# Cholesterol medication adherence and its determinants in community dwelling older adults in India: Evidence from the Longitudinal Ageing Study in India (2017–2018)

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**KEYWORDS**
cholesterol, hypercholesterolemia, lipid, medication adherence

**Received:** 8 January 2024, **Revised:** 15 June 2024, **Accepted:** 19 June 2024

Popul. Med. 2024;6(July):19

https://doi.org/10.18332/popmed/190246

## ABSTRACT

**INTRODUCTION** Amidst rising cardiovascular disease rates globally, hypercholesterolemia emerges as a critical factor, especially in rapidly urbanizing nations like India. This study determines the prevalence of hypercholesterolemia among older adults in India, and ascertains its sociodemographic, lifestyle, and clinical determinants. We also ascertained the adherence to cholesterol lowering therapies and their determinants among previously diagnosed patients with hypercholesterolemia.

**METHODS** We conducted a cross-sectional analysis of secondary data from the Longitudinal Ageing Study in India (LASI Wave 1: 2017–2018) involving 66606 participants aged ≥45 years including 2310 participants with high cholesterol. Multivariable logistic regression was employed to analyze determinants of high cholesterol and medication adherence, which was assessed by whether participants self-reported taking regularly cholesterol-lowering medication.

**RESULTS** The weighted prevalence of (self-reported) high cholesterol was 2.28% (95% CI: 2.07–2.51). On adjusted analysis, participants of a higher socio-economic status (AOR=2.02; 95% CI: 1.40–2.92), urban residence (AOR=1.80; 95% CI: 1.46–2.22), obese (AOR=4.94; 95% CI: 2.80–8.70), with comorbidities such as diabetes (AOR=2.41; 95% CI: 1.52–3.83) and hypertension (AOR=3.41; 95% CI: 2.18–5.32), had significantly higher odds of having high cholesterol. Medication adherence among those with high cholesterol was suboptimal, with nearly 40% not taking medications regularly. The factors associated with higher odds of non-adherence included being underweight (AOR=3.66; 95% CI: 1.49–9.01), tobacco use (AOR=1.59; 95% CI: 1.01–2.50), and the absence of diabetes or hypertension comorbidity (AOR=1.53; 95% CI: 1.08–2.17).

**CONCLUSIONS** Only six in ten patients in India take medications regularly for high cholesterol, indicative of non-adherence in a substantial proportion of previously diagnosed patients. Tailored interventions are needed for raising awareness, early screening and managing high cholesterol, with healthcare providers focusing on lipid management and comprehensive care, regardless of comorbidities.

## INTRODUCTION

Hyperlipidemia is a major risk factor for coronary and cardiovascular disease, a leading and increasing cause of morbidity and mortality worldwide due to ongoing epidemiological and demographic transition, secondary to ageing[1]. Hypercholesterolemia is a type of hyperlipidemia, characterized by elevated levels of low-density lipoprotein cholesterol (LDL-C), and is a major contributor to atherosclerosis and coronary artery disease[2]. Globally, nearly 18 million deaths are attributed to cardiovascular diseases each year, with hyperlipidemia playing a pivotal role[3]. In India, the burden of hypercholesterolemia has been steadily rising especially in the older population with recent estimates suggesting that approximately 24% of the Indian adult population has elevated cholesterol levels, rendering them increasingly vulnerable to coronary and cardiovascular diseases[4,5]. Factors such as increasing urbanization, dietary transition towards high-fat and processed foods, sedentary lifestyles, and increasing stress levels are risk factors associated with high cholesterol levels[6,7]. Furthermore,

genetic predispositions among certain Indian ethnicities make them particularly susceptible to high cholesterol levels[8].

The strict adherence to therapies, as per standard treatment guidelines of hyperlipidemia, reduces the occurrence of cardiovascular events with high cost-effectiveness[9,10]. Medication adherence has been defined by the World Health Organization as the 'the degree to which use of medication by the patient corresponds with the prescriber's instructions' and includes the stages of initiation, implementation, and persistence[11,12]. Primary non-adherence signifies the inability of the patient to obtain regular drug refills, usually for chronic disease, due to challenges in drug access especially related to drug affordability.

Medication non-adherence to cholesterol lowering therapies is a major public health challenge worldwide with only an estimated 50% of the patients requiring the therapy being adherent to treatment[13]. In the lower middle-income countries, overall adherence to hypercholesterolemia is significantly lower, as a smaller fraction of patients are initiated on treatment. Furthermore, even among patients initiated on cholesterol lowering therapies, the rates of adherence tend to fall within a year signifying poor persistence with therapy[14]. Non-adherence to cholesterol-lowering therapies is associated with a heightened cardiovascular risk profile, characterized by elevated levels of low-density lipoprotein cholesterol (LDL-C) and a greater tendency for atherosclerotic progression, thereby increasing the incidence of myocardial infarctions, strokes, and other severe cardiovascular events, ultimately compromising both patient well-being and healthcare system resources[15,16].

Although India has the largest global cohort of patients with diabetes (DM) and hypertension (HTN) who are at high risk of cardiovascular events especially when comorbid with uncontrolled hyperlipidaemia[17], there is limited information on access and adherence to cholesterol lowering therapies in this vulnerable population with most existing studies being single-centered clinic-based studies and having small sample sizes[18-20]. Given its considerable impact on public health, understanding the prevalence and determinants of hypercholesterolemia among older adults in India is crucial for designing effective preventive and therapeutic interventions. Additionally, exploring the medication adherence is essential to identify barriers to healthcare access and utilization, facilitating the development of targeted strategies to improve health outcomes.

In this study, we utilized data from a nationally representative dataset with the objectives of determining the prevalence of hypercholesterolemia among older adults in India and ascertaining its sociodemographic, lifestyle, and clinical determinants. Furthermore, we also ascertained adherence to cholesterol lowering therapies and its determinants among previously diagnosed patients with hypercholesterolemia.

## METHODS

### Study design and participants

We performed a secondary data analysis of data from the Longitudinal Ageing Study in India (LASI), specifically focusing on Wave 1 (2017–2018). LASI is a nationally representative cross-sectional survey that aims to assess the health, economic, and social well-being of the older population in India. Data were collected from 73396 participants aged ≥45 years, as well as their spouses (of any age) across Indian states and union territories. LASI employed a comprehensive multistage stratified cluster sampling design to ensure the data collected were nationally representative of the older population in India. The first stage involved selecting Primary Sampling Units (PSUs), which were villages in rural areas and Census Enumeration Blocks (CEBs) in urban areas. These PSUs were chosen based on a probability proportional to size sampling method to ensure that larger PSUs had a higher chance of being selected, maintaining the representativeness of the sample. In the second stage, within each selected PSU, households were systematically chosen. Finally, in the third stage, individuals aged ≥45 years were selected from these households. Additionally, all spouses of the selected individuals, regardless of their age, were included in the survey to provide a comprehensive understanding of the household dynamics and health status.

Data were collected by trained field investigators through face-to-face interviews using a structured questionnaire. The questionnaire included sections on demographic information, health status, lifestyle factors, medical history, and medication usage. In addition to the questionnaire, physical measurements such as height, weight, and blood pressure were taken to provide objective health indicators. Biomarkers, including blood samples, were also collected to measure levels of glucose, cholesterol, and other critical health markers. More details on sampling, survey design and data collection tools are reported in the national report of LASI[21]. The present study includes a total sample size of 66606 individuals aged ≥45 years.

LASI was approved by an ethical committee of the Indian Council of Medical Research (ICMR) and was conducted in accordance with the relevant guidelines and regulations. Informed consent was obtained from all participants prior to their participation in the study. Since the LASI Wave I dataset is an anonymous publicly available dataset with no identifiable information about the participants, no separate ethical approval was required for the present secondary data analysis.

### Outcome variables

Presence of high cholesterol (HC) was assessed through self-reported information. Participants were asked whether (yes or no) they had ever been diagnosed with high cholesterol by a healthcare professional. Medication adherence was assessed among those having high cholesterol using a single

item: 'Do you regularly take medications to help lower your cholesterol?' with patients reporting 'no' to the question considered as non-adherent and those reporting 'yes' considered as adherent.

### Covariates

Several covariates were considered in the analysis, including age (45–59, 60–69, 70–79 and ≥80 years), sex (male or female), education level (no/up to primary, up to secondary school, high school, and college or higher), monthly per capita expenditure (MPCE) quintiles (poorest to richest), marital status (never married, currently married/cohabiting, and separated/widowed/others), residence (urban or rural), religion (Hindu, Islam or others), tobacco use (yes or no), alcohol consumption (yes or no), body mass index (BMI, kg/m$^2$) (classified as per Asian classification as underweight: <18.5, normal weight: 18.5–22.9, overweight: 23.0–24.9 and obese: ≥25.0)[22], and presence of comorbidities such as DM (yes or no) and HTN (yes or no). Presence of DM, HTN and chronic heart diseases were assessed using separate self-reported questions: 'Has any health professional ever diagnosed you with the following chronic conditions or diseases: diabetes or high blood sugar (yes or no), hypertension or high blood pressure (yes or no), and chronic heart diseases (yes or no)'.

### Statistical analysis

Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. The prevalence of high cholesterol was calculated as the proportion of participants who self-reported a diagnosis of high cholesterol. Proportions of treatment seeking behavior were reported for those having HC, DM-HC comorbidity, HTN-HC comorbidity and chronic heart disease-HC comorbidity.

Bivariate analyses were performed to assess the association between presence of high cholesterol and various demographic and clinical variables. Multivariable logistic regression analysis was conducted to examine the association between high cholesterol and participant characteristics. Adjusted analysis was conducted wherein variables found to be significantly associated ($p<0.05$) with the outcome were included in the final adjusted model. Adjusted odds ratios (AORs) and their respective 95% confidence intervals (CIs) were reported to quantify the strength of the associations.

Similarly, a multivariable logistic regression was conducted to assess the predictors associated with medication adherence among those with high cholesterol. Two separate adjusted models were constructed after conducting unadjusted analysis. Model 1 included all variables in the adjusted model, while Model 2 included only those variables that were found to be significantly associated ($p<0.05$) with the outcome.

Model assumptions such as multicollinearity were

**Table 1. Socio-economic and demographic characteristics of the study population (N=66606)**

| Characteristics | n (weighted %) |
|---|---|
| **Age** (years) | |
| 45–59 | 34704 (49.77) |
| 60–69 | 19211 (29.39) |
| 70–79 | 9250 (15.17) |
| ≥80 | 3441 (5.67) |
| **Sex** | |
| Male | 31039 (45.94) |
| Female | 35567 (54.06) |
| **Education level** | |
| Not educated/up to primary | 16359 (46.51) |
| Up to secondary school | 12290 (32.97) |
| High school | 2852 (9.11) |
| College or higher | 3752 (11.41) |
| **Marital status** | |
| Never married | 868 (1.19) |
| Currently married/cohabiting | 49946 (73.86) |
| Separated/widowed/other | 15786 (24.95) |
| **Religion** | |
| Hinduism | 48710 (81.96) |
| Islam | 7804 (11.51) |
| Other | 10083 (6.53) |
| **MPCE quintile** | |
| Poorest | 13180 (20.86) |
| Poorer | 13403 (21.24) |
| Middle | 13371 (20.49) |
| Richer | 13410 (19.42) |
| Richest | 13239 (17.99) |
| **Residence** | |
| Rural | 43238 (68.53) |
| Urban | 23365 (31.47) |
| **BMI** (kg/m$^2$) | |
| Underweight | 11001 (21.39) |
| Normal weight | 22227 (37.49) |
| Overweight | 9116 (14.03) |
| Obese | 17568 (27.09) |
| **Tobacco consumption** | |
| No | 41999 (62.83) |
| Yes | 24022 (37.17) |
| **Alcohol use** | |
| No | 54188 (84.89) |
| Yes | 11853 (15.11) |
| **DM-HTN comorbidity** | |
| None | 43827 (68.01) |
| Only DM | 3320 (4.47) |
| Only HTN | 14028 (19.65) |
| DM-HTN comorbidity | 5244 (7.88) |

MPCE: monthly per capita expenditure. BMI: body mass index. DM: diabetes. HTN: hypertension.

**Table 2. Distribution of factors associated with self-reported high cholesterol (HC)**

| Characteristics | No HC (N=64123) n (weighted %) | Have HC (N=2310) n (weighted %) | OR (95% CI) | AOR[a] (95% CI) |
|---|---|---|---|---|
| **Age** (years) | | | | |
| 45–59 ® | 33487 (97.95) | 1126 (2.05) | 1 | 1 |
| 60–69 | 18403 (97.17) | 765 (2.83) | 1.39 (1.14–1.70) * | 1.12 (0.88–1.44) |
| 70–79 | 8887 (98.04) | 336 (1.96) | 0.96 (0.76–1.20) | 0.82 (0.52–1.32) |
| ≥80 | 3346 (97.64) | 83 (2.36) | 1.15 (0.45–2.95) | 1.60 (0.27– 9.57) |
| **Sex** | | | | |
| Male ® | 29967 (97.74) | 972 (2.26) | 1 | - |
| Female | 34156 (97.7) | 1338 (2.3) | 1.01 (0.83–1.24) | |
| **Education level** | | | | |
| Not educated/up to primary ® | 15643 (97.21) | 678 (2.79) | 1 | 1 |
| Up to secondary school | 11536 (96.14) | 711 (3.86) | 1.40 (1.15–1.70) * | 1.02 (0.79–1.31) |
| High school | 2663 (96.79) | 176 (3.21) | 1.16 (0.83–1.60) | 0.80 (0.57–1.12) |
| College or higher | 3449 (93.64) | 285 (6.36) | 2.37 (1.57–3.57) ** | 1.43 (0.85–2.39) |
| **Marital status** | | | | |
| Never married ® | 844 (98.59) | 22 (1.41) | 1 | - |
| Currently married/cohabiting | 48049 (97.63) | 1769 (2.37) | 1.69 (0.81–3.57) | |
| Separated/widowed/other | 15228 (97.95) | 519 (2.05) | 1.46 (0.67–3.18) | |
| **Religion** | | | | |
| Hinduism ® | 47220 (98.04) | 1365 (1.96) | 1 | 1 |
| Islam | 7320 (97.09) | 469 (2.91) | 1.49 (1.19–1.88) * | 1.39 (1.01–1.92) * |
| Other | 9578 (94.81) | 476 (5.19) | 2.73 (2.21–3.38) ** | 2.37 (1.84–3.06) ** |
| **MPCE quintile** | | | | |
| Poorest ® | 12897 (98.76) | 243 (1.24) | 1 | 1 |
| Poorer | 13068 (98.17) | 303 (1.83) | 1.48 (0.99–2.19) | 1.33 (0.91–1.93) |
| Middle | 12969 (98.14) | 371 (1.86) | 1.51 (0.99–2.28) | 1.40 (0.87–2.23) |
| Richer | 12854 (97.6) | 531 (2.4) | 1.95 (1.49–2.55) ** | 1.37 (0.95–1.97) |
| Richest | 12335 (95.63) | 862 (4.37) | 3.63 (2.79–4.72) ** | 2.02 (1.40–2.92) ** |
| **Residence** | | | | |
| Rural ® | 42221 (98.7) | 936 (1.3) | 1 | 1 |
| Urban | 21902 (95.55) | 1374 (4.45) | 3.55 (2.94–4.28) ** | 1.80 (1.46–2.22) ** |
| **BMI** ($kg/m^2$) | | | | |
| Underweight ® | 10928 (99.48) | 74 (0.52) | 1 | 1 |
| Normal weight | 21867 (99) | 354 (1) | 1.94 (1.26–3.00) * | 1.98 (1.22–3.20) * |
| Overweight | 8733 (97.12) | 381 (2.88) | 5.68 (3.66–8.81) ** | 4.21 (2.50–7.09) ** |
| Obese | 16274 (94.75) | 1292 (5.25) | 10.62 (6.92–16.29) ** | 4.94 (2.80–8.70) ** |
| **Tobacco consumption** | | | | |
| No ® | 40241 (97.23) | 1752 (2.77) | 1 | 1 |
| Yes | 23484 (98.6) | 533 (1.4) | 0.50 (0.41–0.60) ** | 0.87 (0.69–1.10) |
| **Alcohol use** | | | | |
| No ® | 52244 (97.7) | 1934 (2.3) | 1 | - |
| Yes | 11497 (97.89) | 355 (2.11) | 0.92 (0.74–1.14) | |
| **DM-HTN comorbidity** | | | | |
| None ® | 43330 (99.08) | 500 (0.92) | 1 | 1 |
| Only DM | 3110 (96.17) | 210 (3.83) | 4.27 (2.95–6.18)** | 2.41 (1.52–3.83)** |
| Only HTN | 13182 (95.63) | 844 (4.37) | 4.90 (3.59–6.67)** | 3.41 (2.18–5.32)** |
| DM-HTN comorbidity | 4488 (92.06) | 756 (7.94) | 9.26 (6.63–12.91)** | 4.57 (2.85–7.33)** |

a AOR: adjusted odds ratio; adjusted for age, education level, religion, MPCE quintile, residence, BMI, tobacco consumption and DM-HTN comorbidity. MPCE: monthly per capita expenditure. BMI: body mass index. DM: diabetes. HTN: hypertension. HC: high cholesterol. ® Reference categories. *p<0.05, **p<0.001.

**Table 3. Distribution of factors associated with adherence to cholesterol lowering drugs in patients with high cholesterol (self-reported)**

| Characteristics | On regular treatment for HC | | OR (95% CI) | Model 1 | Model 2 |
|---|---|---|---|---|---|
| | Yes (N=1445) n (weighted %) | No (N=863) n (weighted %) | | AOR (95% CI) | AOR (95% CI) |
| **Age** (years) | | | | | |
| 45–59 ® | 646 (55.98) | 479 (44.02) | 1 | - | - |
| 60–69 | 498 (63.18) | 267 (36.82) | 0.74 (0.51–1.07) | 0.76 (0.51–1.11) | |
| 70–79 | 240 (65.56) | 95 (34.44) | 0.67 (0.43–1.04) | 0.61 (0.3–1.25) | |
| ≥80 | 61 (77.21) | 22 (22.79) | 0.38 (0.08–1.76) | 0.12 (0.02–0.81) * | |
| **Sex** | | | | | |
| Male ® | 605 (61.14) | 367 (38.86) | 1 | - | - |
| Female | 840 (61.05) | 496 (38.95) | 1.00 (0.70–1.45) | 1.08 (0.72–1.63) | |
| **Education level** | | | | | |
| Not educated/up to primary ® | 438 (61.46) | 240 (38.54) | 1 | 1 | - |
| Up to secondary school | 454 (60.09) | 256 (39.91) | 1.06 (0.72–1.56) | 1.05 (0.68–1.62) | |
| High school | 103 (62.07) | 73 (37.93) | 0.97 (0.56–1.70) | 1.37 (0.69–2.73) | |
| College or higher | 183 (69.02) | 102 (30.98) | 0.72 (0.37–1.38) | 0.98 (0.54–1.78) | |
| **Marital status** | | | | | |
| Never married ® | 11 (45.38) | 11 (54.62) | 1 | 1 | - |
| Currently married/cohabiting | 1097 (60.6) | 670 (39.4) | 0.54 (0.15–1.95) | 0.39 (0.08–1.92) | |
| Separated/widowed/other | 337 (63.29) | 182 (36.71) | 0.48 (0.13–1.84) | 0.38 (0.07–2.02) | |
| **Religion** | | | | | |
| Hinduism ® | 855 (62.74) | 509 (37.26) | 1 | 1 | - |
| Islam | 305 (60.54) | 164 (39.46) | 1.10 (0.71–1.69) | 1.11 (0.64–1.93) | |
| Other | 285 (53.78) | 190 (46.22) | 1.45 (0.99–2.12) | 1.53 (0.99–2.39) | |
| **MPCE quintile** | | | | | |
| Poorest ® | 147 (52.79) | 96 (47.21) | 1 | 1 | - |
| Poorer | 184 (60.21) | 118 (39.79) | 0.74 (0.36–1.53) | 1 (0.49–2.06) | |
| Middle | 241 (62.19) | 130 (37.81) | 0.68 (0.32–1.43) | 0.78 (0.38–1.59) | |
| Richer | 344 (64.31) | 186 (35.69) | 0.62 (0.36–1.07) | 0.73 (0.37–1.46) | |
| Richest | 529 (61.83) | 333 (38.17) | 0.69 (0.41–1.16) | 0.79 (0.41–1.55) | |
| **Residence** | | | | | |
| Rural | 535 (49.71) | 401 (50.29) | 2.19 (1.57–3.05) ** | 1.33 (0.87–2.02) | 1.89 (1.32–2.70) ** |
| Urban ® | 910 (68.37) | 462 (31.63) | 1 | 1 | 1 |
| **BMI** ($kg/m^2$) | | | | | |
| Underweight | 34 (31.71) | 40 (68.29) | 3.79 (1.71–8.37) * | 3.66 (1.49–9.01) * | 2.62 (1.24–5.56) * |
| Normal weight | 219 (54.85) | 135 (45.15) | 1.45 (0.94–2.23) | 1.38 (0.84–2.27) | 1.28 (0.83–1.97) |
| Overweight | 242 (62.6) | 139 (37.4) | 1.05 (0.66–1.66) | 1.03 (0.63–1.68) | 1.02 (0.63–1.64) |
| Obese ® | 811 (63.74) | 480 (36.26) | 1 | 1 | 1 |
| **Tobacco consumption** | | | | | |
| No ® | 1114 (63.35) | 638 (36.65) | 1 | 1 | 1 |
| Yes | 316 (53.61) | 216 (46.39) | 1.50 (1.03–2.17) * | 1.59 (1.01–2.5) * | 1.40 (0.95–2.07) |

Continued

**Table 3.** Continued

| Characteristics | On regular treatment for HC | | OR (95% CI) | Model 1 | Model 2 |
|---|---|---|---|---|---|
| | Yes (N=1445) n (weighted %) | No (N=863) n (weighted %) | | AOR (95% CI) | AOR (95% CI) |
| **Alcohol use** | | | | | |
| No ® | 1222 (61.49) | 711 (38.51) | 1 | 1 | - |
| Yes | 209 (57.85) | 146 (42.15) | 1.16 (0.77–1.77) | 1.07 (0.63–1.82) | |
| **Diabetes-hypertension** (DM-HTN) | | | | | |
| None | 253 (56.93) | 246 (43.07) | 1.62 (0.90–2.90) | 2.04 (1.2–3.45) * | 1.55 (0.89–2.72) |
| Only DM | 132 (64.52) | 78 (35.48) | 1.18 (0.69–2.02) | 1.13 (0.57–2.26) | 1.34 (0.73–2.45) |
| Only HTN | 502 (58.3) | 341 (41.7) | 1.53 (1.08–2.17) * | 1.4 (0.9–2.19) | 1.42 (0.98–2.08) |
| DM-HTN comorbidity ® | 558 (68.16) | 198 (31.84) | 1 | 1 | 1 |
| **HCP visit in last 12 months** | | | | | |
| No ® | 181 (52.67) | 133 (47.33) | 1 | 1 | - |
| Yes | 1247 (62.21) | 722 (37.79) | 0.68 (0.44–1.03) | 0.67 (0.41–1.09) | |

Model 1: full model, all variables. Model 2: only significant variables with p<0.05 in unadjusted analysis. a AOR: adjusted odds ratio; adjusted for age, education level, religion, MPCE quintile, residence, BMI, tobacco consumption and DM-HTN comorbidity. MPCE: monthly per capita expenditure. BMI: body mass index. DM: diabetes. HTN: hypertension. HCP: healthcare professional. HC: high cholesterol. ® Reference categories. *p<0.05, **p<0.001.

checked for each multivariable regression analysis using variance inflation factors (VIFs). Model diagnostics, including goodness-of-fit tests, were performed to validate the final models. We used appropriate sampling weights throughout the analysis to account for the survey design. A significance level of 5% was used to determine statistical significance throughout the analysis. All statistical analyses were conducted using Stata version 15.1 (StataCorp, USA).

## RESULTS

### Participant characteristics

A total of 66606 participants with mean age of 60.32 years (SD=10.80) were included in the analysis, of which 2310 participants reported having high cholesterol. Demographic characteristics of the study sample are summarized in Table 1. The majority of the participants were female (54.06%), currently married/cohabiting (73.86%), and resided in rural areas (68.53%). An estimated 4.5% of the participants had only DM, 19.7% had HTN, and 7.9% had DM-HTN comorbidity. The weighted prevalence of self-reported high cholesterol was 2.28% (95% CI: 2.07–2.51) and age-adjusted prevalence was 2.30% (95% CI: 1.44–3.68).

### Determinants of high cholesterol

Multivariable logistic regression analysis was performed to assess the determinants of high cholesterol (Table 2). After adjusting for covariates that were found to be significant in the unadjusted analysis, it was found that participants with high cholesterol were more likely to belong to the richest quintiles (AOR=2.02; 95% CI: 1.40–2.92), reside in urban areas (AOR=1.80; 95% CI: 1.46–2.22), be obese (AOR=4.94; 95% CI: 2.80–8.70), have DM (AOR=2.41; 95% CI: 1.52–3.83), HTN (3.41; 95% CI: 2.18–5.32) and DM-HTN (AOR=4.57; 95% CI: 2.85–7.33) comorbidities. There were no significant differences in the sex, marital status, or alcohol consumption between those with and without high cholesterol.

### Medication adherence for high cholesterol

Among participants with self-reported high cholesterol, only 61.09% (95% CI: 56.74–65.27) reported currently taking medicines for their condition (Table 3). Upon full model adjusted analysis (Model 1), we found that participants who were underweight (AOR=3.66; 95% CI: 1.49– 9.01), tobacco users (AOR=1.59; 95% CI: 1.01–2.50) and with no DM/HTN comorbidities (AOR=1.53; 95% CI: 1.08–2.17) were more likely to not take treatment for high cholesterol compared to their counterparts. In Model 2, after adjusting for covariates found to be significant in the unadjusted analysis, being a rural resident (AOR=1.89; 95% CI: 1.32–2.70) and underweight (AOR=2.62, 95% CI: 1.24–5.56) were the significant predictors of receiving no treatment for HC.

Table 4 reports the medication adherence among those with additional comorbidities of DM, HTN and chronic heart disease. The proportion of individuals currently not on treatment for HC was found to be 32.62% among DM-HC comorbid patients, 37.55% among HTN-HC comorbid patients and 24.98% among chronic heart disease-HC patients. However, upon adjusted logistic regression analysis, we found no significant predictors of medication adherence among these participants with comorbidities.

**Table 4. Medication adherence for cholesterol lowering treatment in patients with high cholesterol and other chronic comorbidities**

| Characteristics | DM-HC comorbid (N=966) | | HTN-HC comorbid (N=1599) | | Chronic heart disease-HC comorbid (N=409) | |
|---|---|---|---|---|---|---|
| | Not on regular treatment for HC (N=276) n (weighted %) | On regular treatment for HC(N=690) n (weighted %) | Not on regular treatment for HC (N=539) n (weighted %) | On regular treatment for HC (N=1060) n (weighted %) | Not on regular treatment for HC (N=79) n (weighted %) | On regular treatment for HC (N= 330) n (weighted %) |
| **Age** (years) | | | | | | |
| 45–59 | 126 (36.19) | 272 (63.81) | 261 (41.06) | 412 (58.94) | 24 (24.8) | 102 (75.2) |
| 60–69 | 97 (29.96) | 251 (70.04) | 193 (37.45) | 390 (62.55) | 32 (24.32) | 122 (75.68) |
| 70–79 | 46 (28.58) | 140 (71.42) | 73 (32.62) | 207 (67.38) | 20 (30.0) | 84 (70.0) |
| ≥80 | 7 (40.16) | 27 (59.84) | 12 (19.85) | 51 (80.15) | 3 (6.899) | 22 (93.1) |
| **Sex** | | | | | | |
| Male | 132 (30.51) | 296 (69.49) | 210 (36.06) | 432 (63.94) | 53 (29.8) | 183 (70.2) |
| Female | 144 (34.64) | 394 (65.36) | 329 (38.69) | 628 (61.31) | 26 (17.31) | 147 (82.69) |
| **MPCE quintile** | | | | | | |
| Poorest | 31 (38.12) | 75 (61.88) | 64 (42.74) | 111 (57.26) | 13 (35.89) | 43 (64.11) |
| Poorer | 36 (34.95) | 86 (65.05) | 75 (44.57) | 128 (55.43) | 14 (25.29) | 42 (74.71) |
| Middle | 40 (44.09) | 114 (55.91) | 89 (42.74) | 176 (57.26) | 8 (23.3) | 60 (76.7) |
| Richer | 60 (26.14) | 165 (73.86) | 118 (32.13) | 253 (67.87) | 18 (23.14) | 72 (76.86) |
| Richest | 109 (29.32) | 250 (70.68) | 193 (33.99) | 392 (66.01) | 26 (21.6) | 113 (78.4) |
| **TOTAL** | 276 (32.62) | 690 (67.38) | 539 (37.55) | 1060 (62.45) | 79 (24.98) | 330 (75.02) |

MPCE: monthly per capita expenditure. HTN: hypertension. HC: high cholesterol.

## DISCUSSION

Early diagnosis and prompt initiation of guideline-based treatment for hyperlipidemia and hypercholesterolemia is necessary to improve health outcomes in patients at high-risk of adverse cardiovascular events. The present study observed self-reported high cholesterol prevalence of only 2.3% amongst older adults suggestive of a significant degree of underreporting due to lack of awareness and screening in healthcare facilities. Nevertheless, these findings align with prior studies that have reported a relatively lower prevalence of high cholesterol in India compared to some Western countries[23,24]. While the prevalence in India appears lower than in some Western countries, the absolute numbers of affected individuals in India are substantial given the country's large population, underscoring the need for continued surveillance, awareness, and diagnostic and treatment interventions to address the public health challenge of hypercholesterolemia[25].

The multivariable logistic regression analysis revealed several determinants associated with high cholesterol among Indian older adults. Notably, participants from non-Hindu religious groups were more likely to have high cholesterol, a finding corroborating evidence from previous studies conducted elsewhere[26,27]. This suggests potential variations in dietary (such as vegetarianism) and lifestyle patterns among different religious groups as influencing factors, warranting further investigation into dietary practices and cultural factors that may contribute to this phenomenon[28].

Socio-economic status played a significant role in high cholesterol prevalence, as participants in the richest quintiles were more likely to have high cholesterol, a finding that could be linked to dietary choices and better access to healthcare resources. Evidence from previous studies also supports this view[29]. Additionally, residence in urban areas was associated with a higher likelihood of high cholesterol, which may be attributed to urbanization-related lifestyle changes, including unhealthy dietary habits and reduced work and leisure time physical activity[30].

The strong association between obesity and high cholesterol is consistent with the well-established linkage between excess body weight and dyslipidaemia[31]. Furthermore, individuals with comorbid conditions, such as DM, HTN, or both, had a substantially increased risk of high cholesterol, signifying the necessity of addressing these comorbidities collectively to mitigate cardiovascular risk[17].

Among participants with self-reported high cholesterol, nearly four in ten patients reported not taking medications regularly for their condition, indicative of non-adherence in

a substantial proportion of previously diagnosed patients with high cholesterol. Patients having DM, HTN, or obesity were more likely to be adherent to treatment possibly due to increased frequency of contact with the health-system, self-perception of increased risk, and prioritization of treatment in the high-risk groups. Tobacco users were more likely to be non-adherent to treatment for high cholesterol, similar to previous evidence, suggestive of poor self-care practices[32]. Interestingly, individuals without comorbidities of DM or HTN were less likely to seek treatment for high cholesterol possibly due to reduced risk perception. Consequently, individuals with multiple chronic health conditions in India may be more likely to receive more comprehensive care, including lipid-lowering medications, while those with high cholesterol as a standalone condition may be undertreated, suggestive of the need for sensitization of healthcare providers to also initiate and prioritize lipid management in these patients[33]. Finally, a substantial proportion of individuals with self-reported high cholesterol and DM, HTN, and heart disease were not adherent to treatment, despite the presence of these multiple risk factors suggestive of either poor treatment seeking behavior by patients, or therapeutic inertia by clinical providers.

### Strengths and limitations

The study strengths include the large sample size from a nationally representative survey conducted by trained field workers with standardized instruments. However, there are certain major study limitations. First, cholesterol status was assessed from self-report which possibly contributed to lower estimation of the burden of hypercholesterolemia. Furthermore, the survey did not distinguish between different types of cholesterol, such as LDL (low-density lipoprotein), HDL (high-density lipoprotein), or total cholesterol, limiting our ability to analyze specific cholesterol-related health risks. This could be due to the low awareness of hypercholesterolemia among the Indian population[34], which may have led this large population-based survey to exclude inquiries about different types of cholesterol among the participants. Second, medication adherence in the participants was assessed using a single item question that could not differentiate non-adherence from non-initiation of prescribed medications due to absence of screening or therapeutic inertia amongst healthcare providers, primary non-adherence due to challenges of drug accessibility and financial constraints, or secondary non-adherence from patient related factors such as carelessness and forgetfulness. Third, the survey did not inquire on the specific nature of the cholesterol lowering therapy and it is possible that a small but significant proportion of participants were on alternative or traditional medicine, a question that should be incorporated in future rounds of the survey.

### Implications

The findings of this study have several implications for the public health system and healthcare management practices in India. First, despite the relatively lower prevalence of high cholesterol compared to some Western countries, the absolute number of affected individuals in India is substantial. This highlights the need for continued awareness campaigns, early screening, and appropriate management of high cholesterol, particularly among older adults[35]. Efforts to address high cholesterol should account for the sociodemographic and clinical determinants identified in this study. Tailored interventions for different sociodemographic groups, urban and rural populations, and individuals with comorbidities may help improve adherence and overall management of high cholesterol[10]. Healthcare providers should prioritize lipid management, even in the absence of other comorbidities, and ensure that underweight individuals and tobacco users receive adequate attention and guidance regarding their cholesterol levels. Furthermore, standard treatment guidelines for lipid management should be implemented in Indian health settings to ensure early detection and management of patients at risk of complications from hyperlipidemia.

## CONCLUSIONS

A very low prevalence of self-reported high cholesterol among older adults in India suggests underestimation of the problem due to ineffective clinical screening. Only six in ten individuals with a previous diagnosis of cholesterol are adherent to cholesterol lowering therapies, suggestive of the need to strengthen health systems and awareness generation to reduce the risk of cardiovascular complications in this medically vulnerable population.

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**CONFLICTS OF INTEREST**
The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none was reported.

**FUNDING**
There was no source of funding for this research.

**ETHICAL APPROVAL AND INFORMED CONSENT**
LASI was approved by an ethical committee of the Indian Council of Medical Research (ICMR) and was conducted in accordance with the relevant guidelines and regulations. Informed consent was obtained from all participants prior to their participation in the study. Since the LASI Wave I dataset is an anonymous publicly available dataset with no identifiable information about the participants, no separate ethical approval was required for the present secondary data analysis.

**DATA AVAILABILITY**
The data supporting this research are available from the IIPS upon permission (https://www.iipsindia.ac.in/lasi).

**AUTHORS' CONTRIBUTIONS**
VM: data analysis, writing of first draft. SB: concepts, writing, reviewing and editing of manuscript. Both authors read and approved the final version of the manuscript.

**PROVENANCE AND PEER REVIEW**
Not commissioned; externally peer reviewed.