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Research Article

Social and economic inequalities in adult mortality in India

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Research Article

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Abstract

BACKGROUND
Low- and middle-income countries (LMICs) have limited evidence of adult mortality due to a lack of reliable data. We estimated social (caste and religion) and economic (wealth quintile) inequality in adult mortality using three rounds of the National Family Health Survey (NFHS 1998–1999, NFHS 2015–2016, and NFHS 2019–2021).

METHODS
We estimated the probability of death in the 15–59 age group by social and economic characteristics. We employed the Cox proportional hazards model to assess the risk of death associated with these characteristics, adjusting for other relevant predictors.

RESULTS
Disparities in adult mortality across social and economic groups have persisted for more than two decades, with only marginal reductions in social inequality. In India, the probability of death between ages 15 and 59 (45q15 per 1,000 persons) remains consistently higher among the socially disadvantaged Scheduled Castes (SCs) and Scheduled Tribes (STs) for both men and women. After adjusting for economic factors and regional heterogeneity, Cox proportional hazards models across NFHS rounds indicate that Muslim men have a lower hazard ratio of death than upper-caste Hindu men and that the elevated mortality risk among SCs and STs relative to upper-caste Hindu men is attenuated. Among adult women, upper-caste Hindu women demonstrate the lowest hazard ratios for adult mortality. Higher wealth status is strongly associated with lower mortality risk; individuals from the richest households experience substantially reduced mortality, approximately 60% lower for men and 40% lower for women compared with those from the poorest households across all survey periods.

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CONTRIBUTION

This study estimates adult mortality differentials across socioeconomic groups in LMICs using Cox proportional hazards models while accounting for regional heterogeneity.

1. Introduction

Mortality statistics are essential for evaluating public health performance and informing planning, policy, and resource allocation. They help improve health outcomes, reduce health inequalities, and guide efforts to protect population well-being. Globally, in recent decades under-5 mortality has declined substantially, whereas reductions in adult mortality have been more modest over the same period (United Nations 2024). During the Millennium Development Goals (MDGs) era, the primary focus was on reducing under-5 and maternal mortality, with two of the eight goals dedicated to these outcomes (García-Moreno and Amin 2016). In the post-2015 development agenda, the Sustainable Development Goals (SDGs) replaced the MDGs, and many targets under SDG-3 (health and well-being) are aimed at reducing adult mortality (United Nations 2015). Adult mortality has profound socioeconomic effects on households, often greater than those of child or elderly deaths. The loss of a working adult can reduce income and labour supply, disrupt children's education, lead to early marriages of orphaned girls, and cause a decline in nutritional standards (Alam and Barkat-e-Khuda 2014; Case, Paxson, and Ableidinger 2004; Dhakad and Saikia 2023c; Evans and Miguel 2007; Fortson 2011; Kadiyala et al. 2011). Consequently, elevated adult mortality can hinder progress toward several SDGs, including poverty reduction, zero hunger, quality education, and gender equality. Addressing adult mortality in low- and middle-income countries (LMICs) is therefore essential for advancing socioeconomic development and achieving global health goals.

Adult mortality (in the 15–59 age group) remains relatively high in LMICs, accounting for a large share of global adult deaths (United Nations 2019). India continues to exhibit higher adult mortality than the global average (Dhakad and Saikia 2023a; United Nations 2019). However, weak and incomplete vital registration systems across most LMICs limit the availability of reliable mortality data (Karlinsky 2024). In some Asian countries, including India, mortality is monitored through the Sample Registration System (Bhat 2002), but the absence of socioeconomic information in these data restricts their usefulness for studying the mortality determinants. Consequently, research on adult mortality patterns in India remains comparatively limited relative to the extensive body of work on under-5 mortality.

To address the challenge of limited mortality data, many countries have begun collecting information through sample-based surveys such as the Demographic and

Health Survey (DHS) (Korenromp et al. 2004). In India, a component of the DHS known as the National Family Health Survey (NFHS) records household deaths occurring before the survey along with detailed household characteristics. This provides a unique opportunity to examine the socioeconomic gradient in adult mortality in the Indian context.

The socioeconomic gradient in India, the world's most populous country, is measured through caste, religion, and economic status and their interaction (Barik, Desai, and Vanneman 2018; PK 2005). The caste system in the Vedic period in ancient India was largely based on occupation and on the traits of persons. Originally, caste identity was mobile in one's lifetime as a person changed their occupation or evolved in terms of characteristics. However, caste identity later shifted to birth only. At the lowest tier are the Dalits, termed Scheduled Castes (SCs) in the Indian constitution. Forest dwellers in geographically isolated areas with distinctive sociocultural identities are termed the Scheduled Tribes (STs). As they usually live in geographically isolated areas, such as the plains or mountainous forest, with limited interaction with the mainstream population, they are subject to marginalization. The category of Other Backward Classes (OBCs) includes a wide range of socially and economically marginalized caste groups that have historically lacked access to resources and opportunities (Bandi 2025). In contrast, the highest rungs of the caste hierarchy, often identified as upper castes, have traditionally held social, ritual, and economic privilege (Macdonell 1914). India is also home to a wide range of religious communities, including Hindus, Muslims, Christians, Sikhs, Buddhists, and Jains. Hindus constitute the largest religious group, with Muslims forming the second largest. While caste stratification originated within Indic faiths such as Hinduism, Sikhism, and Buddhism, similar hierarchical divisions are also observed among Indian adherents of Abrahamic religions, including Islam and Christianity. For example, Dalit Muslims are considered untouchable by upper-caste Muslims and Hindus in areas such as dining, everyday social interactions, housing, and access to religious sites (Trivedi et al. 2016).

A limited number of studies have focused on estimating mortality disparities by socioeconomic group beyond the under-5 age bracket (Asaria et al. 2019; Barik, Desai, and Vanneman 2018; Dhakad and Saikia 2023a; Gupta 2021; Gupta et al. 2024; Gupta and Sudharsanan 2022; Kumari and Mohanty 2020; Saikia, Bora, and Luy 2019; Vyas, Hathi, and Gupta 2022). There are significant disparities in health outcomes between different socioeconomic groups across various age groups, with individuals from marginalized social groups, such as lower castes and economically disadvantaged classes, experiencing poorer health outcomes compared to those from more privileged socioeconomic backgrounds (Barik, Desai, and Vanneman 2018; Bora, Raushan, and Lutz 2019; Das, Kapoor, and Nikitin 2010; Dhakad and KC 2023; Dommaraju, Agadjanian, and Yabiku 2008; Nguyen et al. 2013; Subramanian, Smith, and

Subramanyam 2006). Studies based on the NFHS estimated life expectancy at birth and found considerable variations by caste, religion, economic status, and region (Asaria et al. 2019; Gupta 2021; Gupta and Sudharsanan 2022; Kumari and Mohanty 2020; Vyas, Hathi, and Gupta 2022). Individuals belonging to SCs and STs consistently exhibit lower life expectancies than those from higher castes in India. While Vyas, Hathi, and Gupta (2022), using decomposition techniques, revealed that economic status only marginally contributes to the social gap in longevity, Asaria et al. (2019) highlighted a significant wealth disparity, finding a 7.6-year gap in life expectancy at birth (e0) between the richest 20% and the poorest 20% of households in India.

Most existing studies have primarily examined socioeconomic disparities in life expectancy at birth, with relatively few focusing specifically on adult (ages 15–59) mortality and its determinants in India (Barik, Desai, and Vanneman 2018; Saikia and Ram 2010). Dhakad and Saikia (2023a) estimated adult mortality by socioeconomic group, while Saikia et al. (2019) provided estimates of life expectancy at age 15 by educational attainment and by other socioeconomic characteristics, such as the caste, religion, and income of either deceased adults or their offspring. However, previous approaches to adult mortality estimation primarily focused on group-level analysis, consequently failing to quantify the individual hazard risk. Furthermore, these investigations usually examined socioeconomic factors in isolation, typically omitting controls for other critical socioeconomic or regional heterogeneity. Notably, standard group-level life expectancy calculations do not incorporate such controls.

Despite the critical policy relevance of understanding premature adult mortality, the question of how multiple socioeconomic factors collectively influence mortality risk, after accounting for regional variation, remains insufficiently addressed in the Indian context. A clearer understanding of the health implications of these socioeconomic indicators is essential for developing effective strategies aimed at reducing mortality in the adult population**.** While a single earlier study by Saikia and Ram (2010) utilized NFHS 1998–1999 to explore socioeconomic and lifestyle determinants of adult mortality, the present study fills this analytical gap by comprehensively analysing the socioeconomic determinants of adult mortality among individuals aged 15–59 in India, leveraging various rounds of the NFHS. The research adopts a deeper focus on social and economic inequality in adult mortality. Specifically, it meticulously examines disparities across social groups and economic status (measured by household wealth quintiles) while simultaneously controlling for regional heterogeneity, including differences based on rural/urban residence and state/union territory (UT) differences. Finally, it presents trends in socioeconomic inequality in adult mortality covering a span of two decades.

2. Data

This study relies primarily upon data derived from the NFHS. This survey began in India during the early 1990s as a major component of the globally executed DHS, which is routinely conducted in more than 90 countries.

The NFHS collects individual-level information spanning a comprehensive range of demographic, health, and family welfare indicators. These indicators include but are not limited to fertility, family planning, reproductive health, maternal and child health, and infant and child mortality. The International Institute for Population Sciences (IIPS) acts as the nodal agency, administering the survey under the direction of the Ministry of Health and Family Welfare, often with technical support from partners such as ORC Macro (IIPS and ICF 2017, 2021; IIPS and ORC Macro 2000). The survey employs a multistage cluster random sampling design, utilizing a two-stage process for both rural and urban areas. In the initial stage of sampling, villages were chosen as the primary sampling units (PSUs) in rural regions, while census enumeration blocks (CEBs) were selected in urban areas. Following this, the second stage involved the random selection of specific households within each of the chosen PSUs (rural) and CEBs (urban). Prior to the final selection of households, comprehensive mapping and listing of all households were executed within the designated first-stage PSUs and CEBs (IIPS and ICF 2021).

The NFHS is India's first nationally representative repetitive household survey that collects information about death in the household in the three years preceding the survey. It collects death information through the following questions:

1) Did any usual member of this household die in the last three years?
2) What was the person's sex and age, and when did they die? Did the person die during pregnancy, during childbirth, or within two months after the end of pregnancy or childbirth?
3) Was the death due to an accident, violence, poisoning, drowning, disaster, homicide, or suicide?

The NFHS household questionnaire also collects household socioeconomic profiles, which facilitate determining mortality patterns based on socioeconomic group.

The NFHS has been conducted in five rounds: the first survey, in 1992–1993, followed by subsequent rounds in 1998–1999, 2005–2006, 2015–2016, and 2019–2021 (IIPS 1995; IIPS and ICF 2017, 2021; IIPS and Macro International 2007; IIPS and ORC Macro 2000). Four of these five rounds included data on household deaths; the third round (NFHS 2005–2006) is the only exception. This study utilizes data from the second (NFHS 1998–1999), fourth (NFHS 2015–2016), and fifth (NFHS 2019–2021) rounds of the survey. The inclusion of these successive data collection points allows for a robust

analysis of how mortality patterns have evolved over time, specifically concerning individuals' socioeconomic characteristics. Moreover, the NFHS employed a comparable sampling design across these different rounds, which simplifies the process of conducting trend analysis and comparing outcome variables over two decades.

3. Methods

The mortality estimates derived from NFHS data are considered reliable for adult age groups. Previous studies have validated NFHS mortality estimates by comparing them with India's official statistics from the Sample Registration System for the corresponding periods (Asaria et al. 2019; Dhakad and Saikia 2023b; Gupta 2021; Gupta et al. 2024; Gupta and Sudharsanan 2022; Kumari and Mohanty 2020; Vyas, Hathi, and Gupta 2022).

In this study, we analysed adult deaths in the 15–59 age group over the 24 months (two years) preceding each of the three NFHS survey rounds. Table 1 details the number of households interviewed in each survey round and the number of usual residents within these households. Individuals within the 15–59 age group were selected as the study sample. Finally, the table provides data on the number of deaths within the 15–59 age group during the two years preceding each survey.

Table 1: Sample description of individuals analysed by surveys in the study, various rounds of the NFHS, India

Survey name	Households interviewed	Number of usual residents (all ages)	Sample analysed (15–59 age group)	Death in the 15–59 age group
NFHS 1998–99	109,041	507,459	26,3362	2458
NFHS 2015–16	628,900	2,849,676	1598337	11699
NFHS 2019–21	636,699	2,843,858	1634525	12368

Source: Author's calculation using NFHS 1998–1999, NFHS 2015–2016, and NFHS 2019–2021 data.

To investigate disparities in adult mortality across social and economic groups, we estimated the probability of dying between the ages of 15 and 59 (45q15 per 1,000). Additionally, we employed survival analysis to estimate hazard ratios of death by socioeconomic groups while controlling for other relevant predictors.

3.1 Probability of dying in the age group 15–59

The age-specific death rate (ASDR) is calculated based on recent household deaths. In computing the ASDR, the numerator comprises the total number of deaths within the two years, categorized by the age group in which the person died. The denominator is the

person-years of exposure for each age group during the same period. To calculate a person's exposure, we adopted an approach similar to that used by Luy (2002, 2003). Lifelines were created for each deceased individual, starting from the age two years prior to the interview and continuing to their age at death. For surviving individuals, lifelines were constructed using information on their two years before the interview and their age at the time of the interview. These mortality rates were estimated separately for men and women, stratified by social groups and economic status. To convert age-specific mortality rates into age-specific probabilities of death (${}_nq_x$), we applied a_x, representing the average number of years lived in the interval by individuals who died, taken from the United Nations World Population Prospects for a comparable reference period (United Nations 2024). In addition, we computed 95% confidence intervals (CIs) for the rates by applying a cluster-bootstrap procedure to obtain the standard errors (Gupta and Sudharsanan 2022).

For social categorisation, individuals are classified into five mutually exclusive social groups based on the caste and religion of their household head: SCs, STs, Muslims, OBCs, and upper castes. SCs and STs include all individuals who report belonging to a Scheduled Caste or Scheduled Tribe, regardless of religion, so these categories comprise individuals from all religious backgrounds. The Muslim social group represents individuals who declare their religion to be Islam and excludes those who report belonging to an SC or ST. OBCs and upper castes represent only the Hindu religion. Table A-1 in the appendix indicates that these five groups collectively account for 95% of deaths and person-years in the dataset. The remaining 5% (others/missing) were Sikhs, Jains, Buddhists, Christians, Parsis, as well as those whose religion was reported as "don't know." This category also includes Hindus whose caste status was missing or reported as "don't know" and who therefore could not be classified as SC, ST, OBC, or upper caste. This classification follows similar approaches used in other studies (Gupta and Sudharsanan 2022; Vyas, Hathi, and Gupta 2022) and India Human Development Survey data (Desai et al. 2010).

Furthermore, we estimated the probability of dying between ages 15 and 59 based on household economic status, which is measured by household wealth quintiles: poorest, poorer, middle, richer, and richest.

Table A-1 details the number of deaths and number of individuals in the 15–59 age group, disaggregated by sex and socioeconomic group, for NFHS 1998–1999, NFHS 2015–2016, and NFHS 2019–2021. In NFHS 1998–99, there were 1,392 deaths among men and 1,066 deaths among women. The NFHS 2015–2016 recorded 7,288 deaths among men and 4,411 deaths among women. In the NFHS 2019–2021 survey, there were 7,830 male deaths and 4,538 female deaths. The larger sample sizes of NFHS 2015–2016 and NFHS 2019–2021 account for the higher number of recorded deaths compared to NFHS 1998–1999. Notably, NFHS 2019–2021 reported a higher number of deaths than

NFHS 2015–16, which can be attributed to the bigger sample size in NFHS 2019–2021 and increased deaths during the COVID-19 pandemic.

3.2 Survival analysis

Furthermore, we performed survival analysis to estimate the hazard ratio of death among individuals aged 15–59 by socioeconomic characteristics. This study utilized Cox proportional hazard (CPH) regression to estimate the risk of death based on socioeconomic characteristics. The survival status of adults aged 15–59 was measured over the preceding 24 months (two years); this constitutes time-to-event data. The time-to-death data include information on whether the event occurred and the time at which the event occurred. Consequently, the time-to-death data include censored cases.

For adults aged 15–59, the deaths of those who died in the 24 months preceding the survey were considered events. Adults who were still alive, had not reached their 60th birthday, and were event-free at the end of the study period were treated as censored cases in the analysis (Austin 2017). Conventional regressions (e.g., logistic) can account for information on whether an event occurred or not. However, they do not consider the time when an event occurred. Consequently, they fail to address the issue of censoring. The principal advantage of the CPH model over conventional methods is its ability to account for the censoring inherent in the data**.**

To examine the risk of adult mortality across social groups and economic strata, we employed both bivariate and multivariate CPH models separately for men and women, using data from NFHS 1998–1999, NFHS 2015–2016, and NFHS 2019–2021. The bivariate models estimated the unadjusted associations between each predictor variable and adult death without controlling for other covariates. In contrast, the multivariate models assessed the adjusted associations, accounting for regional heterogeneity in India as captured by rural/urban residence and state/UT differences.

Three multivariate models were specified. Model 1 examined the association between adult mortality and social group, controlling only for regional heterogeneity. Model 2 assessed the relationship between adult mortality and economic status, also adjusting for regional heterogeneity. Model 3 simultaneously included both social group and economic status to evaluate their relative contributions to adult mortality risk after accounting for regional heterogeneity. This modelling strategy enabled us to disentangle and quantify the gross and net effects of social and economic factors on adult mortality, offering a comprehensive understanding of their influence. All mortality estimates were weighted to ensure national representativeness. The proportional hazards assumption was assessed using Schoenfeld residuals.

4. Results

4.1 Probability of death between ages 15 and 59

Table 2 presents the probability of death between ages 15–59 (45q15) for men and women by social group and economic status for various rounds of the NFHS. In NFHS 1998–1999, the probability of death was 268 (255–281) per 1,000 for men and 208 (194–222) per 1,000 for women. By NFHS 2019–2021, this probability had decreased to 221 (214–228) per 1,000 for men and 125 (120–130) per 1,000 for women, indicating a slower decline in mortality for men (approximately 17%) compared to women (approximately 40%) over the period. Notably, the probability of death for men was higher in NFHS 2019–2021 than in NFHS 2015–2016, likely due to the COVID-19 pandemic in 2020–2021.

The probability of death varies significantly by social affiliation for both sexes. Adults from socially disadvantaged caste groups, such as SCs and STs, exhibit higher 45q15 for both men and women across the surveys. Conversely, Muslims, followed by upper-caste and OBC Hindus, reported lower adult mortality among men across all survey periods. Among women, upper-caste groups, followed by Muslims and OBC Hindus, exhibited lower mortality between NFHS 1998–1999 and NFHS 2015–2016. However, in NFHS 2019–2021, Muslim women reported marginally higher adult mortality than in NFHS 2015–2016, resulting in higher adult mortality among Muslim women compared to OBCs and upper-caste Hindu women.

The decline in mortality among men was more pronounced among STs (approximately 25%) and OBCs (approximately 23%), whereas Muslims and upper castes experienced less than a 12% improvement between NFHS 1998–1999 and NFHS 2019–2021. For women, those in SCs experienced the fastest improvement in adult mortality (approximately 44%), whereas Muslim women reported a slower decline of about one-third during the same period.

A large disparity in adult mortality rates exists between economically disadvantaged and affluent households. Individuals from the poorest households consistently experience mortality rates about 40% higher for men and about 45% higher for women compared to their richest counterparts across all surveys. Adults living in poor households exhibited slower improvements in mortality rates compared to their economically advantaged counterparts, perpetuating their survival disadvantages during adult ages.

Table 2: Probability of death among adults aged 15–59 (expressed per 1,000 persons), by social affiliation and economic status, India, NFHS 1998–1999, NFHS, 2015–2016, and NFHS 2019–2021

Variables	NFHS 1998–1999		NFHS 2015–2016		NFHS 2019–2021	
	Male	Female	Male	Female	Male	Female
Social group						
ST	296(256–335)	257(218–295)	248(233–262)	147(136–158)	254(238–269)	146(135–156)
SC	347(300–394)	243(204–283)	258(235–282)	152(134–171)	256(236–276)	137(122–152)
Muslim	225(178–272)	206(168–244)	180(158–203)	124(108–141)	196(174–218)	132(118–146)
OBC	283(260–307)	209(186–233)	201(191–211)	126(117–135)	212(202–222)	124(117–131)
Upper-caste Hindu	228(204–253)	169(145–194)	181(167–195)	99(87–111)	197(183–211)	98(88–108)
Other/missing	238(187–290)	179(128–229)	186(155–218)	117(77–156)	227(192–262)	107(85–128)
Wealth Index						
Poorest	350(312–387)	249(215–282)	266(252–280)	167(154–180)	280(267–294)	157(146–168)
Poorer	301(265–337)	237(209–266)	225(213–236)	151(141–162)	257(243–271)	140(129–151)
Middle	273(237–308)	216(189–243)	216(201–231)	138(123–152)	225(209–242)	133(123–144)
Richer	233(207–259)	213(184–241)	205(190–220)	106(94–119)	203(189–216)	116(105–127)
Richest	195(173–217)	133(109–158)	151(134–167)	83(73–93)	158(144–171)	87(78–95)
Overall	268(255–281)	208(194–222)	209(202–215)	127(121–132)	221(214–228)	125(120–130)

Notes: SCs and STs are from all religions; Muslims include Muslim OBCs and Muslim upper castes; OBCs include OBCs from Hindu religions; upper castes include upper-caste Hindus. A cluster-bootstrap technique was applied to estimate 95% confidence intervals, drawing a total of 100 bootstrap samples.
Source: Author's calculation using NFHS 1998–1999, NFHS 2015–2016, and NFHS 2019–2021 data for the two years preceding the survey date.

4.2 Regression results

Figures 1–3 present the hazard ratios (HRs) for adult mortality estimated from CPH models using data from three rounds of the NFHS in India. The detailed estimates for Figures 1–3 are provided in the corresponding Tables 3–5. Panel A in each figure displays the bivariate associations between adult mortality and key predictors: social group and economic status (without controlling for the other predictors) for NFHS 1998–1999 (Figure 1), NFHS 2015–2016 (Figure 2), and NFHS 2019–2021 (Figure 3).

The bivariate estimates indicate that, relative to upper-caste adults, individuals from SCs, STs, and OBCs exhibit higher mortality risks among both men and women across all three survey rounds. Among men, Muslims exhibit a lower risk of death compared with upper-caste Hindus in the bivariate analysis, However, the upper bound of the hazard ratio's confidence interval exceeds 1, indicating that the association is not statistically conclusive. In contrast, among women, Muslim females show a higher hazard ratio of death compared with upper-caste Hindu females only in NFHS 2019–2021. The hazard ratio of death declines with increasing wealth status across the surveys for both men and women. Further, Panel B (Model 1) and Panel C (Model 2) of these figures show the association of adult mortality with social group and economic status, respectively, after controlling for only the rural/urban and states/UT variables. The results show that after

controlling for regional heterogeneity, the association of deaths with social groups remained very similar to the bivariate model.

Table 3: Results of Cox proportional hazard model: HR of death in adult age by social affiliation and economic status, NFHS 1998–1999, India

Predictors	Bivariate		Model 1 (social group)		Model 2 (economic status)		Model 3 (social group and economic status)	
	Male	Female	Male	Female	Male	Female	Male	Female
Social group								
Upper caste (ref)								
SC	1.251(1.03–1.52)**	1.572(1.271–1.944)***	1.161(0.951–1.418)	1.452(1.168–1.806)***			0.976(0.791–1.206)	1.317(1.045–1.659)**
ST	1.605(1.289–1.999)***	1.523(1.18–1.966)***	1.647(1.297–2.091)***	1.294(0.983–1.703)*			1.314(1.022–1.689)**	1.159(0.869–1.547)
Muslim	0.834(0.651–1.068)	1.11(0.857–1.439)	0.838(0.65–1.08)	1.165(0.89–1.524)			0.769(0.594–0.995)**	1.092(0.83–1.437)
OBC	1.26(1.063–1.493)***	1.265(1.037–1.541)**	1.129(0.94–1.356)	1.119(0.907–1.381)			1.029(0.853–1.241)	1.051(0.847–1.305)
Others/missing	1.024(0.752–1.395)	0.943(0.659–1.35)	1.03(0.745–1.425)	1.099(0.755–1.598)			0.997(0.721–1.378)	1.099(0.757–1.596)
Wealth quintile								
Poorest (ref)								
Poorer	0.821(0.675–0.998)**	0.934(0.757–1.154)			0.795(0.653–0.967)**	0.979(0.792–1.212)	0.81(0.665–0.988)**	1.001(0.807–1.24)
Middle	0.692(0.569–0.84)***	0.8(0.646–0.989)**			0.644(0.527–0.786)***	0.87(0.7–1.081)	0.666(0.54–0.82)***	0.905(0.724–1.131)
Richer	0.591(0.488–0.717)***	0.71(0.571–0.883)***			0.526(0.423–0.653)***	0.831(0.653–1.057)	0.549(0.438–0.689)***	0.88(0.685–1.131)
Richest	0.49(0.402–0.596)***	0.435(0.344–0.55)***			0.394(0.307–0.507)***	0.531(0.397–0.711)***	0.409(0.313–0.535)***	0.582(0.425–0.796)***
Place of Residence								
Rural (ref)								
Urban	0.861(0.751–0.988)**	0.628(0.531–0.743)***	0.924(0.796–1.073)	0.674(0.563–0.806)***	1.25(1.045–1.496)**	0.854(0.691–1.055)	1.29(1.074–1.548)***	0.838(0.677–1.036)

Notes: Confidence intervals (95%) in parentheses; ***significant at 1%, **significant at 5%, *significant at 10%. Models 1–3 control for rural/urban and states/UT dummies. SCs and STs are from all religions. Muslims include Muslim OBCs and Muslim upper castes. OBCs include those from Hindu religions. Upper castes include upper-caste Hindus.
Source: Author's calculation using NFHS 1998–1999 data for the two years preceding the survey date.

Table 4: Results of CPH model: HR of death in adult age by social affiliation and economic status, NFHS 2015–2016, India

Predictors	Bivariate		Model 1 (social group)		Model 2 (economic status)		Model 3 (social group and economic status)	
	Male	Female	Male	Female	Male	Female	Male	Female
Social group								
Upper caste (ref)								
SC	1.323(1.181–1.482)***	1.401(1.216–1.614)***	1.313(1.168–1.475)***	1.32(1.141–1.528)***			1.115(0.988–1.259)*	1.129(0.974–1.31)
ST	1.41(1.245–1.597)***	1.484(1.254–1.755)***	1.415(1.238–1.618)***	1.415(1.169–1.711)***			1.121(0.974–1.289)	1.164(0.958–1.414)
Muslim	0.882(0.761–1.022)*	1.098(0.926–1.303)	0.893(0.766–1.04)	1.066(0.894–1.271)			0.804(0.689–0.938)***	0.958(0.804–1.142)
OBC	1.093(0.984–1.215)*	1.242(1.087–1.418)***	1.053(0.944–1.175)	1.157(1.005–1.332)**			0.958(0.858–1.071)	1.052(0.914–1.21)
Other/missing	1.055(0.859–1.296)	1.15(0.781–1.694)	1.111(0.894–1.38)	1.239(0.832–1.847)			1.065(0.859–1.322)	1.192(0.802–1.773)
Wealth quintile								
Poorest (ref)								
Poorer	0.774(0.706–0.847)***	0.891(0.797–0.995)**			0.737(0.671–0.81)***	0.928(0.827–1.041)	0.754(0.686–0.829)***	0.944(0.84–1.06)
Middle	0.719(0.655–0.789)***	0.764(0.671–0.871)***			0.639(0.578–0.707)***	0.805(0.704–0.92)***	0.662(0.597–0.734)***	0.827(0.72–0.95)***
Richer	0.683(0.617–0.756)***	0.563(0.495–0.642)***			0.568(0.506–0.638)***	0.592(0.507–0.693)***	0.595(0.528–0.67)***	0.614(0.523–0.721)***
Richest	0.515(0.46–0.577)***	0.462(0.395–0.541)***			0.405(0.354–0.463)***	0.473(0.388–0.576)***	0.423(0.367–0.487)***	0.492(0.405–0.598)***
Place of Residence								
Rural (ref)								
Urban	0.931(0.862–1.005)*	0.753(0.673–0.843)***	1.012(0.936–1.095)	0.858(0.764–0.964)**	1.252(1.15–1.363)***	1.093(0.957–1.25)	1.278(1.173–1.391)***	1.106(0.965–1.267)

Notes: Confidence intervals (95%) in parentheses; ***significant at 1%, **significant at 5%, *significant at 10%. Models 1–3 control for rural/urban and states/UT dummies. SCs and STs are from all religions. Muslims include Muslim OBCs and Muslim upper castes. OBCs include those from Hindu religions. Upper castes include upper-caste Hindus.
Source: Author's calculation using NFHS 1998–1999 data for the two years preceding the survey date.

Table 5: Results of CPH model: HR of death in adult age by social affiliation and economic status, NFHS 2019–2021, India

Predictors	Bivariate		Model 1 (social group)		Model 2 (economic status)		Model 3 (social group and economic status)	
	Male	Female	Male	Female	Male	Female	Male	Female
Social group								
Upper caste (ref)								
SC	1.221(1.101–1.354)***	1.419(1.228–1.639)***	1.187(1.067–1.321)***	1.319(1.14–1.526)***			0.988(0.885–1.103)	1.19(1.024–1.382)**
ST	1.251(1.118–1.4)***	1.297(1.099–1.53)***	1.238(1.097–1.397)***	1.253(1.049–1.497)**			0.948(0.835–1.075)	1.092(0.911–1.31)
Muslim	0.858(0.744–0.99)**	1.21(1.02–1.436)**	0.887(0.766–1.027)	1.191(0.999–1.419)*			0.794(0.684–0.921)***	1.115(0.934–1.331)
OBC	1.05(0.954–1.155)	1.239(1.08–1.422)***	1.005(0.911–1.109)	1.166(1.014–1.342)**			0.905(0.819–1.001)*	1.098(0.953–1.265)
Other/missing	1.154(0.958–1.391)	1.118(0.877–1.425)	1.22(1.001–1.487)**	1.152(0.895–1.482)			1.161(0.952–1.415)	1.123(0.873–1.444)
Wealth quintile								
Poorest (ref)								
Poorer	0.866(0.796–0.942)***	0.852(0.763–0.952)***			0.813(0.746–0.885)***	0.863(0.77–0.966)**	0.814(0.747–0.889)***	0.868(0.775–0.973)**
Middle	0.733(0.668–0.804)***	0.801(0.715–0.898)***			0.638(0.578–0.704)***	0.827(0.732–0.936)***	0.639(0.578–0.708)***	0.839(0.741–0.951)***
Richer	0.642(0.584–0.705)***	0.691(0.609–0.785)***			0.523(0.469–0.583)***	0.731(0.639–0.836)***	0.524(0.468–0.587)***	0.748(0.652–0.859)***
Richest	0.513(0.461–0.57)***	0.524(0.459–0.598)***			0.384(0.337–0.438)***	0.554(0.469–0.655)***	0.38(0.332–0.435)***	0.576(0.486–0.684)***
Place of Residence								
Rural (ref)								
Urban	0.915(0.851–0.984)**	0.755(0.682–0.835)***	0.939(0.871–1.012)*	0.796(0.716–0.884)***	1.252(1.148–1.365)***	0.943(0.838–1.062)	1.263(1.159–1.377)***	0.938(0.833–1.057)

Notes: Confidence intervals (95%) in parentheses; ***significant at 1%, **significant at 5%, *significant at 10%. Models 1–3 control for rural/urban and states/UT dummies. SCs and STs are from all religions. Muslims include Muslim OBCs and Muslim upper castes. OBCs include those from Hindu religions. Upper castes include upper-caste Hindus.
Source: Author's calculation using NFHS 1998–1999 data for the two years preceding the survey date.

Panel D (Model 3) shows the association between adult mortality, social group, and economic status after controlling for each and regional heterogeneity. The results indicate that the mortality differentials across social groups narrow somewhat once economic status and regional characteristics are accounted for. Muslim men consistently show a lower risk of death than upper-caste men across the survey rounds after controlling for regional variables and economic status. In NFHS 2019–2021, for example, Muslim men experienced about a 21% lower risk of death (HR = 0.794, CI = 0.684–0.921). The results show that adjusting for economic status further strengthens the mortality advantage among Muslim men, suggesting that economic differences mask part of their survival advantage relative to upper-caste men. Men belonging to OBCs also had marginally lower mortality than upper-caste men in NFHS 2019–2021 (HR = 0.905, CI = 0.819–1.001), although no differences are observed in earlier rounds. For SCs and STs, the

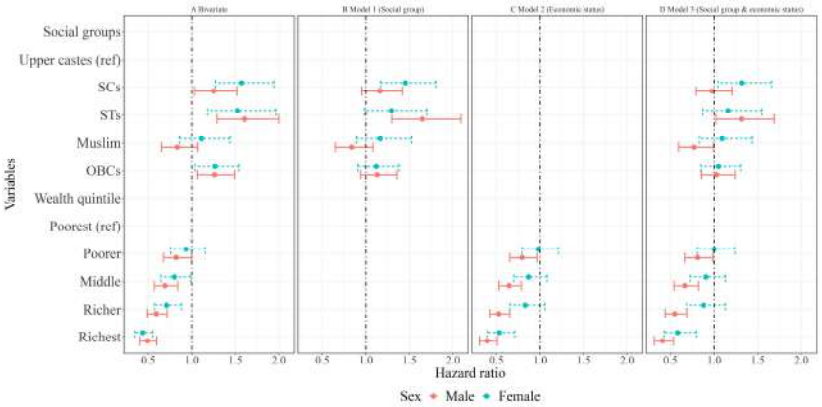
mortality disadvantage diminishes after accounting for economic status and regional heterogeneity.

During NFHS 1998–1999, ST men had a higher mortality risk (HR = 1.314, CI = 1.022–1.689), and during NFHS 2015–2016, SC men exhibited slightly high mortality risk (HR = 1.115, CI = 0.988–1.259) relative to upper-caste men. However, in NFHS 2019–2021, the mortality risks among SC and ST men converge with those of upper-caste men once economic and regional differences are taken into account.

Compared to upper-caste females, SC females have a somewhat higher risk of death in NFHS 1998–1999 (HR = 1.129, CI = 0.974–1.31) and NFHS 2019–2021 (HR = 1.19, CI = 1.024–1.382). The risk of death among STs, OBCs, and Muslims does not statistically differ than that for upper-caste females after controlling for wealth status and regional characters.

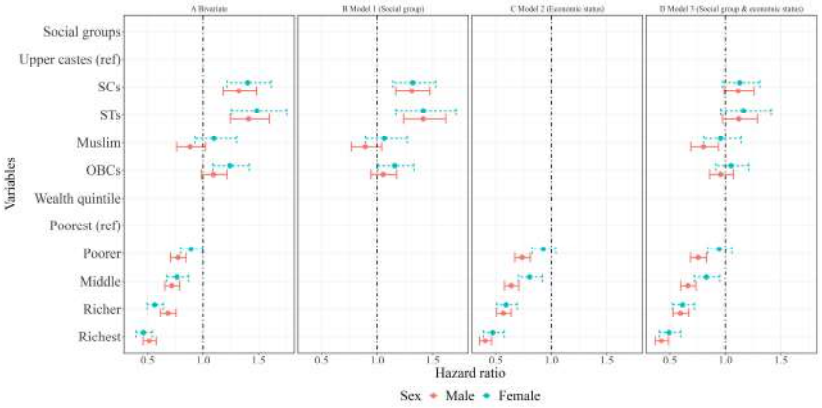
Panel D (Model 3) further illustrates the association between economic status and adult mortality. The results indicate that, even after adjusting for regional heterogeneity and social group differences, the relationship between wealth and adult mortality remains stronger for both men women. Notably, the association between wealth and adult mortality is larger for men than women. In NFHS 2019–2021, compared with men residing in the poorest households, the risk of death was approximately 19% lower for men in poorer households (HR = 0.814, CI = 0.747–0.889), 36% lower for the middle-income group (HR = 0.639, CI = 0.578–0.708), 48% lower for the rich (HR = 0.524, CI = 0.468–0.580), and 62% lower for men in the richest households (HR = 0.380, CI = 0.332–0.435). Among women, those from poorer households had a 14% lower hazard of death (HR = 0.868, CI = 0.775–0.973), those from middle-income households had a 17% lower hazard (HR = 0.839, CI = 0.741–0.951), and those in the richest households had a 62% lower risk of death (HR = 0.576, CI = 0.486–0.684) compared with those in the poorest households.

Figure 1: Estimated HR for adult mortality, by social affiliation and economic status, India, NFHS 1998–1999



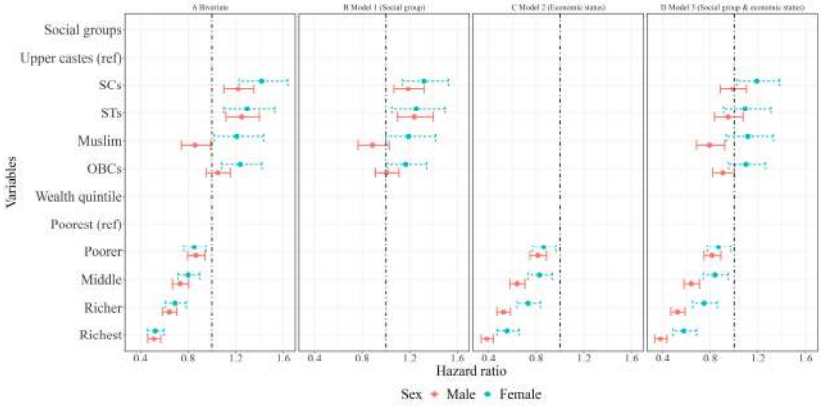
Notes: SCs and STs are from all religions. Muslims include Muslim OBCs and Muslim upper castes. OBCs include OBCs from Hindu religions. Upper castes include upper-caste Hindus. Models 1, 2, and 3 control for regional heterogeneity (rural/urban and state/UT).
Source: Author's calculation using NFHS 1998–1999 data for the two years preceding the survey date.

Figure 2: Estimated HR for adult mortality, by social affiliation and economic status, India, NFHS 2015–2016



Notes: SCs and STs are from all religions. Muslims include Muslim OBCs and Muslim upper castes. OBCs include OBCs from Hindu religions. Upper castes include upper-caste Hindus. Models 1, 2, and 3 control for regional heterogeneity (rural/urban and state/UT).
Source: Author's calculation using NFHS 1998–1999 data for the two years preceding the survey date.

Figure 3: Estimated HR for adult mortality, by social affiliation and economic status, India, NFHS 2019–2021



Notes: SCs and STs are from all religions. Muslims include Muslim OBCs and Muslim upper castes. OBCs include OBCs from Hindu religions. Upper castes include upper-caste Hindus. Models 1, 2, and 3 control for regional heterogeneity (rural/urban and state/UT).
Source: Author's calculation using NFHS 1998–1999 data for the two years preceding the survey date.

5. Discussion

The present study examines socioeconomic inequalities in adult mortality across India over the past two decades. Historically, socioeconomically marginalized groups have faced persistent disadvantages affecting nearly all aspects of life, including education, income, and occupation (Hoff and Pandey 2004). These disadvantages manifest clearly in adverse health and mortality outcomes. Unlike many Western contexts – where socioeconomic groups are primarily distinguished by income, occupation, education, and race – in India key determinants also include religion and caste. The study analyses trends in the adult mortality rate across socioeconomic subgroups in India, simultaneously estimating the hazard risk of adult deaths based on socioeconomic characteristics observed over the past two decades.

The results of the present study suggest that social affiliation and economic status are highly important factors impacting the risk of adult mortality in India. The probability of death among adults aged 15–59 is higher among socially disadvantaged groups, particularly SCs and STs, for both men and women. Among men, Muslim men exhibited the greatest survival advantage, whereas among women, upper-caste groups had better survival outcomes.

Mortality in the working or adult ages is highly associated with work status, type of employment, education, income, marriage, obesity, wealth, and smoking (Barik, Desai,

and Vanneman 2018; Bobak et al. 2003; Clark and Royer 2013; Dhakad et al. 2026; Duleep 1986). Higher adult mortality in socially disadvantaged caste groups in India may be associated with occupation and working conditions (Johnson, Sorlie, and Backlund 1999; Paglione et al. 2020). The caste system is based on the principles of hereditary occupation and hierarchy. People of socially advantaged caste groups enjoy greater wealth and opportunities, whereas low-caste group members perform blue-collar jobs, doing the least desirable menial work and exposing themselves to a higher risk of injuries and morbidity. A recent study by Dhakad and Saikia (2023c) found disproportionately high mortality due to external causes among socially disadvantaged adults. The mortality disadvantage among adults from deprived castes may also be linked to a higher prevalence of substance abuse (Saikia and Debbarma 2020). Systemic barriers to accessing public services and health care further heighten vulnerability to health risks among these marginalized populations (Thapa et al. 2021).

The survival disadvantage among individuals from SC and ST communities is evident in the bivariate and partially adjusted models (Model 1) but becomes statistically inconclusive in the fully adjusted model after controlling for regional and economic factors, particularly among men. This suggests that the observed survival disadvantage among SCs and STs is largely attenuated once differences in economic status are accounted for. Conversely, Muslim men experience a survival advantage even after adjusting for these factors. These findings align with prior research, which has shown lower under-5 mortality among Muslim children compared with Hindu children, despite Muslim women facing relatively poorer socioeconomic conditions (Brainerd and Menon 2015; Guillot and Allendorf 2010). Similarly, Saikia and Ram (2010) also found that Muslim adults face a lesser risk of death. Kumari and Mohanty (2020) document a higher life expectancy at adult ages among Muslims compared with Hindus in India. One plausible explanation for this differential relates to health-related behaviours, particularly substance use. Recent evidence indicates that alcohol consumption among Muslim adults is substantially lower than among other religious groups, a factor that may confer protection against adult and premature mortality through reduced risks of chronic diseases and injuries (Singh and Kumar 2024). In addition, Muslims are more urbanised on average in several Indian states, which may translate into better access to health services, markets, and health-promoting infrastructure. Prior research suggests that such urban advantages can partially offset socioeconomic disadvantage and contribute to lower mortality risks in the case of child mortality in India (Guillot and Allendorf 2010). While this relationship has been established largely in the context of child mortality, analogous urban advantages may also shape survival of Muslim adults, warranting further empirical investigation. Among women, hazard ratios consistently show a survival advantage for upper-caste Hindus, OBCs, and Muslims when compared to women from SCs and STs.

Economically affluent groups exhibit a lower risk of adult mortality, and economic inequality in adult deaths has remained substantial over the past two decades in India. The slower improvement in mortality rates among economically poor individuals, especially men, underscores the persistent disadvantage they face. Economic status is negatively associated with adult mortality, even after controlling for regional heterogeneity and social groups, particularly among men. Wealth influences health by shaping access to education, employment, health care, nutrition, and living environments (Adler et al. 1994; Chetty et al. 2016; Mackenbach et al. 2008). Adults in affluent areas are more likely to access health care resources, adopt healthy behaviours, and maintain healthier lifestyles (Adler and Ostrove 1999; Banks et al. 2006; Smith 2007). Wealthier individuals also have greater means to consume nutritious food, exercise regularly, and engage in recreational activities that promote good health (Rai 2015).

The results from this study have great implications for improving survival among socially and economically disadvantaged groups. Since mortality rates are indicators of overall health and well-being, the findings of this study help us recognize the most disadvantaged social and economic groups of India. Social and health policies should prioritize socioeconomically disadvantaged groups to mitigate high adult mortality rates. This will help efforts to achieve the Sustainable Development Goals for India and globally. Enhancing economic stability and reducing poverty could substantially improve adult mortality rates across all social groups. While social group–specific interventions are essential, they should be complemented by broader economic and health policies to maximize their effectiveness in reducing mortality among disadvantaged populations.

This study has several limitations. Due to limited information on deceased individuals, only a restricted set of predictors could be included to examine socioeconomic disparities in mortality. Numerous other important predictors, such as educational attainment, employment status, behaviours such as substance use, sleep patterns, diet, and early life conditions, also shape adult mortality but were not captured in the dataset (Dhakad et al. 2026). Additionally, household surveys rely on retrospective reporting of deaths, which may introduce recall bias, underreporting, systematic misreporting of age at death, and age heaping (Preston, Heuveline, and Guillot 2000). However, to minimize recall bias, this study uses more recent deaths. Furthermore, statistically controlling for factors such as wealth, region, and rural/urban residence may underestimate the full impact of caste disadvantage, as access to economic mobility and urban residence is itself constrained by caste hierarchies.

Despite these methodological limitations, this study effectively utilizes available survey data to illuminate socioeconomic disparities in adult mortality in India. The findings clearly demonstrate that both social affiliation and economic status play major roles in shaping adult mortality risks. Future research should prioritize examining cause-specific mortality patterns across socioeconomic groups to better identify population-

specific vulnerabilities. However, reliable data on causes of death in India remain limited. Further research incorporating additional factors, such as education, employment, and health behaviours, will help provide a more comprehensive understanding of adult mortality disparities and support the development of evidence-based policy solutions aimed at reducing these inequalities.

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7. Authors' contribution

M.D. conceptualized the study, designed the methodology, and performed the data analysis and visualization. M.D. contributed to the interpretation of the results and wrote the manuscript. N.S. helped in methodology development and contributed to reviewing and editing the paper. Both authors read and approved the final manuscript.

Conflict of interest declaration

The authors affirm that they have no conflict of interest to disclose.

AI usage statement

Artificial intelligence tools were utilized solely to assist the language editing.

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Appendix

Table A-1: Number of deaths and total individual in15–59 age group stratified by social affiliation and economic status, NFHS 1998–1999, NFHS 2015–2016, NFHS 2019–2021, India

Variables	NFHS 1998–1999						NFHS 2015–2016						NFHS 2019–2021					
	Male			Female			Male			Female			Male			Female		
cat	Died	Survive	Total	Died	Survive	Total	Died	Survive	Total	Died	Survive	Total	Died	Survive	Total	Died	Survive	Total
Social groups																		
SC	237	21370	21607	208	20636	20844	1540	140959	142499	898	141781	142679	1727	154199	155926	1049	162025	163074
ST	225	16100	16325	165	16397	16562	1513	143797	145310	918	147358	148276	1593	146545	148138	839	156658	157497
Muslim	116	15511	15627	112	14852	14964	618	94707	95325	471	98320	98791	603	88816	89419	478	95105	95583
OBC	361	31817	32178	270	30726	30996	2226	247045	249271	1377	251309	252686	2444	244825	247269	1448	260569	262017
HC	373	39676	40049	256	38022	38278	1071	122602	123673	583	124777	125360	1070	113559	114629	510	118097	118607
Others/ Missing	80	7898	7978	55	7899	7954	320	37135	37455	164	36848	37012	393	40528	40921	214	41231	41445
Wealth Index																		
Poorest	263	17701	17964	212	18223	18435	1712	140063	141775	1117	149401	150518	1982	152532	154514	1180	168994	170174
Poorer	249	20327	20576	212	19872	20084	1607	164596	166203	1081	167352	168433	1870	169215	171085	1057	180417	181474
Middle	274	25822	26096	239	24511	24750	1510	166088	167598	902	166242	167144	1592	165235	166827	959	172504	173463
Richer	320	31786	32106	228	29946	30174	1362	157912	159274	705	158851	159556	1341	155939	157280	741	161750	162491
Richest	286	36736	37022	175	35980	36155	1097	157586	158683	606	158547	159153	1045	145551	146596	601	150020	150621
Place of residence																		
Rural	944	85957	86901	811	85227	86038	5066	542939	548005	3285	562926	566211	5824	579770	585594	3582	622511	626093
Urban	448	46415	46863	255	43305	43560	2222	243306	245528	1126	237467	238593	2006	208702	210708	956	211174	212130
Overall	1392	132372	133764	1066	128532	129598	7288	786245	793533	4411	800393	804804	7830	788472	796302	4538	833685	838223

Notes: SCs and STs are from all religions. Muslims include Muslim OBCs and Muslim upper castes. OBCs include OBCs from Hindu religions. Upper castes include upper-caste Hindus. Models 1, 2, and 3 control for regional heterogeneity (rural/urban and state/UT).
Source: Author's calculation using NFHS 1998–1999 data for the two years preceding the survey date.