1.120	1.093	1.057	1.013	0.986	0.960	0.932	0.912	0.898	0.883	0.856	0.838	0.818	0.798	
1969	0.1158	1.136	1.461	1.199	1.193	1.137	1.134	1.153	1.154	1.124	1.077	1.016	0.977	0.943	0.911	0.894	0.884	0.875	0.853	0.836	0.817	0.793	
1968	0.1177	1.131	1.465	1.149	1.227	1.180	1.176	1.202	1.196	1.163	1.101	1.020	0.964	0.920	0.884	0.868	0.862	0.859	0.843	0.829	0.811	0.785	
1967	0.1246	1.128	1.543	1.214	1.384	1.242	1.224	1.250	1.238	1.202	1.129	1.025	0.951	0.896	0.852	0.833	0.826	0.824	0.807	0.791	0.772	0.745	
1966	0.1261	1.126	1.550	1.177	1.419	1.291	1.272	1.299	1.277	1.236	1.151	1.028	0.940	0.876	0.829	0.809	0.804	0.807	0.796	0.781	0.765	0.738	
1965	0.1275	1.126	1.561	1.157	1.450	1.330	1.309	1.337	1.306	1.262	1.168	1.030	0.932	0.863	0.813	0.792	0.788	0.794	0.785	0.772	0.757	0.731	
1964	0.1230	1.128	1.501	1.034	1.346	1.341	1.331	1.362	1.324	1.277	1.175	1.029	0.928	0.858	0.809	0.790	0.790	0.802	0.803	0.794	0.782	0.756	
1963	0.1236	1.134	1.519	1.043	1.345	1.337	1.327	1.358	1.321	1.274	1.173	1.029	0.930	0.862	0.812	0.793	0.791	0.802	0.800	0.791	0.777	0.752	
1962	0.1244	1.140	1.540	1.064	1.340	1.323	1.313	1.344	1.311	1.265	1.168	1.030	0.935	0.869	0.820	0.801	0.797	0.804	0.799	0.787	0.772	0.747	
1961	0.1250	1.148	1.564	1.085	1.330	1.304	1.295	1.325	1.297	1.253	1.160	1.030	0.941	0.878	0.829	0.810	0.804	0.807	0.799	0.785	0.768	0.743	
1960	0.1252	1.160	1.589	1.097	1.314	1.285	1.278	1.307	1.283	1.242	1.152	1.029	0.945	0.885	0.838	0.818	0.811	0.812	0.800	0.785	0.767	0.741	
1959	0.1261	1.167	1.612	1.105	1.317	1.285	1.277	1.307	1.284	1.242	1.153	1.030	0.946	0.886	0.838	0.818	0.810	0.810	0.797	0.781	0.762	0.736	
1958	0.1278	1.168	1.634	1.110	1.338	1.302	1.294	1.323	1.299	1.255	1.162	1.033	0.945	0.881	0.832	0.810	0.801	0.801	0.788	0.772	0.753	0.726	
1957	0.1290	1.174	1.656	1.101	1.353	1.320	1.311	1.340	1.313	1.268	1.170	1.034	0.942	0.875	0.824	0.801	0.793	0.794	0.782	0.766	0.747	0.721	
1956	0.1297	1.184	1.682	1.087	1.360	1.334	1.324	1.354	1.324	1.278	1.176	1.034	0.938	0.868	0.817	0.793	0.786	0.789	0.779	0.762	0.744	0.717	
1955	0.1308	1.191	1.706	1.083	1.373	1.347	1.336	1.367	1.335	1.288	1.182	1.035	0.936	0.864	0.812	0.787	0.780	0.783	0.773	0.757	0.738	0.712	
1954	0.1323	1.195	1.728	1.092	1.386	1.353	1.342	1.373	1.341	1.293	1.186	1.038	0.937	0.864	0.811	0.786	0.777	0.778	0.767	0.750	0.731	0.704	
1953	0.1355	1.187	1.749	1.131	1.422	1.364	1.351	1.381	1.352	1.302	1.193	1.045	0.941	0.868	0.812	0.785	0.772	0.769	0.754	0.735	0.714	0.688	
1952	0.1354	1.203	1.779	1.132	1.407	1.347	1.335	1.366	1.340	1.292	1.186	1.042	0.943	0.873	0.818	0.791	0.778	0.773	0.757	0.736	0.715	0.688	
1951	0.1360	1.216	1.812	1.129	1.407	1.345	1.334	1.365	1.338	1.291	1.185	1.042	0.943	0.873	0.818	0.791	0.777	0.771	0.755	0.734	0.712	0.685	
1950	0.1355	1.228	1.834	1.092	1.410	1.355	1.344	1.376	1.346	1.298	1.188	1.040	0.938	0.866	0.810	0.784	0.772	0.769	0.755	0.736	0.715	0.688	

Source: Author

Table 4: Results of the polishing of age-specific probabilities of death (q_{ij}) with geometric mean as the polishing function – male population.

Year	Geometric mean $q_{..}$	Age																				
		0-1	1-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
		q_j																				
		0.0871	0.0898	0.0404	0.0129	0.0073	0.0111	0.0146	0.0172	0.0204	0.0264	0.0344	0.0485	0.0687	0.0989	0.1449	0.2060	0.2891	0.4005	0.5269	0.6605	0.7822
q_i	r_{ij} (Multipliers)																					
2019	0.0476	0.562	0.296	0.411	0.657	0.712	0.744	0.843	0.965	1.077	1.134	1.104	1.171	1.325	1.245	1.263	1.346	1.354	1.381	1.426	1.502	1.590
2018	0.0480	0.583	0.313	0.427	0.665	0.714	0.742	0.834	0.954	1.056	1.111	1.106	1.171	1.318	1.238	1.243	1.336	1.349	1.370	1.414	1.489	1.576
2017	0.0486	0.607	0.333	0.447	0.672	0.717	0.744	0.826	0.944	1.036	1.089	1.108	1.170	1.305	1.225	1.220	1.322	1.342	1.356	1.401	1.474	1.559
2016	0.0497	0.625	0.350	0.469	0.677	0.722	0.756	0.829	0.939	1.028	1.079	1.105	1.165	1.287	1.208	1.205	1.307	1.330	1.343	1.386	1.456	1.537
2015	0.0514	0.636	0.365	0.493	0.680	0.730	0.778	0.841	0.939	1.032	1.081	1.096	1.153	1.261	1.189	1.200	1.291	1.312	1.328	1.369	1.433	1.506
2014	0.0535	0.643	0.378	0.520	0.682	0.742	0.806	0.861	0.945	1.043	1.090	1.083	1.137	1.230	1.169	1.201	1.275	1.291	1.315	1.352	1.409	1.473
2013	0.0559	0.648	0.392	0.550	0.687	0.756	0.836	0.883	0.954	1.055	1.096	1.071	1.117	1.193	1.150	1.203	1.259	1.269	1.301	1.335	1.384	1.437
2012	0.0582	0.654	0.404	0.580	0.691	0.770	0.863	0.901	0.965	1.063	1.093	1.063	1.098	1.153	1.134	1.206	1.246	1.250	1.291	1.323	1.364	1.408
2011	0.0602	0.664	0.420	0.613	0.700	0.784	0.881	0.913	0.977	1.061	1.073	1.062	1.080	1.109	1.122	1.201	1.234	1.234	1.283	1.314	1.348	1.385
2010	0.0618	0.679	0.440	0.648	0.714	0.799	0.889	0.915	0.990	1.048	1.036	1.069	1.065	1.065	1.113	1.189	1.224	1.222	1.277	1.309	1.338	1.368
2009	0.0630	0.699	0.465	0.686	0.730	0.811	0.889	0.911	1.001	1.029	0.991	1.079	1.052	1.025	1.106	1.173	1.214	1.212	1.271	1.305	1.330	1.355
2008	0.0640	0.720	0.491	0.721	0.750	0.823	0.884	0.905	1.011	1.008	0.948	1.088	1.043	0.993	1.101	1.156	1.203	1.202	1.263	1.299	1.321	1.343
2007	0.0648	0.743	0.518	0.753	0.772	0.834	0.878	0.901	1.018	0.992	0.915	1.091	1.036	0.973	1.097	1.141	1.189	1.191	1.251	1.287	1.307	1.328
2006	0.0657	0.766	0.547	0.781	0.796	0.842	0.873	0.902	1.022	0.982	0.899	1.083	1.032	0.968	1.093	1.132	1.172	1.176	1.233	1.266	1.286	1.307
2005	0.0666	0.784	0.573	0.800	0.823	0.850	0.874	0.912	1.022	0.982	0.902	1.063	1.031	0.980	1.089	1.129	1.151	1.157	1.208	1.234	1.257	1.280
2004	0.0678	0.804	0.602	0.821	0.853	0.858	0.877	0.926	1.017	0.987	0.917	1.034	1.031	1.003	1.084	1.129	1.128	1.135	1.178	1.196	1.220	1.245
2003	0.0686	0.819	0.623	0.825	0.867	0.860	0.880	0.942	1.010	0.994	0.942	1.007	1.036	1.035	1.084	1.136	1.111	1.118	1.153	1.163	1.189	1.215
2002	0.0697	0.838	0.650	0.838	0.882	0.861	0.882	0.955	0.999	0.998	0.967	0.981	1.040	1.065	1.084	1.141	1.096	1.103	1.129	1.131	1.158	1.185
2001	0.0709	0.856	0.681	0.859	0.895	0.864	0.885	0.964	0.986	0.995	0.984	0.963	1.042	1.085	1.084	1.143	1.085	1.091	1.108	1.105	1.130	1.156
2000	0.0716	0.879	0.713	0.877	0.881	0.856	0.876	0.960	0.968	0.979	0.988	0.957	1.045	1.095	1.092	1.146	1.088	1.091	1.101	1.097	1.119	1.144
1999	0.0725	0.901	0.748	0.911	0.874	0.852	0.867	0.948	0.947	0.955	0.980	0.958	1.045	1.092	1.099	1.144	1.095	1.094	1.098	1.095	1.111	1.134
1998	0.0731	0.919	0.776	0.934	0.857	0.847	0.856	0.932	0.928	0.929	0.965	0.966	1.046	1.085	1.110	1.143	1.109	1.105	1.104	1.103	1.113	1.133
1997	0.0739	0.940	0.808	0.963	0.844	0.842	0.845	0.911	0.907	0.900	0.946	0.975	1.044	1.075	1.118	1.140	1.124	1.117	1.112	1.113	1.117	1.133
1996	0.0748	0.960	0.841	0.996	0.841	0.841	0.835	0.888	0.887	0.873	0.924	0.981	1.040	1.065	1.123	1.137	1.136	1.128	1.121	1.123	1.122	1.134
1995	0.0757	0.976	0.871	1.023	0.849	0.843	0.826	0.864	0.867	0.851	0.905	0.983	1.035	1.061	1.123	1.135	1.146	1.137	1.131	1.132	1.126	1.133
1994	0.0769	0.991	0.900	1.049	0.866	0.848	0.821	0.842	0.850	0.834	0.889	0.979	1.029	1.061	1.120	1.133	1.151	1.144	1.139	1.138	1.129	1.130
1993	0.0782	1.003	0.927	1.075	0.894	0.857	0.819	0.824	0.835	0.822	0.877	0.972	1.021	1.063	1.113	1.131	1.151	1.146	1.144	1.139	1.126	1.123
1992	0.0793	1.015	0.953	1.098	0.914	0.863	0.820	0.809	0.823	0.815	0.868	0.965	1.015	1.065	1.107	1.130	1.151	1.147	1.147	1.138	1.124	1.116
1991	0.0805	1.027	0.981	1.126	0.937	0.871	0.822	0.798	0.813	0.811	0.863	0.958	1.008	1.064	1.100	1.128	1.147	1.145	1.145	1.133	1.116	1.105
1990	0.0815	1.041	1.009	1.161	0.952	0.875	0.823	0.788	0.805	0.811	0.861	0.954	1.003	1.060	1.095	1.125	1.143	1.140	1.139	1.125	1.106	1.093
1989	0.0824	1.056	1.040	1.200	0.961	0.877	0.824	0.781	0.799	0.813	0.863	0.953	1.000	1.053	1.093	1.122	1.137	1.133	1.129	1.114	1.094	1.081
1988	0.0835	1.070	1.072	1.241	0.966	0.881	0.831	0.783	0.799	0.819	0.869	0.953	0.997	1.043	1.091	1.116	1.128	1.122	1.113	1.099	1.077	1.064
1987	0.0845	1.084	1.102	1.279	0.970	0.884	0.837	0.787	0.800	0.827	0.877	0.956	0.997	1.034	1.090	1.109	1.117	1.109	1.096	1.082	1.059	1.047
1986	0.0857	1.098	1.134	1.315	0.979	0.890	0.843	0.794	0.803	0.836	0.888	0.960	0.998	1.028	1.088	1.099	1.102	1.093	1.076	1.062	1.038	1.029
1985	0.0871	1.108	1.163	1.340	0.996	0.900	0.851	0.804	0.810	0.845	0.899	0.965	1.000	1.027	1.086	1.087	1.083	1.074	1.054	1.040	1.017	1.009
1984	0.0886	1.116	1.188	1.353	1.021	0.915	0.860	0.818	0.820	0.855	0.912	0.970	1.004	1.029	1.083	1.073	1.062	1.054	1.032	1.017	0.996	0.988
1983	0.0901	1.123	1.215	1.360	1.054	0.933	0.870	0.835	0.831	0.865	0.925	0.975	1.009	1.034	1.078	1.056	1.038	1.033	1.010	0.994	0.974	0.967
1982	0.0917	1.131	1.242	1.362	1.090	0.957	0.885	0.855	0.845	0.876	0.937	0.979	1.011	1.038	1.070	1.037	1.012	1.010	0.987	0.969	0.952	0.947

Year	Geometric mean $q_{\cdot}$	Age																					
		0-1	1-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	
		q_j																					
	0.0871	0.0898	0.0404	0.0129	0.0073	0.0111	0.0146	0.0172	0.0204	0.0264	0.0344	0.0485	0.0687	0.0989	0.1449	0.2060	0.2891	0.4005	0.5269	0.6605	0.7822	0.8705	
q_i	r_{ij} (Multipliers)																						
1981	0.0931	1.142	1.274	1.364	1.126	0.985	0.906	0.878	0.861	0.886	0.947	0.981	1.011	1.038	1.059	1.016	0.986	0.986	0.963	0.944	0.930	0.927	
1980	0.0944	1.158	1.313	1.368	1.161	1.019	0.934	0.906	0.879	0.898	0.956	0.980	1.006	1.032	1.043	0.993	0.959	0.961	0.937	0.919	0.908	0.907	
1979	0.0954	1.178	1.359	1.377	1.189	1.057	0.970	0.937	0.899	0.910	0.961	0.977	0.997	1.020	1.024	0.969	0.934	0.935	0.912	0.894	0.885	0.888	
1978	0.0963	1.200	1.410	1.389	1.212	1.096	1.010	0.970	0.920	0.922	0.965	0.972	0.987	1.004	1.004	0.946	0.912	0.912	0.888	0.871	0.864	0.870	
1977	0.0973	1.221	1.461	1.407	1.233	1.131	1.048	0.999	0.939	0.933	0.967	0.967	0.976	0.988	0.984	0.926	0.893	0.891	0.867	0.851	0.846	0.854	
1976	0.0982	1.238	1.502	1.406	1.230	1.153	1.079	1.023	0.957	0.944	0.971	0.965	0.969	0.975	0.969	0.914	0.882	0.878	0.852	0.838	0.834	0.843	
1975	0.0996	1.248	1.535	1.410	1.225	1.162	1.097	1.038	0.969	0.954	0.975	0.965	0.966	0.966	0.959	0.907	0.877	0.870	0.843	0.830	0.826	0.836	
1974	0.1013	1.251	1.557	1.409	1.209	1.153	1.098	1.042	0.976	0.962	0.981	0.968	0.969	0.964	0.955	0.909	0.881	0.870	0.842	0.830	0.825	0.832	
1973	0.1040	1.246	1.578	1.415	1.205	1.138	1.091	1.041	0.983	0.971	0.989	0.974	0.974	0.964	0.953	0.912	0.886	0.871	0.841	0.830	0.824	0.827	
1972	0.1062	1.239	1.584	1.398	1.184	1.120	1.082	1.040	0.989	0.981	0.997	0.981	0.980	0.965	0.951	0.918	0.893	0.876	0.847	0.837	0.829	0.826	
1971	0.1082	1.229	1.580	1.364	1.162	1.112	1.084	1.048	1.003	0.996	1.008	0.986	0.983	0.962	0.945	0.919	0.897	0.880	0.852	0.844	0.835	0.827	
1970	0.1104	1.221	1.581	1.315	1.149	1.118	1.101	1.069	1.026	1.017	1.021	0.990	0.979	0.953	0.933	0.912	0.894	0.879	0.855	0.848	0.838	0.825	
1969	0.1125	1.212	1.581	1.258	1.156	1.150	1.143	1.111	1.062	1.046	1.036	0.989	0.967	0.934	0.909	0.893	0.880	0.870	0.853	0.848	0.837	0.820	
1968	0.1146	1.204	1.582	1.195	1.175	1.203	1.206	1.171	1.110	1.081	1.052	0.986	0.950	0.910	0.880	0.866	0.858	0.855	0.845	0.843	0.833	0.812	
1967	0.1223	1.193	1.655	1.270	1.344	1.280	1.277	1.234	1.164	1.120	1.070	0.984	0.929	0.880	0.842	0.827	0.820	0.819	0.808	0.802	0.791	0.768	
1966	0.1239	1.189	1.659	1.222	1.367	1.336	1.342	1.293	1.209	1.151	1.083	0.980	0.913	0.859	0.818	0.803	0.799	0.804	0.800	0.796	0.786	0.761	
1965	0.1254	1.188	1.668	1.196	1.390	1.380	1.392	1.338	1.243	1.174	1.093	0.978	0.902	0.845	0.801	0.786	0.784	0.792	0.792	0.788	0.779	0.754	
1964	0.1203	1.194	1.610	1.049	1.256	1.387	1.419	1.364	1.259	1.185	1.096	0.975	0.898	0.842	0.800	0.788	0.789	0.804	0.813	0.816	0.809	0.785	
1963	0.1210	1.199	1.629	1.060	1.257	1.381	1.412	1.359	1.257	1.184	1.097	0.977	0.901	0.845	0.803	0.790	0.790	0.803	0.810	0.811	0.804	0.780	
1962	0.1217	1.206	1.650	1.085	1.256	1.364	1.391	1.342	1.245	1.178	1.097	0.981	0.908	0.853	0.811	0.797	0.794	0.803	0.807	0.806	0.798	0.774	
1961	0.1223	1.214	1.674	1.113	1.251	1.341	1.364	1.319	1.230	1.168	1.095	0.985	0.917	0.862	0.821	0.806	0.801	0.805	0.805	0.803	0.793	0.769	
1960	0.1224	1.227	1.701	1.129	1.239	1.319	1.340	1.298	1.215	1.159	1.092	0.987	0.923	0.869	0.828	0.813	0.807	0.809	0.805	0.802	0.791	0.768	
1959	0.1233	1.234	1.725	1.139	1.243	1.318	1.339	1.298	1.216	1.160	1.094	0.989	0.925	0.870	0.829	0.813	0.805	0.807	0.801	0.797	0.785	0.762	
1958	0.1251	1.234	1.746	1.144	1.261	1.337	1.359	1.318	1.233	1.173	1.101	0.991	0.922	0.865	0.823	0.805	0.797	0.797	0.792	0.788	0.775	0.752	
1957	0.1262	1.239	1.769	1.132	1.271	1.357	1.382	1.339	1.250	1.186	1.107	0.991	0.917	0.858	0.814	0.796	0.788	0.791	0.787	0.783	0.770	0.746	
1956	0.1268	1.251	1.798	1.114	1.272	1.372	1.401	1.356	1.262	1.194	1.110	0.989	0.911	0.850	0.806	0.788	0.782	0.787	0.785	0.781	0.769	0.744	
1955	0.1278	1.260	1.826	1.108	1.282	1.385	1.415	1.369	1.272	1.201	1.113	0.988	0.908	0.846	0.800	0.782	0.776	0.781	0.781	0.776	0.764	0.739	
1954	0.1290	1.266	1.853	1.116	1.293	1.389	1.419	1.373	1.277	1.206	1.117	0.990	0.909	0.846	0.799	0.780	0.773	0.777	0.775	0.770	0.757	0.732	
1953	0.1319	1.261	1.879	1.158	1.330	1.398	1.423	1.380	1.287	1.215	1.126	0.998	0.915	0.849	0.801	0.779	0.766	0.765	0.760	0.753	0.740	0.715	
1952	0.1315	1.281	1.916	1.159	1.317	1.375	1.401	1.359	1.269	1.204	1.121	0.997	0.918	0.853	0.806	0.784	0.772	0.770	0.763	0.756	0.742	0.717	
1951	0.1319	1.295	1.953	1.156	1.317	1.372	1.399	1.357	1.267	1.202	1.120	0.997	0.918	0.853	0.805	0.784	0.771	0.769	0.761	0.753	0.739	0.715	
1950	0.1316	1.306	1.972	1.116	1.315	1.385	1.418	1.372	1.277	1.208	1.120	0.993	0.911	0.846	0.797	0.777	0.767	0.768	0.763	0.756	0.742	0.717	

Table 5: Results of the polishing of age-specific probabilities of death (q_{ij}) with geometric mean as the polishing function – female population.

Year	Geometric mean $q_{\cdot}$	Age																				
		0-1	1-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
		q_j																				
		0.0829	0.0953	0.0444	0.0159	0.0088	0.0140	0.0172	0.0185	0.0197	0.0226	0.0268	0.0358	0.0522	0.0767	0.1175	0.1726	0.2507	0.3570	0.4857	0.6263	0.7567
$q_{\cdot}$	r_{ij} (Multipliers)																					
2019	0.0398	0.619	0.318	0.438	0.578	0.609	0.592	0.644	0.705	0.852	1.002	1.076	1.373	1.400	1.303	1.399	1.447	1.514	1.562	1.649	1.749	1.855
2018	0.0404	0.646	0.340	0.455	0.580	0.607	0.588	0.639	0.698	0.846	0.991	1.081	1.391	1.401	1.305	1.386	1.432	1.495	1.533	1.618	1.714	1.819
2017	0.0411	0.673	0.364	0.472	0.581	0.609	0.590	0.639	0.692	0.842	0.979	1.083	1.400	1.391	1.303	1.371	1.415	1.472	1.505	1.589	1.679	1.782
2016	0.0420	0.700	0.388	0.488	0.584	0.621	0.605	0.646	0.689	0.835	0.965	1.069	1.373	1.358	1.290	1.359	1.398	1.452	1.490	1.573	1.659	1.757
2015	0.0432	0.722	0.412	0.506	0.590	0.644	0.634	0.660	0.690	0.826	0.948	1.038	1.307	1.299	1.265	1.350	1.381	1.436	1.488	1.572	1.654	1.743
2014	0.0445	0.742	0.435	0.524	0.600	0.675	0.672	0.680	0.694	0.814	0.928	1.000	1.221	1.228	1.234	1.341	1.365	1.423	1.495	1.579	1.657	1.734
2013	0.0461	0.762	0.461	0.546	0.615	0.711	0.716	0.701	0.702	0.801	0.905	0.963	1.130	1.154	1.200	1.329	1.350	1.409	1.501	1.586	1.658	1.721
2012	0.0475	0.780	0.484	0.567	0.633	0.747	0.761	0.723	0.714	0.790	0.878	0.935	1.048	1.089	1.173	1.314	1.339	1.395	1.506	1.591	1.657	1.706
2011	0.0489	0.799	0.511	0.595	0.656	0.778	0.798	0.740	0.730	0.779	0.848	0.921	0.983	1.036	1.152	1.290	1.329	1.376	1.499	1.584	1.643	1.682
2010	0.0503	0.821	0.540	0.628	0.683	0.801	0.823	0.750	0.748	0.772	0.816	0.922	0.938	0.999	1.139	1.259	1.321	1.353	1.480	1.564	1.617	1.650
2009	0.0515	0.841	0.567	0.662	0.713	0.818	0.840	0.758	0.769	0.768	0.787	0.933	0.910	0.976	1.133	1.225	1.313	1.327	1.451	1.535	1.583	1.613
2008	0.0527	0.861	0.596	0.698	0.742	0.830	0.851	0.763	0.790	0.767	0.764	0.948	0.894	0.964	1.129	1.192	1.302	1.299	1.416	1.498	1.542	1.573
2007	0.0539	0.880	0.624	0.734	0.769	0.842	0.860	0.771	0.809	0.770	0.749	0.960	0.888	0.962	1.125	1.164	1.288	1.269	1.377	1.455	1.497	1.529
2006	0.0552	0.895	0.649	0.765	0.791	0.855	0.871	0.782	0.825	0.777	0.748	0.963	0.890	0.968	1.117	1.145	1.269	1.241	1.339	1.410	1.450	1.483
2005	0.0567	0.909	0.676	0.796	0.806	0.873	0.886	0.800	0.834	0.786	0.760	0.952	0.897	0.980	1.102	1.134	1.244	1.212	1.301	1.362	1.402	1.435
2004	0.0583	0.917	0.698	0.825	0.821	0.894	0.905	0.823	0.841	0.799	0.783	0.935	0.909	0.997	1.084	1.129	1.214	1.184	1.264	1.313	1.352	1.385
2003	0.0598	0.933	0.725	0.850	0.817	0.908	0.921	0.845	0.841	0.808	0.807	0.913	0.923	1.016	1.068	1.132	1.188	1.163	1.235	1.272	1.311	1.343
2002	0.0614	0.942	0.748	0.877	0.819	0.920	0.939	0.868	0.842	0.818	0.833	0.895	0.939	1.033	1.054	1.134	1.163	1.143	1.205	1.233	1.271	1.303
2001	0.0632	0.948	0.770	0.911	0.831	0.930	0.956	0.891	0.846	0.827	0.855	0.885	0.955	1.043	1.044	1.131	1.139	1.124	1.176	1.197	1.232	1.261
2000	0.0644	0.962	0.795	0.942	0.825	0.923	0.962	0.904	0.845	0.826	0.863	0.884	0.969	1.048	1.045	1.129	1.127	1.116	1.157	1.175	1.207	1.235
1999	0.0658	0.971	0.820	0.984	0.835	0.914	0.967	0.915	0.849	0.825	0.864	0.892	0.979	1.045	1.049	1.120	1.116	1.108	1.136	1.154	1.181	1.207
1998	0.0670	0.989	0.852	1.026	0.841	0.902	0.966	0.919	0.851	0.819	0.856	0.903	0.986	1.038	1.057	1.110	1.109	1.103	1.120	1.140	1.161	1.186
1997	0.0681	1.002	0.878	1.063	0.850	0.893	0.962	0.921	0.854	0.813	0.848	0.914	0.990	1.030	1.066	1.100	1.104	1.099	1.107	1.128	1.145	1.169
1996	0.0692	1.014	0.903	1.095	0.865	0.890	0.956	0.920	0.858	0.811	0.842	0.922	0.990	1.023	1.073	1.089	1.097	1.095	1.096	1.118	1.132	1.154
1995	0.0701	1.026	0.928	1.119	0.880	0.897	0.948	0.917	0.861	0.811	0.840	0.923	0.986	1.019	1.077	1.080	1.088	1.090	1.087	1.108	1.121	1.141
1994	0.0710	1.037	0.952	1.136	0.897	0.911	0.939	0.912	0.864	0.815	0.843	0.918	0.979	1.019	1.077	1.072	1.077	1.084	1.080	1.099	1.111	1.130
1993	0.0719	1.046	0.973	1.152	0.919	0.933	0.931	0.908	0.868	0.822	0.850	0.909	0.971	1.019	1.074	1.064	1.064	1.075	1.072	1.087	1.099	1.117
1992	0.0727	1.058	0.996	1.167	0.931	0.951	0.922	0.900	0.869	0.828	0.856	0.901	0.963	1.020	1.071	1.060	1.054	1.069	1.067	1.079	1.091	1.107
1991	0.0736	1.067	1.019	1.192	0.946	0.970	0.916	0.894	0.870	0.834	0.863	0.895	0.957	1.020	1.068	1.055	1.044	1.060	1.059	1.068	1.080	1.094
1990	0.0747	1.077	1.044	1.230	0.956	0.981	0.913	0.888	0.871	0.837	0.867	0.893	0.953	1.017	1.067	1.051	1.036	1.052	1.049	1.056	1.067	1.080
1989	0.0759	1.087	1.070	1.278	0.963	0.987	0.914	0.884	0.871	0.839	0.870	0.897	0.952	1.013	1.066	1.048	1.031	1.043	1.038	1.044	1.052	1.064
1988	0.0773	1.095	1.095	1.331	0.968	0.988	0.918	0.882	0.872	0.842	0.872	0.905	0.954	1.007	1.067	1.044	1.026	1.035	1.026	1.031	1.035	1.046
1987	0.0788	1.102	1.120	1.381	0.971	0.985	0.925	0.885	0.875	0.845	0.876	0.913	0.957	1.002	1.067	1.041	1.022	1.026	1.013	1.017	1.018	1.027
1986	0.0804	1.105	1.138	1.416	0.974	0.983	0.936	0.892	0.879	0.851	0.883	0.923	0.961	1.000	1.066	1.037	1.017	1.018	1.001	1.003	1.001	1.009
1985	0.0822	1.106	1.155	1.433	0.978	0.983	0.951	0.907	0.887	0.861	0.894	0.930	0.965	0.999	1.064	1.032	1.011	1.010	0.989	0.989	0.984	0.989
1984	0.0841	1.105	1.170	1.431	0.983	0.985	0.970	0.928	0.898	0.875	0.909	0.935	0.968	1.002	1.059	1.026	1.003	1.001	0.977	0.973	0.967	0.969
1983	0.0862	1.103	1.186	1.415	0.991	0.991	0.992	0.955	0.912	0.894	0.928	0.939	0.972	1.005	1.052	1.018	0.991	0.990	0.964	0.956	0.948	0.948
1982	0.0884	1.103	1.204	1.394	1.002	1.002	1.018	0.987	0.930	0.916	0.950	0.944	0.975	1.008	1.041	1.006	0.977	0.976	0.947	0.936	0.927	0.925

Year	Geometric mean $q_{\cdot}$	Age																				
		0-1	1-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	-55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
		q_j																				
		0.0829	0.0953	0.0444	0.0159	0.0088	0.0140	0.0172	0.0185	0.0197	0.0226	0.0268	0.0358	0.0522	0.0767	0.1175	0.1726	0.2507	0.3570	0.4857	0.6263	0.7567
	q_i	r_{ij} (Multipliers)																				
1981	0.0907	1.103	1.224	1.372	1.019	1.019	1.049	1.022	0.953	0.943	0.975	0.952	0.979	1.010	1.027	0.991	0.959	0.958	0.927	0.912	0.902	0.900
1980	0.0931	1.104	1.246	1.354	1.043	1.044	1.084	1.060	0.981	0.973	1.003	0.965	0.984	1.008	1.010	0.972	0.938	0.935	0.903	0.885	0.875	0.873
1979	0.0955	1.106	1.269	1.343	1.073	1.076	1.124	1.099	1.015	1.007	1.031	0.982	0.990	1.004	0.991	0.950	0.914	0.909	0.875	0.854	0.845	0.845
1978	0.0980	1.106	1.291	1.337	1.108	1.110	1.162	1.135	1.051	1.042	1.059	1.003	0.996	0.998	0.971	0.928	0.891	0.882	0.847	0.825	0.816	0.817
1977	0.1007	1.104	1.310	1.336	1.146	1.142	1.195	1.167	1.088	1.077	1.085	1.024	1.003	0.992	0.954	0.908	0.871	0.858	0.821	0.799	0.789	0.792
1976	0.1030	1.105	1.329	1.326	1.168	1.163	1.216	1.189	1.121	1.105	1.103	1.042	1.008	0.987	0.941	0.895	0.860	0.843	0.806	0.782	0.772	0.774
1975	0.1056	1.103	1.346	1.320	1.185	1.170	1.220	1.198	1.148	1.128	1.113	1.054	1.011	0.984	0.934	0.889	0.855	0.836	0.798	0.773	0.761	0.761
1974	0.1080	1.099	1.359	1.309	1.189	1.160	1.204	1.194	1.167	1.143	1.115	1.060	1.012	0.983	0.933	0.891	0.861	0.840	0.801	0.775	0.760	0.756
1973	0.1109	1.095	1.377	1.302	1.197	1.141	1.178	1.183	1.181	1.154	1.112	1.060	1.011	0.983	0.935	0.897	0.871	0.848	0.809	0.781	0.762	0.752
1972	0.1132	1.090	1.383	1.279	1.193	1.120	1.149	1.172	1.193	1.165	1.108	1.059	1.009	0.983	0.938	0.905	0.884	0.860	0.822	0.792	0.769	0.753
1971	0.1151	1.082	1.381	1.247	1.191	1.107	1.129	1.169	1.211	1.181	1.112	1.059	1.006	0.979	0.937	0.909	0.891	0.870	0.833	0.803	0.776	0.754
1970	0.1168	1.079	1.385	1.206	1.200	1.106	1.120	1.176	1.232	1.204	1.123	1.060	1.001	0.970	0.929	0.904	0.891	0.873	0.840	0.809	0.780	0.753
1969	0.1186	1.075	1.389	1.165	1.232	1.127	1.130	1.200	1.263	1.238	1.148	1.068	0.994	0.954	0.910	0.887	0.877	0.864	0.836	0.806	0.778	0.749
1968	0.1203	1.071	1.395	1.124	1.278	1.164	1.155	1.238	1.301	1.282	1.183	1.079	0.987	0.933	0.885	0.862	0.854	0.847	0.824	0.797	0.771	0.742
1967	0.1267	1.074	1.478	1.182	1.427	1.213	1.184	1.274	1.332	1.321	1.221	1.093	0.983	0.913	0.857	0.830	0.820	0.813	0.789	0.761	0.736	0.707
1966	0.1280	1.074	1.488	1.153	1.474	1.256	1.216	1.314	1.366	1.360	1.256	1.104	0.977	0.895	0.835	0.807	0.797	0.795	0.774	0.749	0.727	0.700
1965	0.1293	1.075	1.500	1.137	1.512	1.289	1.243	1.345	1.391	1.390	1.281	1.112	0.974	0.883	0.820	0.790	0.780	0.781	0.762	0.738	0.718	0.692
1964	0.1253	1.074	1.438	1.033	1.431	1.302	1.261	1.370	1.413	1.410	1.294	1.114	0.970	0.876	0.813	0.785	0.779	0.786	0.775	0.756	0.738	0.713
1963	0.1260	1.080	1.456	1.040	1.428	1.298	1.259	1.367	1.410	1.406	1.289	1.112	0.971	0.879	0.817	0.789	0.781	0.786	0.773	0.753	0.734	0.709
1962	0.1268	1.086	1.477	1.057	1.416	1.286	1.251	1.355	1.401	1.394	1.277	1.109	0.973	0.886	0.826	0.796	0.788	0.790	0.774	0.751	0.731	0.705
1961	0.1274	1.095	1.501	1.074	1.400	1.270	1.240	1.340	1.389	1.378	1.262	1.104	0.976	0.895	0.836	0.806	0.796	0.795	0.775	0.750	0.728	0.701
1960	0.1276	1.106	1.524	1.082	1.380	1.254	1.228	1.326	1.378	1.364	1.248	1.099	0.977	0.902	0.844	0.815	0.804	0.800	0.778	0.752	0.728	0.700
1959	0.1285	1.113	1.548	1.089	1.381	1.254	1.228	1.326	1.378	1.364	1.247	1.098	0.978	0.903	0.845	0.815	0.803	0.798	0.776	0.748	0.723	0.696
1958	0.1302	1.115	1.570	1.094	1.404	1.269	1.241	1.340	1.391	1.376	1.257	1.103	0.978	0.899	0.839	0.808	0.795	0.790	0.767	0.739	0.715	0.687
1957	0.1314	1.121	1.593	1.087	1.422	1.284	1.253	1.354	1.404	1.390	1.269	1.107	0.976	0.893	0.831	0.799	0.786	0.782	0.761	0.733	0.709	0.681
1956	0.1321	1.130	1.616	1.074	1.433	1.297	1.263	1.367	1.414	1.403	1.280	1.110	0.974	0.888	0.825	0.792	0.779	0.776	0.756	0.729	0.705	0.678
1955	0.1335	1.135	1.637	1.071	1.449	1.309	1.273	1.379	1.425	1.415	1.289	1.113	0.974	0.884	0.820	0.787	0.772	0.770	0.750	0.722	0.699	0.671
1954	0.1352	1.137	1.655	1.079	1.461	1.316	1.281	1.387	1.432	1.421	1.293	1.116	0.976	0.886	0.821	0.786	0.770	0.765	0.744	0.715	0.691	0.663
1953	0.1387	1.127	1.672	1.116	1.494	1.328	1.294	1.397	1.445	1.429	1.299	1.122	0.980	0.889	0.822	0.785	0.767	0.758	0.733	0.702	0.676	0.647
1952	0.1390	1.140	1.697	1.115	1.476	1.315	1.285	1.387	1.436	1.419	1.289	1.118	0.981	0.895	0.830	0.792	0.773	0.761	0.735	0.702	0.675	0.646
1951	0.1397	1.151	1.727	1.113	1.476	1.314	1.284	1.386	1.436	1.418	1.287	1.117	0.981	0.896	0.831	0.792	0.773	0.760	0.733	0.700	0.672	0.643
1950	0.1390	1.164	1.749	1.078	1.481	1.322	1.288	1.394	1.441	1.427	1.295	1.118	0.978	0.889	0.824	0.785	0.767	0.757	0.732	0.701	0.675	0.646

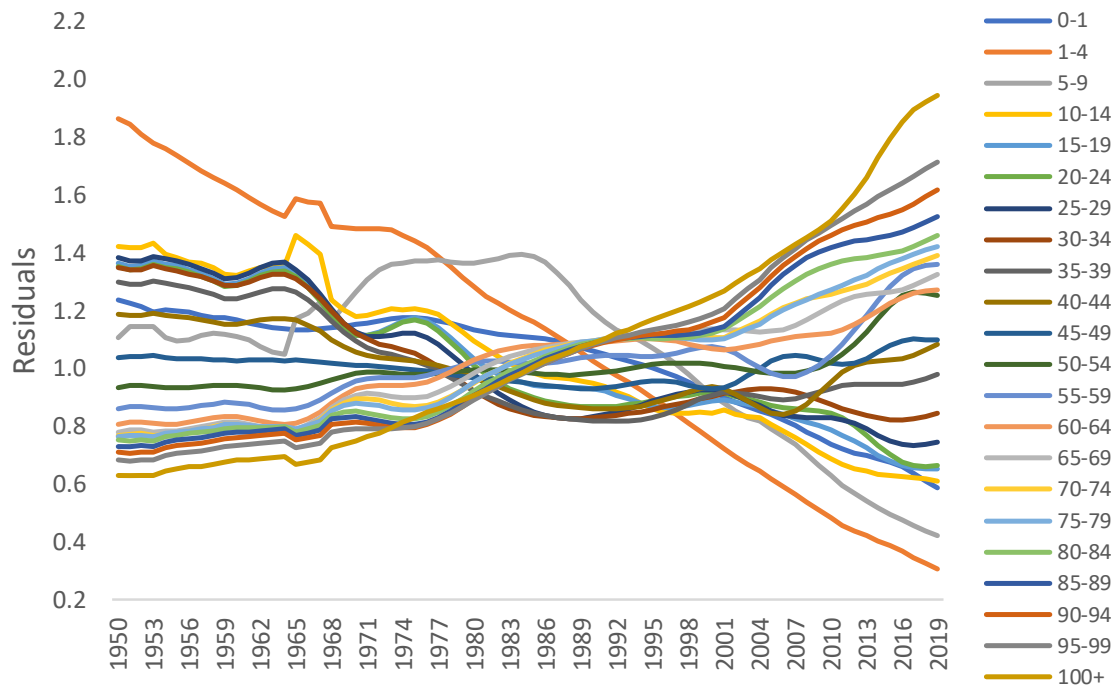


Figure 4: Change in age-specific residuals (r_{ij}) over time – total population

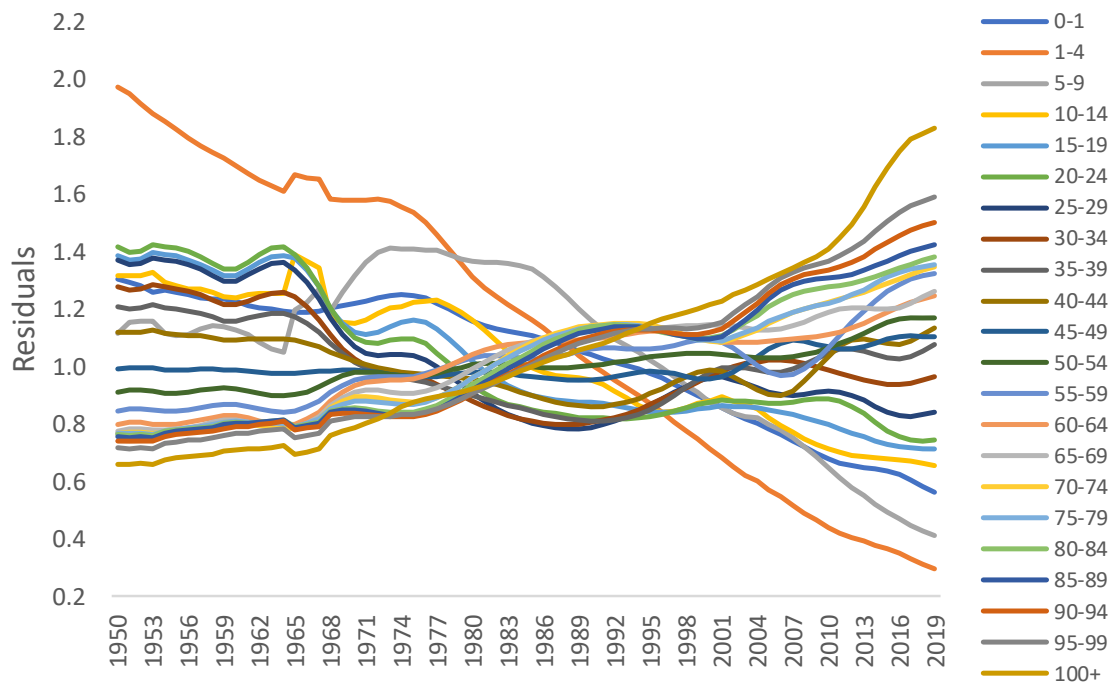


Figure 5: Change in age-specific residuals (r_{ij}) over time - male population

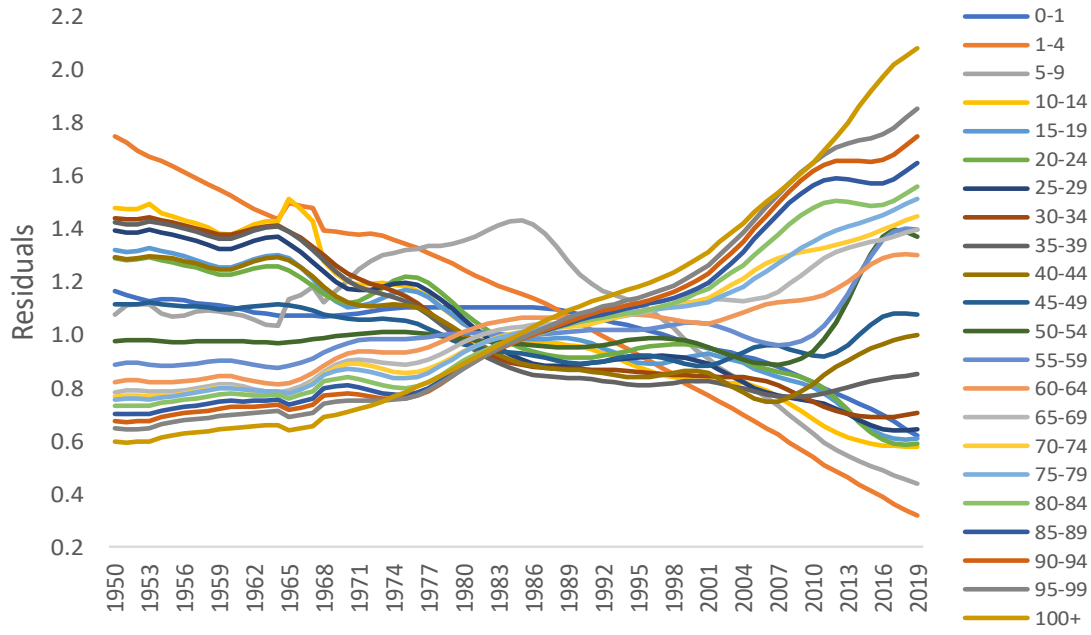


Figure 6: Change in age-specific residuals (r_{ij}) over time - female population

The transition in age-specific probabilities of death may be analysed in terms of age-specific residuals. An increase in the residuals over time is an indication that there is a deceleration in transition in the probability of death whereas a decrease in the residuals is an indication that there is an acceleration in transition in the probability of death. The time trend in residuals in different age groups is depicted in figure 4 for the total population and in figures 5 and 6 for male and female population respectively while average annual per cent change (AAPC) in total, male and female populations are presented in table 4.

Table 4 and figures 4 to 6 suggest that transition in the probability of death in different age groups in India has been different. The AAPC in r_{ij} is negative and statistically significant in ages younger than 40 years but positive and statistically significant in ages 50 years and older. This means that transition in the probability of death in ages younger than 40 years accelerated while that in ages 50 years and above decelerated over time. The transition accelerated the most rapidly in the age group 1-4 years where $r_{i,1-4}$ decreased at a rate of more than 2.5 per cent per year during the period under reference. In 1950, $q_{1950,1-4}$ was almost 87 per cent higher than the underlying probability of death determined by $q_{..}$, $q_{1950,..}$, and $q_{.,1-4}$ but in 2019, $q_{1950,1-4}$ was almost 70 per cent lower than the underlying probability of death. On the other hand, there has been virtually no change in the probability of death in age groups 40-44 and 45-49 years as the AAPC in $r_{i,40-44}$ and $r_{i,45-49}$ has not been found to be statistically significantly different from zero.

Transition in male age-specific probabilities of death has been different than the transition in female age-specific probabilities of death. In the age group 0-10 years, transition in male probability of death accelerated more rapidly than that in female probability of death. However, in the age group 10-49 years, transition in female probability of death accelerated more rapidly than that in male probability of death. In ages 50 years and above, transition in female probability of death decelerated more rapidly than that in male probability of death. Table 4 and figures 4 to 6 suggest that transition in the probability of death in ages younger than 50 years accelerated during 1950-2021 but that in ages 50 years and older decelerated. The deceleration in transition in the probability of death in ages 50 years and older appears to be responsible for the slowing down of the improvement in the life expectancy at birth.

Table 4: Average annual percent change (AAPC) in r_{ij} during 1950-2019 in India

Age	Person					Male					Female				
	AAPC %	Confidence interval		t	P> t	AAPC %	Confidence interval		t	P> t	AAPC %	Confidence interval		t	P> t
		Lower	Upper				Lower	Upper				Lower	Upper		
0-1	-1.066	-1.122	-1.010	-37.194	< 0.001	-1.206	-1.270	-1.142	-36.550	< 0.001	-0.901	-0.932	-0.870	-56.215	< 0.001
1-4	-2.559	-2.622	-2.496	-78.212	< 0.001	-2.694	-2.751	-2.637	-90.656	< 0.001	-2.412	-2.492	-2.333	-58.990	< 0.001
5-9	-1.454	-1.564	-1.344	-25.720	< 0.001	-1.511	-1.632	-1.390	-24.285	< 0.001	-1.359	-1.474	-1.243	-22.925	< 0.001
10-14	-1.252	-1.590	-0.913	-7.201	< 0.001	-0.996	-1.243	-0.748	-7.844	< 0.001	-1.378	-1.666	-1.088	-9.278	< 0.001
15-19	-1.098	-1.272	-0.925	-12.355	< 0.001	-0.983	-1.131	-0.834	-12.909	< 0.001	-1.173	-1.391	-0.955	-10.483	< 0.001
20-24	-1.072	-1.260	-0.884	-11.123	< 0.001	-0.961	-1.138	-0.783	-10.571	< 0.001	-1.237	-1.509	-0.965	-8.856	< 0.001
25-29	-0.919	-1.050	-0.788	-13.666	< 0.001	-0.713	-0.877	-0.549	-8.494	< 0.001	-1.151	-1.269	-1.033	-19.019	< 0.001
30-34	-0.681	-0.788	-0.574	-12.430	< 0.001	-0.410	-0.565	0.255	-5.159	< 0.001	-1.038	-1.103	-0.972	-30.738	< 0.001
35-39	-0.412	-0.532	-0.292	-6.725	< 0.001	-0.184	-0.326	-0.041	-2.526	0.012	-0.728	-0.860	-0.596	-10.772	< 0.001
40-44	-0.146	-0.251	-0.042	-2.753	0.006	-0.015	-0.108	0.078	-0.314	0.754	-0.326	-0.479	-0.172	-4.142	< 0.001
45-49	0.104	0.020	0.188	2.431	0.015	0.162	0.076	0.248	3.694	< 0.001	-0.016	-0.171	0.138	-0.207	0.836
50-54	0.426	0.302	0.550	6.736	< 0.001	0.356	0.223	0.488	5.270	< 0.001	0.519	0.436	0.602	12.290	< 0.001
55-59	0.662	0.545	0.779	11.147	< 0.001	0.647	0.519	0.775	9.945	< 0.001	0.662	0.584	0.740	16.663	< 0.001
60-64	0.666	0.546	0.786	10.915	< 0.001	0.638	0.498	0.777	9.005	< 0.001	0.675	0.544	0.806	10.150	< 0.001
65-69	0.764	0.656	0.872	13.904	< 0.001	0.679	0.571	0.787	12.387	< 0.001	0.865	0.729	1.000	12.584	< 0.001
70-74	0.863	0.759	0.967	16.369	< 0.001	0.822	0.714	0.931	14.944	< 0.001	0.935	0.796	1.074	13.252	< 0.001
75-79	0.916	0.816	1.016	18.046	< 0.001	0.841	0.744	0.937	17.110	< 0.001	1.029	0.905	1.154	16.286	< 0.001
80-84	0.967	0.851	1.083	16.435	< 0.001	0.861	0.776	0.947	19.761	< 0.001	1.086	0.966	1.206	17.813	< 0.001
85-89	1.069	0.955	1.182	18.564	< 0.001	0.925	0.821	1.030	17.452	< 0.001	1.231	1.107	1.355	19.536	< 0.001
90-94	1.201	1.094	1.307	22.196	< 0.001	1.036	0.905	1.166	15.630	< 0.001	1.367	1.250	1.484	23.088	< 0.001
95-99	1.354	1.280	1.427	36.236	< 0.001	1.186	1.117	1.254	34.162	< 0.001	1.532	1.457	1.608	40.076	< 0.001
100+	1.701	1.586	1.815	29.328	< 0.001	1.507	1.404	1.610	28.873	< 0.001	1.865	1.792	1.938	50.565	< 0.001

Source: Author

Impact of COVID-19 Pandemic

The estimates prepared by the United Nations suggest that the life expectancy at birth in India decreased from around 70.9 years in 2019 to 67.2 years in 2021 or a decrease of around 3.7 years. Comparable estimates of life expectancy at birth in India from the official sample registration system are not available. The decrease in the life expectancy at birth may be attributed to the excess mortality associated with the COVID-19 pandemic. It is possible to estimate excess deaths associated with COVID-19 pandemic by projecting age-specific probabilities of death that prevailed in the country in 2019 up to 2021 to obtain likely no-COVID-19 scenario and then comparing projected age-specific probabilities of death with the observed age-specific probabilities of death. The WHO defines excess mortality as, “the mortality above what would be expected based on the non-crisis mortality rate in the population of interest.” These include both direct effects of COVID-19 (deaths directly attributed to COVID-19) and the indirect knock-on effects on the health system and the society, along with deaths that are averted. (Knutson et al, 2022).

We have projected age-specific probabilities of death up to the year 2021 in the absence of COVID-19 associated mortality by estimating APC in r_j for the most recent period during which the trend has been linear on the log scale for male and female population for different age groups and the results are given in table 5. The Jointpoint regression analysis was carried out to identify the most recent period in which the trend in the probability of death was linear. Based on the values of APC so obtained, we projected r_{ij} for 2020 and 2021 and then the age-specific probabilities of death in the year 2020 and the year 2021 in the absence of the deaths associated with the COVID-19 pandemic. These projected age-specific probabilities of death in the absence of COVID-19 pandemic have then been converted into the likely age-specific death rates in the absence of excess deaths associated with the COVID-19 pandemic. Based on these projected age-specific death rates in the absence of the COVID-19 pandemic, the projected number of deaths in the absence of COVID-19 pandemic have been estimated calculated for the year 2020 and 2021 for male and female population separately. The difference between the actual number of deaths in the year 2020 and 2021 and the projected number of deaths for the year 2020 and 2021 in the no-COVID-19 pandemic scenario provided an estimate of excess deaths associated with the COVID-19 pandemic in the country.

Our estimates suggest that there were around 4.29 million COVID-19 associated excess deaths – 2.44 million male deaths and 1.85 million female deaths - in India during 2020-2021. In 2020, or during the first wave of the pandemic, COVID-19 associated excess deaths are estimated to be around 0.70 million – 0.45 million male and 0.25 million female. COVID-19 associated excess deaths, however, increased to more than 3.59 million – 1.99 million male and 1.60 million female - in 2021 or during the second wave of the pandemic. The estimated number of COVID-19 associated excess deaths are presented in table 6. The number of COVID-19 associated excess death increased rapidly after 45 years of age and peaked in the age group 65-69 years in both 2020 and in 2021. More than 60 per cent of the excess deaths associated with the COVID-19 pandemic were confined to ages above 60 years.

There is reasonable degree of agreement between our estimates of COVID-19 associated excess deaths and estimates prepared by World Health Organization and other researchers. The World Health Organization has estimated around 4.7 million COVID-19 associated deaths in India between January 2020 and December 2021 and around 4.3 million deaths between June 2020 and June 2021 (Knutson et al, 2022). Jha et al (2022), using data collected from a nationally representative telephone survey and official data related to facility-based COVID-19 deaths and the deaths registered under the civil registration system in 10 states, have estimated more than 3.2 million COVID-19 associated excess deaths during June 2020 to June 2021. Anand et al (2021), using different approaches, estimated that COVID-19 associated excess deaths ranged from around 3.4 million to around 4.9 million during April 2021 to June 2021.

Table 5: Annual per cent change (APC) in age-specific probabilities of death in the most recent period.

Age group	Period		APC	Confidence interval		‘t’	P> t
				Lower	Upper		
Male population							
0-1	2007	2019	-4.854	-4.937	-4.772	-115.453	< 0.001
1-4	2006	2019	-7.042	-7.182	-6.901	-97.013	< 0.001
5-9	2008	2019	-7.987	-8.376	-7.597	-39.396	< 0.001
10-14	2001	2019	-4.100	-4.367	-3.831	-30.025	< 0.001
15-19	2007	2019	-4.279	-4.607	-3.951	-25.607	< 0.001
20-24	2017	2019	-0.376	-6.352	5.981	-0.122	0.903
25-29	2010	2019	-4.174	-4.735	-3.61	-14.567	< 0.001
30-34	2006	2019	-3.522	-3.756	-3.287	-29.597	< 0.001
34-39	2011	2019	-3.145	-3.698	-2.588	-11.192	< 0.001
40-44	2011	2019	-2.787	-3.411	-2.160	-8.815	< 0.001
45-49	2007	2019	-2.723	-2.906	-2.540	-29.473	< 0.001
50-54	2011	2019	-2.047	-2.402	-1.691	-11.425	< 0.001
55-59	2012	2019	-0.980	-1.463	-0.494	-4.038	< 0.001
60-64	1995	2019	-1.538	-1.594	-1.483	-55.164	< 0.001
65-69	2016	2019	0.364	-1.590	2.358	0.371	0.712
70-74	2009	2019	-2.053	-2.323	-1.781	-15.033	< 0.001
75-79	2009	2019	-1.921	-2.118	-1.723	-19.342	< 0.001
80-84	2008	2019	-2.200	-2.370	-2.030	-25.663	< 0.001
85-89	2008	2019	-2.174	-2.336	-2.012	-26.572	< 0.001
90-94	2008	2019	-1.815	-1.947	-1.684	-27.435	< 0.001
95-99	2008	2019	-1.392	-1.490	-1.293	-28.133	< 0.001
Female population							
0-1	2009	2019	-5.571	-5.683	-5.458	-96.67	< 0.001
1-4	2009	2019	-8.177	-8.394	-7.959	-72.22	< 0.001
5-9	2000	2019	-6.646	-6.805	-6.487	-81.231	< 0.001
10-14	2015	2019	-2.368	-4.449	-0.242	-2.231	0.03
15-19	2005	2019	-5.610	-5.910	-5.309	-36.374	< 0.001
20-24	2016	2019	-2.305	-5.541	1.040	-1.389	0.171
25-29	1999	2019	-4.451	-4.584	-4.318	-65.768	< 0.001
30-34	2015	2019	-1.416	-2.634	-0.184	-2.303	0.025
34-39	2008	2019	-1.593	-1.868	-1.318	-11.512	< 0.001
40-44	2006	2019	-0.104	-0.359	0.151	-0.819	0.416
45-49	2011	2019	-0.352	-0.846	0.144	-1.426	0.16
50-54	2016	2019	-1.822	-3.444	-0.173	-2.214	0.031
55-59	2008	2019	1.366	1.139	1.593	12.152	< 0.001
60-64	2011	2019	-0.949	-1.229	-0.668	-6.749	< 0.001
65-69	1974	2019	-1.205	-1.242	-1.168	-65.226	< 0.001
70-74	2007	2019	-1.717	-1.881	-1.551	-20.695	< 0.001
75-79	2012	2019	-1.376	-1.750	-1.000	-7.310	< 0.001
80-84	2016	2019	-0.053	-1.296	1.206	-0.085	0.933
85-89	2009	2019	-2.240	-2.440	-2.040	-22.202	< 0.001
90-94	2016	2019	-0.167	-1.224	0.902	-0.315	0.754
95-99	2017	2019	0.763	-0.811	2.363	0.969	0.337

Source: Author

Table 6: Excess deaths (million) associated with COVID-19 pandemic.

Age	2020			2021			2020-2021		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
0-1	-0.032	-0.016	-0.016	-0.051	-0.026	-0.025	-0.083	-0.042	-0.041
1-4	-0.010	-0.005	-0.005	-0.017	-0.009	-0.008	-0.027	-0.014	-0.014
5-9	-0.003	-0.002	-0.002	-0.006	-0.003	-0.003	-0.009	-0.004	-0.005
10-14	-0.002	-0.001	-0.001	-0.002	-0.001	-0.001	-0.004	-0.002	-0.002
15-19	-0.011	-0.007	-0.004	0.018	0.008	0.010	0.007	0.001	0.006
20-24	-0.017	-0.012	-0.005	0.029	0.013	0.016	0.012	0.001	0.011
25-29	-0.018	-0.013	-0.005	0.035	0.017	0.018	0.018	0.005	0.013
30-34	-0.013	-0.010	-0.003	0.051	0.030	0.021	0.038	0.020	0.018
34-39	-0.004	-0.003	-0.001	0.076	0.047	0.029	0.072	0.044	0.028
40-44	0.009	0.007	0.002	0.101	0.063	0.038	0.110	0.069	0.041
45-49	0.019	0.014	0.005	0.156	0.098	0.057	0.175	0.112	0.063
50-54	0.041	0.027	0.014	0.235	0.136	0.098	0.276	0.164	0.112
55-59	0.071	0.048	0.023	0.312	0.189	0.123	0.383	0.237	0.146
60-64	0.112	0.072	0.040	0.421	0.236	0.184	0.532	0.308	0.224
65-69	0.141	0.087	0.054	0.490	0.274	0.216	0.631	0.361	0.270
70-74	0.126	0.074	0.051	0.479	0.260	0.219	0.604	0.334	0.270
75-79	0.083	0.051	0.032	0.409	0.222	0.187	0.492	0.273	0.219
80-84	0.091	0.060	0.031	0.409	0.212	0.197	0.501	0.272	0.228
85-89	0.084	0.057	0.027	0.316	0.158	0.158	0.400	0.215	0.185
90-94	0.028	0.020	0.008	0.106	0.054	0.052	0.134	0.073	0.061
95-99	0.005	0.004	0.002	0.022	0.011	0.011	0.027	0.015	0.012
100+	0.000	0.000	0.000	0.003	0.001	0.001	0.003	0.002	0.001
Total	0.701	0.454	0.246	3.591	1.991	1.601	4.292	2.445	1.847

Source: Author

Discussions and Conclusions

Mortality transition has not been an area of interest in demographic research in India in recent years. There is no article on mortality transition in the country that has been published in *Demography India*, the official publication of the Indian Association for the Study of Population, since 2015. There have been studies on mortality transition in India in the past (Bhat, 1987; 1989; Bhat and Navaneetham, 1991; Chaurasia, 2006; 2009; Guha, 1991; Jain et al, 1985; Navaneetham, 1993; Preston and Bhat, 1984; Roy and Lahiri, 1987; Visaria, 2004) but, in recent years, interest in mortality transition in the country appears to have waned. The present analysis is probably and so obviously the first to analyse mortality transition in the country since independence.

A revealing finding of the present analysis is that characterisation of mortality transition is sensitive to the summary index of mortality used. Mortality transition in India based on the trend in the geometric mean of the age-specific probabilities of death (Γ) is found to be different from that based on the trend in the life expectancy at birth. The trend in the geometric mean of age-specific probabilities of death suggests that mortality transition has accelerated in the country during 2008-2019 whereas the trend in the life expectancy at birth suggests that transition has decelerated. In 2005, India launched the National Rural Health Mission which was effective from 2007, the period 2005-2007 being the preparatory phase. The Mission was directed towards providing equitable, affordable, and quality health care to the rural population of the country, especially the vulnerable population groups with especial focus on states where mortality transition was slow (Government of India, 2005). The thrust of the Mission was on establishing a fully functional, community-owned, decentralized health delivery system with inter-sectoral convergence at all levels, to ensure simultaneous action on a wide range of determinants of health including water, sanitation, education, nutrition, social and gender equality. In 2013, India launched the National Urban Health Mission to meet the health needs of the urban population with a focus on making available essential primary health care services (Government of India, 2013a). Subsequently, the two Missions were merged to constitute the National Health Mission (Government of India, 2013b). The trend in the geometric mean of age-specific probabilities of death suggests that these Missions have contributed towards accelerating mortality transition in the country whereas the trend in the life expectancy at birth indicates that there has been little impact of these Missions on mortality transition. The trend in the life expectancy at birth also implies that the rapid economic growth that India has witnessed since 2000 also had little impact in accelerating mortality transition in the country.

The contrasting scenario of mortality transition revealed by the trend in geometric mean of the age-specific probabilities of death and the trend in the life expectancy at birth appears to be due to different weights assigned to age-specific probabilities of death in the calculation of the geometric mean of the age-specific probabilities of death and in the calculation of the life expectancy at birth. In the calculation of the geometric mean, equal weights are assigned to the probability of death in different age groups. In the calculation of the life expectancy at birth, higher weights are assigned to the probability of death in older ages compared to the weights assigned to the probability of death in younger ages. As a result, transition in mortality in older ages has a stronger impact on the improvement in the life expectancy at birth. The deceleration in the life expectancy at birth reflects the deceleration in mortality transition in older ages. The present analysis reveals that mortality transition in older ages has decelerated in India during 1950-2019. From the policy and programme perspective, the present analysis suggests that the geometric mean of the age-specific probabilities of death (index Γ) or the geometric mean of the age-specific death rates (index ∇) should be preferred over the life expectancy at birth as the summary index of mortality to analyse mortality transition as the geometric mean of age-specific probabilities of death or age-specific death rates reflects the mortality experience of the real population.

A comparison of the trend in the geometric mean of the age-specific probabilities of death and the trend in the life expectancy at birth provides valuable insight about mortality transition in different age groups. If the annual per cent change (APC) in the geometric mean of the age-specific probabilities of death and the annual per cent change (APC) in the life expectancy at birth is the same, then it can be interpreted that mortality transition is the same in all age groups. If APC in the geometric mean of the age-specific probabilities of death is higher than APC in the life expectancy at birth, then it can be interpreted that mortality transition is faster in younger ages than in older ages. Finally, if the APC in the geometric mean of age-specific probabilities of death is slower than the APC in the life expectancy at birth, then this means that mortality transition is faster in older ages than in younger ages. In India, mortality transition in younger ages has been faster than that in the older ages since independence. The pace of transition has accelerated the most in the age group 1-4 years. The pace of transition decreases with age and is the slowest in the age group 40-44 years. In ages 45 years and above, the pace of transition has decelerated, and the deceleration increased with age.

The analysis also reveals interesting differences in mortality transition in males as compared to females. In younger ages (less than 10 years), mortality transition has been faster in males compared to females. However, in the age group 10-49 years, mortality transition has been faster in females compared to males. In population 50 years and older, mortality transition has been slower in females than in males as the deceleration in the probability of death in the older ages has been more pronounced in females as compared to males.

The present analysis also confirms that the impact of COVID-19 pandemic on mortality in India has been quite substantial as the pandemic appears to have resulted in a loss of almost 3.7 years in the life expectancy at birth and accounted for at least 4 million pandemic associated excess deaths in the country. The loss in the life expectancy at birth in India associated with the pandemic has been amongst the highest across countries for which estimates are prepared by the United Nations Population Division. Moreover, there have been more male excess deaths with the pandemic compared to female deaths.

The analysis suggests that the National Rural Health Mission launched in 2005 and the National Urban Health Mission launched in 2013 have contributed to accelerating mortality transition in the country. This may be viewed as the success of these Missions in meeting the health care needs of the people of the country, although there appears to have been a deceleration in mortality transition in the older ages.

The present analysis calls for promoting health in the substantive and not in the formal context. In the formal context, health of the people is linked to institution-based care whereas, in the substantive context, health is linked to the interaction between the man and the environment. There is a need to strike a balance between the two. Strengthening formal health care is related to creating, strengthening, and expanding the health care delivery system – public or private. In the absence of substantive health care, however, the system may remain unaccepted by the people at large and hence underutilised.

References

- Akinyede O, Soyemi K (2016) Joinpoint regression analysis of pertussis crude incidence rates, Illinois, 1990–2014. *American Journal of Infection Control* 44(12): 1732–1733.
- Anand A, Sandefur J, Subramanian A (2021) Three new estimates of India's all-cause excess mortality during the COVID-19 pandemic. Washington DC, Center for Global Development.
- Bhat PNM (1987) Mortality in India: Levels, Trends and Patterns. Unpublished PhD Dissertation, Philadelphia: University of Pennsylvania.

- Bhat PNM (1989) Mortality and fertility in India, 1881–1961: a reassessment. In Tim Dyson (ed) *India's Historical Demography: Studies in Famine, Disease and Society*. London, Curzon Press, pp. 73–118.
- Bhat PNM, Navaneetham K (1991) Recent trends in age specific mortality in India. *Journal of Institute of Economic Research* 26(1-2): 49–69.
- Chatenoud L, Garavello W, Pagan E, Bertuccio P, Gallus S, La Vecchia C, Negri E, Bosetti C (2015) Laryngeal cancer mortality trends in European countries. *International Journal of Cancer* 138(4): 833–842.
- Chaurasia AR (2006) Mortality transition in urban India 1971–2002. Delhi, Institute of Economic Growth. Discussion Paper No. 113/2006.
- Chaurasia (2010) Mortality transition in India: 1970–2005. *Asian Population Studies* 6(01): 47–68.
- Clegg LX, Hankey BF, Tiwari R, Feuer EJ, Edwards BK (2009) Estimating average annual percent change in trend analysis. *Statistics in Medicine* 20(29): 3670–3682.
- Doucet M, Rochette L, Hamel D (2016) Prevalence and mortality trends in chronic obstructive pulmonary disease over 2001 to 2011: A public health point of view of the burden. *Canadian Respiratory Journal* Article ID 7518287: 10 pages.
- Gillis D, Edwards BPM (2019) The utility of joinpoint regression for estimating population parameters given changes in population structure. *Heliyon* 5: e02515.
- Government of India (2005) *National Rural Health Mission*. New Delhi, Ministry of Health and Family Welfare.
- Government of India (2013a) *National Urban Health Mission*. New Delhi, Ministry of Health and Family Welfare.
- Government of India (2013b) *National Health Mission*. New Delhi, Ministry of Health and Family Welfare.
- Government of India (2022) *SRS Based Abridged Life Tables 2016–20*. New Delhi, Ministry of Home Affairs, Office of the Registrar General and Census Commissioner.
- Guha S (1991) Mortality decline in early twentieth century India: a preliminary enquiry. *Indian Economic and Social History Review* 28(4): 371–391.
- Ingram DD, Malec DJ, Makuc DM, Kruszon-Moran D, Gindi RM, Albert M, Beresovsky V, Hamilton BR, Holmes J, Schiller J, Sengupta M (2018) National center for health statistics guidelines for analysis of trends. *Vital Health Statistics* 2(179): 1–71.
- Jain AK, Visaria L, Visaria P (1985) Mortality trends in India during the 1970s: a critical review. In *Proceedings of the International Population Conference*. Liege, International Union for the Scientific Study of Population, vol. 2, pp. 353–365.
- Jha P, Deshmukh Y, Tumbe C, Suraweera W, Bhowmick A, Sharma S, Novosad P, Fu SH, Newcombe L, Gelband H, Brown P (2022) COVID mortality in India: National survey data and health facility deaths. *Science* 375(6581): 667–671.
- John U, Hanke M (2015) Liver cirrhosis mortality, alcohol consumption and tobacco consumption over a 62-year period in a high alcohol consumption country: A trend analysis. *BMC Research Notes* 8(1): 822.
- Keyfitz N (1977) *Applied Mathematical Demography*. New York, Wiley.
- Kim H-J, Fay MP, Feuer EJ, Midthune DN (2000) Permutation tests for joinpoint regression with applications to cancer rates. *Statistics in Medicine* 19: 335–351.

- Kim J, Kim H-J (2016) Consistent model selection in segmented line regression. *Journal of Statistical Planning and Inference* 170: 106–116.
- Kim H-J, Yu B, Feuer EJ (2009) Selecting the number of change-points in segmented line regression. *Statistica Sinica* 19(2): 597–609.
- Kitagawa EM (1964) Standardized comparisons in population research. *Demography* 1(1): 296–315.
- Knutson V, Aleshin-Guendel S, Karlinsky A, Msemburi W, Wakefield J (2022) Estimating global, and country-specific excess mortality during the COVID-19 pandemic. arXiv:2005.09081v1.
- Lerman PM (1980) Fitting segmented regression models by grid search. *Journal of Royal Statistical Society. Series C (Applied Statistics)* 29(1): 77–84.
- Marriot AL (2010) Colorectal cancer network (CRCNet) user documentation for surveillance analytic software: Joinpoint. *Cancer Care Ontario*: 1–28.
- Missikpode C, Peek-Asa C, Young T, Swanton A, Leinenkugel K, Torner J (2015) Trends in non-fatal agricultural injuries requiring trauma care. *Injury Epidemiology* 42(1): 30.
- Modig K, Rau R, Ahibom A (2020) Life expectancy: what does it measure? *BMJ Open* 10: e035932.
- National Institute of Health. (2020). *Joinpoint Regression Program* (version 4.8.0.1). National Institute of Health, National Cancer Institute. Surveillance Research Program, Division of Cancer Control and Population Sciences.
- Navaneetham K (1993) Mortality decline in India: an analysis of regional and temporal variations. *Demography India* 22(1): 53–63.
- Pollard JH (1982) The expectation of life and its relationship to mortality. *Journal of the Institute of Actuaries* 109(2): 225–240.
- Preston SH, Bhat PNM (1984) New evidence of fertility and mortality trends in India. *Population and Development Review* 10(3): 481–504.
- Puzo Q, Qin P, Mehlum L (2016) Long-term trends of suicide by choice of method in Norway: A joinpoint regression analysis of data from 1969 to 2012. *BMC Public Health* 16: 255.
- Qiu D, Katanoda K, Marugame T, Sobue T (2009) A joinpoint regression analysis of long-term trends in cancer mortality in Japan (1958–2004). *International Journal of Cancer* 124: 443–448.
- Rea F, Pagan E, Compagnoni MM, Cantarutti A, Pigni P, Bagnardi V, Cprap G (2017) Joinpoint regression analysis with time-on-study as time-scale. Application to three Italian population-based cohort studies. *Epidemiology, Biostatistics and Public Health* 14(3): e12616.
- Roy TK, Lahiri S (1987) Recent levels and trends in mortality in India and its major states: an analysis based on SRS data. In K Srinivasan and S Mukherji (eds) *Dynamics of Population and Family Welfare*. Mumbai, Himalaya Publishing House, pp. 279–347.
- Schoen R (1970) The geometric mean of the age-specific death rates as a summary index of mortality. *Demography* 7(3): 317–324.
- Spiegelman M (1955) *Introduction to Demography*. Chicago, The Society of Actuaries.
- Tukey J (1977) *Exploratory Data Analysis*. New York, Reading, Massachusetts, Addison-Wesley.

- Tyczynski JE, Berkel HJ (2005) Mortality from lung cancer and tobacco smoking in Ohio (U.S.): will increasing smoking prevalence reverse current decreases in mortality? *Cancer Epidemiology Biomarkers Preview, United States* 14(5): 1182–1187.
- United Nations (2004) *World Population Projections: The 2004 Revision, Volume III: Analytical Report*. New York, United Nations.
- United Nations (2022) *World Population Prospects 2022*. New York, Department of Economic and Social Affairs, Population Division.
- Vaupel JW (1986) How change in age-specific mortality effects life expectancy. *Population Studies* 40: 147-157.
- Visaria L (2004) Mortality trends and health transition. In T Dyson, R Cassen, L Visaria (eds) *Twenty First Century India: Population, Economy, Human Development and the Environment*. New York, Oxford University Press, pp. 32–56.
- Yerushalmy J (1951) A mortality index for use in place of age-adjusted death rate. *American Journal of Public Health* 41(8): 907-922.
- Zhang NR, Siegmund DO (2007) A modified Bayes information criterion with applications to the analysis of comparative genomic hybridization data. *Biometrics* 63: 22–32.