Journal of Biosocial Science (2024), 56: 6, 929–951
doi:10.1017/S0021932024000270

RESEARCH ARTICLE

Trends in adult mortality rates in India, 1970 to 2018: age–period–cohort analysis

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(Received 20 August 2022; revised 12 March 2024; accepted 20 May 2024; first published online 24 October 2024)

Abstract

High premature adult deaths in developing countries are gaining attention, as recent studies show their increasing impact on overall mortality rates. This paper has twofold objectives: firstly, it investigates the long-term trends and patterns of adult mortality between 1970 and 2018 in India. Secondly, it attempts to detect age, period, and cohort (APC) effects on adult mortality decline over time. Data on age-specific mortality rates and disease-adjusted life years for adult age groups (15–59 years) were collected from the Sample Registration System and the Global Burden of Disease study, respectively. The trends in age-standardized mortality rates were presented graphically, and critical change points were highlighted using a change-point analysis. The intrinsic estimator model was applied to estimate the independent effects of APC on adult mortality. The findings revealed that adult mortality declined between 1970 and 2018 with multiple critical change points. The APC effects showed a notable decline in adult mortality during 2005–2018 and for the recent birth cohorts, 1980–2004. However, the rate of mortality declined slowly over time. Results also indicated that mortality started increasing from mid-adult ages and peaked in older adult ages due to the age effects and provided evidence of a rise in adult life loss due to non-communicable diseases in recent years. Overall, the study underscores the importance of implementing health policies aimed at reducing life loss in the most economically active ages that can have long-term negative implications for the country's economic growth.

Keywords: adult mortality; age–period–cohort; India

Introduction

Recent age-specific mortality studies in developing countries have revealed that premature adult deaths are becoming a significant contributor to overall mortality rates in most of these nations (Timaeus and Jasseh, 2004; Rajaratnam *et al.*, 2010; Kim Streatfield *et al.*, 2014; Wang *et al.*, 2018; United Nations, Department of Economic and Social Affairs, Population Division, 2019). Besides, studies highlighted the growing importance of a substantial variation in adult mortality levels by disease, regions, sex, and socioeconomic groups in contributing to a slow progress in healthy life expectancy until now (Rajaratnam *et al.*, 2010; Rogers and Crimmins, 2011). Previous studies suggest that any further improvement in the overall health of developing societies needs an urgent reappraisal of its adult mortality levels and related disease burden (Rajaratnam *et al.*, 2010; Kim Streatfield *et al.*, 2014; Global Burden of Disease Collaborative Network, 2017; Wang *et al.*, 2018; Yadav, 2021). Thus, reducing one-third of premature mortality between the exact age of 30 and 70 years from any non-communicable diseases (NCDs) through prevention and treatment by 2030 is one of the key targets under the United Nations Sustainable Development Goal 3 (United Nations, 2015).

Like many developing countries, India portrays a poor condition in terms of adult health. It has the third-highest adult mortality rate (probability of dying between the age of 15 and 60 years) in South Asia between 2015 and 2020, following Afghanistan and Bhutan (United Nations, 2019). Age-specific mortality estimates from the Sample Registration System (SRS) and National Family Health Survey over the past three decades also show elevated mortality rates among adults. Presently, premature adult mortality constitutes nearly half of all male deaths and about one-third of female deaths in India (Rao *et al.*, 2021).

Studies analysing long-term mortality trends suggest that the decline in adult mortality was small in the initial phase, followed by a period of stagnation and then a recent increase (Navaneetham, 1993; Saikia and Bhat, 2008; Saikia *et al.*, 2011; Singh and Ladusingh, 2013; 2016). Notably, there was a period of stagnation in male adult mortality in several states from 1996 to 2006 (Ranjan Chaurasia, 2010; Saikia *et al.*, 2013; Ram *et al.*, 2015; Canudas-Romo *et al.*, 2015). These studies also show that the decline in adult mortality was the least pronounced compared to the other ages.

The ongoing epidemiological transition has made adult health conditions in the country more complex and challenging (Arokiasamy and Yadav, 2014; Goli *et al.*, 2023; Hossain *et al.*, 2023). Studies on disease burden highlighted that increasing fatality among Indian adults is attributable to the dual burden of preventable NCDs and multi-morbidities resulting from sedentary lifestyle behaviours (Gajalakshmi *et al.*, 2003; Jha *et al.*, 2006; Jha *et al.*, 2008; Agrawal *et al.*, 2016; Puri *et al.*, 2021; Khan *et al.*, 2022). Additionally, researchers have focused on the social and economic consequences of adult ill health (Barik *et al.*, 2018; Saikia *et al.*, 2019). While recent research on adult mortality has grown, it has largely confined to understanding levels, trends, patterns, determinants, and risk factors without considering age, period, and cohort (APC) effects (Krishnaji and James, 2002; Saikia and Ram, 2010; Saikia *et al.*, 2013; Verma *et al.*, 2017; GBD 2019 Diseases and Injuries Collaborators, 2019; Rao *et al.*, 2021; Yadav, 2021).

Within a broad framework of trend analyses, the APC approach is an approach to demography and epidemiology, providing three types of interpretation for understanding trends and patterns in demographic events or population-based disease rates. It examines changes in these events or rates attributed to socioeconomic, demographic, and environmental factors (*period effects*), conditions specific to a particular birth cohort (*cohort effects*), and variability in the event as a function of ageing (*age effects*) (Holford, 1983; Anderson and Silver, 1989; Willekens and Scherbov, 1991; Yang, 2008; Yang and Land, 2013; Heo *et al.*, 2017; Fosse and Winship, 2019; Liu *et al.*, 2019). APC analyses have the unique ability to provide valuable insights on the multifaceted factors (*viz.* social, historical, and environmental aspects) that influence both individuals and population's life span over time and help identify changes in mortality that happened due to factors such as declining survival as an individual gets older or changes in environmental conditions, as well as conditions during the birth year or during adulthood that shapes future survival. Globally, APC models are widely used to decompose time-varying demographic and epidemiological variables (mortality or morbidity) for designing effective health policies and strategies to reduce premature mortality (Mason and Smith, 1985; Clayton and Schifflers, 1987a; 1987b; Caselli and Capocaccia, 1989; Acosta and van Raalte, 2019). In this paper, Figure 1 illustrates a flowchart depicting the evolution of APC approaches in demography and public health.

Despite a significant transition in India's socioeconomic, demographic, and epidemiological landscapes over the years (Das, 1999; James, 2011; Goli and Arokiasamy, 2013; Yadav and Arokiasamy, 2014; Yadav, 2021; Goli *et al.*, 2023), there has been a lack of comprehensive assessment regarding the APC effects on mortality (overall and for different age groups). Navaneetham's study (1993) is the sole comprehensive attempt to understand the cohort effects posed by the 1960–1974 economic crises on overall mortality trends in India. It revealed that the

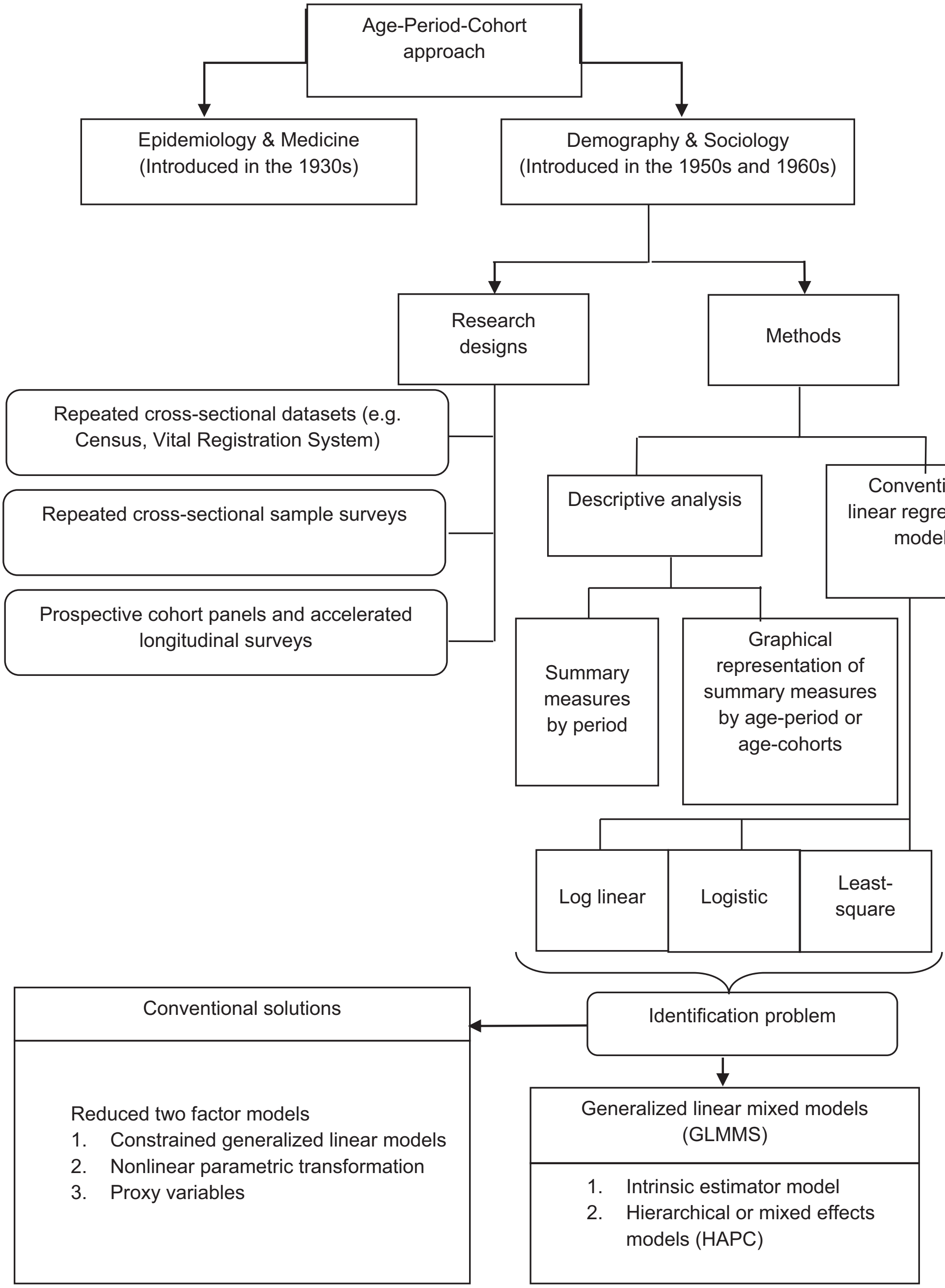

Figure 1. Flow chart of the evolution of APC approaches in demography and public health.

adverse effects of food shortage, price hikes, compression of real wages, and basic entitlement failure were the primary reasons for stagnation or increase in adult mortality in India among those who faced the economic crisis during childhood or adulthood in the 1980s. Another study on trends in cancer mortality rates in Mumbai applied an APC model and showed that changing socioeconomic and lifestyle conditions in India are leading to emerging trends of cancer mortality resembling Western countries (Dhillon *et al.*, 2011). However, very few studies in India have explored the potential impacts of age, period, and cohorts on adult mortality. Therefore, the current study aims to address this research gap by using an APC approach to analyse adult mortality trends over two decades and their associations with age, period, and birth cohorts, providing valuable new insights for shaping adult health policy recommendations and interventions in India.

Methods

Data

This study used age-specific mortality data from the SRS, India, from 1970 to 2018 (ORGI, 1971–2018). SRS is based on a dual record system and is one of the most reliable, routine, and up-to-date sources of vital statistics in the country. SRS statistical reports provide annual estimates of death rates by sex in India and in bigger States/Union Territories. Information on disability-adjusted life years (DALYs) for adult age groups was also extracted from the Global Burden of Disease (GBD) study and Injury Burden 1990 to 2019 dataset. The GBD study was coordinated by the Institute of Health Metrics and Evaluation, which is an independent research institute that generates reliable systematic health statistics by collecting information on deaths and disabilities caused by more than 300 diseases in 195 countries (GBD 2019 Diseases and Injuries Collaborators, 2019).

Statistical analyses

The change-point analysis

The change-point analyser (hereafter, CPA) method, as proposed by Taylor (2000), was applied to detect any major and subtle variations or changes in the time-series adult mortality rates (aged 15–59 years) from 1970 to 2018. This powerful tool also helps determine the direction of change and transitions induced by abrupt and unexpected structural changes in the data (Taylor, 2011; Goli and Arokiasamy, 2013). The CPA-based trend analysis is considered to be more effective and robust than traditional trend line plots or control charts, as it offers detailed statistical information like confidence level and interval to assess the magnitude and robustness of each change that took place (Goli and Arokiasamy, 2013). Details of the estimation procedure can be found elsewhere (Taylor, 2011).

The APC–intrinsic estimator model

This study adopted the intrinsic estimator (IE) model, a statistical approach proposed by Yang *et al.* (2008), to obtain the APC effects. Unlike constrained generalized linear models, the IE method used estimable functions and a singular value decomposition of matrices to break the linear dependency across the APC parameters. Thus, the IE model is less subjective to influence the estimation of regression parameters for APC (Yang *et al.*, 2004; Fu *et al.*, 2011). In the IE model, age-specific death rates (ASDRs) were recorded into five-year age groups for consecutive five-year periods (1970–1974 to 2015–2018) and five-year birth cohorts (1915–1919 to 2000–2004), separately for females and males. The paper assigned ASDRs to their respective five-year birth cohort by subtracting the early age group from the upper and lower period limits. For example, individuals aged 15–19 years during 1970–1974 had their ASDRs assigned to the birth cohort of 1955–1959. This led us to consider 18 birth cohorts in the analysis. The model was specified as follows:

$$y_j = \mu + \alpha age_j + \beta period_j + \gamma cohort_j + \varepsilon_j \quad (1)$$

where y_j is the response variable (*i.e.* ASDRs), the net effect on incidence or mortality for group j. α, β, and γ represent the coefficients of APC effects, μ denotes the model's intercept, and ε_j is the residual in the APC model. The deviance Akaike Information Criterion and Bayesian Information Criterion were used to assess and validate the robustness of the models. The paper used the '*ssc install apc*' add-on file in STATA 14.0 software to apply the IE method to adult mortality data and obtain coefficients, standard errors, confidence intervals, the log-likelihood value, and various other statistics for the APC regression model. The graphical representation of trends in age-specific adult mortality rates by periods was presented using R programming language (R Core Team 2018), while STATA 14.0 version was used for creating DALYs plots (StataCorp, College Station, TX).

Regression-based decomposition of inequality

In this method, first, ASDR-generating function is set as follows:

$$\ln(s_i) = \alpha + \sum_{i=1}^{k} \beta_i x_i + \varepsilon \tag{2}$$

where s_i is the ASDR for $i = 1, \ldots, k$, x_i is the vector of an explanatory variable, β_i is the corresponding regression coefficients that are estimated by ordinary least squre regression, and ε is the residual term, assumed to be unrelated to other variables.

$$\ln(s_i) = \alpha + \sum_{i=1}^{k} Z_i + \varepsilon \tag{3}$$

Here each Z_i for $i = 1, \ldots, k$ is a 'composite' variable, equal to the product of an estimated regression coefficient and an explanatory variable. To calculate inequality decomposition, the value of α is not relevant, as it is constant for every observation. Thus, one may consider the following equation:

$$\ln(\widehat{s_i}) = \alpha + \sum_{i=1}^{k} Z_i \tag{4}$$

where s_i *hat* is the dependent variable or predicted ASDR variable. Then following Shorrocks (1982), Fields and Yoo (2000), and Fields (2003), the contribution of each composite variable to total ASDR by age–cohort and period can be assessed as follows:

$$\boldsymbol{\sigma}^2(\mathbf{s}) = \sum_{=1}^{k} \beta_i \,\mathbf{cov}(\mathbf{s},\ \boldsymbol{x}_i) + \sigma^2(\boldsymbol{\varepsilon}) \tag{5}$$

where $\boldsymbol{\sigma}^2(\mathbf{s})$ is the variance of s and $\mathbf{cov}(\mathbf{s},\ x_i)$ represents the covariance of s with each variable $(\boldsymbol{x}_i)$ and this term can be considered as the relative contribution of the factor components to total ASDR inequality by age–cohort and period which sums to 100%.

Results

Trends in adult mortality

The mortality rates (ASDR) in the adult age group (15–59 years) for each subsequent year from 1970 to 2018 indicate a decline for both males and females. Figure 2 also highlights a gap in mortality rates between males and females, which becomes more prominent from 2000 onwards, with male mortality remaining higher than female mortality starting from 1976 until the recent period. Despite the decline, significant fluctuations in mortality rates obscure the major shifts over the study period.

Figure 3, with Panel A for females and Panel B for males, shows the trends in period-specific mortality rates among different adult age groups (from 15–19 to 55–59 years) between 1970 and 2018. The figure demonstrates a noticeable decline in adult mortality across all age groups, regardless of gender. In earlier periods, females had lower mortality rates in young adult ages but higher mortality compared to males from middle to older adult ages. However, the figures

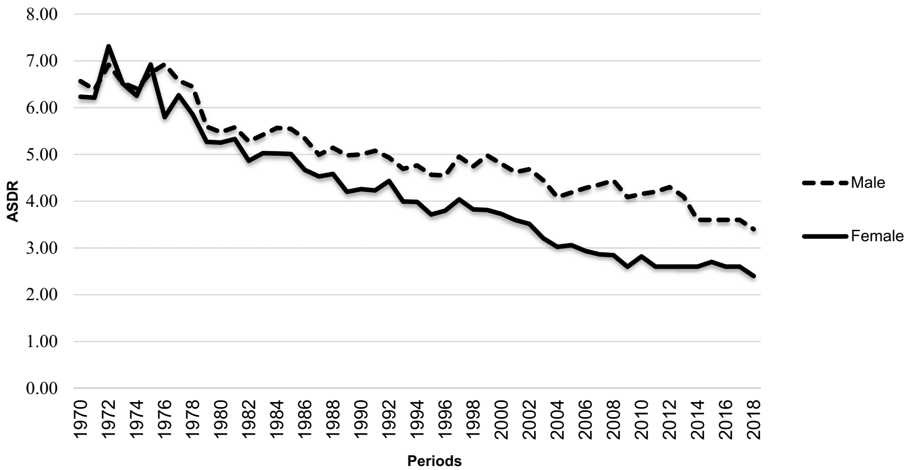

Figure 2. Trends in period-specific mortality rates in adult age groups (15–59 years) by gender in India during 1970–2018.

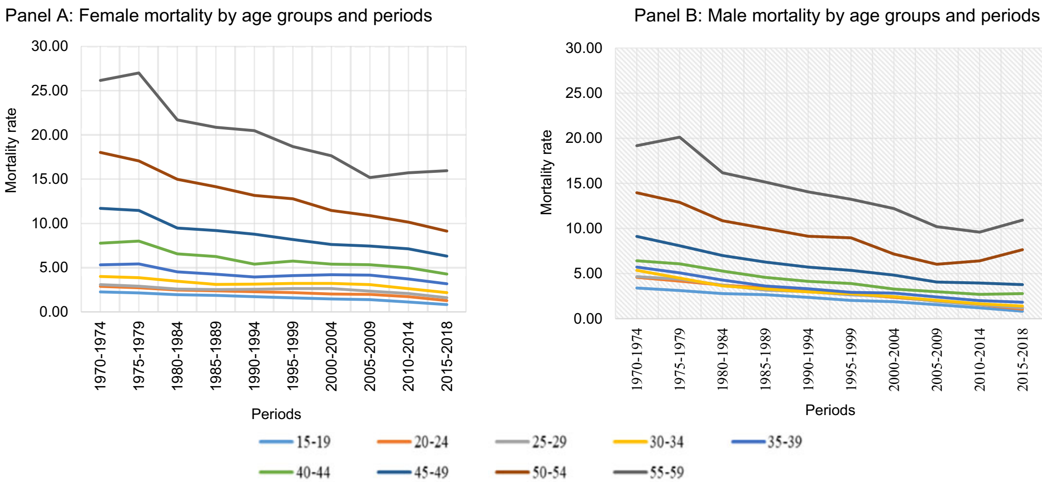

Figure 3. Trends in period-specific mortality rates among different adult age groups and genders in India during 1970–2018.

highlight that female mortality gradually overtook male mortality. Female mortality began to surpass male mortality even in young adult ages (between 15 and 39 years), which became more pronounced starting from 1990 to 1994. The first convergence in adult mortality for males and females was observed in 1995–1999 in the age group of 25–29 years, followed by 2005–2009 for the age group of 20–24 years. By the most recent periods (2015–2018), except for the age group of 15–19 years, adult females had higher mortality than males across all ages. A stagnation of mortality is observed among males aged 25–39 years (during 1980–1984, 2000–2004) and 40–44 years (during 1990–1994, 2000–2004). Overall, the periodic mortality rates indicate an increase in mortality among older adults, specifically those aged 50–59 years, in the recent decades (2005–2018).

Although the trends in period-specific mortality suggest an overall decline in adult mortality levels in India, this analysis is unable to detect any subtle changes or critical change points in the time-series data. Therefore, this paper tried to look for any significant major changes and timing of these changes in adult mortality levels during 1970–2018 using the CPA method. The objective is to identify critical change points in adult mortality rates and assess their timing in relation to significant changes in socioeconomic and demographic indicators in order to provide several policy insights.

Figures 4 and 5 provide results of the change-point analyses for ASDRs in adult ages (15–59 years) by period and cohort, between 1970 and 2018 in India. To account for gender-specific survivorship dynamics, a separate change-point analysis was conducted for females (Panel A) and males (Panel B). The graphical representation and table of significance, with a confidence level at 95%, obtained from CPA show multiple critical change points in adult mortality levels in India. The critical changes in adult mortality rates are indicated by the blueshift-shaded background with control lines.

Figure 4 shows six crucial change points (1979, 1986, 1993, 2003, 2007, and between 2011 and 2012) in adult mortality rates for females, while it detects five change points (1979, 1987, 1993, 2003, and 2014) in male adult mortality rates. The confidence interval and level of change indicate that the most significant major shifts in adult mortality occurred in 1986 for females and in 1987 for males (100% confidence interval with Level 1 change). During this period, female mortality dropped from 5.51 to 4.41, while male mortality decreased from 5.48 to 5.02. The change-point analyses for period-specific adult mortality rates are highly confident about these two time points. The absence of a wider confidence interval for these changes suggests that the timings of these changes can be accurately pinpointed compared to other changes. Level 1 is also an indication of the importance of 1986 and 1987 time periods which are the most visibly apparent in the plot in Figure 4. Additionally, several other critical change points were also observed during 1993, 2003, 2007, 2011, and 2014 and shows that the magnitude of mortality changes has been decreasing over time. However, these change points, while notable, do not meet the criteria for significance outlined in the change-point analysis guidelines.

Figure 5 shows the critical change points by birth cohorts for adult females (Panel A) and males (Panel B), respectively. The results show two critical changes for female birth cohorts (1930 and 1955) and three critical changes for male birth cohorts (1930, 1950, and 1970). The table of significance indicates that the rate of decline was more explicit for the 1955 birth cohort for females (at 100% confidence level with Level 3 change) and 1950 birth cohort for males (between 1935 and 1950 at 99% confidence interval with Level 2 change). During this period, female mortality dropped from 7.58 to 2.51 and for males, it decreased from 9.83 to 5.82.

In addition, state-specific change-point analyses of ASDRs were carried out separately for males and females and presented in Appendix Table 1. The results show significant variations in adult mortality patterns (detected from the predicted change points), across and within states, by gender. Notably, Andhra Pradesh, Kerala, Maharashtra, Rajasthan, Uttar Pradesh, and West Bengal have a higher number of critical change points for males, while Kerala, Karnataka, Tamil Nadu, Madhya Pradesh, Rajasthan, and Odisha for females.

APC estimates: description of their independent effects on adult mortality rates

The study used the APC–IE model for adult mortality rates and run separately for females and males. Table 1 shows the APC regression model estimates covering a total of 9 five-year age groups (15–19 to 55–59 years), 10 five-year period (1970–1974 to 2015–2018), and 18 birth cohorts (10+ 9–1 = 18) (1915–1919 to 2000–2004). The results highlight several stimulating insights related to the distinct sources of mortality variations among Indian adults over the past four decades. The following sections discuss the effects of APC on adult mortality in detail.

Panel A

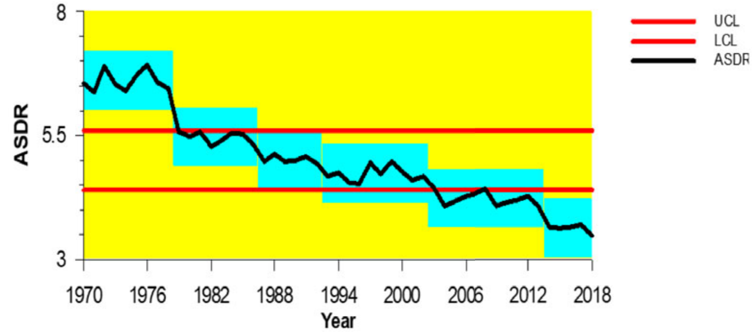

Table of Significant Changes for Female

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Year	Confidence Interval	Conf. Level	From	To	Level
1979	(1979, 1979)	100%	6.3733	5.11	2
1986	(1986, 1986)	100%	5.11	4.4143	1
1993	(1993, 1993)	95%	4.4143	3.799	3
2003	(2003, 2003)	99%	3.799	3.0575	4
2007	(2007, 2007)	98%	3.0575	2.7825	4
2011	(2010, 2012)	95%	2.7825	2.5562	3

Panel B

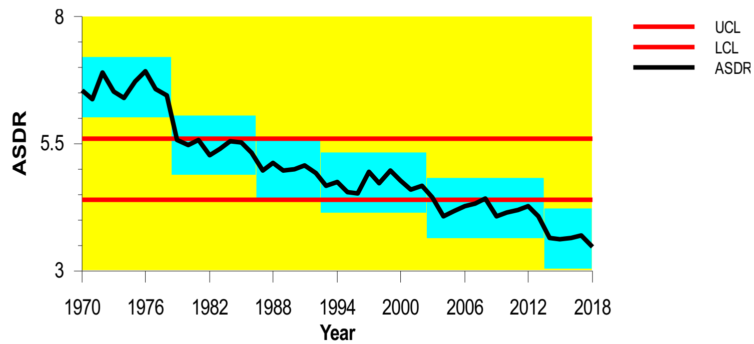

Table of Significant Changes for Male

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Year	Confidence Interval	Conf. Level	From	To	Level
1979	(1979, 1979)	100%	6.6111	5.4763	2
1987	(1987, 1987)	100%	5.4763	5.02	1
1993	(1993, 1996)	96%	5.02	4.733	3
2003	(2003, 2003)	100%	4.733	4.2409	4
2014	(2014, 2014)	100%	4.2409	3.628	3

Figure 4. Change-point analyses of trends in period-specific age-standardized adult mortality rates in India from 1970 to 2018.

Note: Figures and tables in Panel A and B show crucial change points in period-specific adult mortality rates for females and males, respectively. ASDR represents period-specific death rates for adults aged 15–59 years. UCL: upper control limit, LCL: lower control limit, and Level: confidence interval.

Panel A

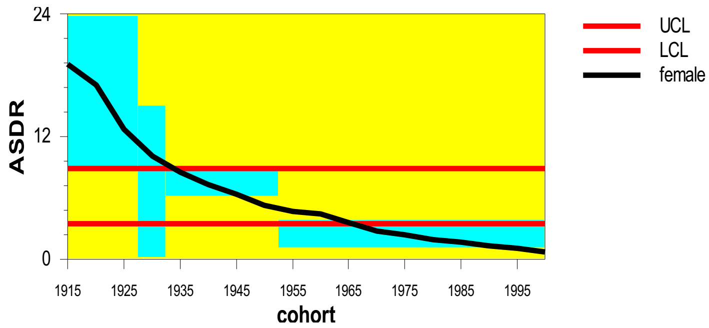

Table of Significant Changes for female

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Birth cohort	Confidence Interval	Conf. Level	From	To	Level
1930	(1930, 1930)	98%	16.317	7.58	3
1955	(1955, 1955)	100%	7.58	2.513	3

Panel B

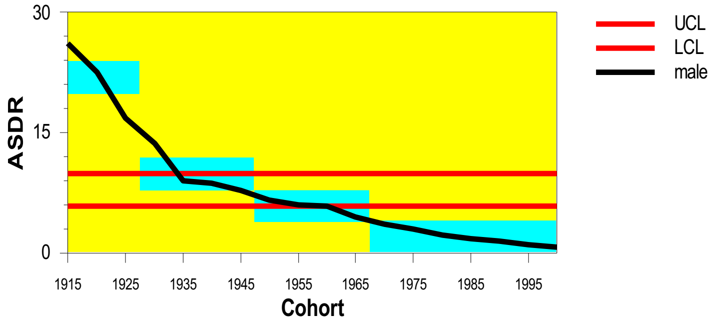

Table of Significant Changes for male

Confidence Level for Candidate Changes = 50%, Confidence Level for Inclusion in Table = 90%, Confidence Interval = 95%, Bootstraps = 1000, Without Replacement, MSE Estimates

Birth cohort	Confidence Interval	Conf. Level	From	To	Level
1930	(1930, 1930)	96%	21.83	9.825	3
1950	(1935, 1950)	99%	9.825	5.815	2
1970	(1970, 1970)	98%	5.815	2.0771	4

Figure 5. Change-point analyses of trends in cohort-specific age-standardized adult mortality rates in India from 1970 to 2018.

Note: Figures and tables in Panels A and B show crucial change points in cohort-specific adult mortality rates for females and males, respectively. ASDR represents cohort-specific death rates for adults aged 15–59 years. UCL: upper control limit, LCL: lLower control limit, and Level: confidence interval.

Table 1. IE regression model: APC analysis of adult mortality in India by gender

	Female				Male			
			95% CI				95% CI	
	Coefficient	*p*-Value	LL	UL	Coefficient	*p*-Value	LL	UL
Age								
15–19	−1.01 (0.20)	0.000	−1.4	−0.62	−1.43 (0.23)	0.000	−1.87	−0.98
20–24	−0.71 (0.17)	0.000	−1.05	−0.37	−1.07 (0.20)	0.000	−1.45	−0.68
25–29	−0.67 (0.18)	0.000	−1.02	−0.32	−0.87 (0.19)	0.000	−1.24	−0.50
30–34	−0.51 (0.17)	0.003	−0.85	−0.17	−0.52 (0.17)	0.002	−0.86	−0.19
35–39	−0.31 (0.16)	0.061	−0.63	0.01	−0.17 (0.15)	0.267	−0.46	0.13
40–44	0.02 (0.15)	0.875	−0.27	0.32	0.24 (0.13)	0.058	0.01	0.50
45–49	0.49 (0.13)	0.000	0.24	0.75	0.75 (0.11)	0.000	0.53	0.97
50–54	1.13 (0.11)	0.000	0.91	1.34	1.31 (0.10)	0.000	1.12	1.51
55–59	1.56 (0.11)	0.000	1.36	1.77	1.75 (0.09)	0.000	1.57	1.93
Period								
1970–1974	0.80 (0.14)	0.000	0.53	1.08	0.51 (0.14)	0.000	0.24	0.79
1975–1979	0.67 (0.13)	0.000	0.41	0.93	0.49 (0.12)	0.000	0.25	0.74
1980–1984	0.43 (0.14)	0.002	0.16	0.69	0.29 (0.13)	0.023	0.04	0.54
1985–1989	0.26 (0.14)	0.067	−0.02	0.53	0.18 (0.13)	0.154	−0.07	0.43
1990–1994	0.11 (0.15)	0.461	−0.18	0.39	0.10 (0.13)	0.460	−0.16	0.35
1995–1999	−0.35 (0.16)	0.028	−0.67	−0.04	−0.32 (0.14)	0.023	−0.6	−0.04
2000–2004	−0.27 (0.16)	0.086	−0.58	0.04	−0.17 (0.14)	0.209	−0.44	0.10
2005–2009	−0.51 (0.17)	0.002	−0.84	−0.18	−0.30 (0.14)	0.031	−0.57	−0.03
2010–2014	−0.66 (0.17)	0.000	−1.00	−0.33	−0.43 (0.14)	0.002	−0.70	−0.15
2015–2018	−0.46 (0.18)	0.009	−0.81	−0.11	−0.36 (0.15)	0.020	−0.66	−0.06
Cohort								
1915–1919	0.47 (0.25)	0.056	−0.01	0.96	0.63 (0.22)	0.005	0.19	1.10
1920–1924	0.46 (0.19)	0.013	0.10	0.83	0.54 (0.17)	0.001	0.21	0.87
1925–1929	0.38 (0.17)	0.029	0.04	0.72	0.40 (0.16)	0.009	0.10	0.71
1930–1934	0.31 (0.17)	0.071	−0.03	0.64	0.31 (0.15)	0.040	0.01	0.61
1935–1939	0.27 (0.17)	0.105	−0.06	0.61	0.25 (0.15)	0.100	−0.05	0.54
1940–1944	−0.03 (0.18)	0.857	−0.38	0.32	−0.12 (0.16)	0.459	−0.44	0.20
1945–1949	0.30 (0.17)	0.080	−0.04	0.63	0.23 (0.16)	0.147	−0.08	0.54
1950–1954	0.18 (0.17)	0.313	−0.17	0.52	0.09 (0.16)	0.584	−0.23	0.41
1955–1959	0.09 (0.17)	0.612	−0.25	0.43	0.02 (0.16)	0.877	−0.29	0.34
1960–1964	0.04 (0.18)	0.800	−0.30	0.39	−0.01 (0.16)	0.950	−0.33	0.31
1965–1969	0.002 (0.20)	0.991	−0.40	0.40	−0.10 (0.19)	0.599	−0.47	0.27
1970–1974	−0.08 (0.24)	0.738	−0.56	0.39	−0.10 (0.22)	0.640	−0.53	0.33
1975–1979	−0.09 (0.28)	0.757	−0.63	0.46	−0.10 (0.25)	0.683	−0.60	0.39

(*Continued*)

Table 1. (*Continued*)

	Female				Male			
			95% CI				95% CI	
	Coefficient	*p*-Value	LL	UL	Coefficient	*p*-Value	LL	UL
1980–1984	−0.20 (0.32)	0.544	−0.83	0.43	−0.17 (0.30)	0.559	−0.76	0.41
1985–1989	−0.32 (0.37)	0.392	−1.04	0.41	−0.30 (0.35)	0.392	−0.98	0.39
1990–1994	−0.40 (0.44)	0.363	−1.27	0.47	−0.37 (0.42)	0.388	−1.20	0.47
1995–1999	−0.60 (0.58)	0.296	−1.74	0.53	−0.52 (0.56)	0.356	−1.62	0.58
2000–2004	−0.79 (1.07)	0.461	−2.88	1.30	−0.68 (1.07)	0.526	−2.77	1.42
Intercept	−17.28 (0.09)	0.000	−17.47	−17.1	−17.17 (0.09)	0.000	−17.35	−17.00
Deviance	9.64				11.52			
AIC	4.17				4.34			
BIC	−242.35				−240.47			

Note: Standard errors are in parentheses.
AIC: Akaike Information Criterion.
BIC: Bayesian Information Criterion.

Age effects

After controlling for period and cohort effects, the analysis shows a decline in mortality between the age 15 and 34 years. Except for these ages, adult mortality does not report any significant decline. The decline in mortality for adults becomes insignificant between the age 35 and 44 years (*p*-value >0.05), regardless of gender. However, the findings show a noticeable increase in mortality for older adults aged 45–59 years. The steepest decline in mortality is observed in the age group of 15–19 years, while the increase in mortality begins in mid-adulthood (45–49 years) and peaks in the oldest age group (55–59 years). Furthermore, the results highlight gender differences in adult mortality decline across age groups, indicating a more substantial decline in mortality among males during early adulthood, followed by a rapid increase in mortality for older adults compared to females.

Period effects

Period effects suggest a continuous improvement in adult survival over time. The results show a downward trend in mortality rates which can be categorized into two phases: a steady decline without notable changes between 1970 and 1994; followed by a noteworthy but uneven decline during 1995–2018. The significant decline in adult mortality began after the mid-1990s, with the highest drop occurring during the period 2010–2014. However, there was a reduction in the magnitude of mortality decline during 2015–2018. The rate of mortality decline was much higher among females than males. The male–female difference for 2005–2009 and 2010–2014 was >0.20, although this gap narrowed in the most recent periods.

Cohort effects

Cohort effects were characterized by a continuous insignificant decline in adult mortality from the earliest to the most recent birth cohorts. However, there is evidence of a decline in mortality starting from the 1965–1969 birth cohort for males and from the 1970–1974 birth cohort for females, continuing to the most recent birth cohorts. Both females and males had insignificant declines in adult mortality during the reference period. The estimated cohort effect suggests that mortality decline started earlier for male cohorts compared to female cohorts.

Table 2. Regression-based decomposition of inequality in ASDRs by age–cohort and period

Age-groups	Coefficient	Standard error	P > t	Contribution (%)
15–19	0.00	0.00	0.000	0.000
20–24	0.38	0.50	0.446	−0.54
25–29	0.45	0.50	0.364	−0.62
30–34	0.63	0.50	0.216	−0.75
35–39	1.21	0.51	0.018	−1.09
40–44	2.30	0.51	0.000	−0.91
45–49	4.32	0.52	0.000	2.09
50–54	8.13	0.53	0.000	16.91
55–59	13.73	0.54	0.000	60.48
Cohort	−0.10	0.01	0.000	7.15
Period	0.16	0.02	0.000	8.89
Residual				8.40
Constant	194.43	16.13	0.000	100.00
R-square	0.92			
N	180			

Relative contribution of the age-groups, period, and cohort to the inequality in ASDR in adults

This section presents the results of a regression-based decomposition of inequality carried out for different five-year age groups, periods, and cohorts to analyse how changes in mortality within different age groups have contributed to the overall change in adult mortality over the past four decades. The analysis (Table 2) indicates a substantial contribution of age effects to the change in adult mortality, followed by period and cohort effects. After controlling for period and cohort effects, it is evident that older adult ages (55–59 years) are the major contributors (60.48%) to the change in adult mortality during the period from 1970 to 2018. Additionally, positive contributions are observed for the age groups between 45 and 54 years, contributing 2.09% and 16.91%, respectively. The findings show no significant contributions from younger adult age groups (>40 years) to the change in mortality during this period. Both period- and cohort-specific conditions also have a positive contribution to this change. However, period effects contribute more (8.89%) in explaining changes in adult mortality than cohort effects (7.15%) in India.

The changing health status of adults

Long-term changes in mortality always coincide with structural shifts in disease burden. To gain a comprehensive understanding of a population health needs, it is crucial to analyse age–sex-specific mortality as well as disease burden. This section employs a summary measure of health status, i.e. the DALYs to unravel changes in adult mortality and disease burden over time. The DALYs represent the sum of the years of life lost due to premature mortality and the years lived with a disability due to prevalent cases of the disease or health condition in a population (WHO, 2011). The ratio of DALYs to total population across adult age groups between 1990 and 2016 in Figure 6 shows an increasing concentration of disease burden among older adults. It also illustrates that the increase in DALYs among older adults has been more rapid in the recent decade. Health loss among adults started rising from age 45–49 years and peaked at 55–59 (from 1.1 to 1.7). A ratio of >1 explains higher health loss relative to its population composition. The

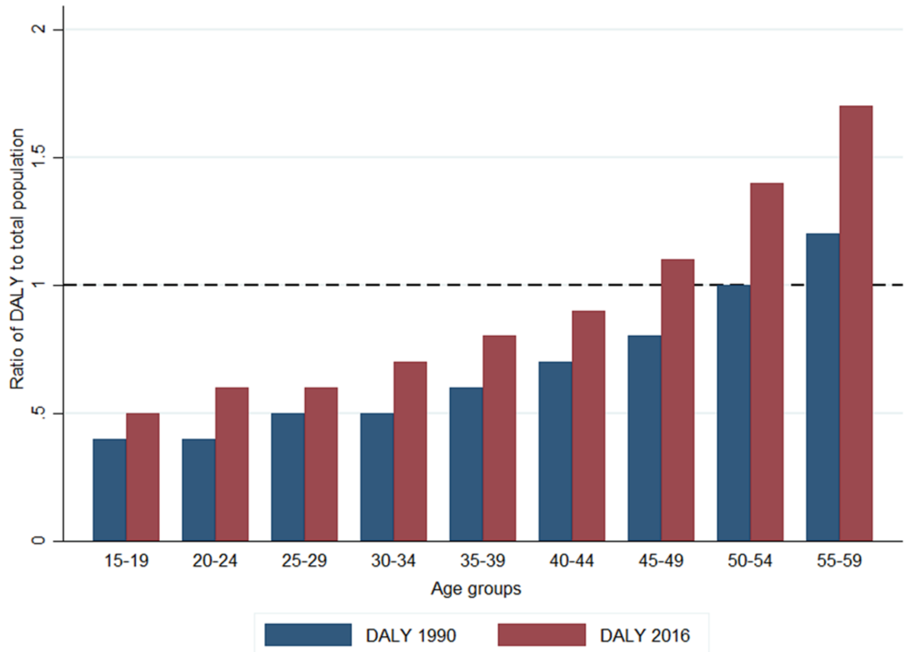

Figure 6. The ratio of DALYs to total population among different adult age groups in India between 1990 and 2016.

proportion of DALYs to the total population in the age group of 55–59 years increased by 42% between 1990 and 2019, indicating worsening health conditions for older adults in recent years.

On the other hand, cause-specific DALYs provide valuable insights into changes in the pattern of morbidity and associated health conditions among adults. Figure 7 shows the disease-specific contribution to DALYs during 1990 and 2019. The distribution of cause-specific DALYs among adult age groups for these two periods reveals a decline in DALYs due to communicable, maternal, neonatal, and nutritional diseases (CMNNDs) and a consistent increase in DALYs affected by NCDs. Specifically, age-standardized DALYs from CMNNDs decreased by nearly 50% for both sexes, while NCDs saw an increase of 39% for males and 50% for females.

In addition to this, injuries also made a substantial contribution to DALYs over the years, particularly among young adult males aged between 15 and 29 years. The trends in DALYs suggest that male adults experienced a growing number of premature deaths due to injuries, accompanied by disability resulting from NCDs, starting soon after young adulthood. Conversely, NCDs have played a crucial role in the surge of health loss among adult females. This analysis indicates that premature deaths and years of healthy life loss and disability due to NCDs among adults were more prevalent in 2019 compared to 1990.

Discussion

This paper analysed trends and patterns in adult mortality over an extended period, exploring changes attributed to APC effects. The current study makes significant contributions to the existing knowledge in four ways regarding the transition and emerging patterns in adult mortality in India.

Firstly, the study uses change-point analyses for the first time, examining critical shifts in adult mortality trends over a more extended period than previously explored in the Indian context. Secondly, it is the first study to investigate APC effects on adult mortality for both males and

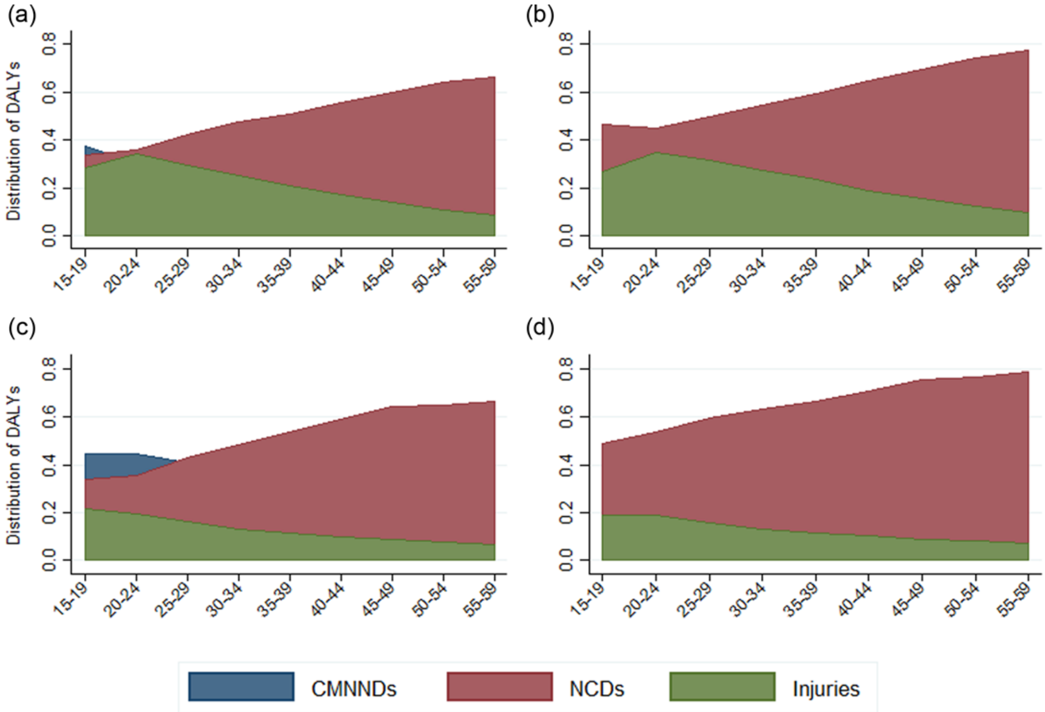

Figure 7. Trends in the contribution of major causes of death to disease-adjusted life years (DALYs) among different adult age groups in India between 1990 and 2016.
Note: Panels (a) and (b) for males; (c) and (d) for females in 1990 and 2016, respectively.

females in India. Thirdly, the APC results are interpreted and qualitatively explained in relation to demographic theories of mortality reduction, socioeconomic development, and epidemiological transition in the country influencing adult mortality during the study period. The study incorporates more factors to understand the APC effect on adult mortality in India compared to the one in the previous study by Navneetham (1993). Lastly, for the first time in the Indian context, the current study uses a comparatively robust method, providing reliable estimates of the independent effects of APC on adult mortality rates.

The period-specific mortality trends and identified critical change points show an overall decline in the level of mortality for adult age groups. This finding supports a shift in age schedule of mortality, observed from younger to older ages, due to a sizeable reduction in child and maternal mortality along with an overall rise in life expectancy for both gender since the mid-1990s in India (Yadav and Arokiasamy, 2020). In addition, the evolution of structural changes in the population and health policy framework post-1960s contributed to a significant improvement in demographic and health indicators including adult survival over time (Goli and Arokiasamy, 2013; Grover and Singh, 2020).

The APC effects provide several insightful findings about the changes in adult mortality associated with unique historical, social, health, and environmental conditions experienced by adults over the study period. The age effects indicate an increase in mortality from middle adulthood, suggesting premature mortality among Indian adults. This finding is consistent with previous studies that reported a growing proportion of premature adult deaths in the annual burden of all deaths in India (Dubey and Mohanty, 2014; Rao *et al.*, 2021). The rising risk of premature mortality from NCDs contributes to a growing NCD-related death toll, driven by the rapidly ageing population in countries such as India (Bloom *et al.*, 2011).

The period effects show improvements in adult survival during the 1970s and 1980s, aligned with a steady decline in crude death rate, marked by the absence of famines, natural calamities (drought and flood), and epidemics (Navaneetham, 1993; Goli and Arokiasamy, 2013). The decline in adult mortality during this period is also paralleled by the implementation of public health programmes between 1968 and 1999, which includes maternal and child health, family planning programmes, and vaccination against infectious diseases (Jain *et al.*, 1985; Bhat, 2002; Rao, 2016). Moreover, in the 1990s, economic development (including reforms in 1991, GDP and income growth, and poverty reduction) along with increased educational opportunities, state interventions in providing basic facilities and healthcare, may have collectively contributed to the decline in adult mortality (Ahluwalia, 2002; Saikia and Bhat, 2008; Saikia and Ram, 2010; Goli and Jaleel, 2014; Nayyar, 2017; Barik *et al.*, 2018; Saikia *et al.*, 2019). Studies have reported that various demand-driven and people-centred interventions in basic facilities gained momentum from 1999 onwards, contributing to healthier and longer lifespans for the Indian population (Krishnaji and James, 2002; Arokiasamy and Goli, 2013). Besides, an increase in overall public spending on healthcare during this period resulted in expanded clinical services, medical technology, and healthcare infrastructure (Rao, 2016; Srinivasan, 2017). Numerous accessible, affordable, and quality public health efforts were developed to eliminate communicable diseases like tuberculosis (DOTS), malaria, and HIV/AIDs (NACO) (Srinivasan, 2010). Despite the decline in mortality over the years, the current study reveals a slowdown in the decline of mortality rates in recent years. This slowdown can be partly attributed to the economic downturns, reduced social and health sector spending in real terms, and the growing burden of NCDs recently (ICMR, PHFI, and IHME, 2017; India State-Level Disease Burden Initiative Collaborators, 2017; Arokiasamy, 2018; Drèze *et al.*, 2020). The study also finds a congruence between the period effects obtained from the APC analysis and the results of the change-point analysis. Both analyses show that the decline in adult mortality began in the late 1980s and continued until the recent decade. Moreover, it suggests that although the reduction in mortality has persisted, the rate of decline has slowed down over time.

The APC regression estimates reveal improvement in adult survival for the recent birth cohorts. Whereas a high mortality rate among older birth cohorts (1915–1949) points to their experiences with historical events of famine and drought followed by consequent crop failures and food shortages, economic depression, and outbreaks of epidemics (Navneetham, 1993). However, the launch of national economic, social, and health programmes during the 1950s resulted in higher socioeconomic attainment among the population (Das *et al.*, 2021). Cohorts experiencing these events benefited from improved survival supported by the results showing a gradual decline in mortality from 1965 to 1969 (for males) and 1970 to 1974 (for females) cohorts continuing to subsequent birth cohorts. Moreover, an increased focus on generating employment, stable prices of goods, reduction of poverty, availability of food and water, primary healthcare and other necessities, universal primary education, and the empowerment of socially disadvantaged classes (scheduled castes, scheduled tribes, and other backward castes) after the ninth five-year plan (1997–2002) significantly impacted cohort survival over time, especially in the 2000–2004 birth cohort who show lower mortality levels (Planning Commission, 1997; 2002; 2008; 2012; Grover and Singh, 2020).

The findings regarding the overall improvement in survival across different ages indicate significant and positive gains for both younger (under 19 years) and adults aged 45 and above over the years. However, changes in morality have a negative impact on the middle (20–44 years) aged adults over time. The study identifies that older adults (aged 55–59 years) are the leading contributors to the shift in adult mortality from 1970 to 2018. Both period- and cohort-specific conditions positively contribute to this change, with period effects exerting a greater influence than cohort effects in explaining changes in adult mortality in India.

The study aims to establish a link between changes in the decline of adult mortality and the ongoing epidemiological transition, capturing a comprehensive understanding of the adult health situation over this study period. The findings reveal that although the decrease in communicable diseases added several years to the length of life, this effect appears to have levelled off and been replaced by the burden of NCDs (Singh *et al.*, 2017) and life loss from chronic morbidity has halted further health gains in adult groups (Menon *et al.*, 2019). Moreover, the positive effects of better nutrition, healthy behaviour, and lifestyle factors seem to have limited impact on adults, whereas risk factors contributing to aggravated adult health, for example, the double burden of malnutrition (undernutrition and overnutrition), smoking and alcohol consumption, physical inactivity, job pressure, fat intake, and competitive mental pressure have been reported to increase over the period (Masironi and Rothwell, 1988; Gajalakshmi *et al.*, 2003; Jha *et al.*, 2008; Yadav and Arokiasamy, 2014; Agrawal *et al.*, 2016; Reubi *et al.*, 2016).

Finally, the study provides valuable insights into the survival status among adults by gender revealing significant gender differences in period effects on adult mortality that were more pronounced during the late 1990s (Canudas-Romo and Saikia, 2013). The results highlight a faster decline in mortality during early adulthood for males compared to females. However, the decline in mortality of males levels off in middle adulthood and is replaced by an increase in mortality during older ages. This points to a greater variability in age at death and weak mortality compression that led to higher mortality among adult males in India (Yadav and Arokiasamy, 2020).

The improvements in mortality for adult females over the study period align with the landmark commitments of the millennium development goals (MDGs) in 2000. The MDGs aimed to reduce child and maternal mortality, discrimination against women, and raise education among women in developing countries, including India (Kundu *et al.*, 2013; Boopathy *et al.*, 2014; UNESCAP, 2015). The advantage in survival in adult females can also be linked to changes in fertility behaviour driven by ongoing fertility transitions in the country (Goli and Arokiasamy, 2013). The combination of fewer and delayed childbearing along with the reduced complex association of age at marriage, educational attainment, low social status of women, increasing acceptance of family planning, and smaller family norms among successive younger birth cohorts have all contributed to higher female survivorship (Goli and Jaleel, 2014; Marphatia *et al.*, 2017).

Limitations

While the study has produced several critical policy-relevant findings, it also has some limitations. The use of the SRS imposes constraints on the scope of analysis. For example, the SRS does not provide age-specific mortality rates by socioeconomic background variables. Thus, the study fails to examine specific risk factors influencing adult mortality changes in India. Moreover, the SRS does not offer information on cause and ASDRs which could have generated a better understanding of adult health in the country. The findings are limited to the national level as the reliability of information claimed to vary by states. For example, data for some periods (1970–1980) are not available for states like Bihar and West Bengal, and estimates for small states and union territories may not be highly reliable due to their small sample size. These data limitations restrict the study from presenting a comprehensive picture of mortality for the entire subcontinent. Finally, this study exclusively relies on the IE method. Despite being a popular method in APC studies, it has received critical reviews regarding its assumptions, validity, and application scope for estimating robust APC results. Several studies have criticized this approach for solving the identification problem without considering any theoretical background information (Bell and Jones, 2013; Held and Riebler, 2013; Luo, 2013; Bell and Jones, 2014; Masters and Powers, 2020). This emphasizes the importance of understanding the method's limitations and checking the reliability of the estimates using alternative methods.

Conclusion

The study underscores the need for long-term and effective healthcare interventions to address adult mortality conditions in India. While there has been an overall improvement in adult survival between 1970 and 2018, it is also evident that Indian adults spend more years of their lives in ill health (Pati *et al.*, 2014; Pandey *et al.*, 2017; Banerjee *et al.*, 2019). Specifically, the higher mortality observed in middle adulthood (40–59 years) and the deceleration in the pace of mortality decline in the most recent period raise significant concerns. This slowdown in adult mortality decline could impact the prospects of overall increase in life expectancy at birth and pose a challenge to public health efforts. However, reducing adult mortality in India can be a complex task, given the substantial variation in adult mortality by state and gender (Yadav, 2021). From a policy perspective, the greater life loss and disabilities among young adult males and older adults may have critical economic implications, particularly as mortality in middle adulthood is known to impact the labour force supply (Herzer & Nagel, 2019). Therefore, the current assessment of adult mortality dynamics using an APC framework draws attention to designing effective preventive and curative healthcare policies and targeted interventions, with a particular focus on NCDs and injuries.

Data availability statement. Estimates of mortality rates from SRS and DALYs from the Indian State-level Disease Burden Initiative by age and sex between 1970 and 2018 for India are available in public open-access repositories as listed in relevant references.

Disclosure statements.

Ethical approval. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Funding statement. This research received no specific grant from any funding agency, commercial entity or not-for-profit organization.

Competing interests. The authors have no conflicts of interest to declare.

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Appendix

Table A1. Change-point analyses: significant change points in period-specific age-standardized adult mortality rates of selected major states in India, from 1970 to 2018

	Men					Women				
		Volume of change					Volume of change			
India/states	Change points	From	To	Confidence interval	Confidence level	Change points	From	To	Confidence interval	Confidence level
Andhra Pradesh	1977	8.21	6.51	(1975, 1977)	96%	1978	7.22	4.94	(1978, 1978)	100%
	1981	6.51	5.57	(1981, 1981)	100%	1987	4.94	4.04	(1987, 1987)	100%
	1993	5.57	4.7	(1993, 1993)	94%	2000	4.04	3.26	(1999, 2002)	100%
	1996	4.7	5.5	(1996, 1996)	98%	2009	3.26	2.82	(2001, 2009)	95%
	2004	5.5	5.08	(2002, 2008)	98%					
	2014	5.08	3.98	(2014, 2014)	100%					
Assam	1977	8.54	5.99	(1977, 1977)	100%	1978	9.61	7.08	(1978, 1978)	100%
	2003	5.99	5.19	(1996, 2007)	99%	1987	7.08	5.43	(1987, 1988)	100%
	2014	5.19	4.2	(2011, 2014)	97%	2004	5.43	4.11	(2002, 2004)	100%
						2011	4.11	3.09	(2010, 2013)	99%
Bihar	1987	5.97	5.01	(1987, 1987)	100%	1986	6.73	5.64	(1986, 1986)	100%
	1999	5.01	4.02	(1999, 2000)	100%	1995	5.64	4.66	(1994, 1997)	99%
	2009	4.02	3.19	(2007, 2009)	98%	2001	4.66	3.41	(2001, 2001)	100%
	2014	3.19	2.42	(2014, 2014)	97%	2011	3.41	2.49	(2010, 2011)	100%
Chhattisgarh	No significant changes					No significant changes				
Delhi	2015	2.97	2.23	(2015, 2015)	98%	2008	2.18	1.68	(2007, 2008)	99%

(*Continued*)

Table A1. (*Continued*)

India/states	Men					Women				
	Change points	Volume of change From	Volume of change To	Confidence interval	Confidence level	Change points	Volume of change From	Volume of change To	Confidence interval	Confidence level
Gujarat	1979	6.71	5.36	(1978, 1981)	100%	1978	5.72	4.72	(1978, 1978)	
	1994	5.36	4.16	(1993, 1994)	100%	1986	4.72	4.08	(1984, 1989)	
						1993	4.08	3.25	(1993, 1993)	
						1998	3.25	2.71	(1997, 2000)	
						2008	2.71	2.38	(2002, 2011)	
Haryana	1976	3.62	4.38	(1976, 1976)	93%	1975	4.17	4.65	(1971, 1984)	95%
	1982	4.38	4.09	(1979, 2018)	90%	1985	4.65	3.14	(1983, 1986)	100%
						2001	3.14	2.25	(1999, 2001)	100%
Himachal Pradesh	No significant changes					2008	2.51	1.8	(2005, 2010)	100%
Jammu & Kashmir	2005	3.11	2.6	(2005, 2017)	92%	2011	2.19	1.89	(2011, 2014)	98%
Kerala	1977	4.55	4.01	(1975, 1978)	99%	1977	3.22	2.37	(1976, 1978)	99%
	1986	4.01	3.8	(1980, 1988)	97%	1984	2.37	1.81	(1984, 1984)	99%
	1993	3.8	3.34	(1993, 1995)	98%	1994	1.81	1.66	(1992, 1999)	93%
	2014	3.34	2.57	(2014, 2014)	100%	2005	1.66	1.37	(2004, 2008)	100%
						2015	1.37	1.77	(2014, 2018)	93%
Karnataka	1979	6.13	4.81	(1979, 1979)	100%	1979	6.01	4.24	(1979, 1979)	100%
	2013	4.81	3.98	(2012, 2013)	98%	1987	4.24	3.37	(1986, 1987)	100%
						2001	3.37	2.85	(2001, 2001)	100%
						2009	2.85	2.66	(2007, 2018)	93%
Maharashtra	1980	5.95	4.55	(1980, 1980)	100%	1982	4.94	3.54	(1982, 1982)	100%
	2002	4.55	4.07	(1996, 2003)	94%	1993	3.54	3	(1991, 1994)	100%
	2010	4.07	3.65	(2008, 2010)	96%	2004	3	2.16	(2004, 2005)	100%
	2015	3.65	3.27	(2013, 2015)	91%					
Madhya Pradesh	1978	6.99	5.62	(1977,1978)	99%	1978	7.04	5.76	(1978, 1978)	99%
	1984	5.62	5.18	(1984, 1997)	98%	1984	5.76	4.84	(1983, 1987)	94%
	2004	5.18	4.39	(2002, 2007)	100%	2002	4.84	3.82	(2000, 2002)	100%
						2008	3.82	2.91	(2008, 2008)	99%
						2016	2.91	2.46	(2015, 2016)	91%
Odisha	1978	8.78	5.98	(1976, 1979)	100%	1979	8.51	6.15	(1977, 1980)	100%
	2003	5.98	4.82	(2001, 2003)	100%	1989	6.15	5.01	(1987, 1980)	100%
	2014	4.82	3.9	(2013,2014)	98%	2003	5.01	3.8	(2001, 2003)	100%
						2008	3.8	3.39	(2008, 2008)	99%
						2014	3.39	2.89	(2014, 2014)	98%
Punjab	1985	3.88	4.87	(1984, 1987)	100%	1975	3.8	2.97	(1973, 1976)	99%
	2000	4.87	4.31	(1993, 2008)	100%	2001	2.97	2.26	(2000, 2001)	100%
						2014	2.26	2.52	(2006, 2017)	95%
Rajasthan	1978	6.52	5.56	(1977, 1980)	99%	1977	6.07	5.04	(1975, 1978)	95%
	1989	5.56	4.57	(1988, 1989)	100%	1986	5.04	3.86	(1985, 1986)	96%

(*Continued*)

Table A1. (*Continued*)

India/states	Men					Women				
	Change points	Volume of change		Confidence interval	Confidence level	Change points	Volume of change		Confidence interval	Confidence level
		From	To				From	To		
	2000	4.57	3.91	(1996, 2000)	91%	1995	3.86	2.96	(1994, 1995)	100%
	2003	3.91	3.58	(2003, 2003)	99%	2003	2.96	2.36	(2003, 2003)	100%
	2012	3.58	3.91	(2012, 2018)	100%	2010	2.36	2.16	(2009, 2015)	91%
Tamil Nadu	1978	7.44	6.04	(1978, 1978)	100%	1978	7.55	5.91	(1977, 1978)	100%
	1988	6.04	5.33	(1986, 1991)	99%	1982	5.91	4.83	(1982, 1982)	98%
	2001	5.33	4.57	(2000, 2001)	100%	1989	4.83	3.93	(1989, 1989)	98%
	2014	4.57	3.93	(2014, 2014)	100%	1995	3.93	3.47	(1995, 1996)	100%
						2005	3.47	2.78	(2005, 2005)	95%
						2008	2.78	2.51	(2008, 2008)	100%
						2016	2.51	2.14	(2016, 2016)	98%
Uttar Pradesh	1978	6.81	5.8	(1975, 1980)	99%	1979	7.22	6.06	(1976, 1981)	99%
	1993	5.8	4.94	(1989, 1994)	98%	1988	6.06	4.79	(1987, 1989)	100%
	2004	4.94	4.52	(2000, 2006)	99%	2004	4.79	3.43	(2004, 2004)	100%
	2014	4.52	3.91	(2012, 2017)	100%					
West Bengal	1987	4.96	4.27	(1984, 1988)	100%	1986	4.88	4.12	(1985, 1986)	97%
	1998	4.27	3.76	(1994, 1998)	93%	1993	4.12	3.48	(1985, 1993)	99%
	2003	3.76	3.46	(2003, 2007)	92%	2001	3.48	2.58	(2001, 2001)	100%
	2015	3.46	2.98	(2014, 2015)	99%	2009	2.58	2.23	(2005, 2011)	99%

Notes: Estimates are based on a thousand bootstraps without replacement. The confidence level for mortality changes is 50% and the confidence level for inclusion in the table is 90%. Confidence interval is at 95%.

Cite this article: Misra S, Singh A, Goli S, and James KS (2024). Trends in adult mortality rates in India, 1970 to 2018: age–period–cohort analysis. *Journal of Biosocial Science* **56**, 929–951. https://doi.org/10.1017/S0021932024000270