Prevalence and risk factors for dyslipidemia among South Indian adults: A community based-NCD study

Sundaresan Mohanraj[1] · Ganesan Velmurugan[1] · Krishnan Swaminathan[2] · Arulraj Ramakrishnan[3]

Abstract

Background Dyslipidemia is a crucial risk factor for atherosclerotic cardiovascular disease. However, there is limited data available on the differences in the prevalence of dyslipidemia between rural and urban populations in India. The aim of the present investigation is to describe the prevalence of dyslipidemia and the risk factors associated with adverse lipid profiles among adults residing in rural, sub-urban, and urban areas of India, and to assess its association with diabetes and hypertension.

Methods We enrolled adults over the age of 20 who lived in three distinct demographic areas in South India: rural, sub-urban, and urban. Data on demographics, lifestyle, disease history, family history, body weight, height, waist circumference, blood pressure, and clinical characteristics were collected for this study. We used chi-square tests and multivariable logistic regression to analyze demographic prevalence and risk factors related to lipid abnormalities among study participants.

Results This study enrolled 2976 randomly selected participants from rural, sub-urban, and urban communities in Tamil Nadu, India. Of these, 865 (29.1%) were rural residents, 1030 (34.6%) were sub-urban residents, and 1081 (36.3%) were urban residents. About 80% of women who lived in the suburban area had higher rates of low-HDL cholesterol. Compared to sub-urban (29.9%, 49%, and 21.1%) and rural (33.4%, 43.4%, and 24.1%) populations, urban populations had higher prevalence rates of hypercholesterolemia, hypertriglyceridemia, and elevated LDL-C (37.3%, 52.5%, and 38.6%), respectively. Men were more likely than women to develop dyslipidemia before the age of 40, but after that age, men showed a reduced risk of dyslipidemia than women, except for low HDL cholesterol. Age group, gender, current drinker, overweight, obesity, diabetes, and hypertension showed a significant association ($p < 0.05$) with dyslipidemia.

Conclusions The study found that more than 85% of the sub-urban and urban population had dyslipidemia (at least one lipid abnormality) compared to rural residents (78.5%). The prevalence rates were higher among those with diabetes and hypertension in urban residents.

Keywords Dyslipidemia · Rural–Urban population · Non-communicable disease (NCD) · Lipid abnormality · Cardiovascular Risk

Introduction

Atherosclerotic cardiovascular disease (ASCVD) is a major cause of morbidity and mortality, with a high incidence and prevalence in low- and middle-income countries. South Asians, in particular, have a higher risk of ASCVD than other ethnic populations [1, 2]. In India, the number of prevalent cases of cardiovascular diseases (CVD) has increased from 25.7 million in 1990 to 54.5 million in 2016 [3]. Dyslipidemia is one of the crucial risk factors for CVD and is characterized by any or a combination of the following: elevated total cholesterol (TC), raised low-density lipoprotein cholesterol (LDL-C), raised triglycerides (TG), and low high-density lipoprotein cholesterol (HDL-C) [4]. These adverse lipid profiles are closely linked to the pathophysiology of atherosclerosis, the key underlying process contributing to most clinical ASCVD events [5].

According to the 2016 Lipid Association of India report, the frequency of hypercholesterolemia varies from 10 to 15% in rural to 25% to 30% in urban populations [6]. There are very few large cohort studies on the epidemiology of

✉ Sundaresan Mohanraj
  mohanraj@kmchrf.org

1 Department of Biochemistry and Microbiology, KMCH Research Foundation, Kovai Medical Center & Hospital, Coimbatore 641014, Tamilnadu, India

2 Department of Endocrinology, KMCH Research Foundation, Kovai Medical Center and Hospital, Coimbatore, India

3 Department of Gastroenterology, KMCH Research Foundation, Kovai Medical Center and Hospital, Coimbatore, India

hypercholesterolemia in India [7–12], but these studies are not representative of different demographic regions in India. However, there is limited data available on the prevalence of lipid abnormalities based on rural versus urban living in India. Urban–rural differences in adverse lipid profiles may be prevalent due to several factors such as less physical activity, high consumption of fast food, and unsaturated fat intake in urban areas, which may contribute to a higher prevalence of dyslipidemia compared to rural areas. The rising rates of non-communicable diseases (NCD) in both urban and rural India demonstrate that lifestyles and urbanization are common but not fully accounted for. Rapid urbanization is initiated by urban expansion into peripheral and rural areas, largely for economic reasons. Although it is not clear how industrialization or urbanization increases the risk of metabolic risk factors among people who have had different early life experiences, several regions of India experience different climate and geographical conditions due to substantial latitude and longitude extensions across the country.

However, we could not find any data regarding the sub-urban population compared with the urban and rural populations. Therefore, the aim of the present investigation was to describe the prevalence of dyslipidemia and the risk factors associated with individual adverse lipid profiles among adults living in rural, sub-urban, and urban areas in India.

Methodology

Study design A community-based cross-sectional study.

Study sites and population details

Rural-population details The Nallampatti Panchayat has population of 3,874 of which 1,929 are males while 1,945 are females as per report released by Census India 2011.

Sub-urban-population details The Chinna Thadagam Panchayat has population of 8,407 of which 4,152 are males while 4,255 are females as per report released by Census India 2011.

Urban-population details The Kalapatti Town Panchayat has population of 39,586 of which 19,936 are males while 19,650 are females as per report released by Census India 2011.

Study areas

The methodology of the study is described in our earlier publications (13, 14). In brief, we selected three different geographic areas based on contacts with administrative heads, logistics, and the ability to conduct long-term follow-up. Nallampatti, a typical farming village about

60 km from Coimbatore, was chosen as a representative rural area. Thadagam, an area rich in brick-kilns 15 km from Coimbatore, and Kalapatti, a city within Coimbatore, were chosen as representative sub-urban and urban areas, respectively. The individual studies were named Nallampatti-NCD study (NNCD), Thadagam-NCD study (TNCD), and Kalapatti-NCD study (KNCD). The studies were conducted in a staggered pattern over a four-week period in each area from April 2015 to June 2016. Each study population was informed of our visit through the distribution of leaflets (door to door) and by "word of mouth" through the local government administrative workers and student volunteers. The exclusion criteria included age less than 20 years or greater than 85 years, pregnancy, and non-residents of the selected regions. Age 20 years and above and native residents were included in this study. All three areas had a defined geographical boundary, and the population data was collected from the Government of India – Census 2011. Only the residents of these regions were invited for the study. The residence of the participants was cross-checked by verification with the government census data and the proof of residence documents, such as Aadhar card, voter ID card, or driving license, provided by the participants. The study design and protocol were approved by KMCH Ethic Committee, and informed written consent was obtained from all participants prior to participation, following the principles of the Declaration of Helsinki. Collected data were evaluated on a weekly basis, and feedback was sent to the study team in the field to correct any discrepancies.

Sample and data collection from sub-urban and urban regions

We administered a detailed questionnaire, as described in previous publications [13, 14], to document the educational status, employment, alcohol intake, smoking status, pesticide exposure, family disease history, and past medical history.

Anthropometry

We measured body weight using an electronic weighing scale (SECA 813), height using a stadiometer (SECA 208), and waist circumference in centimeters using a non-stretchable measuring tape between the costal margins and the iliac crest at the end of expiration. Blood pressure was recorded using the electronic OMRON machine in the sitting position in the right arm (Model HEM-7130, Omron healthcare, Singapore) on two occasions 15 min apart. We used the mean of the two measurements in analyses. Body mass index was calculated using the formula weight (kg)/height (m)^2.

Clinical parameters

We prepared serum and plasma samples from whole blood collected appropriately by standard protocols. HbA1c was measured using an automated HPLC method (D-10-Biorad), cystatin-c was determined by Nephlometric method (BN Prospec-Siemens), glucose was measured using a Hexokinase/ GOD-POD/ endpoint method, and lipid levels were measured using an automated analyzer (Abbott Architect ci8200). Uric acid and creatinine levels were measured by the Endpoint method (Abbott Architect ci8200). Fasting and post-meal glucose were not considered due to logistical issues.

Definitions

Dyslipidemia: National Cholesterol Education Programme (NCEP) [6] guidelines were used for definition of dyslipidemia as follows:

> Hypercholesterolemia – serum cholesterol levels ≥ 200 mg/dl (≥ 5.2 mmol/l).
> Hypertriglyceridemia – serum triglyceride levels ≥ 150 mg/dl (≥ 1.7 mmol/l).
> Low HDL cholesterol – HDL cholesterol levels < 40 mg/dl (< 1.04 mmol/l) for men and < 50 mg/dl (< 1.3 mmol/l) for women.
> High LDL cholesterol – LDL cholesterol levels ≥ 130 mg/dl (≥ 3.4 mmol/l) calculated using the Friedewald equation.

> Hypertension was defined as either having a history of hypertension on medications or a systolic blood pressure of ≥ 140 mm Hg and/ or diastolic blood pressure ≥ 90 mm Hg on two occasions taken 15 min apart, in those without a history of hypertension.
> Overweight was defined as BMI equal to or more than 25 kg/m², and 'obesity' as BMI equal to or more than 30 kg/m².
> Diabetes was defined as either having a history of diabetes on medications or HbA1c level of ≥ 6.5% in those without a history of diabetes.

Statistical analysis

Data were tabulated on Microsoft Excel and transposed to SPSS for statistical analysis (SPSS) (IBM Corporation, Armonk, New York, USA). Data were analysed using SPSS version 20. Chi-square tests and multivariable logistic regression were performed to found the demographical prevalence and risk factors associated with lipid abnormalities

among study participants. We analysed basic characteristics based the dyslipidemia by study sites (rural vs sub-urban vs urban) and sex. Prevalence of dyslipidemia in both men and women were analyzed for three demographic areas. Mean values of BMI, HbA1c and blood pressure were analysed. Prevalence of dyslipidemia in diabetes and hypertension population were analyzed for three demographic areas. Both, men and women were analysed separately as we anticipated that there might be sex differences in location (rural, sub-urban and urban) effects. Multivariable logistic regression model was used to estimate odds ratios for hypercholesterolemia, triglyceridemia, low HDL-C and high LDL-C, adjusting for age and BMI. A p value < 0.05 was considered statistically significant.

Results

A total of 2976 participants were enrolled in this study from rural, sub-urban, and urban communities in Tamil Nadu, India. Of these, 865 (29.1%) were rural residents, 1030 (34.6%) were sub-urban residents, and 1081 (36.3%) were urban dwellers. The general characteristics of the study population based on dyslipidemia are shown in Table 1. In all three demographics, residents with any lipid abnormality had significantly higher risk factors of BMI, waist circumference, HbA1c, total cholesterol, triglycerides, low-HDL, and high-LDL than those with no lipid abnormality. The mean age (SD) of rural residents with any lipid abnormality was significantly higher than that of normal residents ($p < 0.05$), whereas sub-urban and urban dwellers did not differ significantly between normal and any lipid abnormality residents. Similarly, the mean values of systolic and diastolic blood pressure in rural ($p = 0.002$ and $p = 0.05$, respectively) and urban ($p = 0.005$ and $p = 0.002$, respectively) residents with any lipid abnormality were significantly higher than those with no lipid abnormality, while the sub-urban residents with any lipid abnormality were not significantly different from those with no lipid abnormality. The prevalence of dyslipidemia (any lipid abnormality) was similar among sub-urban and urban residents (85.9% vs 86.2%) compared to rural participants (78.5%). Among the three demographics, 8.3% ($n = 72$), 9.1% ($n = 94$), and 16.4% ($n = 177$) of the rural, sub-urban, and urban populations had four lipid abnormalities, respectively. On the other hand, about 21.5% ($n = 186$), 14.1% ($n = 145$), and 13.8% ($n = 149$) of the rural, sub-urban, and urban populations had no lipid abnormalities, respectively. Low HDL-C was the most common dyslipidemia, particularly among sub-urban residents (70% vs 58.2% in rural and 68.1% in urban). The dwellers with high LDL-C were highest in urban areas (38.6%) compared to sub-urban (21.1%) and rural (24.1%) areas.

Table 1 Basic characteristics of the study population based on the dyslipidemia

Clinical parameters	Rural (n = 865)			Sub-urban (n = 1030)			Urban (n = 1081)			Overall p Value
	Normal (n = 186)	Any lipid abnormality (n = 679)	p Value	Normal (n = 145)	Any lipid abnormality (n = 885)	p Value	Normal (n = 149)	Any lipid abnormality (n = 932)	p Value	
Age	46.47 (15.39) [44.25–48.70]	48.79 (13.19) [47.80–49.79]	.04	51.6 (15.9) [49.0–54.2]	50.1 (14.4) [49.1–51.0]	.25	46.5 (17.1) [43.7–49.3]	48.8 (13.3) [47.9–49.6]	.06	.002
BMI	21.16 (3.9) [20.59–21.72]	23.82 (3.97) [23.53–24.12]	<.001	20.8 (4.3) [20.1–21.5]	23.9 (5.4) [23.6–24.3]	<.001	22.0 (4.7) [21.3–22.8]	25.6 (7.2) [25.2–26.1]	<.001	<.001
SBP	126.6 (18.3) [124.0–129.3]	132.08 (21.5) [130.46–133.7]	.002	128.3 (21.7) [124.7–131.8]	130.5 (22.3) [129.1–132.0]	.25	124.0 (23.2) [120.3–127.8]	129.4 (21.6) [128.0–130.8]	.005	.074
DBP	80.60 (11.33) [78.96–82.24]	82.51 (11.9) [81.61–83.41]	.05	77.7 (12.7) [75.7–79.8]	78.4 (11.2) [77.7–79.2]	.52	74.5 (11.8) [72.6–76.5]	77.8 (11.5) [77.0–78.5]	.002	<.001
Waist circumference	84.88 (8.71) [83.6–86.1]	91.07 (9.2) [90.37–91.7]	<.001	84.36 (11.7) [82.4–86.3]	90.2 (10.8) [89.5–91.0]	<.001	85.5 (12.3) [83.5–87.5]	92.9 (10.0) [92.3–93.6]	<.001	<.001
Creatinine	0.76 (0.23) [0.73–0.79]	0.75 (0.18) [0.74–0.77]	.49	0.71 (.31) [0.6–0.7]	0.7 (0.3) [0.6–0.7]	.92	0.8 (0.7) [0.6–0.9]	0.7 (0.2) [0.7–0.7]	.09	<.001
HbA1c	5.7 (0.86) [5.65–5.8]	6.04 (1.16) [5.95–6.13]	.003	5.8 (1.2) [5.6–6.0]	6.2 (1.6) [6.1–6.3]	.001	5.8 (1.1) [5.6–6.0]	6.2 (1.5) [6.1–6.3]	.001	<.001
Uric acid	4.4 (1.3) [4.3–4.6]	4.8 (1.3) [4.7–4.9]	.001	5.1 (1.5) [4.8–5.3]	5.2 (1.5) [5.1–5.3]	.33	4.8 (4.4) [4.1–5.5]	4.9 (1.3) [4.8–5.0]	.43	<.001
TC	165.2 (20.5) [162.2–168.2]	191.2 (40.7) [188.1–194.3]	<.001	165.3 (22.8) [161.5–169.1]	186.3 (40.0) [183.6–188.9]	<.001	164.5 (20.8) [161.2–167.9]	192.9 (39.3) [190.4–195.4]	<.001	.003
TGL	88.1 (26.18) [84.2–91.8]	189.7 (112.1) [181.3–198.2]	<.001	91.9 (28.4) [87.2–96.6]	189.8 (106.5) [182.7–196.8]	<.001	91.8 (29.6) [87.0–96.6]	198.3 (128.0) [190.1–206.5]	<.001	.010
L-HDLC	52.5 (7.4) [51.4–53.6]	41.9 (8.9) [41.2–42.5]	<.001	51.3 (7.2) [50.1–52.5]	39.8 (8.5) [39.2–40.3]	<.001	54.5 (9.5) [52.9–56.1]	40.2 (9.9) [39.5–40.8]	<.001	<.001
H-LDLC	93.2 (19.0) [90.4–96.0]	114.2 (32.6) [111.8–116.7]	<.001	95.6 (20.2) [92.2–98.9]	108.6 (33.4) [106.4–110.8]	<.001	95.9 (18.5) [92.9–98.9]	125.4 (32.7) [123.3–127.5]	<.001	<.001

The values are mean (SD) [95%CI]

(One-way ANOVA test was used to compare means of continuous variables between the normal and any lipid abnormality among the three groups (rural, sub-urban and urban))

BMI Body-mass index; SBP Systolic blood pressure; DBP Diastolic blood pressure; HbA1c Heamoglobin A1c; TC Total cholesterol; TGL Triglyceride; L-HDLC Low- high-density lipoproteins; H-LDLC High- low-density lipoproteins

As shown in Table 2, all lipid abnormalities were higher among women than among men in all three areas of residence, except for triglycerides. Regarding the four components of dyslipidemia, raised triglycerides recorded a higher prevalence in men compared to women in all three areas of participants. In sub-urban residences, raised total cholesterol had a similar prevalence in both men (29.9%; 95% CI 25.8–33.9) and women (29.9%; 95% CI 26.2–33.9), whereas raised total cholesterol had a higher prevalence in rural (32.5%; 95% CI 28.2–37.1 for men and 34.2%; 95% CI 29.8–38.9 for women) and urban settings (36.8%; 95% CI 32.4–41.6 for men and 37.8%; 95% CI 34.1–41.7 for women). The prevalence of low levels of HDL-C was higher in suburban (58.2% for men, 95% CI 53.7–62.7; 80% for women, 95% CI 76.5–83.2) and urban (58.7% for men, 95% CI 54.1–63.2; 74.7% for women, 95% CI 70.8–78.1) areas than in rural areas (52.3% for men, 95% CI 47.7–56.6; 63.8% for women, 95% CI 59.6–68.4). Similarly, raised LDL-C had a higher prevalence among urban dwellers (37.9%; 95% CI 33.1–42.7 for men and 39.2%; 95% CI 35.3–42.9 for women) compared to rural (23.6%; 95% CI 19.8–28 for men and 24.7%; 95% CI 20.9–28.7 for women) and sub-urban populations (20.5%; 95% CI 17.1–24.1 for men and 21.7%; 95% CI 18.2–25.3 for women). The mean and standard deviation values of all lipid abnormalities were highest among the urban population compared to rural and sub-urban dwellers.

Figure 1 presents the prevalence of the four components of dyslipidemia according to age groups and sex in rural, sub-urban, and urban residences. Below the age of 40 years, men were more likely than women to have dyslipidemia, whereas after the age of 40 years, men showed a lower risk of dyslipidemia than women, except for low-HDL cholesterol. The highest prevalence was observed at the age of 40–59 years and declined afterward. In comparison to men, sub-urban women had an 80% prevalence of low-HDL cholesterol, which was higher in residents of rural and urban areas. Overall, women had significantly higher rates of lipid abnormalities than males, except for raised triglycerides, which was higher in men in all three residences.

Table 3 summarizes the lipid abnormalities in residents with diabetes and hypertension according to the area of residence. Among the study participants, the prevalence of diabetes was 16.1%, 25.8%, and 23% in rural, suburban, and urban areas, respectively. Among these participants with diabetes, the prevalence of high total cholesterol (TC), high triglycerides (TG), high low-density lipoprotein cholesterol (LDL-C), and low high-density lipoprotein cholesterol (HDL-C) was 35.3%, 49.6%, 25.2%, and 63.3% among rural dwellers; 34.2%, 62%, 21.4%, and 72.9% among suburban residents; and 41%, 68%, 43.4%, and 72.3% among urban populations. Furthermore, we found that the prevalence of hypertension was 36.4%, 47%, and 39.7% in rural, suburban, and urban areas, respectively. Among these participants with hypertension,

Table 2 Sex specific prevalence of lipid abnormalities in study participants (Chi-square test)

Lipid Profile	Total (n=2976)		Rural (n=865)			Sub-urban (n=1030)			Urban (n=1081)		
	Men (n=1322)	Women (n=1654)	Men (n=415)	Women (n=450)	p value	Men (n=469)	Women (n=561)	p value	Men (n=438)	Women (n=643)	p value
Count (%) [95% CI]											
Hypercholesterolemia	436(33) [30.6–35.6]	565(34.2) [31.9–36.5]	135(32.5) [28.2–37.1]	154(34.2) [29.8–38.9]	0.325	140(29.9) [25.8–33.9]	168(29.9) [26.2–33.9]	0.514	161(36.8) [32.4–41.6]	243(37.8) [34.1–41.7]	0.390
Hypertriglyceridemia	727(55) [52.3–57.7]	722(43.7) [41.1–46.1]	211(50.8) [46.3–55.4]	165(36.7) [32.2–40.9]	0.000	256(54.6) [49.9–58.6]	249(44.4) [40.3–48.8]	0.001	260(59.4) [54.8–63.7]	308(47.9) [43.9–51.6]	0.000
L-HDLC	747(56.5) [53.8–59.3]	1216(73.5) [71.2–75.6]	217(52.3) [47.7–56.6]	287(63.8) [59.6–68.4]	0.000	273(58.2) [53.7–62.7]	449(80) [76.5–83.2]	0.000	257(58.7) [54.1–63.2]	480(74.7) [70.8–78.1]	0.000
H-LDLC	360(27.2) [24.9–29.6]	485(29.3) [27.1–31.6]	98(23.6) [19.8–28]	111(24.7) [20.9 28.7]	0.389	96(20.5) [17.1–24.1]	122(21.7) [18.2–25.3]	0.336	166(37.9) [33.1–42.7]	252(39.2) [35.3–42.9]	0.358

L-HDLC Low- high-density lipoproteins; H-LDLC High- low-density lipoproteins

Fig. 1 Age- and demographic-specific prevalence of dyslipidemia in the study population
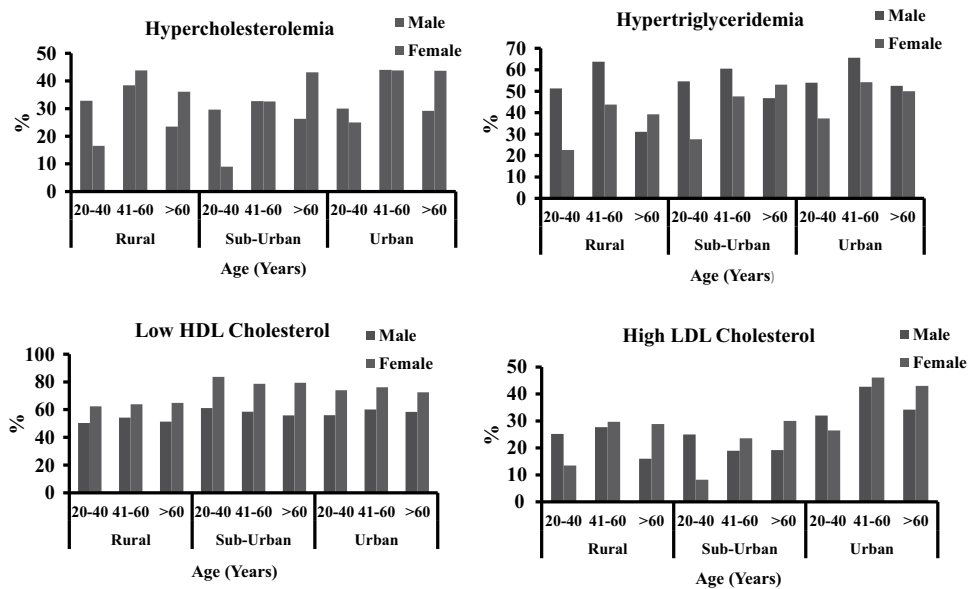
the prevalence of high TC, high TG, high LDL-C, and low HDL-C was 35.9%, 54.6%, 24.1%, and 63.2% among rural dwellers; 36.1%, 56.7%, 25.8%, and 66.8% among suburban residents; and 43.4%, 58.3%, 44.1%, and 69.7% among urban populations. Overall, the prevalence of dyslipidemia in participants with diabetes and hypertension was highest in sub-urban and urban areas compared to rural areas.

Table 4 describes the results of multivariable logistic regression to identify the risk factors associated with lipid abnormalities in the study population. After adjusting for age and BMI, hypercholesterolemia was associated with suburban areas, male gender, age 40–59 years, current drinking, and being underweight. Hypertriglyceridemia was associated with rural areas, male gender, age 40–59 years, current smoking, being underweight, overweight, diabetes, and hypertension. Low HDL-C was associated with rural and suburban areas, male gender, current smoking, current drinking, being underweight, overweight, obesity, and diabetes. High LDL-C was associated with rural and suburban areas, male gender, and being underweight or overweight.

Discussion

In the current study, we investigated the prevalence and risk factors of dyslipidemia among Indian adults aged ≥ 20 in various demographic groups, including rural, sub-urban, and urban populations. Our findings indicate that more than 85% of the sub-urban and urban populations had dyslipidemia (at

Table 3 Prevalence and association of dyslipidemia in diabetic and hypertensive population (Chi-square test)

Diabetic Population (Count and %)				
	Total ($n = 654/2976$)	Rural ($n = 139/865$)	Sub-urban ($n = 266/1030$)	Urban ($n = 249/1081$)
Hypercholesterolemia	242(37)***	49(35.3)***	91(34.2)***	102(41)***
Hypertriglyceridemia	405(61.9)***	69(49.6)**	165(62)***	171(68.7)***
L-HDL	462(70.6)***	88(63.3)NS	194(72.9)NS	180(72.3)**
H-LDL	200(30.6)***	35(25.2)**	57(21.4)*	108(43.4)***
Hypertensive Population (Count and %)				
	Total ($n = 1229/2976$)	Rural ($n = 315/865$)	Sub-urban ($n = 485/1030$)	Urban ($n = 429/1081$)
Hypercholesterolemia	474(38.6)***	113(35.9)NS	175(36.1)***	186(43.4)**
Hypertriglyceridemia	697(56.7)***	172(54.6)***	275(56.7)***	250(58.3)**
L-HDL	822(66.9)NS	199(63.2)*	324(66.8)*	299(69.7)*
H-LDL	390(31.7)***	76(24.1)NS	125(25.8)***	189(44.1)**

*** $= p \leq .001$; ** $= p \leq .01$; * $= p \leq .05$; NS $= p > .05$; L-HDLC- Low- high-density lipoproteins; H-LDLC- High- low-density lipoproteins

Table 4 Association of risk factors with dyslipidemia by multivariable logistic regression: age and BMI adjusted

Risk factors	All demographic data pooled (Odd ratio (95% CI) p Value)			
	Hypercholesterolemia	Hypertriglyceridemia	Low-HDL	High-LDL
Area				
Rural	1.069(0.87–1.31) p = .537	1.28(1.04–1.57)p = .017	1.3(1.1–1.65)p = .005	1.8(1.4–2.2)p < .001
Sub-urban	1.29(1.06–1.6) p = .012	1.07(0.88–1.3)p = .47	0.8(0.65–1.0)p = .023	2.1(1.7–2.6)p < .001
Urban	1(ref)	1(ref)	1(ref)	1(ref)
Sex				
Male	1.3(1.01–1.6)p = .028	0.67(0.54–0.83)p < .001	2.26(1.8–2.8)p < .001	1.3(1.-1.7)p = .01
Female	1(ref)	1(ref)	1(ref)	1(ref)
Age Groups, years				
20–39	1(ref)	1(ref)	1(ref)	1(ref)
40–59	0.70(0.51–1.0)p = .027	0.68(0.51–0.92)p = .013	1.07(0.79–1.5)p = .64	0.87(0.63–1.2)p = .41
≥ 60	1.23(0.72–2.1) p = .458	1.1(0.65–1.8)p = .72	0.96(0.56–1.64)p = .89	1.5(0.84–2.5)p = .17
Education				
None	1(ref)	1(ref)	1(ref)	1(ref)
Primary	0.93(0.73–1.2)p = .55	1.0(0.78–1.3)p = .97	1.1(0.9–1.5)p = .20	0.89(0.69–1.14)p = .36
Secondary	1.12(0.88–1.4)p = .33	0.92(0.72–1.16)p = .45	0.87(0.67–1.1)p = .27	1.0(0.78–1.3)p = .87
Degree	0.93(0.69–1.26)p = .66	1.0(0.77–1.4)p = .82	1.12(0.82–1.5)p = .46	0.76(0.55–1.0)p = .08
Employment status				
Not-working	1(ref)	1(ref)	1(ref)	1(ref)
Employed	0.94(0.76–1.16)p = .56	0.87(0.71–1.1)p = .16	1.0(0.82–1.2)p = .81	1.0(0.8–1.2)p = .80
Smoking				
Non-Smoker	1(ref)	1(ref)	1(ref)	1(ref)
Current Smoker	0.95(0.73–1.23)p = .67	0.73(0.57–0.95)p = .02	0.62(0.48–0.8)p < .001	0.869(0.65–1.14)p = 0.32
Alcohol				
Non-drinker	1(ref)	1(ref)	1(ref)	1(ref)
Drinker	0.71(0.55–0.92)p = .01	1.0(0.8–1.3)p = .86	1.4(1.09–1.8)p = .007	0.8(0.61–1.0)p = .11
Tobacco				
Non-Chewing	1(ref)	1(ref)	1(ref)	1(ref)
Tobacco chewing	1.0(0.82–1.23)p = .94	1.14(0.94–1.4)p = .19	1.1(0.9–1.3)p = .28	0.96(0.78–1.1)p = .75
BMI Categories				
Normal	1(ref)	1(ref)	1(ref)	1(ref)
Underweight	1.81(1.3–2.6)p = .008	3.2(2.3–4.4)p < .001	2.5(1.9–3.4)p < .001	1.8(1.2–2.6)p = .001
Overweight	0.77(0.6–0.98)p = .127	0.62(0.5–0.8)p < .001	0.67(0.53–0.84)p = .001	0.78(0.62–0.98)p = .03
Obesity	1.3(0.8–2.0)p = 0.46	0.9(0.6–1.3)p = .6	0.54(0.34–0.83)p = .006	0.98(0.65–1.4)p = .94
Diabetes				
Normal	1(ref)	1(ref)	1(ref)	1(ref)
Diabetes	1.12(0.92–1.37)p = .268	0.66(0.54–0.8)p < .001	0.79(0.64–0.98)p = .03	1.1(0.93–1.4)p = .18
Hypertension				
Hypertension	0.85(0.71–1.02)p = .087	0.74(0.62–0.88)p = .001	1.3(0.86–1.2)p = .69	0.88(0.73–1.06)p = .20
Normotensive	1(ref)	1(ref)	1(ref)	1(ref)

L-HDLC Low- high-density lipoproteins; *H-LDLC* High- low-density lipoproteins; Dependent variables: Total cholesterol, Triglyceride, Low-high-density lipoproteins and low-density lipoproteins; Controlling variables: Age and BMI

least one lipid abnormality), compared to 78.5% of those living in rural areas. This finding is consistent with a previous ICMR-INDIAB study that found 76.9% of people in the Tamil Nadu region had at least one abnormal lipid.

The main findings of our investigation are as follows: first, the highest prevalence rates of hypercholesterolemia, hypertriglyceridemia, and high LDL-C were observed in the urban population compared to sub-urban and rural populations, respectively. Conversely, L-HDL-C was the most common dyslipidemia, particularly in sub-urban residents. Additionally, the middle-aged group (40–59 years) had a higher prevalence of dyslipidemia, particularly among

women. Furthermore, we observed higher prevalence rates in individuals with diabetes and hypertension across all residence types. Hypercholesterolemia, hypertriglyceridemia, and high LDL cholesterol were more prevalent in individuals with diabetes and hypertension residing in urban areas than in those in rural and sub-urban areas. Moreover, we found that age group, gender, current drinking habits, overweight and obesity, diabetes, and hypertension were significantly associated with dyslipidemia. However, we did not find any association between education, employment status, tobacco chewing, and any dyslipidemia.

The prevalence rates in the present study were comparable to those reported in previous studies. Similar prevalence rates were reported among Asian Indian immigrants in the United States ($n = 1038$) [15], including hypercholesterolemia (43.5%), hypertriglyceridemia (42.3%), low HDL-C (26.4%), and high LDL-C (41.4%). The India Heart Watch study ($n = 6123$)11 reported that the prevalence of hypercholesterolemia was 25.0% (men 24.8%, women 25.3%), high LDL cholesterol was 15.8% (men 16.3%, women 15.1%), hypertriglyceridemia was 36.9% (men 41.2%, women 31.5%), and low HDL cholesterol was 42.5% (men 34.1%, women 53.0%). The recent FitHeart study ($n = 46,919$) reported the prevalence of various cholesterol lipoprotein and triglyceride levels in more than 20 states of India13. They found that hypercholesterolemia was observed in 26.9% (men 24.0%, women 30.8%), hypertriglyceridemia in 42.6% (men 45.6%, women 38.6%), high LDL-C in 60.0% (men 57.6%, women 63.1%), and low HDL cholesterol in 56.0% (men 49.9%, women 64.5%). Another larger ICMR-INDIAB study reported that the prevalence of hypercholesterolemia was found in 13.9%, hypertriglyceridemia in 29.5%, low HDL-C in 72.3%, and high LDL-C in 11.8% of the Indian population12. Misra et al. [16] used different cut point values in their study ($n = 532$). They used hypertriglyceridemia > 200 mg/dl and low HDL-C < 35 mg/dl as cut points among adults aged > 25 years in the urban slums of northern India. They reported that the prevalence of hypercholesterolemia (men 26.8%, women 27.5%), hypertriglyceridemia (men 16.8%, women 12.3%), low HDL-C (men 15.8%, women 16.7%), and high LDL-C (men 26%, women 25.4%) was observed. All these studies reported a low prevalence of hypercholesterolemia compared to hypertriglyceridemia and low HDL-C, which is similar to the findings of the present study. These findings suggest that various components of atherogenic dyslipidemia may be the more important lipid phenotype in Asian Indians [11]. The low HDL-C found among sub-urban and urban dwellers was consistent with an earlier report [12] and showed the unhealthy HDL-C lipid abnormality status among urban populations, which could put them at risk of coronary artery disease (CAD) [17]. However, the mean value of low HDL-C was lower in urban populations compared to rural populations, whereas the mean cholesterol level was higher in urban than in rural populations. These results were consistent with previous surveys,

which have also shown higher mean levels of total cholesterol in urban participants compared to rural participants, with a low mean level of low HDL cholesterol [18]. The higher prevalence of low HDL-C may be part of the Asian Indian Phenotype, which includes increased plasma insulin levels, insulin resistance, increased waist circumference, excess visceral fat, and low adiponectin levels, as reported by Deepa et al. [18]. Additionally, urban residence, comparatively less physical activity, fast food culture, high intake of salt, sugar, and saturated fat may contribute to the higher prevalence of dyslipidemia. The prevalence of hypercholesterolemia, hypertriglyceridemia, and high LDL levels among the rural population was higher than the findings from an earlier report [12]. Moreover, a recent review reported that the prevalence of hypercholesterolemia in the 1990s was 16%, and it has increased to 25–35% among rural India in recent years [19]. The reasons for these results could be attributed to the higher prevalence of current smokers and alcohol consumption among the rural population compared to sub-urban and urban populations. A previous study estimated that current smoking might increase the risk of dyslipidemia in both women and men [20].

On the other hand, Singh et al. [21] reported that the incidence of hypercholesterolemia was 59%, hypertriglyceridemia was 53%, low HDL-C was 89%, and high LDL-C was 98% among diabetes patients. However, these prevalence rates were higher than those of the present study. Bali et al. [22] stated that the prevalence of dyslipidemia in diabetes patients was 81.8%, and among these patients, hypercholesterolemia was 36.5%, hypertriglyceridemia was 57.2%, high LDL levels were 59.3%, and low HDL was 34.4%. The high LDL-C was much higher than in the present study. These above reports were not comparable to the present study owing to the study population, as ours is a general community-based population, but they investigated only diabetes patients from a single health center. Other studies have reported diabetes-dyslipidemia as a frequent comorbidity [23–25]. Furthermore, the prevalence of dyslipidemia was high among hypertensive subjects in our study. This may be owing to dyslipidemia causing endothelial damage, which can lead to a loss of physiological vasomotor activity with consequent elevated systemic blood pressure. A previous report stated that the incidence of dyslipidemia is more frequent in hypertensive than in normal populations [26]. Also, hypercholesterolemia and hypertension can coexist, resulting in dyslipidemic hypertension. The above comorbidities constitute important risk factors for CVD. Therefore, appropriate risk assessments and monitoring of serum lipids among diabetes and hypertensive patients will remain crucial to reduce the risk of CVD mortality.

In this study, we analyzed the associations between individual dyslipidemia and risk factors. After adjusting for age and BMI, we found that area, gender, and BMI were common risk factors for all types of dyslipidemia. Participants

from rural areas showed a significant association with hypertriglyceridemia, low HDL-C, and high LDL-C, while sub-urban participants were associated with hypercholesterolemia, low HDL-C, and high LDL-C. These findings indicate that demographic areas tend to have a greater risk of some dyslipidemias. The reasons for these associations might be lifestyle factors and environmental factors such as exposure to air pollution [27, 28]. Furthermore, in our study, current smoking, current drinking, BMI, diabetes, and hypertension were significantly associated with low HDL-C, consistent with our previous study [12, 29]. Overall, the higher prevalence of dyslipidemia and its associated risk factors found in this study suggest that these risk factors play major roles in blood lipid pathology and must be targeted.

This study builds on previous knowledge about dyslipidemia patterns in the Indian population by taking advantage of a dataset that allows comparisons according to rural, sub-urban, and urban settings. Several researchers have reported urban–rural differences in the prevalence of cardiovascular risk factors and their mortality rates in India. For a country like India, which contains a large number of small towns called semi-urban or sub-urban or census towns, which are very close to major cities (within 10–50 km), despite rapid urbanization, the majority of sub-urban areas in India do not have facilities for screening and early detection of cardiovascular risk factors compared to urban residents. This may be the first study to report the prevalence of dyslipidemia in rural, sub-urban, and urban cohorts in India. This study was based on data from the KMCH-NCD study, which was conducted among participants from three different regions. Therefore, its findings may be seen as representative and convincing. However, several limitations should be considered. The main limitation of our study is that we used a convenience sample rather than a representative sample. In addition, sociodemographic information was obtained through a questionnaire, which may lead to recall bias. Furthermore, the prevalence of dyslipidemia was based on non-fasting blood samples, and information on lipid-lowering therapy and non-fasting blood samples was not collected in this study, which is another limitation. Thus, it is possible that prevalence rates may be exaggerated due to sampling bias. However, recently, the lipid association of India reported that non-fasting lipid concentrations might be a better indicator of average lipid concentrations in the blood than fasting concentrations [6].

Conclusion

This study presents the most recent prevalence of dyslipidemia in rural, sub-urban, and urban India, revealing a higher prevalence of dyslipidemia in urban residents. The middle age group (40–59 years) showed a higher prevalence of dyslipidemia, with women having a higher prevalence than men. Hypercholesterolemia, hypertriglyceridemia, and high LDL cholesterol were more common in urban residents with diabetes and hypertension compared to rural and sub-urban residents. Age group, gender, current alcohol consumption, overweight, obesity, diabetes, and hypertension were identified as common risk factors for dyslipidemia. These findings underscore the need for action to more effectively reduce dyslipidemia and prevent cardiovascular disease in India. Thus, appropriate risk assessments and routine monitoring of serum lipids among patients with diabetes and hypertension will remain crucial in reducing the risk of CVD mortality.

Ethical declarations

References

1. Enas EA, Garg A, Davidson MA, Nair VM, Huet BA, Yusuf S. Coronary heart disease and its risk factors in first-generation immigrant Asian Indians to the United States of America. Indian Heart J. 1996;48:343–53.
2. Talegawkar SA, Jin Y, Kandula NR, Kanaya AM. Cardiovascular health metrics among South Asian adults in the United States: prevalence and associations with subclinical atherosclerosis. Prev Med. 2017;96:79–84.
3. India State-Level Disease Burden Initiative CVD Collaborators. The changing patterns of cardiovascular diseases and their risk factors in the states of India: the Global Burden of Disease Study 1990–2016. Lancet Glob Health. 2018;6(12):e1339–51.
4. Musunuru K. Atherogenic dyslipidemia: cardiovascular risk and dietary intervention. Lipids. 2010;45(10):907–14.
5. Jacobson TA, Ito MK, Maki KC, Orringer CE, Bays HE, Jones PH, et al. National Lipid Association recommendations for

patient-centered management of dyslipidemia: part 1 - executive summary. J Clin Lipidol. 2014;8:473–88.

6. Iyengar SS, Puri R, Narasingan SN, et al. Lipid Association of India Expert Consensus Statement on Management of Dyslipidemia in Indians 2016: Part 1. J Assoc Physicians India. 2016;64(3 suppl):7–52.

7. Reddy KS, Prabhakaran D, Chaturvedi V, et al. behalf of the Sentinel Surveillance System for Indian Industrial Populations Study Group: methods for establishing a surveillance system for cardiovascular diseases in Indian industrial populations. Bull WHO. 2006;84:461–9.

8. Kinra S, Bowen LJ, Lyngdoh T, et al. Sociodemographic patterning of noncommunicable disease risk factors in rural India: a cross sectional study. BMJ. 2010;341:c4974.

9. Shah B, Mathur P. Surveillance of cardiovascular disease risk factors in India: the need and scope. Indian J Med Res. 2010;132:634–42.

10. Pandey RM, Gupta R, Misra A, et al. Determinants of urban-rural differences in cardiovascular risk factors in middle-aged women in India: a cross-sectional study. Int J Cardiol. 2013;163:157–62.

11. Gupta S, Gupta R, Deedwania P, et al. Cholesterol lipoproteins, triglycerides and prevalence of dyslipidemias among urban Asian Indian subjects: a cross sectional study. Indian Heart J. 2014;66:280–8.

12. Joshi SR, Anjana RM, Deepa M, ICMR-INDIAB Collaborative Study Group, et al. Prevalence of dyslipidemia in urban and rural India: the ICMR-INDIAB study. PLos One. 2014;9:e96808.

13. Swaminathan K, Veerasekar G, Kuppusamy S, et al. Noncommunicable disease in rural India: Are we seriously underestimating the risk? The Nallampatti noncommunicable disease study. Ind J Endocrinol Metab. 2017;21:90–5.

14. Velmurugan G, Swaminathan K, Veerasekar G, Purnell JQ, Mohanraj S, et al. Metals in urine in relation to prevalence of pre-diabetes, diabetes and atherosclerosis in rural India. Occup Environ Med. 2018;75:661–7.

15. Misra R, Patel T, Kotha P, Raji A, Ganda O, et al. Prevalence of diabetes, metabolic syndrome, and cardiovascular risk factors in US Asian Indians: results from a national study. J Diabetes Complications. 2010;24:145–53.

16. Misra A, Pandey RM, Devi JR, Sharma R, Vikram NK, et al. High prevalence of diabetes, obesity and dyslipidaemia in urban slum population in northern India. Int J Obes Relat Metab Disord. 2001;25:1722–9.

17. McGill HC Jr, McMahan CA, Malcom GT, Oalmann MC, Strong JP. Effects of serum lipoproteins and smoking on atherosclerosis in young men and women. The PDAY research group. Pathobiological determinants of atherosclerosis in youth. Arterioscler Thromb Vasc Biol. 1997;17(1):95–106.

18. Deepa R, Sandeep S, Mohan V. Abdominal obesity, visceral fat and Type 2 diabetes - '"Asian Indian Phenotype."' In: Mohan V, Rao GHR, editors. Type 2 diabetes in South Asians: Epidemiology, risk factors and prevention. New Delhi: Jaypee Brothers Medical Publishers; 2006. p. 138–52.

19. Gupta R, Rao RS, Misra A, Sharma SK. Recent trends in epidemiology of dyslipidemias in India. Indian Heart J. 2017;69(3):382–92.

20. Lee MH, Ahn SV, Hur NW, Choi DP, Kim HC, Suh I. Gender differences in the association between smoking and dyslipidemia: 2005 Korean National Health and Nutrition Examination Survey. Clin Chim Acta. 2011;412:1600–5.

21. Singh G, Kumar AK. A study of lipid profile in type 2 diabetic Punjabi population. J Exerc Sci Physioth. 2012;8(1):7.

22. Bali K, Vij AK. Pattern of dyslipidaemia in type 2 diabetes mellitus in Punjab. Int J Res Med Sci. 2016;4(3):809–11.

23. Expert Panel on Detection E. Adults ToHBCi: executive summary of the third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III). JAMA. 2001;285(19):2486–97.

24. Pan L, Yang Z, Wu Y, Yin RX, Liao Y, Wang J, Gao B, Zhang L. The prevalence, awareness, treatment and control of dyslipidemia among adults in China. Atherosclerosis. 2016;248:2–9.

25. Wu J, Wang Y, Wang A, Xie J, Zhao X. Association between fasting triglyceride levels and the prevalence of asymptomatic intracranial arterial stenosis in a Chinese community-based study. Sci Rep. 2018;8(1):5744.

26. Thomas F, Bean K, Guize L, Quentzel S, Argyriadis P, Benetos A. Combined effects of systolic blood pressure and serum cholesterol on cardiovascular mortality in young (<55 years) men and women. Eur Heart J. 2002;23(7):528–35.

27. Hata Y, Nakajima K. Life-style and serum lipids and lipoproteins. J Atheroscler Thromb. 2000;7:177–97.

28. Kunzli N, Jerrett M, Garcia-Esteban R, Basagana X, Beckermann B, et al. Ambient air pollution and the progression of atherosclerosis in adults. PLoS ONE. 2010;5:e9096.

29. Choudhury SR, Ueshima H, Kita Y, Kobayashi KM, Okayama A, Yamakawa M, et al. Alcohol intake and serum lipids in a Japanese population. Int J Epidemiol. 1994;23:940–7.