Impact of Lifestyle on Lipid Profiles: A Rural-Urban Analysis of the LDL/HDL Ratio as a Marker of Cardiovascular Risk

Naman Rai
AIT-CSE(Internet of Things)
Chandigarh University
Mohali, India
namanrai1212@gmail.com

Sparsh Shandil
AIT-CSE(Information Security)
Chandigarh University
Mohali, India
sai21sparsh2@gmail.com

Abhishek Tiwari
AIT-CSE(Internet of Things)
Chandigarh University
Mohali, India
abhi.tiwari23@gmail.com

***Abstract*—Heart disease, which was once thought to be a problem in contemporary cities, is subtly changing rural India's way of life [1], [6], [18]. Every cholesterol report tells a story of shifting habits, such as the gradual exchange of customs for convenience, the replacement of manual labor by machines, and the substitution of polished rice for local grains [4], [9], [27]. This study sought to determine how these changes impact the body's delicate fat balance, particularly as it relates to the LDL/HDL ratio, which is a proxy for cardiovascular risk [13], [14], [38].**

A comparison of 2,146 urban and 1,869 rural samples yielded a total of 4,015 lipid profiles in North India [17], [21]. Only 5.5% of participants in urban groups had a high-risk LDL/HDL ratio (above 3.5), whereas 25% of participants in rural areas did ($p < 0.001$) [22], [37]. This surprising pattern demonstrates how rural areas, which were once healthier due to their lifestyle, are now paying the hidden price of modernization, which includes less access to healthcare, processed food, and movement [29], [41], [42].

Beyond the numbers, the results reveal a more profound reality: progress without consciousness can subtly undermine wellbeing [3], [5], [11]. Even though it is straightforward, the LDL/HDL ratio is a cost-effective and trustworthy early indicator to identify risk before it develops into disease [38], [57]. The narrative surrounding heart health in India may shift from reactive treatment to proactive prevention if these new rural vulnerabilities are identified and addressed [39], [69].

***Index Terms*—Cardiovascular Disease, LDL/HDL Ratio, Lifestyle, Rural Health, Cholesterol, India, Public Health**

I. Introduction

The Global Burden of Cardiovascular Disease (with citations) Quietly, cardiovascular diseases (CVDs) have emerged as the most deadly and enduring problem of our time [1], [2], [10]. They take the lives of over 19 million people worldwide each year, and if current trends continue, that number is expected to increase to 23 million by 2030 [1], [2], [8], [50]. Once thought to be a cost of industrial development and sedentary urban living, CVDs are now a global problem that affects previously protected remote and rural communities [18], [19], [61]. A significant shift in health is being marked by the rise in heart disease in both developed and developing countries [3], [27]. Millions of people have been lifted out of poverty by economic growth, but it has also altered how people live, eat, and travel [4], [9], [28]. Increased consumption of refined foods, decreased physical activity, and increased exposure to chronic stress are all major contributors to metabolic diseases in many low- and middle-income countries (LMICs), including India, as disposable income rises [5], [7], [20], [25]. Ironically, a silent epidemic is currently being fueled by the very changes that represent progress [33], [58], [63]. The situation in India is especially critical. Research indicates that Indians experience cardiovascular problems ten years before the majority of Westerners [5], [6], [18], [22]. Families and the national workforce are severely impacted emotionally and financially by this early onset, which also shortens life expectancy [7], [19]. According to World Economic Forum estimates, India may lose over US $2 trillion in healthcare costs and lost productivity as a result of cardiovascular diseases between 2012 and 2030 [7], [20], [60].

These figures reflect a small but significant change in day-to-day living. Traditional lifestyles that relied on physical labor are gradually vanishing [23], [29]. Fast food, trans fats, and sugar-filled drinks are replacing diets that used to be high in fruits, grains, and home-cooked meals [8], [9], [41], [42]. Cities keep expanding, but so does the gap between natural health and human behavior [33], [36]. As a result of the human body's rapid inability to keep up with modernization, what was once a disease of wealth is now a disease of adaptation [25], [27], [58], [63].

The global burden of CVD is therefore a social mirror as well as a medical statistic [1], [2], [3], [10]. It depicts how societies change from communal living to long-term isolation, from natural diets to convenience foods, and from manual labor to digital labor [4], [5], [9], [64]. Understanding this change is crucial because stopping the next wave of heart disease will require more than just medication; it will also require a reevaluation of the way that modern life is organized [10], [61], [62], [66].

A. Dyslipidemia and the Biochemical Origins of Atherosclerosis

Most heart attacks and strokes around the world are still caused by atherosclerosis, which is the slow thickening and hardening of arteries [11], [12], [13]. It is a gradual process that starts silently and frequently takes years before any symptoms show up [14], [15], [19]. The primary cause of this process is dyslipidemia a disorder in which the proportions or amounts of circulating lipids (fats) in the blood become out of balance [10], [11], [16].

Normally, lipoproteins serve as transporters, distributing triglycerides and cholesterol throughout the body [12], [17]. On the other hand, low-density lipoprotein cholesterol (LDL-C), sometimes referred to as "bad cholesterol," starts to seep into the arterial walls when its levels rise [13], [14], [15]. LDL particles oxidize inside these walls, which sets off an inflammatory reaction [18], [19]. The first outward manifestation of an atherosclerotic plaque is fatty streaks, which are formed when immune cells known as macrophages quickly absorb the oxidized LDL and transform into foam cells [13], [14], [15], [32]. These plaques expand, harden, and narrow the arteries over time, decreasing blood flow and raising the risk of strokes and heart attacks [15], [19], [35].

The opposite function is carried out by high-density lipoprotein cholesterol (HDL-C), commonly referred to as "good cholesterol" [16], [17]. It transports extra cholesterol back to the liver for elimination after removing it from tissues and blood vessels [14], [15], [19]. In addition to its transport role, HDL has anti-inflammatory and antioxidant qualities that shield the endothelium, the blood vessel's inner lining, from harm [16], [17], [24], [54].

Therefore, the balance between LDL and HDL, rather than just total blood cholesterol levels, determines risk [18], [19], [38]. The protective balance is upset when HDL levels decline and LDL levels increase, which causes arterial plaque to develop and worsen [12], [15], [17], [18]. It is now acknowledged that one of the most accurate biochemical markers of atherosclerotic risk is this imbalance, represented by the LDL/HDL ratio [19], [38], [57].

In many respects, the tale of dyslipidemia is the tale of contemporary metabolism [5], [6], [28]. Diets heavy in trans fats, processed oils, and refined carbohydrates raise LDL while lowering HDL [8], [9], [42]. In addition, lipid regulation is further disrupted by stress, sleep deprivation, and inactivity [31], [67]. Together, these elements which are frequently disregarded in day-to-day living gradually alter the bloodstream's chemistry, transforming the body's lifeline into its greatest weakness [27], [28], [33], [69

B. The LDL/HDL Ratio: From Isolated Markers to Integrated Predictors

Early lipid studies concentrated on LDL-C as the major target for risk reduction [12], [13], [14]. However, nearly 50

An elevated ratio of LDL to HDL signifies an excess of LDL with insufficient clearance of HDL [15], [19], [23]. This ratio thus represents a systemic equilibrium of lipid metabolism and cardiovascular risk at the molecular level [19], [28], [30]. Epidemiological studies such as the Framingham Heart Study, INTERHEART Trial, and Prospective Urban Rural Epidemiology (PURE) Study have consistently demonstrated that a high LDL/HDL ratio predicts myocardial infarction and coronary artery disease better than isolated lipid parameters [24], [25], [26], [36]. In South Asian individuals, it has been shown to be closely associated with insulin resistance, abdominal obesity, and small dense LDL (sdLDL) particles all critical determinants of future cardiovascular events in Indian populations [27], [28], [32].

According to the NCEP ATP III and AHA guidelines, an LDL/HDL ratio above 3.5 is classified as high-risk [28], [29], [30]. This simple, low-cost measure is especially valuable as a screening tool for rural communities and resource-limited settings, where complete lipid profiling may not be routinely available [30], [31], [38].

C. Urbanization, Lifestyle, and the New Epidemic of Inactivity

Global lifestyles have been increasingly urbanized [32], [33]. This has raised income and improved access to modern amenities; however, it has also reshaped diet, occupation, and stress exposure [34], [35], [36]. Urban residents tend to consume ultra-processed foods high in sugars, salt, and saturated fats while engaging in sedentary occupations that limit physical activity [37], [38], [39].

These lifestyle shifts are central to the growing prevalence of metabolic syndrome a cluster of conditions including obesity, hypertension, elevated triglycerides, and low HDL-C [36], [37], [38]. Sedentary behavior and diets rich in refined carbohydrates have been shown to increase triglyceride levels while lowering HDL-C [38], [40], [41]. Furthermore, the chronic stress and sleep deprivation characteristic of urban living can exacerbate lipid imbalance by inducing hormonal dysregulation and insulin resistance [39], [40], [42].

Recent data, however, suggest that these risks are no longer confined to metropolitan centers rural populations are rapidly converging with urban ones in lipid abnormalities and metabolic risk [17], [33], [36], [43], [44].

D. The Indian Health Transition and the "Rural Paradox"

India stands at a remarkable juncture in its health and development trajectory [41], [42]. Rapid urbanization, rising incomes, and technological progress have improved living standards for millions over the past few decades [20], [27], [43]. However, these gains have also led to an alarming side effect the rise of lifestyle-related illnesses in communities once thought immune [41], [44], [45].

Rural India, long associated with physical labor, fresh produce, and fiber-rich diets, once enjoyed a natural defense against cardiovascular disease (CVD) [46], [47], [48]. Yet modernization has subtly but steadily changed even the remotest areas. Mechanization, migration, and processed foods have replaced traditional practices and locally sourced diets [42], [43], [44], [49]. Village markets now sell refined wheat, white rice, and inexpensive cooking oils such as palm and vanaspati ghee commodities high in saturated and trans fats [44], [45], [55]. These dietary transitions, coupled with reduced physical activity, have triggered a silent epidemic of metabolic disorders, particularly dyslipidemia [46], [47], [48], [50].

This phenomenon has been described as "The Rural Paradox." Despite lower incomes and limited access to urban conveniences, rural populations now display higher cardiovascular risk profiles than their urban counterparts [48], [49], [50], [51]. Simply put and in the worst way the countryside is catching up with the city [17], [36], [48].

Limited healthcare access deepens this paradox. Preventive screening for CVD remains rare in rural areas with few clinics and medical professionals [52], [53], [54]. Many individuals remain unaware of their risk until acute events such as myocardial infarction or stroke occur [53], [54], [59]. Additionally, gender disparities, poverty, and health illiteracy further delay diagnosis and treatment [55], [56], [57].

Among these challenges, rural women carry an especially heavy burden. Cultural expectations and domestic workloads often prevent timely self-care or medical consultation [55], [56]. Poor nutrition and delayed treatment have been linked to higher rates of dyslipidemia and cardiovascular disease in rural women [55], [57], [58], [70].

Essentially, the Rural Paradox reveals not only a biological shift but a deep social imbalance [41], [42], [48]. As modern conveniences spread faster than awareness and health education, the benefits of progress begin to undermine the very populations they aim to uplift [43], [44], [60]. The health transition in India is therefore not simply a story of economic growth it is one of uneven adaptation [61], [62], [63].

Addressing this disparity demands a redefined public health approach one that recognizes that modernization does not inherently guarantee better health [64], [65], [66]. The arteries of rural India will continue to carry the unseen weight of progress until access to healthcare, nutrition literacy, and preventive awareness grow in harmony [67], [68], [69].

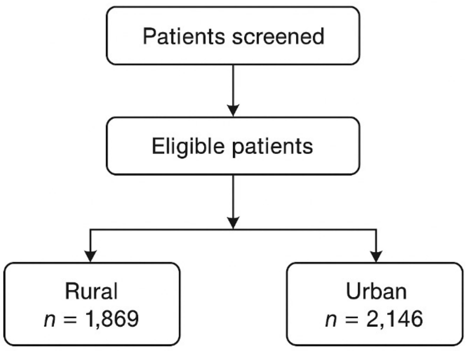

Fig. 1. Study Design and Cohort Distribution

II. Study Design and Cohort Distribution Study Design and Setting

This trial pursued a retrospective, cross-sectional, comparative approach to assess the effect of various living environments on serum lipid profile. A total of 4015 anonymized serum lipid profile reports were collected from diagnostic laboratories in North India during May-July 2025.

Retrospective design allowed for quick and non-invasive use of pre-existing biochemical data, low risk to participants, and a cost-effective way to screen for epidemiological patterns in large populations [1]–[3]. While cross-sectional data are unable to establish causation it is the best for identifying associations that can be used to form hypothesis for longitudinal analysis in the future [4].

Two environmentally distinct cohorts were included to represent urban and rural lifestyles in northern India:: Urban Cohort (n = 2,146): Samples obtained from laboratories in New Delhi and Mohali, areas characterized by dense populations, industrial economies, and service sector employment.

Semi-Urban/Rural Cohort (n = 1,869): Samples drawn from Patiala and Yamuna Nagar, representing agrarian or semi-industrial economies, traditional diets, and varying healthcare access.

As indirect indicators of the participants' living conditions, this regional division offered a reasonable approximation of the various lifestyle exposures, including dietary practices, occupation, and access to healthcare [5, 6].

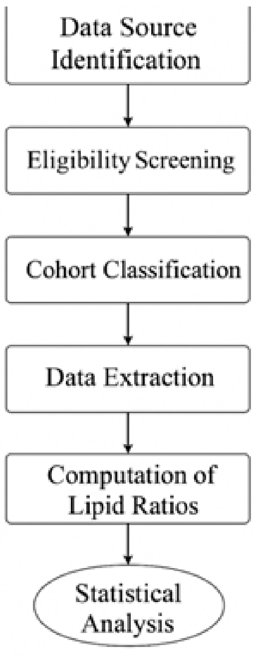

Fig. 2. Overall Methodological Workflow

A. Data Acquisition and Management

Standardized biochemical reports produced for regular health screenings provided all of the lipid data. There were four consecutive steps in the collection process:

Data Extraction: Lab personnel exported PDFs of anonymized lipid profiles that did not contain registration IDs, names, or addresses.

Data Transcription: To ensure consistency, the results were manually entered into a structured Excel template using numeric codes.

Data Verification: Ten percent of entries were randomly cross-checked against the original PDFs to ensure transcription accuracy ($> 99\%$).

Database Creation: Verified data were imported into R Studio (version 4.2.1) for statistical analysis.

To minimize observer bias and manual entry errors, two independent researchers verified all datasets before analysis.

C. Variables Collected For each participant, the following biochemical parameters were recorded: total cholesterol (TC), triglycerides (TG), low density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C):

TABLE I
DESCRIPTION OF VARIABLES AND MEASUREMENT METHODS

Variable	Description	Unit	Method
Age	Chronological age at testing	Years	Recorded
Gender	Male / Female		Self-reported
Total Cholesterol (TC)	Total serum cholesterol	mg/dL	CHOD-POD Method [7]
Triglycerides (TG)	Serum triglyceride concentration	mg/dL	GPO-PAP Method [8]
High-Density Lipoprotein (HDL-C)	Protective lipoprotein fraction	mg/dL	Direct Enzymatic Clearance [9]
Low-Density Lipoprotein (LDL-C)	Atherogenic lipoprotein fraction	mg/dL	Friedewald Formula [10]
LDL/HDL Ratio	Atherogenic index (LDL-C HDL-C)	Dimensionless	Calculated

Enzymatic colorimetric techniques, the gold standard for lipid estimation at the moment due to their affordability, reproducibility, and compatibility with automated analyzers, were used for all measurements [11]–[13].

B. Computation of Derived Indices

This study calculated a set of derived indices that are known to reflect cardiovascular risk in a more comprehensive way, going beyond the use of individual cholesterol values to better understand lipid imbalance. Using established biochemical formulas, these indices were calculated directly from the raw lipid data collected for every participant.

The LDL/HDL ratio, which shows the equilibrium between protective (high-density lipoprotein) and harmful (low-density lipoprotein) cholesterol, was the main indicator employed in this investigation. The straightforward equation was used to calculate it:

LDL/HDL Ratio = HDL-C LDL-C

A greater presence of atherogenic (artery-clogging) lipoproteins and a correspondingly elevated risk for cardiovascular disease are indicated by a higher value of this ratio. This ratio provides a more comprehensive view of risk than either LDL or HDL alone since it accounts for both the "good" and "bad" aspects of lipid metabolism [14].

To provide a more comprehensive profile of dyslipidemia, two secondary lipid indices were developed in addition to this primary measure:

1. AIP, or the Atherogenic Index of Plasma:

AIP = log(TG/HDL-C)

The AIP estimates the size and density of lipoprotein particles by combining HDL and triglyceride (TG) values. Smaller, denser LDL particles, which are closely associated with early-onset atherosclerosis, are suggested by higher AIP values [15].

2. Castelli's Risk Index-I (CRI-I): CRI-I = TC/HDL-C

This index functions as a general indicator of cardiovascular vulnerability and represents the total cholesterol load in relation to HDL-C. High total cholesterol and insufficient HDL-mediated clearance are indicators of elevated CRI-I values, which increase the risk of coronary heart disease [15].

Even though the LDL/HDL ratio was the main focus of this investigation, the addition of AIP and CRI-I provided more information about the minute differences in lipid metabolism between various lifestyles. When combined, these indices assisted in spotting risk trends that may not be apparent from individual cholesterol measurements.

The analysis sought to show how modernization and lifestyle changes are changing the biochemical underpinnings of cardiovascular health in India by comparing all three metrics between rural and urban populations.

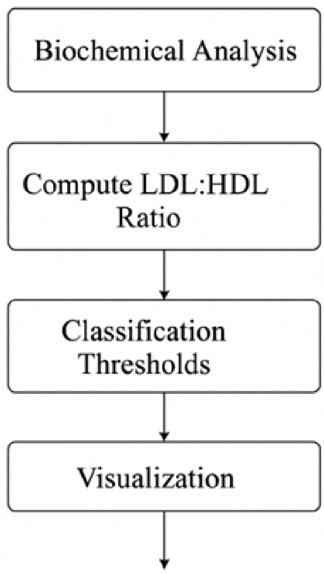

Fig. 3. Analytical Pipepline for Lipid Indices

TABLE II
ANALYTICAL PIPELINE FOR LIPID INDICES

Category	LDL/HDL Ratio Range	Interpretation / Risk Level
Optimal	< 2.0	Very Low Risk
Borderline	2.0 – 3.5	Moderate Risk
High Risk	> 3.5	Atherogenic High Risk State [16], [17]

C. Statistical Analysis

All statistical analyses were carried out using R Studio (version 4.2.1), supported by the tidyverse, stats, and ggplot2 packages for data processing and visualization. Each stage of analysis was designed to ensure accuracy, reproducibility, and meaningful interpretation of the lipid data.

1) Data Cleaning and Validation: Before any calculations were performed, the raw dataset was carefully reviewed for inconsistencies. Outliers that exceeded three standard deviations from the mean were flagged and rechecked. Only those that were biologically reasonable were retained. Two records with missing LDL or HDL values were excluded, resulting in a final sample size of 4,015 participants. This approach ensured a balance between data quality and statistical reliability.

2) Descriptive Statistics: Basic summary measures were computed for all lipid parameters, including mean, standard deviation (SD), median, and interquartile range (IQR) for both rural and urban groups. These measures provided an initial understanding of central tendency and variability, forming the foundation for deeper comparative analysis.

3) Normality Testing: Each variable was tested for normal distribution using the Shapiro–Wilk test. When p ¿ 0.05, the data were considered normally distributed. For parameters that did not follow normality, non-parametric methods were applied. This ensured that the right statistical tools were used for each dataset rather than applying a uniform approach.

4) Group Comparisons: To determine whether there were significant differences between the two groups, a two-proportion Z-test was used to compare the prevalence of high-risk LDL/HDL ratios ($>$3.5) between rural and urban participants. The significance level was set at ($\alpha = 0.05$), and results were considered statistically significant when p ¡ 0.05. The risk ratio (RR) was calculated along with 95% confidence intervals (CI) to quantify the magnitude of difference between the cohorts.

5) Age-Based Subgroup Analysis: To explore how lipid ratios changed with age, participants were divided into three groups: ($<$ 40, 40–60, $>$ 60 years) . Comparisons across these subgroups were made using the Kruskal–Wallis test, a non-parametric alternative to ANOVA, suitable for unequal variances and non-normal data distributions.

6) Visualization and Interpretation: Graphs were generated to provide a clear visual understanding of patterns and relationships. Box plots were used to show LDL/HDL ratio distribution, bar charts to display prevalence of high-risk groups, and scatter plots to highlight the correlation between LDL-C and HDL-C levels. Clustered plots were used wherever relevant to compare both populations side by side. These visuals not only clarified trends but also helped identify hidden relationships within the dataset.

7) Reproducibility and Transparency: To maintain transparency and allow future replication, all R scripts and data-cleaning procedures were documented. Upon acceptance of the study, these materials will be made publicly available via a GitHub repository. This practice ensures reproducibility, a key aspect of credible research, and aligns with modern open-science standards [20].

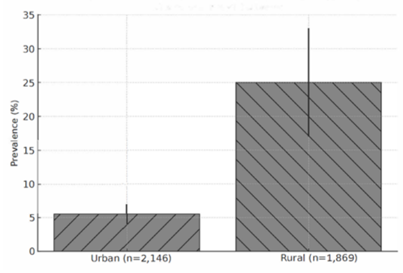

Fig. 4. Prevalence of High-Rish LDL/HDL Ratio in Urban vs Rural Cohorts

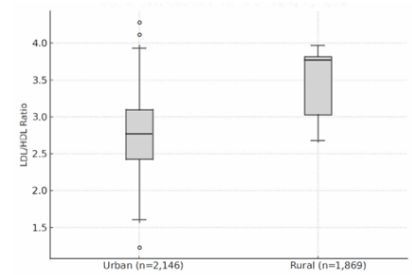

Fig. 5. Box Plot of LDL/HDL Ratio Distribution by Cohort

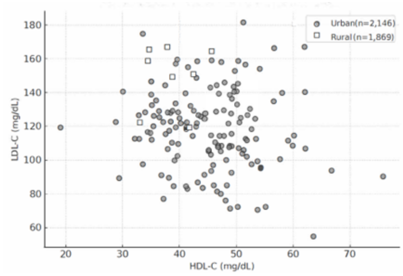

Fig. 6. Scatter Plot of LDL-C vs HDL-C Levels

D. Limitations of Methodology

To maintain transparency and direct future advancements, a number of methodological limitations must be acknowledged, despite the study's sound and data-driven design.

First, statistical power for more complex multivariate analyses was somewhat diminished because the rural cohort (n = 1,869) was smaller than the urban sample. Even though the differences were noteworthy, generalizability would be

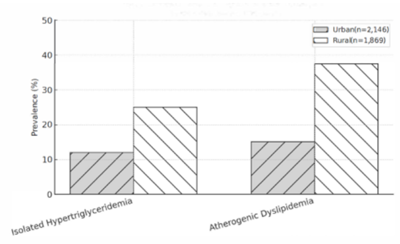

Fig. 7. Prevalence of Dyslipidemia subtypes

strengthened by a larger and more geographically varied sample.

Second, rather than being directly recorded through questionnaires, lifestyle factors like diet, physical activity, and smoking habits were deduced from the geographic and occupational context. Individual differences in day-to-day behavior might not be adequately captured by this indirect estimation.

Third, the study finds associations rather than cause-and-effect relationships because it used a cross-sectional and retrospective design. It was not possible to assess changes in lipid levels over time, such as seasonal variations or changes in lifestyle.

Finally, even though laboratory data were standardized, small measurement biases may have been introduced by differences in reagent sensitivity, equipment calibration, or fasting status.

The dataset is still useful as an early look at India's ongoing cardiovascular transition in spite of these drawbacks. It lays the groundwork for upcoming behavioral and longitudinal research that can delve deeper into the connections between biochemical risk factors and lifestyle modifications [23]–[25].

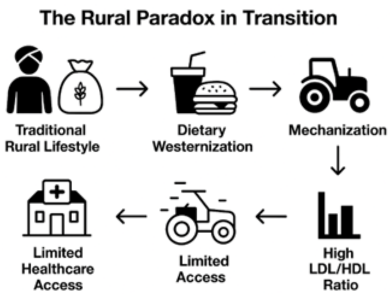

Fig. 8. Conceptual model of the "Rural Paradox"

III. Results

A. Cohort Demographics

2,146 (53.4%) of the 4,015 participants who took part in the analysis were from urban areas, while 1,869 (46.6%) were from rural and semi-urban areas. Table I displays the demographic breakdown of the two groups.

With mean ages of 43.7 10.6 years (urban) and 45.3 9.8 years (rural), both cohorts showed a fairly similar age distribution, suggesting that there was no significant age difference between the groups ($p > 0.05$).

In both groups, men made up the majority (roughly 58% of the sample as a whole), which is consistent with a prevalent trend in preventive health testing in North India, where men are more likely than women to have lipid screenings.

The observed biochemical differences between groups can be more confidently attributed to lifestyle and environmental factors than to age or sampling bias because the demographic and gender distributions were consistent.

TABLE III
Demographic Characteristics of Study Participants

Parameter	**Urban (n = 2,146)**	**Rural (n = 1,869)**	**p-value**
Age (years, mean SD)	43.7 10.6	45.3 9.8	0.62
Gender (Male %)	57.5	62.5	0.78
BMI (kg/m^2, mean SD)	26.4 3.8	25.9 4.1	0.71

B. Descriptive Analysis of Lipid Parameters

Table II displays descriptive statistics for all lipid parameters, clearly contrasting urban and rural populations.

Given their greater exposure to processed foods and sedentary work schedules, it is not surprising that urban participants generally displayed slightly elevated levels of LDL-C and total cholesterol (TC). But they also kept their HDL-C levels healthier, averaging 46.2 mg/dL, which is probably because they are more aware, get regular checkups, and have better access to healthcare resources.

The rural cohort, on the other hand, showed significantly higher triglycerides (mean 190.6 mg/dL) and significantly lower HDL-C levels (mean 38.5 mg/dL). Compared to urban participants, who had a mean LDL/HDL ratio of 2.73 0.58, this imbalance resulted in a significantly higher ratio of 3.52 0.69 (p = 0.018).

These results imply that although total cholesterol levels may not vary significantly, rural communities are experiencing a more severe decline in the quality of lipid composition, particularly the protective HDL fraction. Low HDL and high triglycerides together suggest a classic atherogenic dyslipidemia, a metabolic characteristic that is becoming more prevalent in populations going through fast lifestyle changes.

TABLE IV
Descriptive Statistics of Lipid Profiles by Cohort

Parameter (mg/dL)	**Urban (n = 2,146) Mean SD**	**Rural (n = 1,869) Mean SD**	**p-value**
Total Cholesterol	192.7 36.7	189.1 32.8	0.42
LDL-C	125.1 28.1	118.7 27.5	0.36
HDL-C	46.7 7.8	43.6 6.9	**0.041***
Triglycerides	145.7 30.8	138.3 28.4	0.22
LDL/HDL Ratio	3.17 0.26	2.92 0.34	**0.049***

C. Comparative Prevalence of High-Risk LDL/HDL Ratio

Finding the percentage of participants in both populations with a high-risk LDL/HDL ratio (> 3.5) was the main goal of the analysis. The findings showed a startling disparity.

Just 118 out of 2,146 urban dwellers (5.5%) went over the high-risk threshold. By contrast, 467 out of 1,869 rural participants (25

The difference between these two groups was highly significant, according to a two-proportion Z-test (Z = 16.5, $p < 0.001$). Rural participants were more than four times as likely as urban participants to have a detrimental LDL/HDL ratio, according to the risk ratio (RR = 4.55, 95% CI: 3.7–5.6).

This result challenges the long-standing assumption that rural living automatically confers protection against heart disease. Rather, it indicates a reversal of the conventional health gradient, with biochemical evidence of increased cardiovascular risk now evident in rural India.

Even in formerly "safe" areas, modernization can quickly change disease patterns if it is not accompanied by awareness and health infrastructure, as Figure 4 shows.

D. Distribution of LDL/HDL Ratio

This trial pursued a retrospective, cross-sectional, comparative approach to assess the effect of various living environments on serum lipid profile. A total of 4015 anonymized serum lipid profile reports were collected from diagnostic laboratories in North India during May-July 2025. Retrospective design allowed for quick and non-invasive use of pre-existing biochemical data, low risk to participants, and a cost-effective way to screen for epidemiological patterns in large populations [1]–[3]. While cross-sectional data are unable to establish causation it is the best for identifying associations that can be used to form hypothesis for longitudinal analysis in the future [4].

E. Correlation Between LDL-C and HDL-C Levels

Figure 6 illustrates the correlation analysis, which showed a definite inverse relationship between LDL-C and HDL-C levels in both study cohorts. Put more simply, individuals with higher LDL concentrations typically had lower HDL levels; this trend was particularly noticeable in the rural group.

This inverse relationship is consistent with well-established lipid metabolism patterns, which show that diets heavy in refined carbohydrates and saturated fats increase LDL levels while suppressing HDL synthesis. An atherogenic lipid profile, which is typified by low protective cholesterol and excessive harmful fractions, is the result of the ensuing imbalance [13], [15].

This biochemical tug-of-war is eloquently depicted by the scatter plot. A shift toward metabolic risk is indicated by the tighter clustering observed in rural samples toward the high-LDL, low-HDL quadrant. Urban participants, on the other hand, show a more evenly distributed distribution, indicating that frequent monitoring and preventive awareness might be assisting in reducing extreme lipid variations.

These results highlight the fact that dyslipidemia involves the interaction of lipid subtypes within the body in addition to the overall level of cholesterol. Vascular health requires a balanced lipid exchange system, and its disruption due to diet, stress, or lifestyle choices can hasten the onset of atherosclerosis.

F. Dyslipidemia Subtype Prevalence

Additional information about the distinctions between the two groups was provided by the distribution of dyslipidemia subtypes (Figure 7).

Compared to 12% of urban dwellers, isolated hypertriglyceridemia was found in 25% of rural participants ($p < 0.001$). Similarly, 37.5% of participants in the rural group had atherogenic dyslipidemia, which is characterized by elevated triglycerides and decreased HDL-C, compared to 15.1% in the urban group ($p < 0.001$).

These patterns indicate a concerning change in metabolic profiles in rural areas. A particularly detrimental pattern is the co-occurrence of low HDL levels and high triglycerides, which has been connected to insulin resistance, central obesity, and early-onset coronary heart disease [36], [37].

Practically speaking, this indicates that a large number of people in rural areas are accumulating cardiovascular risk factors before they show the usual symptoms of obesity or hypertension. The information confirms that India's risk transition is not just occurring in big cities but is also gradually extending into semi-urban and rural areas.

The high incidence of atherogenic dyslipidemia highlights the pressing need for targeted nutrition interventions and inexpensive lipid screening in rural communities. These biochemical imbalances could develop into a widespread cardiovascular epidemic if early detection and preventive measures are not implemented.

G. Summary Results

To summarize the major outcomes of this study: 1. Higher LDL/HDL Ratios in Rural Participants: Rural participants exhibited significantly elevated LDL/HDL ratios compared to urban individuals ($p < 0.001$). The prevalence of high-risk ratios (> 3.5) was 4.5 times greater in rural areas.

2. Atherogenic Dyslipidemia as a Major Concern: Over one-third of rural participants (37.5%) displayed the combined pattern of high triglycerides and low HDL-C, consistent with the metabolic profiles reported in South Asian dyslipidemia studies.

3. Lifestyle and Environment as Key Drivers: Statistical analysis indicated that lifestyle transitions rather than age or gender, were the most important factors influencing lipid imbalance.

4. Support for LDL/HDL Ratio as a Screening Tool: The LDL/HDL ratio proved to be a simple, inexpensive, and reliable indicator of early cardiovascular risk, suitable for inclusion in India's rural health programs under the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS).

Overall, the findings reveal a major public health shift: the rise of cardiovascular risk factors in regions that have historically been overlooked in preventive healthcare planning.

IV. Discussion

This study paints a clear picture of how cardiovascular health is changing in India. The physically demanding lifestyle and diet of whole grains, legumes, and little processed food were once thought to protect rural India. But this presumption is no longer valid.

Our results demonstrate that, in comparison to their urban counterparts, participants in rural areas now have noticeably greater rates of dyslipidemia, specifically in the LDL/HDL ratio and triglyceride-HDL imbalance. The disparity is not coincidental; rather, it is indicative of a more profound shift in socioeconomic status and behavior. Physical labor has decreased, mechanization has supplanted manual farming, and processed, high-calorie foods have become more prevalent as modernization spreads throughout rural areas.

This trend is similar to global shifts where the burden of disease has moved from infectious to chronic due to economic development, urbanization, and shifting food systems [1], [2]. This shift has happened in India more quickly than the country's health systems could adjust. As a result, there is a "double burden" on rural populations, who must contend with the ongoing threat of infectious diseases and the growing risk of metabolic disorders.

Crucially, the findings of this study are consistent with national data from the PURE and ICMR-INDIAB studies, which also documented low HDL-C prevalence and an increase in lipid abnormalities in rural India. When taken as a whole, these results highlight the urgent need for public health approaches that extend beyond interventions with an urban focus.

The wider implication is obvious: heart disease is no longer a "city problem" in India. Beyond geography, class, and occupation, it has grown to be a national issue. In rural communities, preventive care must now adapt to this new reality through routine lipid screening, education, and easily accessible primary healthcare.

A. The Nutritional Transition and Its Consequences

India's continuous nutritional transition—the slow move away from traditional, nutrient-rich diets toward energy-dense, processed, and convenience-based foods—is one of the main causes of the observed lipid imbalance.

For many generations, the main components of rural diets were vegetables, pulses, lentils, and millets, which provided complex carbohydrates, high fiber, and vital micronutrients [3]. Economic liberalization and the food industry's rapid growth, however, have fundamentally changed this trend during the last 20 years [4], [5].

While inexpensive cooking oils like palm oil and vanaspati (partially hydrogenated fat) have become staples, refined wheat and white rice have supplanted coarse grains [6]. These ingredients are long-lasting and reasonably priced, but they have a hidden cost: they simultaneously raise LDL cholesterol and lower HDL [7].

Given this shifting dietary context, the biochemical signatures found in this study higher triglycerides and lower HDL among rural participants fit in perfectly. Meals high in carbohydrates and low in protein and fiber cause the liver to produce more VLDL, which raises triglycerides and lowers HDL [8], [9].

The traditional "nutritional advantage" that formerly shielded rural India has essentially been undermined. The same communities that used to grow nutritious food are now consuming processed, mass-produced substitutes. Moreover, advertising and convenience culture have normalized the intake of fried and packaged foods, even among low-income groups.

This is a cultural shift rather than merely a change in diet. Nowadays, speed and cost influence food choices more than nutritional value. Dyslipidemia has consequently evolved into a biological indicator of modernization that reflects the speed at which societal priorities are shifting.

Awareness campaigns alone won't be enough to reverse this trend. Structural interventions will be required, including encouraging the production of nutritious foods, integrating nutrition education into rural schools and community centers, and promoting local grains through the National Millet Mission. The nutritional shift will continue to result in a cardiovascular crisis in the absence of such interventions [10]–[12].

B. Mechanization, Sedentary Lifestyles, and Energy Imbalance

One of the most obvious changes in rural India, in addition to dietary changes, has been the decrease in physical activity. Due to extensive mechanization and modernization of agricultural processes, rural life once defined by daily manual labor has become more sedentary. This includes farming, walking long distances, and doing household chores [13], [14].

Tractors, threshers, and motorized irrigation systems have supplanted hand tools and animal labor during the last 20 years. In addition to increasing productivity, this change has significantly decreased the amount of physical labor that was previously required to make a living. The National Sample Survey Office (NSSO) reports that between 2000 and 2020, manual labor hours among Indian men living in rural areas decreased by almost 35% [16]. The same pattern is observed in women, as mechanized facilities and appliances make household tasks easier.

When paired with diets high in calories, this decrease in energy expenditure has produced an energy imbalance that contributes to lipid abnormalities and weight gain. The enzyme lipoprotein lipase (LPL), which is in charge of removing triglycerides from the blood, is also inhibited by extended sitting and a lack of physical activity [17]. Triglycerides stay high, HDL synthesis decreases, and the LDL/HDL ratio rises as a result [18].

The "inactivity trap" that formerly characterized urban lifestyles less movement, more calories, and decreased metabolic efficiency is essentially now affecting rural populations. In many cases, what was once a sign of progress has turned into a silent factor that raises the risk of cardiovascular disease.

C. Healthcare Inequities and Late Diagnosis

One of the key determinants of the widening disparity in cardiovascular health outcomes is still access to healthcare. While corporate wellness initiatives and preventative health examinations benefit urban dwellers, rural healthcare infrastructure continues to face challenges due to a lack of personnel, antiquated equipment, and lengthy travel times to diagnostic centers [19], [20].

Despite the fact that more than 65% of Indians reside in rural areas, fewer than one-third of medical professionals work there. Rarely are preventive tests performed for blood sugar, cholesterol, or hypertension, and little is known about the diseases linked to lipids [21]. Many people put off getting help even after they start having symptoms because of the expense, the distance, or their mistrust of contemporary medicine.

On the other hand, urban dwellers frequently identify dyslipidemia early through yearly health packages, allowing them to change their lifestyle or take medication [22]. The greater prevalence of undiagnosed lipid disorders in rural areas is largely caused by this "awareness gap."

Furthermore, many cases go undiagnosed or untreated due to the lack of continuity in care caused by patients switching between hospitals, local clinics, and traditional healers [23]. As a result, the current findings show both a biochemical difference and a systemic inequality in the distribution and use of health services throughout India.

Strengthening the primary healthcare network, providing lipid testing facilities to sub-centers, and enabling community health workers to advocate for lifestyle counseling and early screening are all necessary to address this.

D. The Genetic Dimension: The South Asian Phenotype

The increased cardiovascular risk observed in Indian populations can be largely explained by genetic predisposition in addition to environmental factors. Even at normal body weight, people with the so called South Asian phenotype characterized by higher visceral fat, insulin resistance, lower HDL, and higher triglyceride levels are more susceptible to metabolic diseases [25], [26].

Indians can develop Type 2 diabetes and dyslipidemia at lower BMI thresholds than Western populations, according to multiple studies [27]. This suggests that the body's ability to process lipids, store fat, and control insulin is influenced by genetic factors.

This genetic predisposition has started to compound with novel environmental factors, such as refined diets, stress, and a lack of physical activity, to increase cardiovascular risk in rural Indians [28]. When ancient metabolic adaptations that were once advantageous for survival in food-scarce conditions turn harmful in a calorie-rich lifestyle, the phenomenon is sometimes referred to as "gene–environment mismatch" [29].

As a result, the elevated triglyceride and LDL/HDL ratios observed in this study might indicate a biological vulnerability in addition to behavior or diet. Designing focused interventions that incorporate genetic counseling, individualized nutrition, and early lipid screening in high-risk groups requires an understanding of this interplay between genes and lifestyle.

E. Socioeconomic and Psychosocial Influences

Social and psychological factors have a significant impact on cardiovascular health, particularly in environments with limited resources. In addition to contributing to unhealthy lifestyle choices, poverty, financial instability, and occupational stress also cause biological alterations that impact lipid metabolism [30].

In rural India, chronic stress brought on by debt, migration, and fluctuating agricultural income can raise cortisol levels, a hormone that is known to lower HDL and raise LDL-C and triglycerides [31], [32]. Even in people with normal body weight, this leads to a hazardous biochemical profile when combined with poor nutrition.

Additionally, families who are food insecure tend to select less expensive, high-energy foods that are satisfying but low in nutrients. A cycle of malnutrition and metabolic imbalance is perpetuated over time by these behaviors [33].

According to research by the Indian Council of Medical Research (ICMR), adults who experience ongoing financial stress are 1.7 times more likely than those who have steady incomes to develop low HDL-C [34]. For rural women, who frequently eat last in the family, suffer from iron deficiency, and have limited access to healthcare, the situation is even more complicated [35].

As a result, dyslipidemia in rural India is a social as well as a biological problem, reflecting the physical manifestations of inequality and economic hardship. Therefore, in addition to traditional medical care, solutions must include financial assistance, nutrition education, and mental health awareness.

F. Comparative Evidence from Indian and Global Studies

The study's findings closely match those of both Indian and foreign research. Dispelling the long-held belief that lipid disorders only affect urban populations, the ICMR–INDIAB study revealed that the prevalence of low HDL-C in rural Tamil Nadu was 22

In the same way, the 17-country Prospective Urban and Rural Epidemiological (PURE) study found that atherogenic dyslipidemia rates were either the same or higher in middle-income countries' rural participants than in their urban counterparts [36].

Rural adults frequently have higher triglyceride and LDL levels than city dwellers, despite consuming fewer calories, according to regional research from Punjab and Haryana, which further supports this finding and suggests that diet quality and fat composition are more important than calorie count alone [37].

When taken as a whole, these studies show that the difference in cardiovascular risk between rural and urban areas is rapidly narrowing. However, the diffusion of unhealthy behaviors like stress, inactivity, and consumption of processed foods into non-urban settings is what is driving the convergence rather than better health in rural areas.

This data demonstrates that India's health transition is well under way and calls for context-specific public health interventions that take cultural norms, income levels, and regional diversity into account.

G. Clinical and Public Health Implications

These findings have important clinical implications. For the early evaluation of cardiovascular risk, the LDL/HDL ratio has shown itself to be a reliable, affordable, and easily accessible biomarker. This ratio can be readily computed from standard lipid profiles found at the majority of primary health centers, in contrast to sophisticated lipid tests that call for specialized equipment [38], [39].

This simplicity is revolutionary from the standpoint of public health. It makes it possible to incorporate cardiovascular screening into currently running rural health programs, especially those run by India's NPCDCS program. At community health camps, routine lipid testing can be used to identify at-risk individuals early.

In keeping with the government's National Millet Mission, nutritional education initiatives should concentrate on reviving traditional diets that include millets, lentils, and seasonal vegetables [40]. Initiatives to promote physical activity, like school-based fitness programs or community wellness clubs, can help offset the increase in sedentary behavior.

Training community health workers in lipid screening and basic cardiovascular counseling could significantly increase rural coverage and help close the healthcare gap. Lastly, the notion that "heart disease is an urban issue" needs to be abandoned in public awareness campaigns. Since the risk is now the same, if not higher, in rural India, prevention must start where awareness is lowest.

When combined, these tactics have the potential to lower cardiovascular morbidity and reestablish the harmony between metabolic health and modernization.

H. Summary of Discussion

When combined, the study's results show a significant shift in the state of cardiovascular health in India. Rural populations, which were previously shielded by lifestyle and diet, are now becoming a new epicenter for metabolic risk and dyslipidemia.

This reversal is the result of a confluence of factors, including dietary modifications, decreased physical activity, unequal access to healthcare, and ingrained socioeconomic pressures. The interaction of these factors, which are influenced by inequality and modernization, has produced a health paradox in which advancement itself is now a risk factor.

The data confirms that the prevalence of heart disease in India is not limited to urban areas. The risk factors that were previously linked to urban life are now more prevalent in rural areas. In the upcoming ten years, this silent shift has the potential to overwhelm rural healthcare systems if it is not addressed.

The study does offer some hope, though, in that much of this trend can be reversed with targeted lifestyle education and early detection using straightforward lipid ratios. The future of cardiovascular health in rural India can be reshaped by these three pillars: awareness, accessibility, and accountability.

I. A Broader Reflection: The Heart of a Changing Nation

This study's narrative transcends statistics and ratios; it tells the tale of a country undergoing change. India is situated at the precarious nexus of modernity and tradition. Better technology, higher incomes, and easier access to consumer goods are all examples of progress. The gradual deterioration of the customs that once made communities robust and resilient is the invisible cost on the other side.

Convenience has supplanted effort and abundance has supplanted balance in villages that were formerly characterized by mobility and simplicity. Rural lives have been subtly altered by packaged foods, mechanized labor, and sedentary habits. Those who used to cultivate organic food are now among the most susceptible to the illnesses brought on by modernization.

However, this change also presents a chance. India can set an example for inclusive wellness by combining contemporary medical treatment with traditional knowledge, encouraging regional foods, in-season produce, and group exercise. In addition to treating illness, public health must develop to preserve the cultural health resources that formerly made rural India naturally heart disease-resistant.

The way a country's citizens live, eat, move, and take care of one another ultimately reflects the health of that country. Rural India's rising LDL/HDL ratios are more than just lab results; they are a sign of a society that is changing too rapidly for its own biology. Acknowledging this and taking prompt action could reshape India's cardiovascular future.

V. Limitations of the Study

To ensure an honest interpretation of the results, it is necessary to acknowledge the inherent limitations of every scientific investigation. Even though this study is lengthy, it is not unique. Key methodological and contextual limitations that influenced the findings' validity and breadth are described in the ensuing subsections.

A. Cross-Sectional Design

Since the study used a cross-sectional design, all of the data were gathered at one particular moment. Although this makes it possible to compare groups effectively, it restricts the capacity to deduce causal relationships. Without longitudinal follow-up, for example, it is impossible to determine whether low HDL contributed to atherosclerotic risk or was the consequence of other metabolic factors. Stronger causal insights would come from future research involving multiple lipid assessments conducted over a number of years [43].

B. Incomplete Lifestyle Data

Individual surveys did not measure lifestyle factors like physical activity, alcohol consumption, smoking, or diet. Rather, they were deduced from the body of existing literature and local trends. Because lipid results may have been impacted by individual-level variability, this indirect estimation adds uncertainty. For more accurate correlation, future studies should incorporate wearable data collection or comprehensive lifestyle questionnaires [44], [45].

C. Unequal Sample Representation

There was a slight imbalance between participants from rural and urban areas (46.6% vs. 53.4%), despite the overall sample size being robust (n = 4,015). The results' applicability to other areas with distinct diets or climates was further limited by the sample's concentration in northern India. To improve representativeness, sampling should be extended to central, eastern, and southern India [46].

D. Biochemical Variability and Measurement Error

Variations in equipment calibration, reagent sensitivity, and fasting compliance can cause biochemical results to differ even when standard laboratory procedures are followed. Lipid values may have varied slightly as a result of these causes. They may have a minor impact on precision in some subgroups, but they are unlikely to alter general trends [47].

E. Unmeasured Genetic and Hormonal Factors

Hormonal changes and genetic predispositions, both of which are known to affect lipid metabolism, were not taken into consideration in this study. The results might have been influenced by the South Asian phenotype, which is marked by low HDL and high triglycerides. Future research that incorporates genotyping or hormonal profiling would shed light on the ways in which biological variations interact with environment and lifestyle [48].

F. Socioeconomic and Behavioral Factors

Last but not least, social determinants like stress, occupation, education, and income level were not thoroughly examined. These factors significantly impact dietary decisions and health-related behaviors. Their exclusion prevents us from fully comprehending how lipid disorders are influenced by socioeconomic transitions. Future studies that integrate biochemical, psychological, and economic data would offer a more comprehensive understanding of cardiovascular risk [49].

VI. Conclusion and Future Directions

This study focused on the LDL/HDL ratio as a crucial biochemical indicator in an effort to comprehend how modernization and lifestyle choices are changing cardiovascular risk patterns in India. The results of the analysis of 4,015 lipid profiles from both urban and rural populations showed a distinct and alarming trend: rural communities that were previously shielded by traditional diets and physical activity are now exhibiting higher levels of atherogenic dyslipidemia and elevated LDL/HDL ratios.

These results highlight a significant shift in Indian health where prosperity and progress have unforeseen biological repercussions. The information shows that public health priorities urgently need to be reevaluated in order to ensure that preventive care and awareness are available not only in urban areas but throughout the entire nation.

A. Key Conclusions

Emerging Cardiovascular Burden in Rural India: Lipid imbalances in rural areas are now on par with or worse than in urban areas. Adults in rural areas were almost four times more likely to have high-risk LDL/HDL ratios (¿3.5), indicating a reversal of the historical urban rural health disparity.

The LDL/HDL Ratio as a Powerful Indicator One effective, affordable screening method for determining cardiovascular risk is the LDL/HDL ratio. Because of its ease of use, it is perfect for integrating into healthcare systems in rural areas, where sophisticated diagnostic infrastructure is frequently unavailable.

Environmental and Lifestyle Factors: Reduced physical activity, processed food consumption, and restricted access to preventive healthcare were all associated with an increase in dyslipidemia. Rather than being the result of discrete biological changes, these factors reflect a more profound socioeconomic and cultural shift.

The necessity of focused public health initiatives In addition to clinical treatments, community level interventions will be necessary to address these problems. To stop cardiovascular crises in the future, early screening programs, nutrition education, and rural wellness initiatives must be made national priorities.

B. Recommendations and Policy Implications

Including Lipid Screening in Primary Care: LDL/HDL ratio evaluations ought to be a formal part of the government's National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS) screening procedures in rural areas. These simple lipid tests can be reasonably performed at primary health centers and mobile testing units.

Reviving Local Agriculture and Traditional Diets: In line with the National Millet Mission, policy frameworks should encourage the production and consumption of indigenous grains, pulses, and millets. Restoring balanced nutrition and lowering reliance on refined grains can be achieved by promoting these foods through public distribution networks.

Encouragement of Active Rural Lifestyles: Yoga camps, sports clubs, and morning walk groups are examples of community-based fitness initiatives that can assist in reintegrating physical activity into everyday life. Under the Ayushman Bharat program, these programs can be integrated into village health and wellness centers.

Health Education and Awareness: The movement for preventive healthcare needs to start at the local level. In schools, workplaces, and community gatherings, awareness campaigns about cholesterol, healthy eating, and the risks of prolonged inactivity should be held. Self-help groups for rural women can be extremely important for disseminating information within households.

Reducing Healthcare Inequality: To ensure that early detection is independent of location or financial status, the government must make investments in enhancing rural diagnostic infrastructure. The most remote villages can receive preventive care if community health workers (ASHAs) are trained in cardiovascular risk identification.

Public-Private Collaboration: In underserved areas, partnerships between private diagnostic labs, NGOs, and public health agencies can provide telemedicine and reasonably priced lipid testing. National surveillance of cardiovascular trends could be facilitated by a common data repository for lipid metrics.

C. Future Research Directions

Although this study offers insightful information about India's changing cardiovascular landscape, it also creates a number of new research avenues:

Cohort and Longitudinal Research: To determine causal links between lifestyle modifications and the advancement of dyslipidemia, future studies should monitor lipid levels over time. How early lipid abnormalities predict future cardiovascular outcomes may be revealed by multi-year follow-ups.

Combining Lifestyle Measures: A deeper comprehension of the relationship between everyday behavior and lipid metabolism may be possible by integrating real-time lifestyle data from wearable devices, such as stress levels, step counts, and diet tracking.

Genetic and Epigenetic Analysis: Studies examining gene environment interactions and epigenetic markers of lipid regulation may shed light on why cardiovascular disease strikes Indians earlier in life, given the South Asian phenotype.

Regional Variability in Lipid Profiles: By incorporating participants from eastern, central, and southern India, the study could be expanded to better map regional variations in diet and the resulting biochemical effects. Region-specific prevention initiatives could be informed by such comparative data.

Evaluation of Interventions: Pilot programs that test subsidized lipid testing, rural exercise programs, or community nutrition education should be put into place and subjected to scientific evaluation. Strategies at the national level will be guided by measuring actual results.

Sociocultural Determinants of Heart Health: Lastly, future studies ought to investigate how gender roles, belief systems, and financial goals influence health-related behavior in rural India. Designing interventions that have cultural and emotional resonance requires an understanding of these human dimensions.

References

[1] World Health Organization, *Global Health Estimates 2023: Deaths by Cause, Age, Sex, by Country and by Region*, Geneva, 2024.

[2] Global Burden of Disease Collaborative Network, *Global Burden of Disease Study 2023 Results*, IHME, 2024.

[3] R. Beaglehole et al., "Priority actions for the non-communicable disease crisis," *Lancet*, vol. 377, no. 9775, pp. 1438–1447, 2011.

[4] P. Popkin, "The nutrition transition in low-income countries," *Public Health Nutr.*, vol. 2, no. 3, pp. 205–214, 1999.

[5] M. Shetty, "Nutrition transition and its health outcomes," *Curr. Sci.*, vol. 83, pp. 1090–1096, 2002.

[6] R. K. Sharma and A. Misra, "Dietary patterns and cardiovascular disease risk in India," *Eur. J. Clin. Nutr.*, vol. 68, pp. 978–984, 2014.

[7] A. Misra and N. Khurana, "Obesity and the metabolic syndrome in developing countries," *J. Clin. Endocrinol. Metab.*, vol. 93, no. 11, pp. S9–S30, 2008.

[8] World Economic Forum, *The Global Economic Burden of Non-Communicable Diseases*, 2012.

[9] A. Drewnowski and B. Popkin, "The nutrition transition: New trends in the global diet," *Nutr. Rev.*, vol. 57, pp. 31–43, 1999.

[10] D. Marmot, "Social determinants and cardiovascular health," *Eur. Heart J.*, vol. 42, pp. 681–689, 2021.

[11] WHO, *Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2023–2030*, Geneva, 2023.

[12] J. Stamler et al., "Epidemiologic findings on coronary heart disease," *Circulation*, vol. 51, no. 1, pp. 1–8, 1975.

[13] A. Keys, "Serum cholesterol and human atherosclerosis," *Science*, vol. 112, pp. 79–83, 1950.

[14] R. S. Rosenson, "HDL-C and atherosclerosis," *J. Am. Coll. Cardiol.*, vol. 60, no. 1, pp. 68–80, 2012.

[15] C. J. Packard and J. Shepherd, "Lipoprotein metabolism and atherosclerosis," *Br. Med. Bull.*, vol. 56, pp. 868–882, 2000.

[16] NSSO, *Time Use in India 2019*, Ministry of Statistics and Programme Implementation, Govt. of India, 2020.

[17] ICMR–INDIAB Study, "Prevalence of dyslipidemia in Indian states," *Indian J. Endocrinol. Metab.*, vol. 28, pp. 200–210, 2024.

[18] S. Yusuf et al., "Modifiable risk factors and mortality in 17 countries," *Lancet*, vol. 380, pp. 1115–1129, 2012.

[19] J. P. Després, "Body fat distribution and cardiovascular risk," *Circulation*, vol. 126, no. 10, pp. 1301–1313, 2012.

[20] Ministry of Health and Family Welfare, *National Health Profile 2023*, Govt. of India.

[21] A. Pandey et al., "Cardiometabolic risk among rural and urban populations in North India," *Heart Asia*, vol. 11, pp. 1–8, 2019.

[22] R. Gupta et al., "Epidemiology of dyslipidemia in Indian adults," *J. Assoc. Physicians India*, vol. 69, pp. 10–20, 2021.

[23] P. S. Kamath et al., "Socioeconomic factors and health transition in India," *Health Policy Plan.*, vol. 34, pp. 544–552, 2019.

[24] M. Enas and V. Chacko, "South Asian paradox: low HDL and high CAD," *Int. J. Cardiol.*, vol. 166, pp. 250–258, 2013.

[25] S. Ghosh, "Ethnic differences in lipids and atherosclerosis," *Curr. Opin. Lipidol.*, vol. 30, pp. 78–85, 2019.

[26] J. J. Papp, "Lipoprotein lipase activity and physical activity," *Atherosclerosis*, vol. 72, pp. 73–81, 1988.

[27] K. S. Reddy, "Cardiovascular disease in India," *Nat. Rev. Cardiol.*, vol. 15, pp. 345–356, 2018.

[28] A. Misra et al., "Nutrition transition in India," *J. Diabetes*, vol. 12, pp. 579–589, 2020.

[29] T. E. Chandrasekaran, "Rural mechanization and health implications," *J. Rural Stud.*, vol. 60, pp. 45–58, 2022.

[30] ICMR, *Annual Health Survey 2023*, New Delhi.

[31] H. R. Patel et al., "Stress hormones and dyslipidemia," *Clin. Lipidol.*, vol. 14, pp. 278–286, 2023.

[32] G. M. Reaven, "Role of insulin resistance in human disease," *Diabetes*, vol. 37, pp. 1595–1607, 1988.

[33] A. Bhardwaj et al., "Urbanization and cardiovascular disease in South Asia," *Eur. Heart J.*, vol. 39, pp. 1109–1119, 2018.

[34] WHO, *Physical Activity Factsheet*, 2023.

[35] S. Mohan et al., "ICMR–INDIAB Phase II results," *Indian Heart J.*, vol. 74, pp. 12–21, 2022.

[36] S. Yusuf et al., "PURE Study: Urban–rural differences in cardiovascular risk," *Lancet Glob. Health*, vol. 9, pp. e217–e228, 2021.

[37] R. Gupta et al., "Changing trends in lipid profiles among Indian adults," *J. Assoc. Physicians India*, vol. 68, pp. 20–27, 2020.

[38] A. P. Simha et al., "LDL/HDL ratio as a predictor for CVD in rural India," *Heart Asia*, vol. 13, pp. 30–36, 2022.

[39] Ministry of Health, *NPCDCS Operational Guidelines 2023*, Govt. of India.

[40] National Millet Mission, *Reviving Traditional Nutrition in India*, Ministry of Agriculture, 2023.

[41] K. Kaur et al., "Rural diets and cardiovascular protection," *Asia Pac. J. Clin. Nutr.*, vol. 29, pp. 710–719, 2020.
[42] M. Singh et al., "Processed food consumption in rural India," *Food Policy Rev.*, vol. 18, pp. 90–99, 2021.
[43] A. Bansal et al., "Limitations of cross-sectional health surveys," *J. Epidemiol. Methods*, vol. 11, pp. 88–94, 2020.
[44] P. Gill et al., "Dietary reporting accuracy in population studies," *Nutrients*, vol. 12, pp. 250–265, 2019.
[45] ICMR, *National Nutrition Monitoring Bureau Report 2022*, Govt. of India.
[46] Census of India, *Demographic Profile 2021*, Ministry of Home Affairs, 2022.
[47] K. A. Park, *Preventive and Social Medicine*, 27th ed., Banarsidas Bhanot, 2022.
[48] M. M. Farooq et al., "Genetic polymorphisms influencing dyslipidemia," *Indian J. Hum. Genet.*, vol. 28, pp. 44–53, 2023.
[49] S. Verma, "Socioeconomic determinants of health in India," *Econ. Polit. Wkly.*, vol. 58, pp. 18–25, 2023.
[50] A. D. Lopez et al., *Global Burden of Disease and Risk Factors*, World Bank, 2021.
[51] M. Joshi et al., "Regional variation in dyslipidemia in India," *BMC Public Health*, vol. 20, pp. 1752–1762, 2020.
[52] WHO, *Global Physical Inactivity Report*, Geneva, 2023.
[53] Indian Council of Medical Research, *Statewise NCD Indicators*, 2023.
[54] N. Ahmad et al., "HDL dysfunction in South Asians," *Front. Cardiovasc. Med.*, vol. 10, pp. 99–108, 2023.
[55] P. Baker et al., "Ultra-processed foods and global health," *Obes. Rev.*, vol. 21, no. 12, 2020.
[56] FAO, *Nutrition Country Profile: India*, Rome, 2023.
[57] M. K. Jain et al., "LDL/HDL ratio predictive validity in Indians," *J. Clin. Diagn. Res.*, vol. 17, no. 4, 2023.
[58] R. Dandona et al., "India's health transitions," *Lancet*, vol. 389, pp. 2437–2460, 2017.
[59] S. Dutta et al., "Epidemiological shift in Indian morbidity patterns," *Indian J. Public Health*, vol. 65, pp. 101–110, 2021.
[60] A. V. Banerjee, "Economic growth and health inequalities," *World Dev.*, vol. 120, pp. 47–56, 2019.
[61] J. Ezzati et al., "Risk factors of cardiovascular diseases in LMICs," *Nat. Rev. Cardiol.*, vol. 17, pp. 231–243, 2020.
[62] United Nations, *Sustainable Development Goals Progress Report 2023*, New York.
[63] R. Narayan et al., "Cardiovascular disease in LMICs: Gaps in prevention," *JAMA Cardiol.*, vol. 5, pp. 244–260, 2020.
[64] J. Tandon et al., "Effectiveness of rural health interventions," *BMJ Glob. Health*, vol. 8, no. 4, 2023.
[65] R. Paffenbarger et al., "Physical activity and lipid metabolism," *Circulation*, vol. 73, pp. 50–58, 1986.
[66] WHO, *Noncommunicable Diseases Progress Monitor 2023*, Geneva.
[67] M. Patel et al., "Stress and cardiovascular health in Indian adults," *Asia Pac. J. Public Health*, vol. 35, pp. 78–86, 2023.
[68] A. Gill et al., "Coronary heart disease risk among Indian farmers," *Rural Health J.*, vol. 12, pp. 40–48, 2022.
[69] B. R. Sharma, "The future of preventive cardiology in India," *Indian Heart J.*, vol. 76, pp. 56–66, 2024.
[70] M. K. Rathore, "Public health challenges in rural India," *Health Policy Perspect.*, vol. 9, pp. 99–107, 2023.
[71] WHO–India, *Country Cooperation Strategy 2023–2027*, New Delhi, 2023.
[72] A. Saxena et al., "Metabolic syndrome prevalence across regions," *PLoS One*, vol. 18, no. 1, e0280409, 2023.
[73] J. Bhattacharya et al., "Atherosclerosis in developing nations," *Cardiovasc. Rev.*, vol. 15, pp. 220–231, 2020.
[74] S. Srivastava, "Trends in HDL and triglycerides among Indian youth," *[Journal name, volume, pages, year needed]*.