Housing environment and associated health disparities in older adults: A propensity scores matching approach

Amiya Saha [1]

[1] **Research scholar**, Department of Family & Generations, International Institute for Population Sciences, Mumbai; **Email**: amiyasaha.iipsphd@gmail.com

Background

The housing environment of older adults play a crucial role in determining their health and well-being, particularly in rapidly developing countries like India (1). As the population of older adults continues to grow in India, understanding the relationship between housing environment and health outcomes become increasingly important for public health policy and intervention strategies (2). Numerous studies have demonstrated the multifaceted influence of housing on the health of older adults. For instance, research by Sims et al. (2020) found that poor housing quality, characterized by issues such as dampness, mold, and inadequate heating, was associated with increased risks of respiratory problems, cardiovascular diseases, and mental health issues among older adults (3). Similarly, a study by Om et al. (2022) revealed that housing instability, such as frequent moves or homelessness, was linked to higher rates of chronic conditions and mortality in older populations (4). Research conducted in developed countries has demonstrated associations between poor housing quality and increased risks of chronic diseases, functional limitations, mental health issues, and overall mortality among older populations (2,5,6).

In the Indian context, where socio-economic disparities are prevalent and housing conditions vary widely across regions, the link between housing and health among older adults warrants special attention. Limited research specific to India suggests that inadequate housing environments, including overcrowding, lack of sanitation facilities, poor ventilation, and structural deficiencies, may contribute to a range of health problems among older adults (7–9). Furthermore, the unique cultural and social contexts in India, such as traditional family structures, intergenerational living arrangements, and access to healthcare services, may influence the relationship between housing environments and health outcomes for older adults (10,11). Moreover, housing affordability has emerged as a critical determinant of health in later life. High housing costs relative to income can lead to financial strain and housing insecurity, which in turn may compromise older adults' ability to afford healthcare, medications, and nutritious food, thereby exacerbating health disparities (2,12,13). Also, the built environment surrounding housing, including neighborhood safety, access to green spaces, and availability of amenities and services, significantly influences the health behaviors and outcomes of older adults (14,15). Despite the growing recognition of the importance of housing conditions for older adults' health in India, there remains a paucity of comprehensive research

examining this relationship. Therefore, this study aims to contribute to the existing literature by investigating the association between housing conditions and health outcomes among older adults in India, with a focus on identifying potential socio-economic and demographic determinants.

Literature review

In India, where economic and social inequities are pronounced, inadequate housing can exacerbate physical, mental, and social health challenges among older adults. This literature review aims to synthesize existing research on how housing environments contribute to health disparities among older adults in India, focusing on the impact of physical housing conditions, mental health stressors, and socioeconomic and gender-related factors. According to the existing literature, four key health-related issues were identified as significantly influencing the health outcomes of older adults residing in poor housing conditions. These are as follow-

Housing environment and depression

The relationship between housing environment and depression among older adults is a critical area of study, revealing how living conditions can significantly impact mental health. Various dimensions of the housing environment, including physical conditions, neighborhood characteristics, and social interactions within the home, contribute to the mental well-being of the elderly. The physical condition of housing is a primary factor influencing depression among older adults (16). Poor housing conditions, such as inadequate heating, dampness, mold, and insufficient ventilation, have been consistently linked to higher levels of depression (17). According to a study by Kim et al., (2007), substandard housing conditions are associated with increased psychological distress, including symptoms of depression (18). The study highlights that inadequate housing can exacerbate stress and anxiety, contributing to poor mental health outcomes (18). Furthermore, the lack of essential facilities such as proper sanitation, safe drinking water, and adequate space can lead to a sense of helplessness and despair among older adults (19). A study by McLaren et al., (2013) found that older adults living in inadequate housing reported significantly higher levels of depressive symptoms compared to those in better housing conditions (20). Also, the presence of social and recreational amenities encourages physical activity and social interactions, which are beneficial for mental health (21). The quality of social interactions within the home environment significantly affects the mental health of older adults (22). Living alone or experiencing poor familial relationships can lead to social isolation and loneliness, which are major contributors to depression (23). This underscores the importance of fostering positive social interactions and support systems within the home to enhance mental health outcomes for the older adults.

Housing environment and self-rated health

Housing environment and self-rated health has been extensively studied in many pioneering work, revealing significant correlations that impact overall well-being, particularly among older adults (24). Poor housing conditions, including inadequate heating, dampness, mold, and structural deficiencies, have been consistently associated with negative health outcomes (25). Swope and Hernandez (2019) found that individuals living in substandard housing reported poorer self-rated health, with issues such as respiratory problems, allergies, and other health issues being prevalent (26). Space and overcrowding are significant determinants (27). Hansen et al., (2021) has also found that overcrowded living conditions were linked to higher stress levels, reduced privacy, and poorer self-rated health (27). Overcrowding can lead to increased exposure to communicable diseases and heightened stress due to lack of personal space, both of which adversely affect health perceptions (27). Additionally, socioeconomic factors intertwined with housing environments influence self-rated health. Individuals in lower socioeconomic brackets often reside in poorer housing conditions, compounding the negative health impacts (28). The housing affordability and tenure type (ownership versus rental) were important predictors of self-rated health, with homeowners generally reporting better health outcomes than renters (29).

Housing environment, functional limitations and falls/ injuries

Numerous studies have highlighted the association between inadequate housing and functional limitations (30–32). According to a study by Hellar et al. (2024), the physical characteristics of a home, such as accessibility, safety features, and the overall maintenance of the dwelling, are critical in supporting the functional abilities of older adults (33). Homes that lack essential modifications like handrails, ramps, or adequate lighting can pose significant challenges and increase the risk of falls and injuries, leading to a decline in functional capabilities (34). In the context of India, where a substantial proportion of the older population lives in substandard housing conditions, the relationship between housing environment and functional limitations becomes even more pronounced (35). Alam and Karan (2011) found that poor housing conditions, characterized by overcrowding, lack of sanitation, and inadequate ventilation, were significantly associated with higher levels of functional limitations among older adults in India (36). These conditions not only impede mobility and self-care but also contribute to the onset of chronic illnesses and disabilities (37). Furthermore, psychological aspects of housing, such as a sense of security and control over one's environment, play a vital role in functional health. According to Lawton and Nahemow's ecological model of aging, the fit between an individual's abilities and their living environment is crucial for optimal functioning. Poor housing environments can lead to stress and a sense of helplessness, further diminishing functional abilities (38). Social factors within the housing environment also contribute to functional limitations (39). Older adults living in socially isolated or unsafe neighborhoods may have limited opportunities for physical activity and social engagement, which are essential for maintaining

functional health (40). In India, the lack of community support and accessible public spaces often exacerbates the functional limitations faced by older adults in impoverished housing conditions (41).

Contribution of the study

Housing environment and associated health disparities in older adults in India is underpinned by several critical factors. Firstly, India is experiencing rapid urbanization coupled with a significant demographic shift towards an aging population. According to the United Nations Population Fund, (42) the proportion of the elderly population in India is expected to rise from 8% in 2015 to 19% by 2050. This demographic shift necessitates a closer examination of the living conditions and health outcomes of older adults, as the quality of housing environments has been shown to directly impact health and well-being (43). Housing conditions in India vary widely, with a substantial portion of the elderly population living in substandard housing (35). Poor housing environments, characterized by inadequate ventilation, lack of sanitation, and overcrowding, have been linked to adverse health outcomes (44). These conditions can exacerbate chronic health issues, increase the risk of infectious diseases, and contribute to mental health problems such as depression and anxiety (41). However, there is a paucity of rigorous, large-scale studies in India that systematically examine the relationship between housing environment and health disparities among older adults using advanced statistical methods.

Many previous studies indicate that inadequate housing conditions, such as lack of sanitation, overcrowding, poor ventilation, and unsafe structures, are prevalent in many parts of India, particularly in urban slums and rural areas (45). These conditions are associated with a higher prevalence of respiratory diseases, cardiovascular conditions, and mental health disorders among the elderly (46). The World Health Organization (WHO) emphasizes the need for age-friendly environments that support healthy aging, highlighting the role of adequate housing in promoting physical and mental well-being (47). Moreover, socio-economic disparities exacerbate the impact of poor housing on health. Older adults from lower socio-economic strata are more likely to reside in substandard housing and have limited access to healthcare and social services, further widening health disparities (48). Addressing these disparities is crucial for achieving health equity and improving the quality of life for the elderly population.

Using propensity score matching (PSM) as a methodological approach allows for a more accurate estimation of the causal effects of housing conditions on health outcomes by reducing selection bias. This method is particularly valuable in observational studies where randomized controlled trials are not feasible. By matching individuals with similar characteristics from different housing environments, the study can isolate the impact of housing on health disparities, providing robust and actionable insights (49). Thus, this

study aims to fill a significant gap in the literature by providing empirical evidence on the relationship between housing environments and health disparities among older adults in India. Previous studies have predominantly focused on general health outcomes without accounting for the specific influence of housing conditions (50). Conducting a study using propensity score matching will allow for a more precise understanding of the causal relationship between housing environment and health disparities. This approach will help identify vulnerable groups and inform targeted interventions to improve housing conditions and health outcomes for older adults in India. By providing detailed and robust evidence on the impact of housing conditions on health outcomes, this research will contribute significantly to the formulation of effective policies and interventions aimed at improving the quality of life for older adults in India.

Methods

Data

This study utilized data from the Longitudinal Ageing Study in India (LASI) Wave 1, conducted in 2017–18, which includes data from Sikkim (51). LASI is a comprehensive, large-scale survey designed to study the health and aging of older adults aged 45 and above across India. The sample for this study was selected using a multistage stratified area probability cluster sampling design, targeting non-institutionalized residents across 31 states (including Sikkim) and six Union Territories of India. LASI Wave 1 employed a three-stage sampling process in rural areas and a four-stage process in urban areas. The first stage involved selecting Primary Sampling Units (PSUs), such as sub-districts (Tehsils/Talukas). In rural areas, the second stage involved selecting villages, while in urban areas, wards were selected. The third stage involved the random selection of a Census Enumeration Block (CEB) in each urban area, with several households chosen for the fourth stage. This detailed sampling framework was designed to ensure representative samples at each stage. All households and eligible individuals provided written informed consent (51). The study adhered to ethical standards for human subject protection, with four types of consent forms used: household informed consent, individual informed consent, consent for the collection of blood samples for storage and future use (DBS), and proxy consent. The Indian Council of Medical Research (ICMR) provided the necessary guidelines and ethical approval for conducting the LASI.

Selection of the study sample

As the LASI Wave 1 has covered 43% of older adults aged 60 years and above with comprehensive information on reported depression, self-rated health, functional limitation and falls/injuries made up the majority of our study's sample (51). Initially, household data was merged with individual data to prepare the dataset. Body Mass Index (BMI) data from biomarkers were used in this study to calculate the BMI of each individual. Thus, in the next step, biomarker data has been merged with the final data. Therefore, the

total sample for the study after excluding the incomplete information on dependent variable (depression, self-rated health, functional limitation and falls/injuries), explanatory variable (housing environment) and all other covariates were reduced to 28,225. A flow chart for choosing the sample study is shown in **figure 1**.

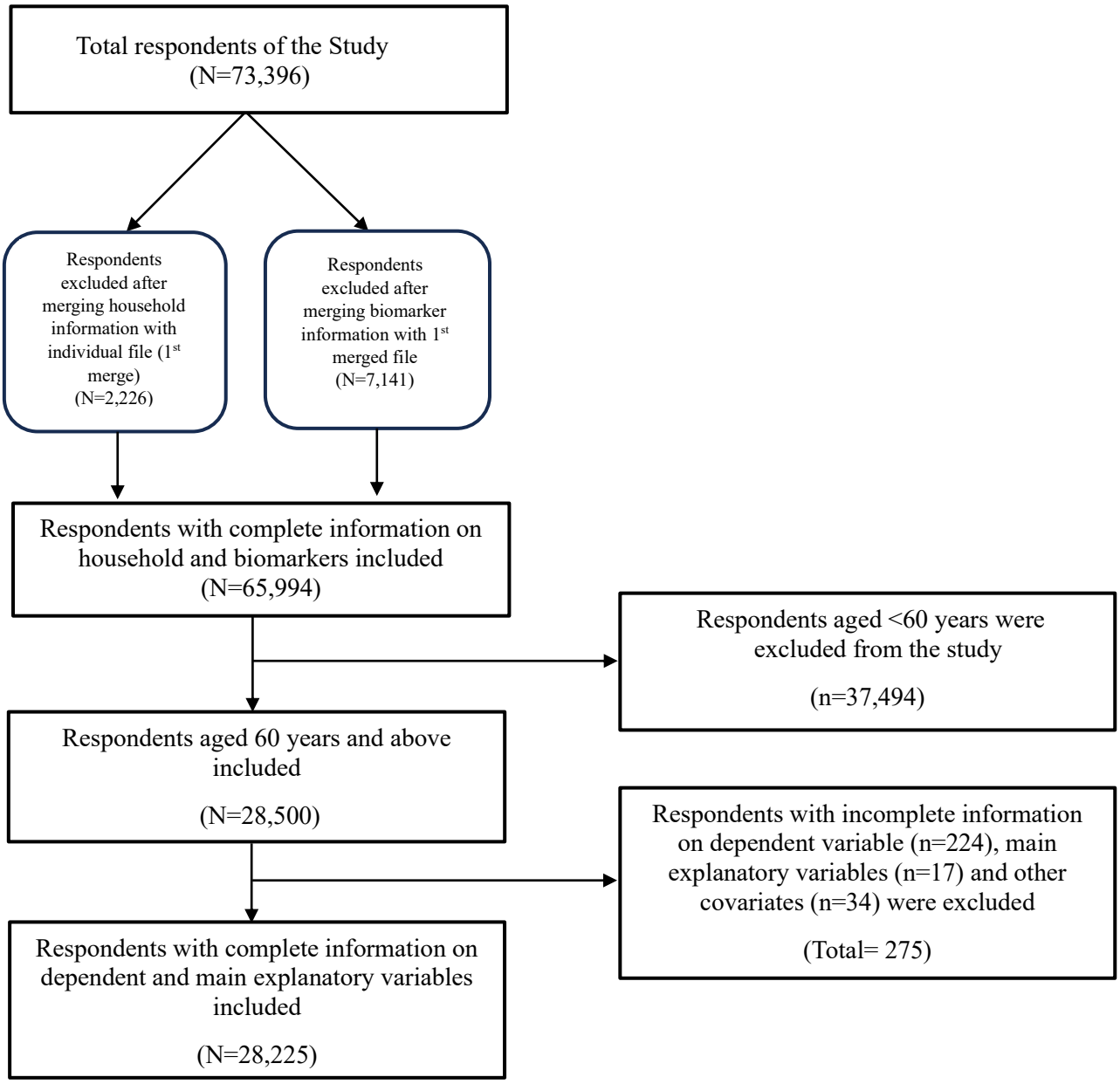

Figure 1. Flow chart showing the sample selection for the study

Measures

Dependent variables

We have included four main outcome variables in our study which is detailed below:

First, in the individual schedule, a question was asked to the respondents, *"Overall, how is your health in general?"* with responses of "Very good," "Good," "Fair," "Poor," and "Very poor" (51). The outcome variable, i.e., self-rated health, is binary in nature in the present study. We considered fair, poor, and very poor as poor (coded as 1), whereas very good and good are considered good (coded as 0) (52).

Second outcome of interest i.e., depressive symptoms was measured based on the Centre for Epidemiologic Studies Depression Scale (CES-D-10) among older adults, and it has four scale options, ranging from (1) rarely or never (<1 day) to (4) most of the time (5–7 days) (51). Respondents were asked ten different questions regarding their experiences over the past week, including difficulty concentrating, feeling depressed, low energy, afraid of something, alone, irritated by things, everything is an effort, and feeling cheerful, hopeful, and satisfied. Among the 10 items on the scale, the first seven were based on negative symptoms, and the final three on positive symptoms. Those who responded to negative symptoms by stating "rarely or never (1 day)" and "occasionally (1 or 2 days)" were given a zero score, while the other two categories were coded as one. In addition, when positive symptoms were present, scoring was reversed. The composite score spanned a scale of 0 to 10, where a value of four or higher was considered indicative of depression (53).

Third, functional limitations included limitations in ADL and IADL in the study. In the individual survey schedule, questions on ADL consisted of limitations in six activities related to dressing which includes putting on chappals or shoes, walking across a room, difficulties in bathing, eating, getting in or out of bed and using the toilet, including getting up and down (51). Further, combining these six ADLs into one variable, we constructed a variable coded as 0 for “no ADL” if the respondent had no limitations in performing any ADLs and 1 “ADL” if respondents had any limitation in performing any ADL (54). Furthermore, IADL consists of seven limitations related to instrumental activities: difficulty preparing a hot meal (cooking and serving), shopping for groceries, making telephone calls, taking medications, doing work around the house or garden, and managing money, such as paying bills, keeping track of expenses, and getting around or finding addresses in unfamiliar places (51). IADLs was also recoded as 0 “no IADL” if the respondent had no limitation in performing any IADLs and 1 “IADL” if respondents had any limitation in performing any IADL (54).

Fourth, falls/injuries was considered by asking “In the past two years, have you sustained any major injury” in the individual survey. Binary responses were coded 0 as “no” and 1 as “yes”

Main explanatory variables

Housing environment was considered as the mail explanatory factor in the study. Four main factors were taken into consideration for housing environments. First, the sanitation was considered based on the two questions a. "what type of toilet facility does your household use;" responses were considered as "unimproved" and coded as "0" if the respondent responds with others and no facility, use open space or field, responses were considered as "improved" and coded as "1" if the respondent respond with Flush or pour flush toilet, Pit latrine and Twin pit/composting toilet" and b. "Do you share this toilet facility with other households;" binary responses were coded no as "0" and yes as "1." We then summed the scores and coded 0 as "unimproved" and 1 and 2 as "improved" (55).

Second, water supply in the household was considered by asking "What is the main source of drinking water for members of your household" in the LASI questionnaire. Binary responses were coded 0 as "unimproved" if respondents respond tanker, cart with small tank, surface water (river/dam/lake/ponds/stream/canal/irrigation channel), bottled water/pouch water and others and 1 as "improved" if respondents respond piped water, public tap/standpipe, tube well or bore well, dug well, spring water and rain water (55).

Third, cooking condition was considered based on three questions a. "what is your main source of cooking fuel;" responses were coded 0 as "unimproved" if respondents respond kerosene, charcoal/lignite/coal, crop residue, wood/shrub, dung cake and 1 as "improved" if respondents respond liquefied petroleum gas (LPG), biogas and electric. b. "in this household, is food mostly cooked on a mechanical stove, on a traditional chullah or over an open fire;" responses were coded 0 as "unimproved" if they respond open fire and others and 1 as "improved" if they respond mechanical stove/improved cook stove and traditional chullah. c. "Is the cooking usually done in the house, in a separate building, or outdoors;" the responses were coded 0 as "unimproved" if they respond in the house, outdoors and others and 1 as "improved" if they respond in a separate building. Further, we summed the scores and coded 0 and 1 as "unimproved and 2 and 3 as "improved;" it means that if the household has at least two improved cooking condition then only it is considered as an improved household (55).

Fourth, housing material was considered by asking "what is the type of house (including roof, wall and floor)." Binary responses were coded 0 as "unimproved" if respondents respond semi pucca (combination of temporary and permanent material) and kutcha (temporary material) and 1 as "improved" if respondents respond pucca (permanent material) (55–57).

Finally, we summed all the factors associated with housing environment to generate a new score and prepare our main explanatory variable included in the study. House with ≥ 3 scores out of the maximum obtainable

4 scores were classified as “improved” housing environment (IHE) while houses with ≤ 2 were categorized as “unimproved” housing environment (UHE) (58).

Covariates

Age of the respondents were available in "young-old," "old-old," and "oldest-old" (53). Sex of the respondent was available in male-female categories(59). There were four categories for educational status: No education/ primary not completed," "Primary," "Secondary," and "Higher" (60). Caste was coded as Scheduled castes (SC), Scheduled Tribes (ST), Other Backward Class (OBC) and others (61). Religion was categorized into Hindu, Muslim, Christian, and others (60,62). Place of residence (rural/urban) was determined according to the administrative division of India followed in Census of India, 2011 (45). Households in urban areas included those in towns, wards and Census Enumeration Blocks whereas, households in rural areas include those in villages (size varies from 0-10,000 population). Consumption of tobacco was categorized by asking three questions to the older adults during survey; (i) Have you ever smoked tobacco (cigarette, bidi, cigar, hookah, cheroot) or used smokeless tobacco (such as chewing tobacco, gutka, pan masala, etc.)?” Those who responded no was coded as “never consumed tobacco.” (ii) “What type of tobacco product have you used or consumed?” Those who responded Smokeless tobacco (such as chewing tobacco, gutka, pan masala, etc.) was coded as “Currently consumed smokeless tobacco” and both Smoke and smokeless tobacco was coded as “Consumed both smoking and smokeless tobacco.” (iii) "Do you currently smoke any tobacco products (cigarettes, bidis, cigars, hookah, cheroot, etc.)?” Those who responded yes was coded as “currently smoking” (59). Similarly, consumption of alcohol was categorized by asking three questions to the older adults during survey; (i) Have you ever consumed any alcoholic beverages such as beer, wine, liquor, country liquor etc.?” (ii) “In the past three months, on an average, how frequently [on how many days], have you had at least one alcoholic drink? (For example, beer, wine, or any drink, such as country liquor, containing alcohol.?.” (iii) “In the last 3 months, how frequently on average, have you had at least 5 or more drinks on one occasion?” Those who responded no was coded as “never consumed alcohol.” Consumed none, less than once a month in past three months was coded as “frequently consumed but not a heavy drinker”; those who drank one to four times a week, one to four times a day, or five or more times a day but did not drink more than five drinks at once in the previous 30 days was coded as “Infrequently consumed but not a heavy drinker” and those who, at least once during the previous 30 days, consumed five or more alcoholic beverages was coded as “heavy drinker” (59). The study focused on assessing the body mass index (BMI), which is a measure of weight in relation to height, among elderly participants. The BMI values were determined using the height and weight measurements of the respondents. The BMI results were then classified according to the World Health Organization's classification system, which categorizes individuals as underweight (BMI <18.5 kg/m2), normal weight

(BMI 18.5–24.9 kg/m2), overweight (BMI 25.0–29.9 kg/m2), and obese (BMI ≥30.0 kg/m2) (54). The perception of discrimination was assessed using six questions, including statements such as, "You receive less courtesy or respect compared to others," "People treat you as if you are not intelligent," "People behave as if they are fearful of you," and "You experience threats or harassment." In addition, respondents' answers were classified into binary categories: "yes" if they reported experiencing discrimination on an almost daily basis, almost every day, a few times a month, or less than once a year, and "no" if they indicated never experiencing discrimination (53). Current research has classified marital status into binary classification, including currently in union and currently not in union. Ill-treatment was categorized as "no" and "yes" (63). Community involvement was assessed through the process of coding responses to survey questions regarding affiliation with social organizations, religious groups, clubs, or societies. The participants' responses were classified into two categories, namely "yes" and "no" (53). By utilizing data on household consumption, the study evaluated the monthly per capita consumption expenditure (MPCE) quintile. Surveying sample households involved the use of question sets containing 11 and 29 questions related to expenditures on food and non-food items, respectively. Food expenses were recorded over a seven-day reference period, while non-food expenditures were collected over 30-day and 365-day reference periods. Standardization of expenses for both food and non-food items were carried out using the 30-day reference period. The MPCE, serving as a comprehensive consumption indicator, was computed and categorized into three five quintiles, ranging from Q1 as "poorest," to Q5 as "richest", providing a summary representation of patterns (52,63). The region was coded as "North," "West," "Northeast," "East," "Central" and consumption "South" in this study (59).

Methodological strategy

Bivariate analysis

Bivariate cross-tabulations were performed to show the percentage distribution of health disparities across different housing environments. These percentages were adjusted using sampling weights to ensure accurate representation.

Multivariate analysis for the effect of housing conditions on health outcomes in older adults

Logistic regression was conducted to estimate the odds of various health disparities associated with different housing environments. The analysis focused on four health outcomes: depression, self-rated health, functional limitations, and falls/injuries, with the housing environment serving as the independent variable and age, sex, education, and other selected variables included as covariates.

To assess the effect of the independent variable on each health outcome, four separate logistic regression models were run, each addressing one of the outcomes of interest. The equations for these models are provided below.

Equation 1

$$\text{Logit (Depression)} = \ln(\text{Depression}/1 - \text{Depression}) = \alpha + \beta_1 * \chi_{1\,(\text{Age})} + \beta_2 * \chi_{2(\text{Sex})} + \beta_3 * \chi_{3(\text{Education})} + \beta_4 * \chi_{4(\text{Caste})} + \beta_5 * \chi_{5(\text{Religion})} + \beta_6 * \chi_{6(\text{Residence})} + \beta_7 * \chi_{7(\text{Tobacco Consumption})} + \beta_8 * \chi_{8(\text{Alcohol consumption})} + \beta_9 * \chi_{9(\text{BMI})} + \beta_{10} * \chi_{10(\text{Perceived discrimination})} + \beta_{11} * \chi_{11(\text{Marital Status})} + \beta_{12} * \chi_{12(\text{Illtreatment})} + \beta_{13} * \chi_{13(\text{Community involvement})} + \beta_{14} * \chi_{14(\text{MPCE})} + \beta_{15} * \chi_{15(\text{Region})} + €$$

Equation 2

$$\text{Logit (SRH)} = \ln(\text{SRH}/1 - \text{SRH}) = \alpha + \beta_1 * \chi_{1\,(\text{Age})} + \beta_2 * \chi_{2(\text{Sex})} + \beta_3 * \chi_{3(\text{Education})} + \beta_4 * \chi_{4(\text{Caste})} + \beta_5 * \chi_{5(\text{Religion})} + \beta_6 * \chi_{6(\text{Residence})} + \beta_7 * \chi_{7(\text{Tobacco Consumption})} + \beta_8 * \chi_{8(\text{Alcohol consumption})} + \beta_9 * \chi_{9(\text{BMI})} + \beta_{10} * \chi_{10(\text{Perceived discrimination})} + \beta_{11} * \chi_{11(\text{Marital Status})} + \beta_{12} * \chi_{12(\text{Illtreatment})} + \beta_{13} * \chi_{13(\text{Community involvement})} + \beta_{14} * \chi_{14(\text{MPCE})} + \beta_{15} * \chi_{15(\text{Region})} + \beta_{16} * \chi_{16(\text{SES Variables})} + €$$

Equation 3

$$\text{Logit (Functional limitation)} = \ln(\text{Functional limitation}/1 - \text{Functional limitation}) = \alpha + \beta_1 * \chi_{1\,(\text{Age})} + \beta_2 * \chi_{2(\text{Sex})} + \beta_3 * \chi_{3(\text{Education})} + \beta_4 * \chi_{4(\text{Caste})} + \beta_5 * \chi_{5(\text{Religion})} + \beta_6 * \chi_{6(\text{Residence})} + \beta_7 * \chi_{7(\text{Tobacco consumption})} + \beta_8 * \chi_{8(\text{Alcohol consumption})} + \beta_9 * \chi_{9(\text{BMI})} + \beta_{10} * \chi_{10(\text{Perceived discrimination})} + \beta_{11} * \chi_{11(\text{Marital Status})} + \beta_{12} * \chi_{12(\text{Illtreatment})} + \beta_{13} * \chi_{13(\text{Community involvement})} + \beta_{14} * \chi_{14(\text{MPCE})} + \beta_{15} * \chi_{15(\text{Region})} + \beta_{16} * \chi_{16(\text{SES Variables})} + €$$

Equation 4

$$\text{Logit (Injuries)} = \ln(\text{Injuries}/1 - \text{Injuries}) = \alpha + \beta_1 * \chi_{1\,(\text{Age})} + \beta_2 * \chi_{2(\text{Sex})} + \beta_3 * \chi_{3(\text{Education})} + \beta_4 * \chi_{4(\text{Caste})} + \beta_5 * \chi_{5(\text{Religion})} + \beta_6 * \chi_{6(\text{Residence})} + \beta_7 * \chi_{7(\text{Tobacco Consumption})} + \beta_8 * \chi_{8(\text{Alcohol consumption})} + \beta_9 * \chi_{9(\text{BMI})} + \beta_{10} * \chi_{10(\text{Perceived discrimination})} + \beta_{11} * \chi_{11(\text{Marital Status})} + \beta_{12} * \chi_{12(\text{Illtreatment})} + \beta_{13} * \chi_{13(\text{Community involvement})} + \beta_{14} * \chi_{14(\text{MPCE})} + \beta_{15} * \chi_{15(\text{Region})} + \beta_{16} * \chi_{16(\text{SES Variables})} + €$$

Propensity score matching (PSM) analysis for the effect of housing conditions on health outcomes in older adults

Due to the limited understanding of the causal relationship between housing environments and various health outcomes, particularly in developing countries, this study aims to bridge this gap by utilizing a causal framework (64). In the causal framework, we examine the differences in health outcomes by comparing situations where individuals living in unimproved housing environments receive specific treatments to hypothetical scenarios where these same individuals do not receive such treatments. We applied propensity score matching (PSM) to the sample of individuals living in unimproved housing, a method widely recognized as an effective alternative for causal analysis (65). In Propensity Score Matching (PSM), various observed predictors are combined to generate a propensity score, which reflects each individual's probability of being assigned to the treatment group. Kernel matching is then applied using this score to create a matched sample of participants from both the treatment and control groups. The propensity score serves as a balancing measure for the observable predictors, ensuring that the distribution of these variables is similar between the treatment and comparison groups. Individuals residing in unimproved housing were placed in the treatment group and matched with individuals in the control group using a one-to-one matching approach.

Thus, the basic PSM model was

$$e(x) = Pr\ (Z = 1 \mid X{=}x) \ldots\ldots\ldots\ldots\ldots\ldots$$

Where, Z=0 if an individual living in an unimproved housing

Z=1 if an individual living in an improved housing

X = background observed covariates

We demonstrate the PSM analysis findings as Average Treatment Effect (ATE) and Average Treatment Effect on the Treated (ATT) and Average Treatment Effect on Untreated (ATU). Average Treatment Effect (ATE) is basically the effect of the intervention across the whole population, while Average Treatment Effect on the Treated (ATT) is the average of the individual causal effects just among those who were treated and Average Treatment Effect on Untreated (ATU) is the average of the individual causal effects among those who were not treated. The formula for ATE, ATT and ATU are as follows:

$$ATE = E\ [Z_1] = E\ (Y_1 - Y_0) = E\ (Y_1) - E(Y_0)$$

Where, E (Z_1) denotes the estimated values of Y for all the units in the treatment group, and E (Y_0) is the estimated value of Y for all the units in the control group.

Here, E (Z_1) represents the estimated values of (Y) for all units within the treatment group, while E (Y_0) corresponds to the estimated values of Y for all units within the control group.

$$ATT = E\,(Y_1 - Y_0 |\ Z = 1) = E\,(Y_1 \mid Z = 1) - E\,(Y_0 |\ Z = 1)$$

Where, (Z) = (0, 1) represents the control and treatment groups. The term $E\,(Y_0 \mid Z = 1)$ refers to the counterfactual mean, which cannot be directly observed from the data. This value reflects the average outcome that treated individuals would have experienced under an improved housing environment, which is unobserved.

$$ATU = E\,(Y_1 - Y_0 \mid Z = 0) = E\,(Y_1 \mid Z = 0) - E\,(Y_0 \mid Z = 0)$$

Where, (Z) = (0, 1) represents the control and treatment conditions. The term, $E\,(Y_0 \mid Z = 0)$ denotes the observed mean, reflecting the average health outcome for individuals residing in an unimproved housing environment. Meanwhile, $E\,(Y_1 \mid Z = 0)$ represents the counterfactual mean outcome for those living in an unimproved housing environment, indicating the average outcome that the control group would have experienced under unimproved housing conditions, which is not directly observed.

Results

Summary profile of the respondents

A detailed summary of the respondents has been given in the **supplementary table 1**.

Prevalence of health differences for living in different housing environments

Tables 1 and **table 2** highlight the health disparities associated with different housing environments. The prevalence of depression was 18% higher among the oldest-old living in unimproved housing compared to those in improved housing (44.84% vs. 26.79%). Among SC/ST groups in unimproved housing, the prevalence of depression was 10% higher than their counterparts in improved housing (36.22% vs. 25.90%). Urban residents in unimproved housing experienced a 13% higher prevalence of depression compared to rural residents (38.45% vs. 25.72%). Additionally, respondents who smoked and lived in unimproved housing had a 12% higher prevalence of depression (36.51% vs. 24.37%), while those who frequently consumed alcohol had a 7% higher prevalence (31.11% vs. 23.88%). Similarly, the prevalence of poor self-rated health (SRH) was 15% higher among the oldest-old living in unimproved housing compared to those in improved housing (45.21% vs. 30.30%). Female respondents in unimproved housing reported poor SRH 6% more frequently than those in improved housing (29.69% vs. 23.55%). Among individuals not in a marital union, those in unimproved housing had a 6% higher prevalence of poor SRH compared to those in improved housing (30.89% vs. 24.76%). Lastly, urban residents living in unimproved housing experienced

a 12% higher prevalence of poor SRH compared to those in improved housing (33.55% vs. 21.03%) (**table 1**).

Table 1. Prevalence of depression and self-rated health among older adults stratified by housing environment

	Depression			Self-rated health		
	Unimproved	**Improved**	***p value for differences***	**Unimproved**	**Improved**	***p value for differences***
Age						
Young-old	32.90	25.03	<0.001	22.47	19.20	<0.05
Middle-old	35.95	26.66	<0.001	29.30	25.82	0.173
Oldest-old	44.84	26.79	<0.001	45.21	30.30	<0.01
Sex						
Male	32.83	22.60	<0.001	23.68	21.09	<0.001
Female	37.04	28.55	<0.001	29.69	23.55	0.191
Education						
No Schooling	35.89	28.46	<0.001	27.82	24.69	0.464
Up to Primary	29.95	24.01	<0.05	23.65	24.20	0.998
Up to Secondary	32.01	25.52	0.08	18.76	23.01	0.404
Secondary & above	28.07	19.70	<0.001	18.41	14.96	0.058
Caste						
Others	34.34	25.77	<0.001	24.42	20.47	<0.001
SC/ST	36.22	25.90	<0.001	25.13	22.74	<0.05
OBC	34.30	25.58	<0.001	29.23	23.64	<0.05
Religion						
Others	32.02	19.13	<0.001	31.48	26.39	0.202
Hindu	35.02	25.98	<0.001	26.61	21.37	<0.001
Muslim	36.56	28.11	<0.001	26.15	27.23	0.720
Residence						
Rural	34.80	25.70	<0.001	26.37	23.4	0.056
Urban	38.45	25.72	<0.001	33.55	21.03	<0.001
Tobacco Consumption						
Never consumed	35.87	26.43	<0.001	28.99	22.12	<0.001
Currently smoking	36.51	24.37	<0.001	23.08	23.51	0.427
Consuming smokeless tobacco	32.41	23.39	<0.001	23.65	20.67	0.981
Both smoking and smokeless tobacco	38.94	28.76	<0.05	25.8	21.5	0.108
Not responded	32.03	26.04	-	36.96	32.14	-
Alcohol consumption						
Never consumed	35.60	26.24	<0.001	27.82	22.24	<0.001
Frequently	31.11	23.88	<0.01	19.06	20.12	0.689
Infrequent	33.44	21.68	<0.001	23.98	25.54	0.810
heavy drinker	25.01	21.74	0.158	13.24	11.17	0.182
Body Mass Index (BMI)						
Underweight	37.39	29.99	<0.001	29.26	24.16	<0.05
Normal	32.57	25.06	<0.001	23.49	22.07	0.228
Overweight	35.85	24.76	<0.001	25.29	19.87	0.058

Obese	31.48	20.09	0.166	35.74	19.08	<0.05
Missing	51.53	41.84	-	69.31	64.13	-
Perceived discrimination						
No	31.09	22.31	<0.001	26.50	21.91	<0.05
Yes	49.28	46.48	<0.05	28.0	25.22	<0.01
Marital Status						
Not in union	40.03	30.43	<0.001	30.89	24.76	0.061
Currently in union	31.90	23.09	<0.001	24.27	21.06	<0.01
Illtreatment						
No	34.01	24.91	<0.001	26.18	21.87	<0.01
Yes	47.39	47.74	0.622	34.61	36.43	0.815
Community involvement						
No	35.06	25.73	<0.001	26.96	22.74	<0.01
Yes	34.11	25.28	<0.01	23.14	16.51	0.081
MPCE						
Q1	35.80	30.91	<0.001	28.47	24.29	<0.05
Q2	33.01	25.21	<0.01	26.60	22.52	0.589
Q3	34.01	24.52	<0.001	23.97	19.9	0.279
Q4	35.32	24.29	<0.001	27.26	22.69	<0.05
Q5	39.45	24.91	<0.001	27.88	22.92	<0.01
Region						
North	28.0	26.53	0.278	24.77	21.23	0.076
West	26.42	17.43	<0.001	20.92	12.09	<0.001
Northeast	24.48	15.43	<0.001	20.62	19.86	<0.01
East	33.22	28.15	0.143	25.95	25.02	0.318
Central	38.53	30.71	<0.001	24.59	20.54	0.156
South	43.69	28.26	<0.001	38.51	30.9	0.079

Notes: MPCE: Monthly Per Capita Consumption Expenditure; Q1 represents poorest; Q2 represents poorer; Q3 represents middle; Q2 represents richer; Q2 represents richest.

The prevalence of functional limitations varied significantly between young-old and male respondents based on their housing conditions. Young-old individuals in unimproved housing had a prevalence rate of 50.14% compared to 39.02% in improved housing, while for males, the rates were 49.25% versus 37.82%, respectively, indicating an 11% difference in both groups. Among obese respondents, those in unimproved housing experienced a 14% higher prevalence of functional limitations than those in improved housing. Additionally, respondents who perceived discrimination (61.39% vs. 55.20%) and those not in a marital union (65.26% vs. 58.20%) living in unimproved housing reported higher prevalence rates of functional limitations than their counterparts. The oldest-old in unimproved housing reported a 5% higher prevalence of falls or injuries compared to those in improved housing. Moreover, individuals in unimproved housing who consumed alcohol heavily or received ill-treatment had a 11% and 7% higher prevalence of falls or injuries, respectively, than their counterparts (**table 2**).

Table 2. Prevalence of functional limitation and falls/injuries among older adults stratified by housing environment

	Functional limitation	**Falls/ Injuries**

	Unimproved	Improved	*p value for differences*	Unimproved	Improved	*p value for differences*
Age						
Young-old	50.14	39.02	<0.001	16.38	13.23	<0.001
Middle-old	62.95	54.71	<0.001	16.82	15.47	<0.01
Oldest-old	75.60	70.78	<0.01	21.37	16.29	<0.05
Sex						
Male	49.25	37.82	<0.001	16.36	11.42	<0.001
Female	63.20	55.63	<0.001	17.63	16.80	<0.01
Education						
No schooling	59.28	56.99	<0.05	16.93	14.32	<0.001
Up to primary	45.54	37.96	0.169	20.77	13.45	<0.01
Up to secondary	37.21	38.22	0.096	14.70	15.22	0.285
Secondary & above	35.05	30.6	0.125	13.59	14.13	<0.05
Caste						
Others	56.29	44.57	<0.001	16.47	14.14	<0.01
SC/ST	53.57	48.17	<0.001	17.08	13.42	<0.01
OBC	59.16	48.58	<0.001	17.20	14.64	<0.001
Religion						
Others	56.38	46.21	<0.05	14.88	12.25	0.054
Hindu	56.69	46.67	<0.001	16.96	14.70	<0.001
Muslim	55.42	51.16	<0.001	18.52	12.01	<0.001
Residence						
Rural	57.03	50.35	<0.001	17.0	14.43	<0.01
Urban	49.29	42.87	<0.001	17.32	13.97	<0.001
Tobacco Consumption						
Never consumed	58.35	47.52	<0.001	16.23	14.32	<0.001
Currently smoking	50.80	39.63	<0.001	14.96	11.75	0.538
Consuming smokeless tobacco	56.34	50.42	<0.001	19.59	15.61	0.076
Both smoking and smokeless tobacco	50.96	39.03	<0.05	16.65	14.14	0.817
Not responded	62.51	51.81	-	17.32	13.42	-
Alcohol consumption						
Never consumed	58.09	47.93	<0.001	17.00	14.37	<0.001
Frequently	47.21	44.0	<0.01	16.12	12.99	0.192
Infrequent	49.30	41.05	<0.001	16.88	13.06	0.051
Heavy drinker	53.77	33.92	0.110	28.20	17.36	0.519
Body Mass Index (BMI)						
Underweight	58.68	51.73	<0.001	17.61	14.25	<0.05
Normal	53.36	44.88	<0.001	16.56	13.07	<0.001
Overweight	56.95	44.48	<0.001	14.95	13.79	<0.01
Obese	65.80	51.81	<0.01	14.19	19.86	0.059
Missing	90.63	79.95	-	31.10	27.59	-
Perceived discrimination						
No	55.20	46.17	<0.001	15.87	13.97	<0.001
Yes	61.39	52.92	<0.001	21.20	15.81	<0.001
Marital Status						

Not in union	65.26	58.20	<0.001	18.05	17.51	<0.01
Currently in union	51.07	40.99	<0.001	16.38	12.41	<0.001
Illtreatment						
No	55.51	46.85	<0.001	15.97	13.93	<0.001
Yes	68.99	54.64	<0.01	29.75	22.50	<0.05
Community involvement						
No	56.77	47.98	<0.001	17.04	14.34	<0.001
Yes	50.32	33.22	<0.001	16.64	12.41	0.627
MPCE						
Q1	56.72	47.12	<0.001	14.48	13.46	<0.01
Q2	56.59	48.59	<0.001	15.99	12.30	<0.001
Q3	58.32	44.49	<0.001	17.96	14.52	<0.01
Q4	53.72	48.69	<0.001	20.21	13.37	<0.001
Q5	56.63	46.71	<0.001	19.88	17.22	<0.001
Region						
North	44.0	42.19	<0.001	10.55	10.94	0.479
West	66.39	48.59	<0.001	17.24	10.2	<0.001
Northeast	39.77	42.89	0.177	15.92	15.81	0.268
East	57.03	48.6	<0.001	21.81	19.97	0.115
Central	50.52	39.25	<0.001	15.8	15.3	0.994
South	67.94	53.69	<0.001	12.89	14.48	<0.001

Notes: MPCE: Monthly Per Capita Consumption Expenditure; Q1 represents poorest; Q2 represents poorer; Q3 represents middle; Q2 represents richer; Q2 represents richest.

Geographical heterogeneity between housing environments and associated health

Geographical heterogeneity between housing environments and associated health outcomes is shown in **figure 2**. Respondents from states such as Andhra Pradesh (10.48%), Assam (11.75%), Haryana (10.28%), Karnataka (11.44%), Sikkim (13.46%), Tripura (12.86%), and the Union Territory of Delhi (31.3%) reported a higher prevalence of depression linked to living in unimproved housing conditions. A notable difference in the higher prevalence of poor self-rated health (SRH) due to living in unimproved housing was observed in states like Andhra Pradesh (10.59%), Goa (34.6%), Kerala (13.73%), and Tamil Nadu (15.56%). Similarly, a higher prevalence of functional limitations associated with living in unimproved housing was identified in Andhra Pradesh (14.9%), Arunachal Pradesh (18.17%), Chhattisgarh (15.05%), Maharashtra (21.15%), Telangana (12.7%), and West Bengal (13.6%). Furthermore, a higher prevalence of falls and injuries due to living in unimproved housing was reported in Assam (7.51%), West Bengal (7.24%), and the Union Territory of Puducherry (15.32%) compared to those living in improved housing.

Figure 2. Geographical heterogeneity between housing environment and associated health outcomes among older adults in India

	Depression		Self-rated health		Functional limitation		Falls/ Injuries	
States	**Unimproved**	**Improved**	**Unimproved**	**Improved**	**Unimproved**	**Improved**	**Unimproved**	**Improved**
Andhra Pradesh	**33.58**	23.10	**33.49**	22.90	**64.63**	49.73	**14.19**	11.46
Arunachal Pradesh	**29.54**	28.02	**13.05**	6.84	**28.13**	9.96	7.44	**8.63**
Assam	**27.76**	16.01	**26.14**	22.88	39.33	**48.66**	**26.55**	19.04
Bihar	**24.91**	21.77	**21.65**	20.45	**58.10**	49.70	**23.14**	22.78
Chhattisgarh	**30.73**	24.99	**9.91**	9.80	**49.30**	34.25	**10.46**	8.73
Goa	**29.37**	15.04	**63.13**	28.53	**58.90**	47.44	7.23	**8.15**
Gujarat	**22.18**	12.43	**15.92**	11.51	**49.62**	38.39	**13.45**	7.92
Haryana	**40.64**	30.36	**26.95**	21.25	**51.77**	44.75	4.74	**10.96**
Himachal Pradesh	10.40	**15.67**	23.57	**25.41**	**56.79**	48.24	10.39	**14.36**
Jharkhand	**34.55**	27.42	**22.94**	15.20	**54.08**	48.43	15.70	**15.88**
Karnataka	**47.23**	35.79	**13.06**	9.19	**66.32**	61.49	12.48	**28.63**
Kerala	**38.70**	27.90	**62.54**	48.81	**55.55**	37.74	13.30	12.57
Madhya Pradesh	**40.26**	33.60	**26.55**	15.99	**50.54**	44.39	**14.76**	14.59
Maharashtra	**28.26**	19.45	**22.91**	12.13	**73.80**	52.65	**18.96**	11.13
Manipur	**14.97**	9.54	**14.87**	13.36	**48.87**	32.71	6.86	**8.38**
Meghalaya	**15.87**	9.92	**6.79**	2.90	**43.81**	25.64	2.10	**3.14**
Mizoram	17.43	**20.60**	**19.66**	10.90	31.60	**32.48**	**6.59**	1.36
Nagaland	**12.29**	3.40	7.95	**13.06**	**28.30**	7.41	0.92	**8.02**
Odisha	**19.00**	16.94	22.56	**22.65**	29.65	**29.87**	15.54	**21.11**
Punjab	12.79	**13.41**	**24.73**	23.71	**59.48**	51.33	14.42	**14.97**
Rajasthan	**26.44**	22.92	**23.68**	18.77	**34.30**	29.67	**11.25**	9.31
Sikkim	**33.81**	20.35	**17.67**	5.08	**55.07**	45.76	**11.47**	4.11
Tamil Nadu	**45.29**	26.0	**65.36**	49.80	**72.02**	55.09	**13.28**	8.25
Telangana	**39.56**	27.30	**27.47**	19.82	**68.63**	55.93	**11.04**	8.77
Tripura	**30.49**	17.63	**24.64**	21.50	**43.31**	37.92	11.09	**12.94**
Uttar Pradesh	**38.57**	29.93	**25.47**	24.10	**50.68**	37.26	**17.19**	16.44
Uttarakhand	21.48	**27.19**	**21.16**	19.72	**52.62**	41.86	6.67	**13.18**
West Bengal	**52.04**	39.29	**35.15**	32.73	**70.12**	56.52	**25.26**	18.02
UTs								
Andaman and Nicobar	**51.04**	42.33	6.48	**10.67**	**46.70**	43.58	3.20	**16.87**
Chandigarh	0	**12.0**	0.00	**19.01**	**50.0**	44.12	0	**15.11**
Dadra and Nagar Haveli	**23.72**	15.05	**18.91**	12.14	**56.10**	51.43	**10.39**	9.39
Daman and Diu	**33.15**	16.38	**16.54**	10.01	36.57	**46.07**	**18.04**	12.31
Delhi	**70.07**	38.77	**26.03**	14.96	**44.04**	38.87	0	**7.45**
Jammu and Kashmir	**66.50**	47.91	**34.37**	31.54	**67.26**	65.33	9.51	**9.68**
Lakshadweep	**22.62**	13.99	**19.78**	19.48	**46.35**	36.74	**10.32**	7.28
Puducherry	**45.51**	33.42	**38.85**	38.10	**40.71**	37.54	**29.22**	13.90

Determinants of health differences among older adults living in improved housing environments

Figure 3 illustrates the determinants of health disparities attributed to improved housing environments among older adults. Respondents residing in better housing conditions with higher education levels were significantly less likely to experience depression (OR: 0.74; CI: 0.59, 0.93), poor self-rated health (OR: 0.63; CI: 0.49, 0.80), and functional limitations (OR: 0.47; CI: 0.38, 0.58). Additionally, obese individuals living in improved housing environments were 39% less likely to report depression (OR: 0.61; CI: 0.43, 0.86). Those who were currently married and living in better housing conditions also showed a negative association with depression (OR: 0.78; CI: 0.67, 0.90), functional limitations (OR: 0.82; CI: 0.71, 0.94), and falls or injuries (OR: 0.77; CI: 0.60, 0.98).

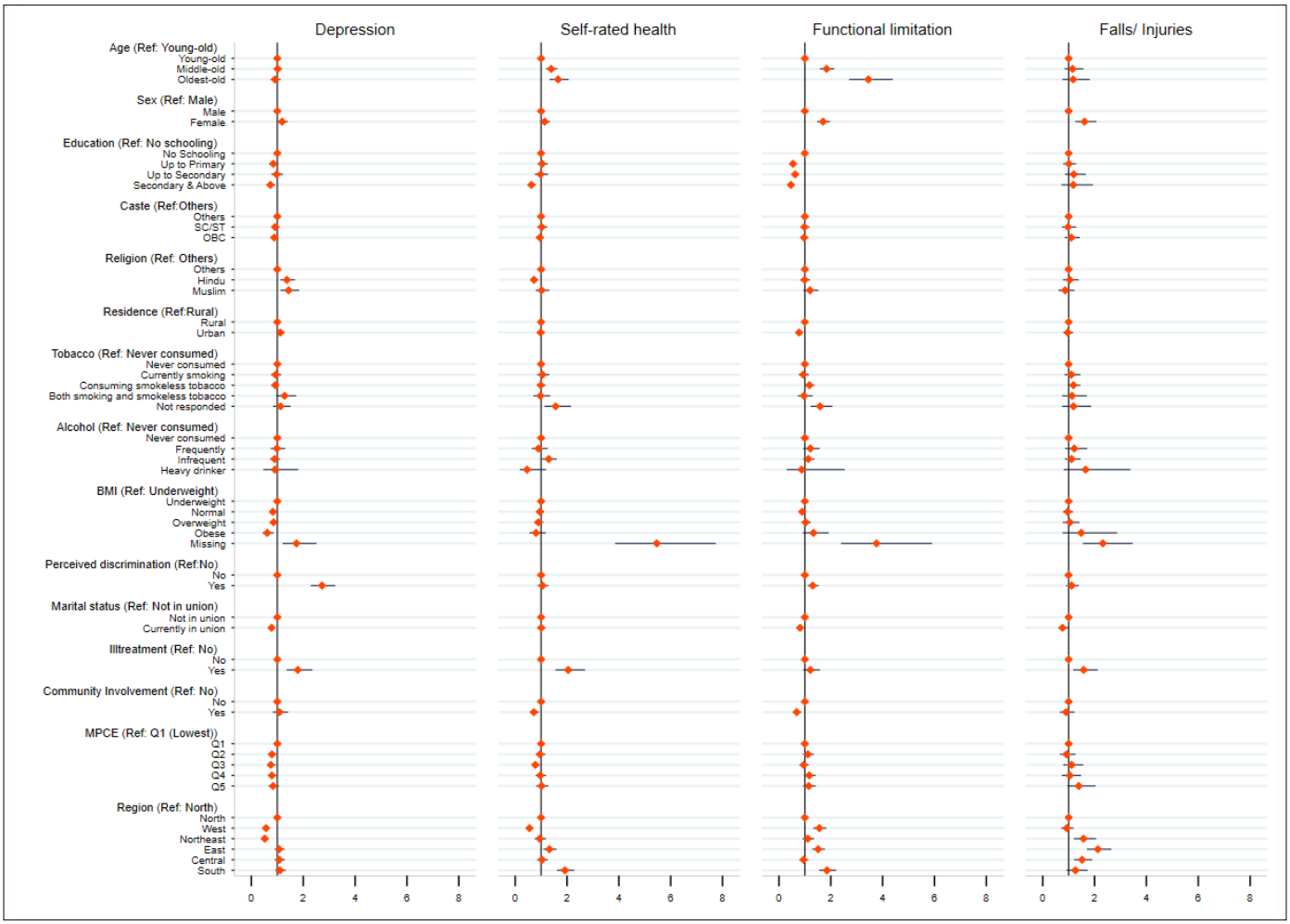

Figure 3. Logistic regression estimates for different health outcomes by their background characteristics among older adults living in and improved housing environment

Determinants of health differences among older adults living in unimproved housing environments

Health disparities related to living in substandard housing among older adults are illustrated in **figure 4**. Advancing age was significantly correlated with negative health outcomes in this demographic. Specifically, older adults living in inadequate housing were more likely to experience depression (OR: 1.47; CI: 1.16, 1.87), poor SRH (OR: 2.54; CI: 2.02, 3.21), functional limitations (OR: 2.77; CI: 2.15, 3.57), and falls or injuries (OR: 1.38; CI: 1.04, 1.82). Additionally, those who reported perceived discrimination and lived in substandard housing had twice the odds of experiencing depression (OR: 2.01; CI: 1.71, 2.37) and a 20% higher likelihood of developing functional limitations (OR: 1.20; CI: 1.01, 1.42). Older adults who faced ill-treatment in these environments were 54% more likely to report poor SRH (OR: 1.54; CI: 1.19, 2.00), 65% more likely to report functional limitations (OR: 1.65; CI: 1.27, 2.14), and 88% more likely to report falls or injuries (OR: 1.88; CI: 1.37, 2.58) compared to those not living in such conditions.

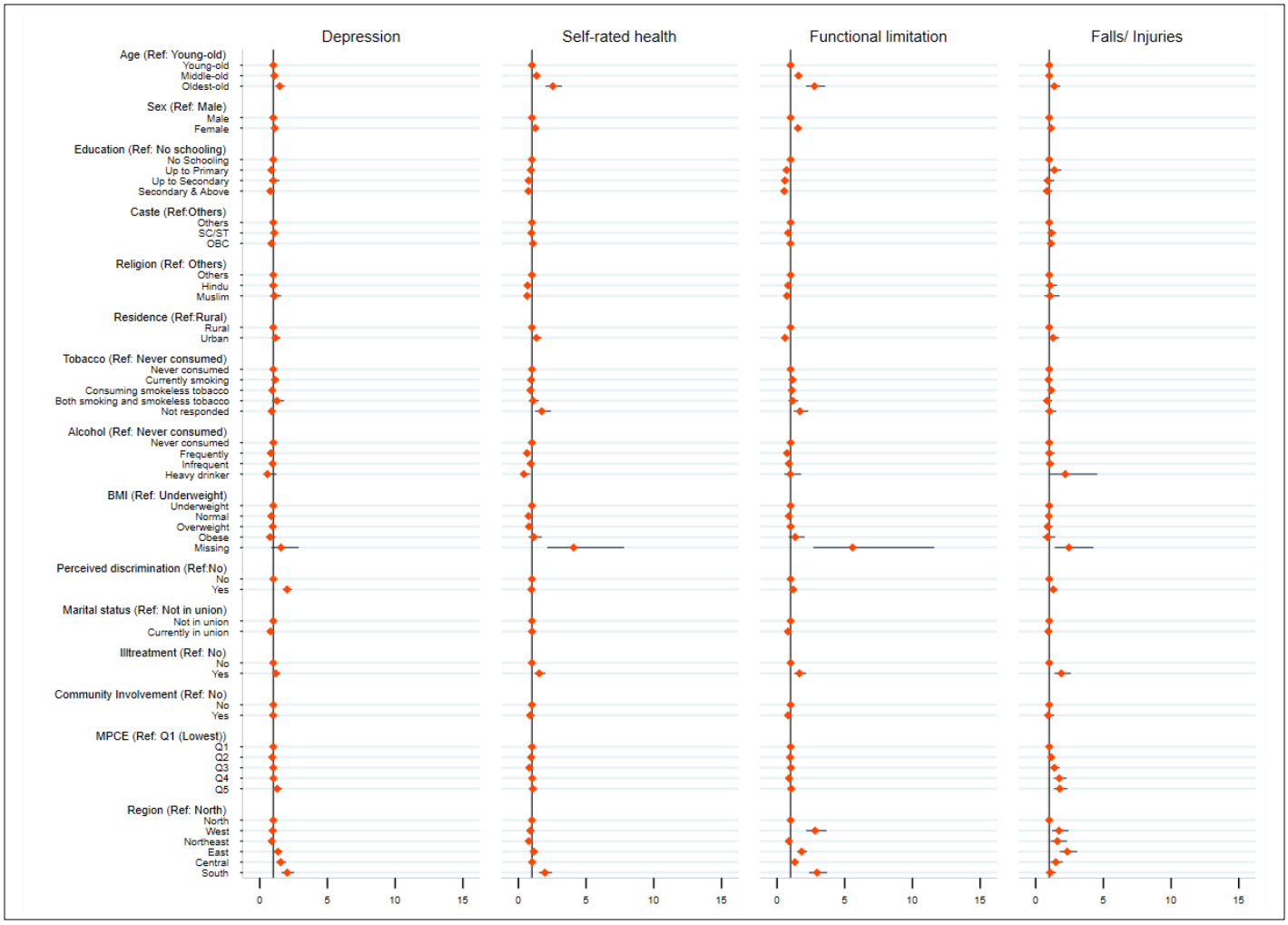

Figure 4. Logistic regression estimates for different health outcomes by their background characteristics among older adults living in and unimproved housing environment

Estimates of the effect of housing environments on health differences

The adjusted odds of reporting various health outcomes due to living in unimproved housing are detailed in **table 3**. The unadjusted model indicates that older adults residing in unimproved housing are significantly more likely to experience adverse health outcomes. After adjusting for demographic factors in **model 2**, the odds of depression were 42% higher (OR: 1.42; CI: 1.29, 2.56), poor self-rated health (SRH) was 19% higher (OR: 1.19; CI: 1.08, 1.32), functional limitations were 20% higher (OR: 1.20; CI: 1.09, 1.32), and falls/injuries were 14% higher (OR: 1.14; CI: 1.00, 1.30) among those in unimproved housing. In **model 3**, which controls for demographic and socioeconomic status, the odds of reporting depression were 34% higher (OR: 1.34; CI: 1.21, 1.48) and functional limitations were 20% higher (OR: 1.20; CI: 1.09, 1.33). The fully adjusted **model 4** shows that the odds of reporting depression were 30% higher (OR: 1.30; CI: 1.17, 1.44), poor SRH was 15% higher (OR: 1.15; CI: 1.04, 1.28), and functional limitations were 20% higher (OR: 1.20; CI: 1.08, 1.32) for older adults living in unimproved housing.

Table 3. Logistic regression estimates for different health outcomes among older adults living in an unimproved housing environment in India

	Model 1: Unadjusted Odds Ratio	**Model 2**: Adjusted OR by model 1+ demographics	**Model 3**: Adjusted OR by model 2+ SES	**Model 4**: Adjusted OR by model 3+ HB
Health outcomes	uOR [95% CI]	aOR [95% CI]	aOR [95% CI]	aOR [95% CI]
Depression	1.56*** [1.42,1.71]	1.42*** [1.29,1.56]	1.34*** [1.21,1.48]	1.30*** [1.17,1.44]
Self-rated health	1.27*** [1.16,1.40]	1.19** [1.08,1.32]	1.19** [1.07,1.32]	1.15** [1.04,1.28]
Functional limitation	1.46*** [1.34,1.59]	1.20*** [1.09,1.32]	1.20*** [1.09,1.33]	1.20*** [1.08,1.32]
Falls/Injuries	1.24** [1.05,1.45]	1.14* [1.00,1.30]	1.17* [1.02,1.35]	1.16* [1.00,1.33]

***Note**:* uOR: Unadjusted Odds Ratio; aOR: Adjusted Odds Ratio; SES: Socioeconomic Status; HB: Health Behavioural; Demographic factors include age, sex, education, place of residence and region; SES includes caste, religion, marital status, monthly per capita consumption expenditure (MPCE), perceived discrimination and community involvement; Health Behavioural factors include tobacco consumption, alcohol consumption, body mass index and illtreatment behaviour; CI: Confidence Interval; * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Propensity matching score estimates the effect of housing environments on health differences

Using propensity score matching (PSM) analysis, **table 4** illustrates the causal link between the housing environment and various health outcomes among older adults. Initially, without controlling for the unmatched sample, older adults living in unimproved housing conditions experienced a 7.0 percentage point (pp) increase in depression. The Average Treatment Effect on the Treated (ATT) and Average Treatment Effect (ATE) revealed that living in unimproved housing led to a 4.2 pp and 6.0 pp higher likelihood of depression, respectively. Similarly, the ATT and ATE for reporting poor self-rated health (SRH) were 1.6 pp and 2.4 pp higher among those in unimproved housing conditions. Additionally, the ATT for functional limitations and falls/injuries showed a 3.3 pp and 1.4 pp increase, respectively, for those living in unimproved housing compared to those in improved housing conditions.

Covariate balance plot using kernel density

The balance plot displaying the covariates of the treatment and control groups, both before and after matching, is presented in **figure 5**. This figure demonstrates that both groups achieved balance, ensuring the estimated treatment effects are unbiased. Additionally, the Love plot in **figure 6** illustrates the standardized percentage bias across all covariates in both the matched and unmatched samples.

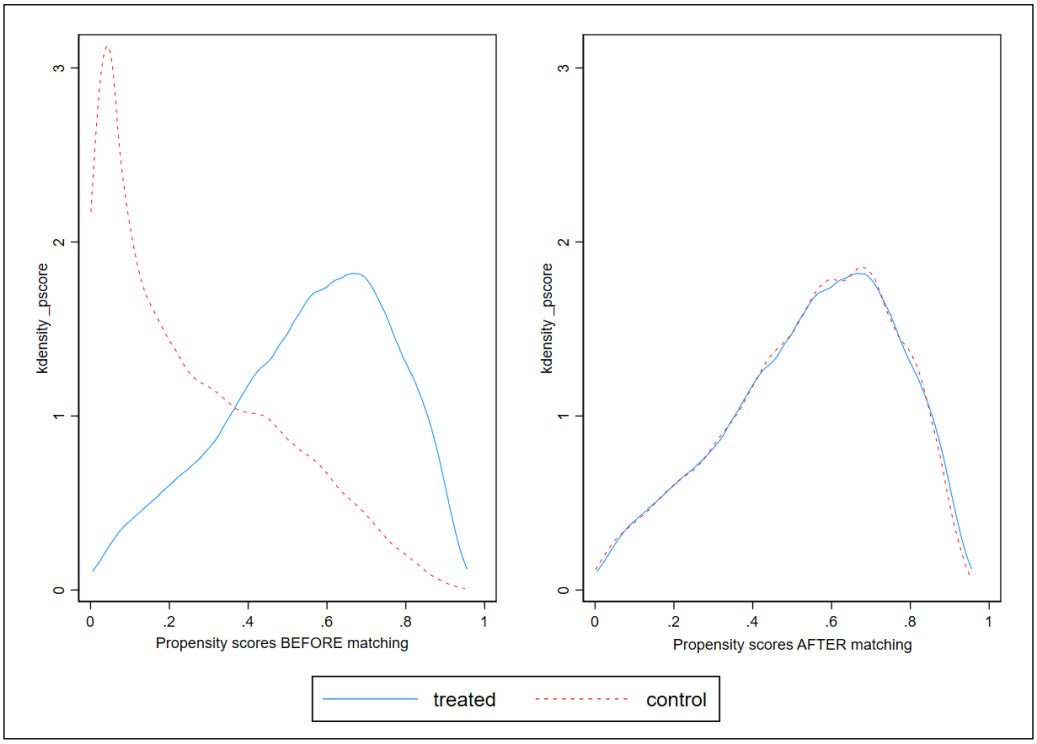

Figure 5. Kernel density plot for covariance balance before and after matching

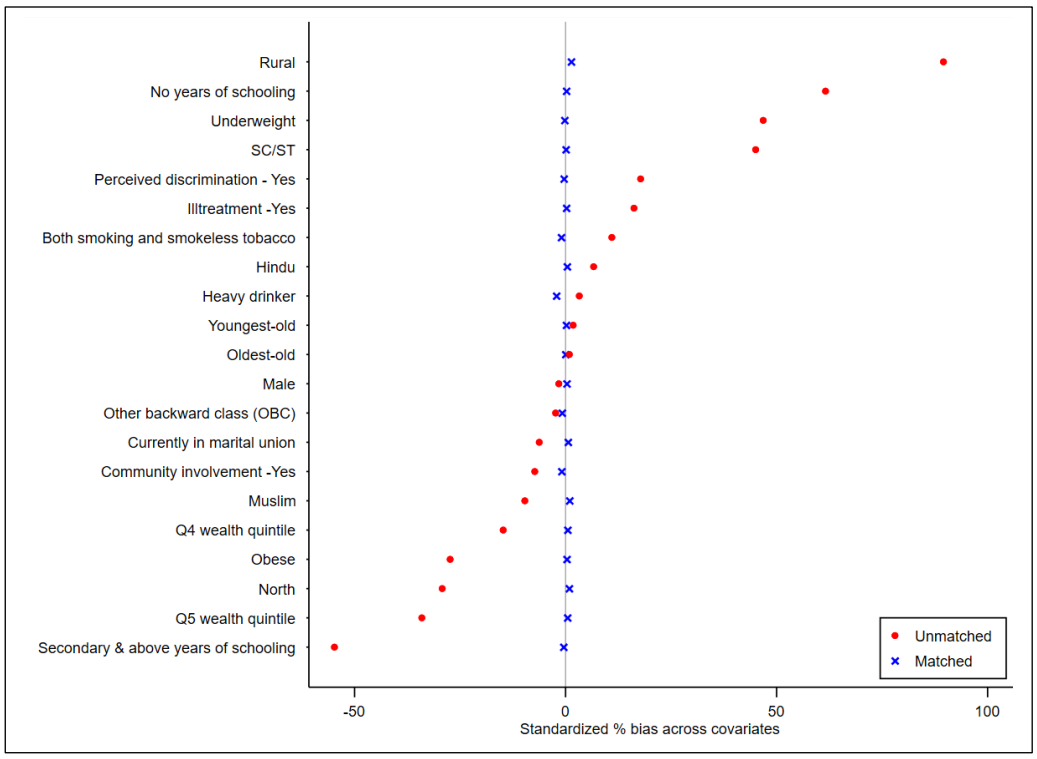

Figure 6. Love plot

Discussion

Using nationally representative data, the study provides a nuanced exploration of how housing conditions impact health outcomes among India's aging population. As the country undergoes rapid urbanization and demographic shifts, understanding the intersection of housing quality and health becomes increasingly vital. This research employs propensity score matching to mitigate confounding factors, thereby offering robust insights into the causal relationships between poor housing environments and health disparities in older adults. We highlight four key findings from this study. First, depression and poor self-rated health (SRH) were most prevalent among the oldest-old living in substandard housing, while functional limitations were more common among the young-old in similar conditions. Second, examining geographical differences, we found that Andhra Pradesh had the highest prevalence gaps in depression, poor SRH, and functional limitations. Other states, including Assam, Haryana, Sikkim, Goa, and Arunachal Pradesh, also showed significant health disparities linked to living in inadequate housing. Third, even after adjusting for socioeconomic, demographic, and health-related behaviors, depression remained the most pronounced health issue among older adults in substandard housing, followed by functional limitations and poor SRH. Fourth, our analysis of the causal relationship between housing conditions and health outcomes revealed

that living in inadequate housing significantly increases the likelihood of depression among older adults compared to those in improved housing.

This study highlights a notable link between housing conditions and health disparities among the oldest-old population. It confirms the hypothesized connection between the quality of housing environments and the health outcomes of older adults in India (66–72). Furthermore, our study also proves the assumption of increasing age among older adults is associated with depression and other health issues such as, poor SRH and functional limitation due to living in unimproved housing condition in Indian context (73–75). This phenomenon can be understood through various perspectives, including physiological vulnerabilities, socioeconomic factors, and the impact of living environments on mental and physical health. As people age, they naturally experience a decline in physiological functions, making them more susceptible to health issues, which is further compounded by the lack of basic amenities and environmental controls in substandard housing (76). Poor housing conditions can lead to increased exposure to environmental hazards such as inadequate ventilation, poor sanitation, and limited access to clean water, exacerbating chronic illnesses and susceptibility to diseases, all of which contribute to poor SRH (2). Additionally, the psychological impact of aging in inadequate housing environments cannot be overlooked, as older adults are at a higher risk of experiencing depression due to a combination of biological, social, and environmental factors (77,78). The World Health Organization (WHO) has identified depression as one of the most common mental health disorders among older adults, particularly those living in impoverished conditions (79). The absence of a safe and comfortable living environment can lead to feelings of isolation, helplessness, and a perceived lack of control, significant risk factors for depression (80).

Socioeconomic status plays a critical role in determining housing quality and access to healthcare services (12). In India, older adults from lower socioeconomic backgrounds are more likely to live in unimproved housing conditions characterized by inadequate infrastructure, overcrowding, and limited healthcare access (74). The **cumulative disadvantage model** explains that lifelong socioeconomic disadvantages compound over time, leading to greater health disparities in old age (81). The lack of access to healthcare services in unimproved housing areas can delay the diagnosis and treatment of health conditions, leading to further health deterioration (82). Additionally, we find geographical heterogeneity in health differences due to living in unimproved housing. This finding is aligned with other previous studies (83,84) which explains poor housing conditions are often linked to inadequate access to healthcare, clean water, and sanitation, which exacerbates health issues. Geographical heterogeneity in health differences due to living in unimproved housing conditions, particularly in states like Andhra Pradesh, Assam, and Goa, can be attributed to a combination of factors unique to each region. In Andhra Pradesh, the prevalence of poor housing conditions in rural and semi-urban areas contributes to a higher incidence of health issues,

exacerbated by limited access to healthcare and sanitation facilities (85). Assam faces similar challenges, compounded by its diverse topography and frequent flooding, which often deteriorate housing structures and hinder access to essential services (86). Additionally, Assam's socio-economic disparities, particularly among indigenous and marginalized communities, lead to inadequate housing and related health disparities (87). Goa, despite being a more affluent state, experiences health differences due to pockets of poor housing among migrant workers and lower-income residents, where inadequate living conditions and access to healthcare services are prevalent (88). Inadequate housing conditions are often located in areas with limited healthcare infrastructure, complicating timely and appropriate care access (89).

Another important finding of our study from the causal relationship is that living in unimproved housing had maximum impact on the increasing likelihood of depression among older adults as compared to other health issues such as, poor SRH, functional limitation and falls/injuries. It may be primarily due to the cumulative psychological and emotional stressors associated with poor living conditions. Unimproved housing often lacks basic amenities, is overcrowded, and has poor sanitation, leading to chronic exposure to environmental stressors like noise, pollution, and inadequate temperature control (90). Study also suggests that these factors can create a persistent state of discomfort and anxiety, exacerbating feelings of hopelessness and isolation, which are key contributors to depression (91). Furthermore, older adults may feel trapped in these living conditions due to financial constraints or mobility issues, intensifying their sense of helplessness (92). Unlike more physical health issues like functional limitations or injuries, which are often more visible and can prompt intervention, depression may be less recognized or addressed, particularly in contexts where mental health resources are limited (93). The stigma around mental health issues in many communities further compounds the problem, making it harder for older adults to seek help, thus reinforcing the cycle of depression (94). Further study is needed despite finding a strong association between poor housing environments and health disparities among older adults through logistic regression, as causal analysis can provide more definitive insights into these relationships. While logistic regression establishes correlations, it does not necessarily imply causation, and there may be underlying factors influencing both housing conditions and health outcomes. For example, socio-economic status, access to healthcare, and pre-existing health conditions could confound the observed associations. Causal analysis, through methods like propensity score matching or instrumental variable approaches, can help isolate the effect of the housing environment on health by accounting for these potential confounders. This deeper understanding is crucial for developing targeted interventions and policies that can effectively address the root causes of health disparities linked to poor housing conditions. Additionally, causal analysis can identify specific aspects of the housing environment that have the most significant impact on health, guiding resource allocation and intervention strategies to where they are most needed.

Strength and limitations

One of the key strengths is the use of propensity score matching, which enhances the validity of causal inferences by minimizing selection bias and balancing covariates between groups, allowing for a more accurate comparison of health outcomes between those living in different housing conditions. The use of nationally representative data provides comprehensive coverage and generalizability of the findings across diverse geographic and socio-economic contexts in India. This approach ensures that the results are reflective of the broader population, offering valuable insights for policymakers. However, limitations exist, including potential residual confounding from unmeasured variables that could influence both housing conditions and health outcomes. Additionally, the cross-sectional nature of the survey data limits the ability to establish temporal causality, as it captures only a snapshot in time rather than longitudinal changes. Self-reported data on health and housing conditions may also introduce reporting biases, affecting the accuracy of the results. Despite these limitations, the study provides crucial evidence on the link between housing environments and health disparities among older adults, highlighting the need for targeted interventions.

Conclusion

Utilizing a robust analytical approach with propensity score matching, the research reveals a significant association between substandard housing environments and increased health disparities, including higher rates of depression, poor self-rated health (SRH), and functional limitations. The results highlight that inadequate housing conditions are a critical determinant of adverse health outcomes, exacerbating existing health disparities among older adults. This insight is crucial for policymakers and urban planners, as it underscores the need for targeted interventions to improve housing conditions as a means of enhancing health equity. By addressing issues such as poor sanitation, inadequate infrastructure, and environmental hazards, and by integrating health considerations into housing policies, it is possible to mitigate the adverse effects observed. However, the study also acknowledges limitations, such as the potential for residual confounding and the inability to establish temporal causality due to the cross-sectional nature of the data. Despite these limitations, the findings provide a compelling argument for prioritizing housing improvements in efforts to reduce health disparities among older adults. Future research should aim to further explore these relationships through longitudinal studies and more granular data to better understand the causal mechanisms and develop effective strategies for intervention. Overall, improving housing conditions emerges as a vital component of public health strategies aimed at enhancing the well-being of older adults.

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Supplementary table 1. Descriptive profile of the respondents stratified by housing environment

	Unimproved		Improved	
	Observation	**Percentage**	**Observation**	**Percentage**
Age				
Young-old	7,218	60.23	9,619	59.22
Middle-old	3,532	29.48	4,903	30.19
Oldest-old	1,233	10.29	1,720	10.59
Sex				
Male	5,724	47.76	7,759	47.77
Female	6,260	52.24	8,482	52.23
Education				
No Schooling	10,186	85.0	9,160	56.40
Up to Primary	919	7.67	2,235	13.76
Up to Secondary	483	4.03	1,326	8.17
Secondary & Above	396	3.30	3,520	21.67
Caste				
Others	2,150	17.94	5,577	34.34
SC/ST	4,517	37.69	3,165	19.49
OBC	5,317	44.37	7,500	46.18
Religion				
Others	643	5.36	1196	7.37
Hindu	10027	83.67	13287	81.81
Muslim	1314	10.97	1758	10.83
Residence				
Rural	11226	93.68	9232	56.84
Urban	757	6.32	7010	43.16
Tobacco Consumption				
Never consumed	6,094	50.85	10,565	65.05
Currently smoking	1,692	14.12	1,786	10.99
Consuming smokeless tobacco	3,258	27.19	2,884	17.76
Both smoking and smokeless tobacco	545	4.55	398	2.45
Not responded	394	3.29	609	3.75
Alcohol consumption				
Never consumed	9,958	83.26	14,124	87.24
Frequently	679	5.67	593	3.66
Infrequent	1,234	10.32	1,371	8.47
heavy drinker	90	0.75	102	0.63
Body Mass Index (BMI)				
Underweight	4,765	39.77	2,832	17.44
Normal	5,842	48.75	8,228	50.66
Overweight	1,000	8.35	3,570	21.98
Obese	195	1.62	1,350	8.32
Missing	181	1.51	261	1.60
Perceived discrimination				
No	9,388	78.34	13,959	85.95
Yes	2,596	21.66	2,282	85.95
Marital Status				

Not in union	4,617	38.53	5,788	35.64
Currently in union	7,366	61.47	10,453	64.36
Illtreatment				
No	11,069	92.37	15,675	96.51
Yes	914	7.63	566	3.49
Community involvement				
No	11,547	96.36	15,296	94.18
Yes	436	3.64	945	5.82
MPCE				
Q1	3,483	29.06	2,572	15.84
Q2	2,887	24.09	3,305	20.35
Q3	2,524	21.06	3,387	20.85
Q4	1,919	16.02	3,490	21.49
Q5	1,171	9.77	3,487	21.47
Region				
North	1,005	8.39	2,664	16.40
West	1,373	11.46	3,274	20.16
Northeast	283	2.36	581	3.58
East	3,934	32.83	2,998	18.46
Central	3,419	28.53	2,615	16.10
South	1,969	16.43	4,110	25.30

Note: MPCE: Monthly Per Capita Consumption Expenditure; Q1 represents poorest; Q2 represents poorer; Q3 represents middle; Q2 represents richer; Q2 represents richest.

Supplementary table 2. Logistic regression estimates of depression and self-rated health by housing environment among older adults

	Depression				Self-rated health			
	Unimproved		Improved		Unimproved		Improved	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Age								
Young-old	ref		ref		ref		ref	
Middle-old	1.08	[0.93,1.27]	1.02	[0.88,1.18]	1.35***	[1.15,1.58]	1.40***	[1.20,1.63]
Oldest-old	1.47**	[1.16,1.87]	0.91	[0.74,1.13]	2.54***	[2.02,3.21]	1.66***	[1.33,2.08]
Sex								
Male	ref		ref		ref		ref	
Female	1.1	[0.92,1.32]	1.19*	[1.01,1.41]	1.26*	[1.04,1.51]	1.15	[0.98,1.36]
Education								
No Schooling	ref		ref		ref		ref	
Up to Primary	0.86	[0.67,1.11]	0.85	[0.69,1.05]	0.92	[0.71,1.19]	1.04	[0.86,1.26]
Up to Secondary	1.01	[0.69,1.46]	0.98	[0.78,1.23]	0.76	[0.53,1.09]	0.99	[0.77,1.27]
Secondary & Above	0.78	[0.54,1.12]	0.74**	[0.59,0.93]	0.74	[0.51,1.07]	0.63***	[0.49,0.80]
Caste								
Others	ref		ref		ref		ref	
SC/ST	1.07	[0.87,1.31]	0.91	[0.77,1.09]	0.96	[0.78,1.17]	1.03	[0.85,1.24]
OBC	0.86	[0.71,1.03]	0.89	[0.77,1.02]	1.07	[0.88,1.31]	0.95	[0.82,1.11]
Religion								
Others	ref		ref		ref		ref	
Hindu	0.98	[0.73,1.32]	1.37**	[1.12,1.68]	0.68*	[0.50,0.92]	0.73**	[0.59,0.89]
Muslim	1.08	[0.74,1.56]	1.44**	[1.12,1.85]	0.65*	[0.45,0.95]	1.03	[0.80,1.32]
Residence								
Rural	ref		ref		ref		ref	
Urban	1.17	[0.90,1.52]	1.12	[0.97,1.28]	1.33*	[1.04,1.71]	0.98	[0.85,1.14]
Tobacco consumption								
Never consumed	ref		ref		ref		ref	
Currently smoking	1.12	[0.90,1.40]	0.94	[0.76,1.15]	0.93	[0.74,1.16]	1.04	[0.83,1.29]
Consuming smokeless tobacco	0.92	[0.78,1.09]	0.92	[0.78,1.07]	0.88	[0.74,1.06]	0.98	[0.83,1.16]
Both smoking and smokeless tobacco	1.27	[0.91,1.78]	1.27	[0.94,1.72]	1.09	[0.79,1.50]	0.98	[0.71,1.35]
Not responded	0.87	[0.63,1.21]	1.11	[0.83,1.50]	1.73**	[1.25,2.41]	1.55**	[1.13,2.14]
Alcohol consumption								
Never consumed	ref		ref		ref		ref	
Frequently	0.82	[0.61,1.09]	0.99	[0.75,1.31]	0.64**	[0.47,0.88]	0.91	[0.65,1.27]
Infrequent	0.95	[0.77,1.18]	0.9	[0.73,1.11]	0.92	[0.74,1.13]	1.31*	[1.06,1.62]
heavy drinker	0.57	[0.26,1.25]	0.92	[0.46,1.82]	0.40*	[0.19,0.87]	0.47	[0.18,1.21]
Body Mass Index (BMI)								
Underweight	ref		ref		ref		ref	
Normal	0.84*	[0.73,0.97]	0.82*	[0.71,0.96]	0.75***	[0.64,0.88]	0.95	[0.82,1.11]
Overweight	0.96	[0.74,1.24]	0.85	[0.70,1.03]	0.79	[0.60,1.03]	0.89	[0.73,1.09]
Obese	0.76	[0.49,1.18]	0.61**	[0.43,0.86]	1.15	[0.76,1.74]	0.80	[0.55,1.18]
Missing	1.56	[0.85,2.87]	1.73**	[1.20,2.50]	4.09***	[2.14,7.83]	5.48***	[3.87,7.75]
Perceived discrimination								

No	ref		ref		ref		ref	
Yes	2.01***	[1.71,2.37]	2.72***	[2.29,3.23]	0.96	[0.80,1.15]	1.05	[0.86,1.28]
Marital Status								
Not in union	ref		ref		ref		ref	
Currently in union	0.79**	[0.67,0.92]	0.78***	[0.67,0.90]	1.01	[0.85,1.18]	1.01	[0.87,1.17]
Illtreatment								
No	ref		ref		ref		ref	
Yes	1.19	[0.95,1.50]	1.79***	[1.36,2.35]	1.54***	[1.19,2.00]	2.05***	[1.56,2.70]
Community involvement								
No	ref		ref		ref		ref	
Yes	0.99	[0.75,1.32]	1.1	[0.84,1.43]	0.86	[0.62,1.19]	0.72**	[0.56,0.91]
MPCE								
Q1	ref		ref		ref		ref	
Q2	0.92	[0.78,1.10]	0.79*	[0.65,0.97]	0.94	[0.78,1.13]	0.96	[0.79,1.16]
Q3	0.99	[0.82,1.21]	0.75*	[0.60,0.94]	0.81	[0.65,1.00]	0.78*	[0.64,0.95]
Q4	1.01	[0.82,1.24]	0.79*	[0.64,0.97]	1.01	[0.82,1.25]	0.96	[0.79,1.18]
Q5	1.28*	[1.01,1.64]	0.83	[0.66,1.05]	1.06	[0.81,1.39]	1.01	[0.80,1.28]
Region								
North	ref		ref		ref		ref	
West	0.95	[0.72,1.25]	0.56***	[0.46,0.69]	0.87	[0.64,1.18]	0.55***	[0.44,0.68]
Northeast	0.87	[0.66,1.15]	0.51***	[0.41,0.64]	0.77	[0.56,1.04]	0.94	[0.75,1.18]
East	1.34**	[1.09,1.66]	1.07	[0.90,1.27]	1.13	[0.91,1.42]	1.32**	[1.09,1.59]
Central	1.54***	[1.23,1.94]	1.08	[0.90,1.29]	1.01	[0.79,1.29]	1.03	[0.85,1.26]
South	2.01***	[1.60,2.52]	1.09	[0.91,1.31]	1.92***	[1.51,2.43]	1.90***	[1.60,2.25]
Pseudo R^2	0.0424		0.0584		0.0559		0.0617	

Note: OR: Odds Ratio; MPCE: Monthly Per Capita Consumption Expenditure; Q1 represents poorest; Q2 represents poorer; Q3 represents middle; Q4 represents richer; Q5 represents richest.CI: Confidence Interval; * p<0.05, ** p<0.01, *** p<0.001

Supplementary table 3. Logistic regression estimates of functional limitation and falls/injuries by housing environment among older adults

	Functional limitation				**Falls/ Injuries**			
	Unimproved		**Improved**		**Unimproved**		**Improved**	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Age								
Young-old	ref		ref		ref		ref	
Middle-old	1.58***	[1.35,1.85]	1.85***	[1.59,2.15]	1.00	[0.82,1.24]	1.15	[0.85,1.57]
Oldest-old	2.77***	[2.15,3.57]	3.46***	[2.72,4.40]	1.38*	[1.04,1.82]	1.18	[0.76,1.82]
Sex								
Male	ref		ref		ref		ref	
Female	1.54***	[1.29,1.85]	1.71***	[1.48,1.98]	1.13	[0.91,1.39]	1.62***	[1.26,2.07]
Education								
No Schooling	ref		ref		ref		ref	
Up to Primary	0.70**	[0.56,0.89]	0.55***	[0.46,0.65]	1.37*	[1.00,1.88]	1.02	[0.80,1.30]
Up to Secondary	0.58***	[0.43,0.79]	0.63***	[0.51,0.78]	0.89	[0.58,1.37]	1.20	[0.86,1.67]
Secondary & Above	0.53***	[0.38,0.75]	0.47***	[0.38,0.58]	0.83	[0.56,1.23]	1.19	[0.72,1.95]
Caste								

Others	ref		ref		ref		ref	
SC/ST	0.82*	[0.67,1.00]	0.99	[0.83,1.18]	1.16	[0.88,1.52]	0.98	[0.74,1.30]
OBC	0.99	[0.82,1.20]	0.97	[0.85,1.12]	1.13	[0.90,1.42]	1.1	[0.85,1.43]
Religion								
Others	ref		ref		ref		ref	
Hindu	0.82	[0.63,1.08]	0.99	[0.82,1.20]	1.08	[0.73,1.58]	1.04	[0.78,1.38]
Muslim	0.74	[0.52,1.06]	1.2	[0.94,1.53]	1.07	[0.65,1.76]	0.86	[0.61,1.23]
Residence								
Rural	ref		ref		ref		ref	
Urban	0.58***	[0.44,0.77]	0.78***	[0.69,0.88]	1.28	[0.95,1.71]	0.96	[0.79,1.17]
Tobacco Consumption								
Never consumed	ref		ref		ref		ref	
Currently smoking	1.15	[0.92,1.43]	0.95	[0.77,1.16]	0.95	[0.73,1.25]	1.1	[0.84,1.45]
Consuming smokeless tobacco	1.10	[0.93,1.30]	1.18*	[1.01,1.37]	1.15	[0.94,1.40]	1.18	[0.97,1.45]
Both smoking and smokeless tobacco	1.15	[0.85,1.55]	0.97	[0.72,1.30]	0.85	[0.59,1.22]	1.13	[0.75,1.70]
Not responded	1.69***	[1.24,2.31]	1.60***	[1.23,2.07]	1.06	[0.73,1.54]	1.18	[0.75,1.86]
Alcohol consumption								
Never consumed	ref		ref		ref		ref	
Frequently	0.74*	[0.57,0.96]	1.21	[0.94,1.56]	1.01	[0.72,1.41]	1.22	[0.87,1.72]
Infrequent	0.88	[0.72,1.07]	1.13	[0.94,1.37]	1.04	[0.81,1.34]	1.12	[0.86,1.46]
heavy drinker	0.98	[0.54,1.78]	0.88	[0.30,2.54]	2.17*	[1.04,4.54]	1.66	[0.81,3.39]
Body Mass Index (BMI)								
Underweight	ref		ref		ref		ref	
Normal	0.87*	[0.75,1.00]	0.9	[0.78,1.03]	0.97	[0.81,1.15]	0.96	[0.79,1.17]
Overweight	1	[0.77,1.30]	1.03	[0.86,1.22]	0.89	[0.63,1.25]	1.05	[0.77,1.42]
Obese	1.34	[0.88,2.04]	1.33	[0.92,1.92]	0.87	[0.53,1.45]	1.49	[0.77,2.88]
Missing	5.59***	[2.68,11.64]	3.76***	[2.39,5.91]	2.45**	[1.41,4.26]	2.34***	[1.57,3.50]
Perceived discrimination								
No	ref		ref		ref		ref	
Yes	1.20*	[1.01,1.42]	1.31***	[1.12,1.54]	1.30*	[1.04,1.63]	1.11	[0.90,1.39]
Marital Status								
Not in union	ref		ref		ref		ref	
Currently in union	0.81**	[0.69,0.94]	0.82**	[0.71,0.94]	0.94	[0.78,1.14]	0.77*	[0.60,0.98]
Illtreatment								
No	ref		ref		ref		ref	
Yes	1.65***	[1.27,2.14]	1.21	[0.93,1.58]	1.88***	[1.37,2.58]	1.58**	[1.17,2.12]
Community involvement								
No	ref		ref		ref		ref	
Yes	0.82	[0.61,1.09]	0.69**	[0.55,0.86]	0.92	[0.63,1.35]	0.90	[0.66,1.22]
MPCE								
Q1	ref		ref		ref		ref	
Q2	0.96	[0.81,1.13]	1.12	[0.92,1.35]	1.14	[0.91,1.42]	0.92	[0.67,1.27]
Q3	1.02	[0.84,1.23]	0.96	[0.80,1.15]	1.37*	[1.08,1.75]	1.11	[0.79,1.57]
Q4	0.88	[0.72,1.08]	1.16	[0.96,1.41]	1.74***	[1.33,2.27]	1.05	[0.74,1.48]
Q5	1.04	[0.81,1.33]	1.15	[0.93,1.43]	1.78***	[1.35,2.34]	1.39	[0.94,2.03]

Region								
North	ref		ref		ref		ref	
West	2.80***	[2.15,3.65]	1.56***	[1.32,1.83]	1.72**	[1.21,2.43]	0.92	[0.72,1.19]
Northeast	0.87	[0.68,1.11]	1.12	[0.92,1.36]	1.60*	[1.11,2.32]	1.56**	[1.20,2.04]
East	1.81***	[1.49,2.20]	1.51***	[1.29,1.77]	2.34***	[1.78,3.07]	2.13***	[1.71,2.65]
Central	1.31*	[1.06,1.62]	0.95	[0.80,1.13]	1.48*	[1.10,2.01]	1.52***	[1.21,1.91]
South	2.94***	[2.35,3.66]	1.85***	[1.55,2.21]	1.08	[0.79,1.49]	1.26	[0.91,1.73]
Pseudo R^2	0.0798		0.102		0.0354		0.0353	

Note: OR: Odds Ratio; MPCE: Monthly Per Capita Consumption Expenditure; Q1 represents poorest; Q2 represents poorer; Q3 represents middle; Q4 represents richer; Q5 represents richest.CI: Confidence Interval; * p<0.05, ** p<0.01, *** p<0.001

Supplementary table 4. Common support

Treatment assignment	Off support	On support	Total
Untreated	408	17,467	17,875
Treated	3	10,347	10,350
Total	411	27,814	28,225