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An integrated demographic-public health analysis of structural determinants of non-communicable disease inequality in India

Rama Devi Tadepu, Dr. Rajeev Kumar
Department of Statistics, Vikrant University, Gwalior, Madhya Pradesh, India

Abstract
India's ongoing epidemiological transition has resulted in a rapidly expanding burden of non-communicable diseases (NCDs), yet prevailing explanations continue to emphasize individual lifestyle risk factors. This study reframes NCD prevalence through an integrated demographic–public health lens, conceptualizing age and gender not as background characteristics but as structural determinants that shape patterned vulnerability across the life-course. Drawing on nationally representative datasets, including NFHS-5, LASI, ICMR-INDIAB and related epidemiological evidence, the analysis adopts a descriptive and interpretive approach grounded in social determinants of health and life-course theory. Rather than estimating causal effects, the study examines demographic gradients in diabetes, hypertension, cardiovascular disease and obesity, and interprets these patterns within broader structural contexts. The findings reveal pronounced age gradients in NCD prevalence, with risk escalating sharply after midlife, reflecting cumulative exposure to social and economic conditions. Gender differentials evolve across the life span: men exhibit earlier onset of cardiometabolic conditions, while women experience intensified burden and multimorbidity in later life. The interaction between age and gender demonstrates that inequality unfolds temporally, producing distinct demographic trajectories of vulnerability rather than additive risk patterns. By repositioning age and gender as explanatory axes of structural inequality, this study challenges individualistic prevention models and underscores the need for life-course-oriented and gender-responsive public health strategies. Addressing NCD inequality in India requires not only biomedical capacity but also structural sensitivity in surveillance, planning and intervention design.

Keywords: Non-communicable diseases, structural determinants, age, gender, life-course, health inequality, India, public health

Introduction

India's health profile has undergone a profound transformation over the past several decades. While infectious diseases once dominated the country's morbidity and mortality landscape, chronic non-communicable diseases (NCDs), including diabetes, hypertension, cardiovascular disorders and chronic respiratory illnesses, now account for the majority of health loss (Dandona *et al*., 2017; India State-Level Disease Burden Initiative, 2018; Prabhakaran *et al*., 2018) [9, 15, 33]. This shift is widely described as part of the epidemiological transition, a process through which populations experience declining mortality from communicable diseases alongside rising burdens of chronic conditions associated with demographic ageing, urbanization and socioeconomic transformation (Omran, 1971; Murray *et al*., 2012) [29, 31]. Recent national and global estimates indicate that NCDs now contribute to more than sixty percent of all deaths in India, underscoring the scale and urgency of this transition (World Health Organization, 2022; MoHFW, 2021) [28, 39].

Despite the magnitude of this transformation, dominant explanations of NCDs in India remain heavily focused on individual-level risk factors. Public health discourse frequently emphasizes dietary behavior, tobacco and alcohol consumption and physical inactivity as primary determinants of chronic disease (Beaglehole *et al*., 2011; Nambiar *et al*., 2019) [4, 30]. While these factors are undeniably important, such framings risk oversimplifying a structurally complex problem. Chronic diseases do not arise solely from isolated behavioral choices; they are shaped by the social, economic and institutional environments in which individuals live and age. Social epidemiology has long demonstrated that disease risk follows socially patterned gradients linked to power, resources and opportunity rather than random distribution (Link & Phelan, 1995; Marmot *et al*., 2008) [23, 26]. The WHO Commission on Social Determinants of Health (2008) [37] similarly emphasized that health inequities are produced through "the conditions in which people are born, grow, live, work and age," rather than merely through proximate biological factors.

Within this framework, age and gender emerge as central axes through which health inequalities are structured. Yet in much epidemiological research, they are treated as routine control variables adjusted for statistically but rarely theorized. This practice risks obscuring their structural significance (Krieger, 2003, 2011) [19, 20]. Age is often conceptualized narrowly as a biological marker of physiological decline, with rising disease prevalence attributed to metabolic dysregulation, vascular ageing and cumulative wear (Franceschi *et al*., 2018) [12]. However, life-course epidemiology provides a more expansive explanation by emphasizing that health in later life reflects the accumulation of exposures and experiences across time rather than biological ageing alone (Ben-Shlomo & Kuh, 2002; Kuh *et al*., 2003) [5, 21].

Life-course theory highlights how early-life nutrition, educational opportunity, occupational trajectories, environmental exposures and prolonged psychosocial stress interact across decades to shape chronic disease vulnerability. The concept of cumulative disadvantage (Dannefer, 2003) [10] underscores how inequalities experienced early in life compound over time, producing widening disparities in health outcomes. Complementing

this perspective, the concept of allostatic load illustrates how chronic stress exposure becomes biologically embedded through sustained physiological activation, leading to increased cardiometabolic risk (McEwen & Stellar, 1993) [27]. Hypertension, diabetes and cardiovascular disease therefore reflect not only age-related physiological change but the internalization of long-term social and environmental pressures.

These processes are particularly salient in the Indian context. Intergenerational poverty, childhood undernutrition, informal labor markets and uneven access to primary healthcare remain widespread (Balarajan *et al*., 2011) [2]. Longitudinal evidence suggests that individuals exposed to sustained socioeconomic disadvantage exhibit higher risks of metabolic and cardiovascular conditions in later life (Arokiasamy *et al*., 2017; Bloom *et al*., 2015) [6]. Age, therefore, functions not merely as a chronological marker but as a social indicator of lived inequality, capturing the cumulative imprint of structurally patterned exposures.

Gender operates in similarly structural ways. Beyond biological distinctions, gender reflects socially constructed roles, expectations and power relations that shape exposure to risk and engagement with healthcare systems (Sen & Östlin, 2008; Connell, 2012) [7]. Masculinized norms may influence occupational hazards, substance use and delayed help-seeking behavior (Courtenay, 2000) [8], while women frequently face restricted autonomy, unequal nutritional allocation, caregiving burdens and limited access to institutional care (Das Gupta *et al*., 2011) [11]. In India, patriarchal family structures and gendered divisions of labor further intensify these dynamics (Jejeebhoy *et al*., 2013; Sen, 1999) [17]. National survey data reveal gendered differences in self-rated health, morbidity reporting and healthcare utilization (IIPS & ICF, 2021) [16], suggesting that women's health disadvantages are shaped not only by biological processes but also by structural barriers to recognition and treatment.

Importantly, the interaction between age and gender generates compounded patterns of vulnerability. Older women may experience higher levels of multimorbidity and functional limitation, reflecting both biological transition and lifelong structural disadvantage (Barnett *et al*., 2012) [3]. Gender differences in risk profiles may evolve across the life course, with earlier cardiometabolic manifestation among men and intensified late-life vulnerability among women. Such patterns underscore that demographic variables operate not independently but intersectionally, structuring exposure and opportunity over time (Hankivsky *et al*., 2014) [14].

Despite these theoretical advances, much Indian NCD research remains grounded in individualistic risk-factor models. These models emphasize smoking, diet, obesity and physical inactivity while giving limited attention to the social organization of opportunity that shapes these behaviors (Frohlich & Potvin, 2008; Schrecker & Bambra, 2015) [13, 35]. Access to nutritious food, safe spaces for physical activity, preventive screening and continuous medical care is unevenly distributed across socioeconomic and demographic groups (Marmot, 2015) [25]. Interventions that focus narrowly on lifestyle modification may therefore disproportionately benefit already advantaged populations, inadvertently widening health inequalities (Victora *et al*., 2000; Joe *et al*., 2016) [18].

Furthermore, descriptive disaggregation by age and gender, though common in epidemiological reporting, often lacks conceptual grounding. Studies frequently present stratified prevalence tables without examining how these patterns reflect structural positioning (Patel *et al*., 2011; Prabhakaran *et al*., 2018) [32, 33]. A structural epidemiological perspective insists that such gradients are neither incidental nor purely biological; they reflect the patterned distribution of resources, risks and power within society (Krieger, 2011) [20].

This study builds on the social determinants and life-course frameworks (WHO Commission on Social Determinants of Health, 2008; Solar & Irwin, 2010) [36, 37] to reinterpret demographic variation in non-communicable disease prevalence in India. Drawing on nationally representative datasets, including the National Family Health Survey (NFHS-5) and the Longitudinal Ageing Study in India (LASI), the analysis examines patterns of diabetes, hypertension, cardiovascular disease and related chronic conditions across age and gender groups. Rather than asking why individuals adopt unhealthy behaviors, it asks why particular demographic groups systematically bear disproportionate burdens of disease.

By conceptualizing age and gender as structural determinants rather than background controls, the study shifts attention toward cumulative exposure, gendered social organization and intersectional vulnerability across the life course. In doing so, it aligns with calls within global health scholarship to move beyond individualized risk narratives toward structurally informed public health analysis (WHO Commission on Social Determinants of Health, 2008; Krieger, 2011) [20, 37], contributing to a more conceptually grounded and policy-relevant understanding of NCD inequality in India.

Methodology

1. Study Design

This study adopts an integrated demographic-public health analytical approach that combines nationally representative secondary datasets with theoretical synthesis drawn from social epidemiology, life-course theory and gender-based health frameworks. Rather than pursuing predictive modeling or clinical causality, the objective is interpretive and policy-oriented. The study seeks to situate observed demographic gradients in non-communicable disease (NCD) prevalence within broader structural contexts that shape vulnerability across the life-course.

The design is cross-sectional and descriptive-analytical. It identifies patterns of NCD prevalence across age and gender categories and interprets these patterns through a structural determinants lens. By integrating epidemiological evidence with theoretical frameworks, the study moves beyond isolated prevalence reporting to examine how demographic positioning shapes patterned health inequalities at the population level.

2. Data Sources

The analysis draws upon multiple nationally and internationally recognized secondary datasets to ensure epidemiological robustness and comprehensive demographic coverage. The primary sources informing these findings include the National Family Health Survey (NFHS-5, 2019-2021), which provides biomarker-based estimates of diabetes and hypertension among adults aged

15-49, and the Longitudinal Ageing Study in India (LASI, Wave 1, 2017-2018), a nationally representative survey of ageing and health in India (Arokiasamy *et al*., 2017; Lee *et al*., 2020) [22], which documents chronic disease prevalence among adults aged 45 years and above. Additional data are drawn from the ICMR–INDIAB Multi-Centre Study (2017-2020), which offers state-level and regionally stratified estimates of diabetes prevalence across India. To contextualize cardiovascular patterns and broader mortality trends, the study also incorporates findings from the Global Burden of Disease (GBD) Reports (2019-2021). Peer-reviewed epidemiological literature is used to triangulate these datasets and support interpretive analysis of demographic risk patterns.

3. Variables and Operational Definitions

Primary Outcome Variables

The analysis focuses on major non-communicable diseases (NCDs) that constitute a significant proportion of morbidity and mortality in India. The primary outcome variables include diabetes mellitus, hypertension, cardiovascular disease (CVD) and obesity. Diabetes mellitus is defined as random blood glucose levels ≥140 mg/dL or current use of antidiabetic medication, consistent with biomarker criteria used in national surveys. Hypertension is defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, or current use of antihypertensive medication. Cardiovascular disease is interpreted based on reported clinical diagnoses where available, or through best-available pooled prevalence estimates drawn from nationally representative studies in cases where direct survey measures were not included. Obesity is defined using Asian-specific body mass index (BMI) criteria, with a threshold of ≥25 kg/m² to account for population-specific metabolic risk profiles.

Primary Exposure Variables

The principal exposure variables examined in this study are gender and age. Gender is categorized as male or female, as recorded in the respective survey datasets, reflecting biological sex classifications used in national health reporting. Age is analyzed both as a continuous variable for the purpose of interpreting overall trend patterns and in categorical groupings (15-24, 25-34, 35-44, 45-54, 55-64 and ≥65 years) to capture life-course transitions and identify critical risk thresholds. This dual approach allows for the examination of progressive disease gradients while also identifying stage-specific vulnerabilities across adulthood and later life.

Contextual Covariates (Interpretive Level)

Although not subjected to multivariate statistical modeling, the analysis incorporates discussion of several contextual covariates that may mediate demographic vulnerability. These include tobacco use, alcohol consumption, physical inactivity, educational attainment and occupational and socioeconomic positioning. Rather than being treated as independent predictive variables, these factors are interpreted as structural and behavioral mediators that shape exposure, healthcare access and long-term disease risk across demographic groups. Their inclusion supports the study's broader objective of situating age and gender differences within a structural determinants framework rather than isolating them as purely biological attributes.

4. Analytical Strategy

The analytical approach adopted in this study is descriptive and interpretive rather than predictive. Demographic gradients were identified through age-stratified prevalence comparisons that examined increases in disease prevalence across successive life stages, alongside gender-disaggregated contrasts comparing crude prevalence rates between males and females. Prevalence ratios were used descriptively to illustrate relative differences in disease burden and trends across age categories were interpreted to identify key transition thresholds, particularly within the 45–55 year range. In addition, patterns of convergence and divergence in gender-specific risk profiles were examined in later life to assess intersectional variation in vulnerability.

Descriptive statistics included prevalence estimates and confidence intervals as reported in the source datasets and cross-tabulated comparisons were employed to highlight demographic disparities. This analytical strategy is consistent with the study's objective of interpreting age and gender as structural determinants shaping patterned health inequalities, rather than treating them solely as statistical control variables within predictive models.

5. Methodological Considerations

As a cross-sectional synthesis of secondary datasets, the study does not establish temporal causality. Variations in measurement methods across datasets, potential underdiagnosis, particularly among women, and regional heterogeneity are acknowledged as interpretive limitations. However, the use of large-scale nationally representative surveys enhances the reliability of demographic pattern identification.

6. Ethical Considerations

All data utilized in this study are publicly available, anonymized secondary datasets. No individual-level identifiers were accessed and no primary data collection was undertaken. Accordingly, the study did not require institutional ethical approval and does not pose direct ethical risk to participants.

Results and Discussion: Demographic Gradients as Structural Patterns of Inequality

This section presents and interprets demographic gradients in non-communicable disease (NCD) prevalence across age and gender groups in India. Drawing on nationally representative data from the National Family Health Survey (NFHS-5) and the Longitudinal Ageing Study in India (LASI), the analysis identifies patterned variations in diabetes, hypertension, cardiovascular disease and related chronic conditions. Rather than treating age and gender as descriptive background variables, the findings are interpreted through a structural determinants framework that emphasizes cumulative exposure, gendered social organization and intersectional vulnerability across the life course.

1. Age as Cumulative Structural Exposure

Across datasets, a clear and consistent age gradient emerges in the prevalence of diabetes, hypertension and cardiovascular conditions. Prevalence rates rise progressively across age categories, with particularly sharp increases after midlife. These demographic prevalence

patterns are summarized in Table 1. Among individuals aged 45 years and above, the burden of chronic disease accelerates markedly and among those aged 60 years and older, multimorbidity becomes increasingly common.

Table 1: NCD Prevalence by Age Group in India (Selected Indicators, NFHS-5 & LASI)

Age Group	Hypertension (%)	Diabetes (%)	Cardiovascular Condition (%)	Data Source
15–49 (NFHS-5)	24.5	~8.5	Not separately reported	NFHS-5
45+ (LASI adults ≥45)	~46.7	~12.0	~28‡	LASI
60+ (LASI older adults)	~48–50	~14	~35‡	LASI

While this gradient reflects physiological ageing, it also indicates cumulative structural exposure. Life-course epidemiology emphasizes that chronic disease risk accumulates over time through the interaction of early-life conditions, occupational histories, psychosocial stress and healthcare access (Ben-Shlomo & Kuh, 2002; Kuh *et al*., 2003) [5, 21]. In the Indian context, intergenerational poverty, informal employment, childhood undernutrition and uneven healthcare infrastructure shape long-term vulnerability (Balarajan *et al*., 2011) [2]. As a result, older age groups represent cohorts who have experienced prolonged exposure to structurally patterned disadvantage.

The concept of cumulative disadvantage (Dannefer, 2003) [10] provides an explanatory lens for these patterns. Socioeconomic inequalities experienced earlier in life compound across decades, widening disparities in health outcomes over time. Complementing this perspective, the notion of allostatic load illustrates how chronic stress becomes biologically embedded through sustained physiological activation, contributing to cardiometabolic dysregulation (McEwen & Stellar, 1993) [27]. The steep escalation of hypertension and diabetes in later adulthood thus reflects not merely chronological ageing but the long-term internalization of unequal social conditions.

These findings align with longitudinal evidence from ageing populations in India, which demonstrates higher cardiometabolic risk among individuals exposed to sustained socioeconomic disadvantage (Arokiasamy *et al*., 2017; Bloom *et al*., 2015) [6]. Age, therefore, functions as a marker of cumulative structural exposure rather than simply biological decline.

2. Gender as Socially Structured Vulnerability

Gender-disaggregated patterns reveal differentiated trajectories of NCD burden. In early and middle adulthood, men exhibit higher crude prevalence rates of hypertension and certain cardiometabolic conditions. These patterns correspond with greater exposure to behavioral and occupational risks, including tobacco use, alcohol consumption and work-related stress, shaped by masculinized social norms (Courtenay, 2000) [8].

However, gender differentials evolve across the life course. Among older adults, particularly those aged 60 years and above, women frequently demonstrate elevated levels of multimorbidity and functional limitation. Multimorbidity increases sharply with age and is socially patterned rather than randomly distributed (Barnett *et al*., 2012) [3]. For many women, cumulative caregiving burdens, economic dependence, restricted mobility and limited access to continuous healthcare contribute to late-life vulnerability (Das Gupta *et al*., 2011; Jejeebhoy *et al*., 2013) [11, 17]. A summary of gender-differential risk profiles and clinical manifestations is presented in Table 2.

Table 2: Gender Differentials in Selected NCD Indicators (Adults ≥45, LASI)

Indicator	Males (%)	Females (%)	Source
Hypertension (≥45)	~44	~48‡	LASI
Diabetes (≥45)	~11.9	~11.9‡	LASI
Cardiovascular Conditions	~5.9	~4.6‡	LASI
Multimorbidity	Higher	Higher	LASI

Gender operates not solely as a biological category but as a social structure shaping exposure, recognition and treatment of disease (Sen & Östlin, 2008; Connell, 2012) [7]. National survey data indicate that women often report poorer self-rated health while simultaneously experiencing barriers to institutional healthcare utilization (IIPS & ICF, 2021) [16]. Delayed diagnosis and constrained autonomy in health decision-making further compound risk.

The shifting gender gradient across age groups suggests that vulnerability is temporally structured. Earlier cardiometabolic manifestation among men may reflect occupational and behavioral exposures, while intensified late-life vulnerability among women reflects lifelong structural disadvantage. These findings underscore that gender is not a static variable but a dynamic axis of inequality operating across the life span.

3. Intersection of Age and Gender: Amplified Inequality

The interaction between age and gender reveals that demographic effects are not additive but intersecting. While men demonstrate earlier cardiometabolic manifestation in midlife, women experience accelerated vulnerability in later adulthood, particularly after the menopausal transition. The age-specific convergence and divergence of these trajectories are illustrated in Figure 1.

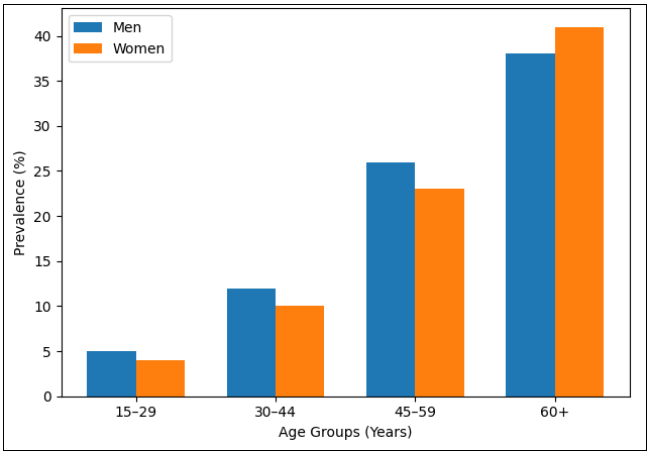

Fig 1: Intersection of Age and Gender in NCD Burden in India (NFHS-5 and LASI patterns)

Intersectionality theory suggests that demographic categories interact to produce distinct patterns of vulnerability rather than independent risk effects (Hankivsky *et al*., 2014) [14]. In this context, ageing processes intersect with gendered social organization, producing trajectories of inequality that unfold over time. These patterns are consistent with structural epidemiological perspectives, which argue that health inequalities are organized through socially patterned distributions of power and opportunity (Krieger, 2011) [20].

The variation in NCD prevalence across age and gender suggests that health disparities arise from socially organized conditions of exposure and opportunity, rather than from individual behavior or physiological decline alone.

4. Public Health and Policy Implications

The demographic gradients identified in this analysis carry important implications for public health planning in India. The steep rise in NCD prevalence after midlife highlights the limitations of late-stage, treatment-centered intervention models. Screening programs that primarily target older adults address the visible consequences of long-term exposure but do little to prevent risk accumulation earlier in life. A life-course-oriented strategy would require sustained investment in early nutrition, occupational safety, psychosocial stress reduction and continuous primary care access (WHO Commission on Social Determinants of Health, 2008) [37].

The age–gender interaction further suggests that gender-neutral policies may inadvertently reproduce inequality. Older women face compounded vulnerabilities shaped by lifelong structural disadvantage, yet outreach, screening and treatment programs often fail to account for gendered barriers to access. Incorporating gender-responsive approaches into NCD prevention and management is therefore essential to achieving equitable outcomes (Sen & Östlin, 2008).

Moreover, the high prevalence of multimorbidity in later life challenges disease-specific vertical program designs. Health systems structured around single conditions are poorly suited to managing coexisting chronic diseases (Barnett *et al*., 2012) [3]. Integrated care models, long-term medication continuity and community-based follow-up mechanisms are necessary to address the complex needs of ageing populations.

Taken together, these findings reinforce the importance of interpreting demographic variables as planning axes rather than descriptive categories. Surveillance systems and policy evaluations must assess differential impact across age and gender groups to avoid reinforcing structurally patterned inequalities.

5. Methodological Reflections

Several limitations should be acknowledged. As a cross-sectional synthesis of secondary datasets, the analysis does not establish temporal causality. Differences in measurement approaches across surveys may affect comparability and potential underdiagnosis, particularly among women, may lead to underestimation of disease burden. Nonetheless, the use of nationally representative datasets strengthens the reliability of identified demographic gradients. By integrating epidemiological evidence with structural theory, the analysis moves beyond descriptive reporting toward a more conceptually grounded interpretation of NCD inequality.

Taken together, the demographic patterns identified in this study indicate that the burden of non-communicable diseases in India is unevenly distributed across the population. Differences across age and gender reflect long-term social processes that shape risk, access to care and health trajectories over time. Acknowledging these patterned disparities is essential not only for accurate interpretation of epidemiological data but also for developing public health responses that address underlying inequities rather than merely their clinical manifestations.

Conclusion

This study examined non-communicable disease prevalence in India through an integrated demographic-public health perspective, positioning age and gender as structural determinants rather than descriptive background variables. By combining nationally representative data with social determinants and life-course frameworks, the analysis identified consistent demographic gradients in diabetes, hypertension, cardiovascular disease and multimorbidity across age and gender groups.

The findings indicate that chronic disease burden reflects more than individual behavior or biological change alone. Age functions as an indicator of accumulated social and economic exposure, while gender shapes differentiated patterns of risk, diagnosis and healthcare access. Their interaction produces distinct trajectories of vulnerability that evolve over time, revealing how demographic positioning structures health outcomes in patterned ways.

These insights carry important implications for public health strategy. Approaches centered primarily on behavioral modification or late-stage treatments are unlikely to reduce inequalities in NCD burden. More effective responses require attention to early-life conditions, gender-responsive outreach and integrated management of coexisting chronic conditions in ageing populations.

By reframing demographic variables as explanatory axes of inequality, this study contributes to a more conceptually grounded understanding of chronic disease patterns in India. Addressing NCD disparities will depend on recognizing how social organization shapes exposure, opportunity and access to care. Such recognition provides a foundation for designing more equitable and structurally informed public health systems.

Future research incorporating longitudinal and intersectional designs can further illuminate how demographic positioning shapes chronic disease trajectories across generations.

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