

## The spectrum of the dyslipidemia in Colombia: The PURE study

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### ABSTRACT

**Background:** Dyslipidemia is a major risk factor for cardiovascular diseases (CVD). Worldwide, a third of ischemic heart disease is due to abnormal cholesterol levels and it is the most common cause of cardiovascular deaths in Colombia. In Colombia, no representative, large-scale study has assessed the prevalence of dyslipidemia. The aim of the present analysis was to identify the magnitude of the problem in Colombia, a middle-income-country with large regional, geographic, and socio-economical differences.

**Material and methods:** The sample comprised 6628 individuals aged 35 to 70 years (mean age 50.7 years, 64.1% women) residing in the four Colombian regions.

**Results:** The overall prevalence of dyslipidemia was 87.7% and was substantially higher among participants older than 50 years, male, rural residents, and those with a lower level of education (66.8%), and with a lower income (66.4%). High non HDL-c was the most common abnormality (75.3%). The values of total cholesterol and non-HDL-cholesterol were higher in areas with the lowest health needs index than in the areas with intermediate and highest health need index, the isolated HDL-c value was much lower.

**Conclusion:** Colombia has a high prevalence of abnormalities of the lipid profile. The causes of the high rates of dyslipidemia were not well define in this study, but were more common in rural and poorer regions and among those with lower socio-economical status. Strategies to tackle the adverse lipid profile to reduce CVD are needed in Colombia, particularly in rural areas and among the areas with the higher health need index.

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### 1. Introduction

Cardiovascular disease (CVD) is the most common cause of mortality, associated with 17.5 million deaths worldwide [1]. Its prevalence is higher in low-middle income (LMIC) than in high income countries (HIC), the former contributing to 80% of global CVD mortality [1]. In Colombia, a middle-income South American country, CVD is also the principal cause of mortality [2]. CVD risk factors have been well documented in international studies such as INTERHEART [3] and INTERSTROKE [4] which showed that dyslipidemia is one of the main

**Abbreviations:** CVD, cardiovascular diseases; PURE, Prospective Urban Rural Epidemiology; LMIC, Low-middle income countries; HIC, High income countries; TC, Total cholesterol; LDL-c, Low density lipoprotein cholesterol; HDL-c, High density lipoprotein cholesterol; TG, Triglycerides; PA, physical activity; BP, Blood pressure; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; HGS, Handgrip strength; HNI, health needs index; OR, Odds ratio.

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risk factors for the disease. According to guidelines, dyslipidemia is characterized by one or more of the following abnormalities: elevated total cholesterol (TC), elevated low density lipoprotein cholesterol (LDL-c), low levels of high density lipoprotein cholesterol (HDL-c), and high levels of triglycerides (TG) [5]. The World Health Organization (WHO) estimated that high TC causes 2.6 million deaths and 29.7 million disability adjusted life years (DALYS) [6]. They also found clear regional differences in the prevalence of lipid abnormalities, reporting that hypercholesterolemia was highest in Europe (54%) and the Americas (48%) and lowest in South East Asian (29.0%) and Africa (22.6%) [6]. Moreover, it has been shown that atherogenic dyslipidemia (high levels of TG and LDL-C small and dense, and low levels of HDL-c) is highly prevalent in Latin American countries [7].

Several studies have assessed the prevalence of dyslipidemia in Colombia [8–11], yet these studies were not large-scale and did not involve multiple regions of the country. The present study consists of an analysis of the spectrum of dyslipidemia in a large sample of the Colombian participants drawn from 10 departments, and enrolled into the Prospective Urban-Rural Epidemiology (PURE) study.

## 2. Materials and methods

### 2.1. Study design and participants

The Prospective Urban Rural Epidemiology (PURE) study is coordinated by the Population Health Research Institute (PHRI, Hamilton, ON, Canada). The design has been previously published [12]. The Ethics Committee of the Cardiovascular Foundation of Colombia approved the study. Participants included urban and rural communities from four areas of Colombia that encompass geographical, ethnic, and socio-economic variations. These areas included the Atlantic area (Departments of Atlántico, Bolívar, Cesar), the Andean area (Departments of Caldas and Tolima), the Pacific area (Departments of Cauca and Nariño) and the Central-East area (Departments of Cundinamarca, include Bogota, Santander and Casanare). These areas include the most populated departments of Colombia, as previously described [13]. We used a multistage approach to sampling; during the first and second stages, the departments and communities were selected, and in the third stage, a representative sample of households was recruited, using a community-sampling framework. The primary sample unit was the community defined as a geographical area, which included a group of people from a common location. Households were defined and selected as part of the rural sample if located at least 50 km from an urban center. The communities are not only the primary sampling units, but also the smallest geographical level at which social and environmental characteristics were measured using a separate assessment of health-related characteristics of the environment which included both objective and perception-based measures. This design enables the identification of both individual level and environmental level determinants of health. Urban and rural communities were selected with the aim of achieving within-community homogeneity in demographic and socioeconomic profiles and areal-level characteristics and also among-community heterogeneity in social and economic circumstances. This was coupled with the pragmatic requirement of optimizing the capacity of local investigators to maintain long-term follow-up of participants. In Colombia, communities from several states/provinces were included to capture regional diversity in terms of socioeconomic status, culture, and physical environment. Households were eligible if at least one member was 35–70 years-old and if the members intended to continue living at that address for four years or more. Medical staff members who were specially trained in the collection of door-to-door samples made a maximum of three attempts to contact someone in each household. All participants selected who provided written informed consent were enrolled.

### 2.2. Data collection and measurement of risk factors

The socio-demographic characteristics of all consenting participants, including date of birth, CVD risk factors described in the INTERHEART study [3] (smoking, hypertension, diabetes, psychosocial factors, alcohol consumption and physical measurements) were recorded, and a basic physical examination (weight, height, body mass index -BMI-, waist circumference -WC-, waist/hip ratio -WHR-) was performed. Younger age was defined as <50 years, and older age as 50 years or more. Education was categorized as high/middle (secondary/high/higher secondary, technical or college/university) and low (none, primary or unknown). A smoker was defined as a participant who had smoked at least one tobacco product daily in the previous 12 months and included those who had quit within the past year. Drinking alcohol was defined as former and current alcohol use (a 'yes' response and a 'no' if alcohol was never consumed). The International Physical Activity Questionnaire was used for the measurement of physical activity (PA) at work, at home and during recreation or sport and leisure time activities. Those who reported activities were equivalent to <600 MET-min/week were defined as having low, 600–3000 MET-min/week as having moderate and >3000 MET-min/week as having high levels of physical activity [14,15].

Blood Pressure (BP) was measured by trained research assistants using a digital sphygmomanometer (Omron HEM-757) with a cuff size of 14–48 cm supplied to all

sites [16,17]. Measurements were taken after the participant was seated for at least 5 min and not having smoked, exercised, eaten or climbed stairs in the last 30 min. BP was taken twice, with a 5-min interval between measurements with the participant sitting upright and his/her right arm supported at heart level. The mean of the two measures was used in the analysis. Hypertension was defined by self-report of the disease and taking BP-lowering treatment or an average systolic blood pressure (SBP) at least 140 mm Hg and/or an average diastolic blood pressure (DBP) of at least 90 mm Hg, measured during the visit [18]. Anthropometric measurements (height, weight, waist circumference and hip circumference) were taken using the guidelines adopted at the NIH-sponsored Arlie Conference [19]. Abdominal obesity was defined as a waist circumference in men/women (cms):  $\geq 90/\geq 80$ . Handgrip strength (HGS) was measured using a Jamar hand dynamometer according to a standardized protocol. For the first study participants, three measurements were made from the participant's non-dominant hand. During the course of the study, the protocol was amended so that three measurements were made from both hands of each participant [12]. Handgrip strength was calculated as the mean of non-dominant and dominant hand divided by weight.

We organized in four regions the 10 participant departments in the PURE study. The regions were Atlantic (Atlántico, Bolívar and Cesar), Central (Caldas and Tolima), Central-East (Santander, Casanare and Cundinamarca including Bogota) and Pacific (Cauca and Nariño). We calculated a health needs index (HNI) based on the health goal models (Gross Domestic Product 2007, Analfabetism (literacy) rate 2005, Unsatisfied

**Table 1**

Socio-demographic characteristics associated with lipid alterations.

Socio-demographic characteristics	Total of participants	Without lipid alterations	Subjects with any lipid alterations
Number (%)	6628 (100%)	814 (12.3%)	5814 (87.7%)
Age (years)	50.7 ± 9.6	48.1 ± 9.7	51.1 ± 9.5
Aged group <sup>§</sup>			
<50 years	3134 (48.8)	490 (62.8)	2644 (46.9)
≥50 years	3285 (51.2)	290 (37.2)	2995 (53.1) <sup>a</sup>
Sex			
Male (%)	2378 (35.9)	91 (11.2)	2287 (39.3)
Female (%)	4250 (64.1)	723 (88.8)	3527 (60.7) <sup>a</sup>
Location			
Urban	3324 (50.2)	458 (56.3)	2866 (49.3)
Rural	3304 (49.8)	356 (43.7)	2948 (50.7) <sup>a</sup>
Education level (%) <sup>¶</sup>			
Without scholar degree/primary	4363 (65.9)	482 (59.5)	3881 (66.8) <sup>a</sup>
Secondary/high school/university	2254 (34.1)	328 (40.5)	1926 (33.2)
Income level (%)			
<350 USD	4392 (66.3)	529 (65.0)	3863 (66.4)
≥350 USD	2236 (33.7)	285 (35.0)	1951 (33.6)
Coronary artery disease (%)	159 (2.4)	14 (1.7)	145 (2.5)
Diabetes (%)	455 (6.9)	36 (4.4)	419 (7.3) <sup>a</sup>
Hypertension (%)	2496 (37.7)	230 (28.3)	2266 (38.9) <sup>a</sup>
Current smoking (%)	861 (13.0)	74 (9.1)	787 (13.6) <sup>a</sup>
Drink alcohol (%)	2939 (44.4)	270 (33.3)	2669 (44.9) <sup>a</sup>
Physical activity <sup>¶¶</sup>			
Low	757 (13.1)	73 (10.4)	679 (13.5)
Moderate	2088 (36.4)	254 (36.2)	1834 (36.4)
High	2892 (50.4)	374 (53.4)	2518 (50.1)
Body mass index (kg/m <sup>2</sup> )	26.3 ± 4.7	25.2 ± 4.9	26.5 ± 4.6 <sup>b</sup>
<20 kg/m <sup>2</sup>	2747 (42.4)	429 (53.7)	2318 (40.8)
25–30 kg/m <sup>2</sup>	2526 (39.0)	261 (32.7)	2265 (39.9)
≥30 kg/m <sup>2</sup>	1204 (18.6)	109 (13.6)	1095 (19.3) <sup>a</sup>
Waist circumference (cm)	86.1 ± 11.5	80.5 ± 11.2	86.8 ± 11.3 <sup>b</sup>
Male	88.2 ± 11.1	78.9 ± 7.93	88.5 ± 11.1 <sup>b</sup>
Female	84.9 ± 11.5	80.7 ± 11.5	85.7 ± 11.3 <sup>b</sup>
Waist/hip ratio	0.88 ± 0.08	0.83 ± 0.07	0.89 ± 0.08 <sup>b</sup>
Abdominal obesity (%)	3717 (56.2%)	352 (43.3)	3365 (58.0) <sup>a</sup>
Handgrip strength kg/kg	0.40 ± 0.15	0.38 ± 0.13	0.40 ± 0.15 <sup>b</sup>
Systolic blood pressure mm Hg	129.4 ± 21.3	123.5 ± 20.5	130.2 ± 21.3 <sup>b</sup>
Diastolic blood pressure mm Hg	80.5 ± 11.9	77.9 ± 11.6	80.9 ± 11.8 <sup>b</sup>
Glucose (mg/dl)	87.1 ± 28.8	83.5 ± 21.8	87.6 ± 29.6 <sup>b</sup>
Total cholesterol (mg/dl)	201.1 ± 45.7	176.0 ± 17.2	204.6 ± 47.3 <sup>b</sup>
LDL cholesterol (mg/dl)	118.9 ± 34.7	101.3 ± 15.4	121.6 ± 35.9 <sup>b</sup>
HDL cholesterol (mg/dl)	41.9 ± 11.7	50.2 ± 8.24	40.7 ± 11.6 <sup>b</sup>
Triglycerides (mg/dl)	181.5 ± 145.4	95.1 ± 27.8	193.6 ± 150.9 <sup>b</sup>

<sup>a,b</sup>Pearson's chi square test and Student's *t*-test *p* < 0.05 comparing participants with any lipid alterations to those without.

<sup>§</sup> 209 missing data for age group.

<sup>¶</sup> 11 missing data for education level.

<sup>¶¶</sup> 896 missing data for physical activity, but there were no statistically significant differences.

Basic Needs Index 2008 [20], and Infant Mortality Rate 2008, Cardiovascular Disease Mortality Rate 2008 [21]), calculated as the algebraic sum of the z-scores for each indicator evaluated. The HNI is social indicator that enables the assessment of health needs in each region. Colombian departments were classified as those having the highest (Cesar, Bolívar, Cauca and Nariño), intermediate (Tolima, Caldas and Atlántico) and lowest (Cundinamarca, Santander and Casanare) health needs within the country.

A 10-mL fasting venous blood sample (≥8 h without any consumption of food or drinks) was obtained for the determination of lipid profile in central clinic lab. Triglycerides (TG), total cholesterol (TC) and high-density lipoprotein cholesterol (HDL-c) were estimated by enzymatic colorimetric method in an automatic analyzer (Hitachi 917, Boehringer Mannheim) and LDL-cholesterol (LDL-C) was calculated. Cholesterol-Non-HDL-c was also calculated as TC minus HDL-c and was considered high with values >150 mg/dl in both sex. Definitions of dyslipidemia were according the National Cholesterol Education Program/Adult Treatment Panel III [22], being categorized in: Hypercholesterolemia (TC ≥ 200 mg/dL); Hypertriglyceridemia (≥150 mg/dL of TG); Low HDL-c (≤50 mg/dL in females and ≤40 mg/dL in males); High LDL-c (≥130 mg/dl); Isolated Hypercholesterolemia (TC ≥ 200 mg/dL and TG < 150 mg/dL); Isolated Hypertriglyceridemia (TG ≥ 150 mg/dL and TC < 200 mg/dL); Isolated Low HDL-c (HDL-c ≤ 50 mg/dL in women and ≤40 mg/dl in men without increased levels of TC and/or TG).

2.3. Statistical analysis

Data were entered into the iDATAfax® system. Data analysis was performed by using STATA/SE (version 11, StataCorp. 2011. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP). Statistical significance was set at p < 0.05. Categorical variables are presented as numbers and percentages with 95% Confidence Intervals (CI). Continuous variables are presented as means and standard deviations. Differences between measures of central tendency and frequencies were assessed with the Student t-test, Mann-Whitney test or Chi-square test according the distribution of frequencies. Chi-square test and odds ratio (OR) with 95% CI were used as a measure for analyzing the association between atherogenic dyslipidemia and other dyslipidemia and independent variables. Cochran – Armitage test and Cuzick test were used to assess the prevalence of types of dyslipidemia and cardiometabolic markers by health need index area, respectively. We used non-conditional logistic regression analyses to estimate the odds ratio (OR) and its corresponding 95% confidence interval (CI). Associations with p < 0.1 in crude analysis were submitted to multivariate analysis to control any potential confounding factors.

3. Results

Table 1 shows the socio-demographic characteristics of the subjects with some type of lipid abnormalities. Of the 6628 individuals aged 35 to 70 (mean age 50.7 years, 64.1% women), 87.7% [95% CI: 86.9–88.5%] presented at least one abnormality in the lipid profile as described in methods. The prevalence was higher in men (96.2% [95% CI: 94.4–96.9%]) that in women (82.9% [95% CI: 81.8–84.1%]). We observed a higher prevalence of lipid abnormalities in participants over 50 years old (92.2%; 95% CI: 90.2–92.1%) and in rural residents (89.2%; 95% CI: 88.2–90.3%).

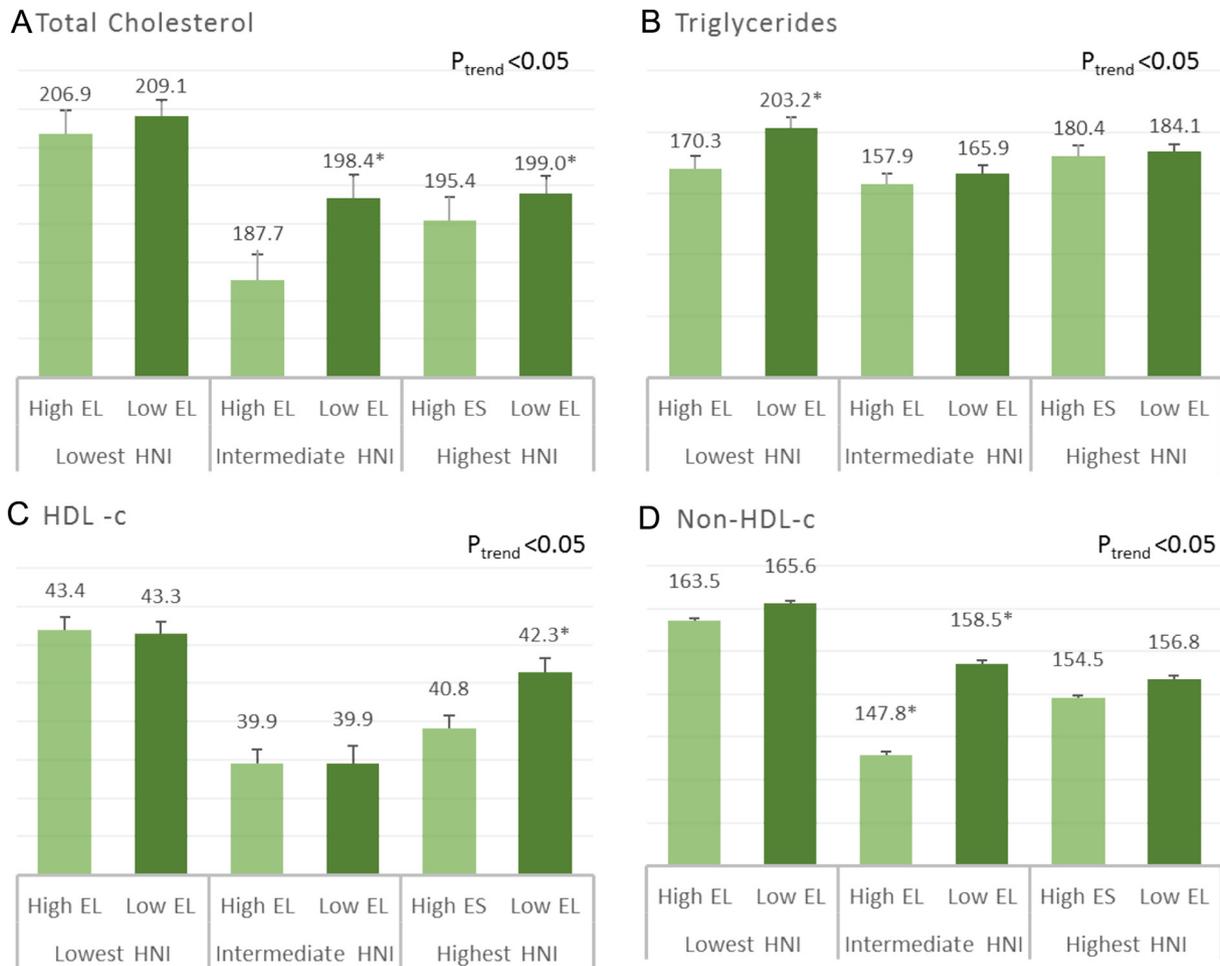
There was a higher proportion of dyslipidemia in participants with no or low education level (66.8%) compared to those with middle/higher education (33.2%). Similarly, higher percentages of lipid abnormalities were observed in 66.4% of the low income participants compared to 33.6% in higher income participants (Table 1). Diabetes, hypertension, smoking, lower physical activity levels, alcohol consumption, obesity, abdominal obesity, and higher levels of glycaemia were more prevalent in participants with lipid abnormalities.

Table 2 shows the prevalence of dyslipidemia by health need index. Nationally, non-HDL-c was the most frequent abnormality (75.3%), followed by low HDL-c (57.1%), hypertriglyceridemia (49.7%) and hypercholesterolemia (48.7%). The prevalence was higher in the rural areas of all regions. Hypercholesterolemia was more prevalent in the regions with the lowest HNI (55.7%) than in the regions with intermediate (43.2%) and highest HNI (44.3%), while low HDL-c was more prevalent in the regions with intermediate (60.8%) and highest HNI (57.5%) than in the regions with lowest HNI (54.4%). Also, low isolated HDL-c was more prevalent in the regions with intermediate and high HNI that in the regions with the lowest HNI. In Colombia, High No-HDL-c was the most prevalent abnormality in all regions, reaching a prevalence of approximately 80% in 3 of the 4 regions. The second most common alteration was low HDL-c with a percentage of 69.5% in the Atlantic region. Hypertriglyceridemia was highest in the Central region (57.7%) (Supplementary material: Table 2a).

Table 2  
Prevalence of dyslipidemia (percent) by health need index and urban and rural residency.

	All states			Lowest HNI			Intermediate HNI			Highest HNI		
	Total N (%)	Urban	Rural	Total N (%)	Urban	Rural	Total N (%)	Urban	Rural	Total N (%)	Urban	Rural
Isolated hypercholesterolemia*	1289 (19.4)	674 (20.3)	615 (18.6)	594 (22.7)	328 (25.3)	266 (20.2)	346 (19.9)	169 (19.4)	177 (20.4)	349 (15.4)	177 (15.4)	172 (15.4)
Isolated hypertriglyceridemia*	1366 (20.6)	698 (21.0)	668 (20.2)	497 (19.0)	243 (18.7)	254 (19.3)	0.002	0.002	0.002	0.597	0.597	0.597
Isolated low HDL-c*	2732 (41.3)	1364 (41.1)	1368 (41.5)	940 (35.9)	467 (35.9)	473 (35.9)	0.713	0.713	0.713	0.104	0.104	0.104
Hypercholesterolemia*	3216 (48.5)	1563 (47.0)	1653 (50.0)	1458 (55.7)	705 (54.3)	753 (57.1)	0.992	0.992	0.992	0.242	0.242	0.242
Hypertriglyceridemia	3293 (49.7)	1587 (47.7)	1706 (51.6)	1361 (52.0)	620 (47.7)	741 (56.2)	0.141	0.141	0.141	0.034	0.034	0.034
Low HDL-c*	3782 (57.1)	1846 (55.5)	1936 (58.7)	1422 (54.4)	679 (52.3)	743 (56.5)	<0.001	<0.001	<0.001	0.674	0.674	0.674
Non-HDL-c*	4988 (75.3)	2502 (75.3)	2486 (75.4)	2115 (80.9)	1046 (80.5)	1069 (81.3)	0.030	0.030	0.030	0.027	0.027	0.027

\* Cochran-Armitage test, p < 0.05 between health need index. Chi-square test, p < 0.05. High density lipoprotein (HDL-c), Triglycerides (TG), Hypercholesterolemia (Cholesterol ≥ 200 mg/L); Hypertriglyceridemia (TG ≥ 150 mg/dl); Low HDL-c (≤50 mg/dl in female or ≤40 mg/dl in male); Non-HDL-c (≥150 mg/dl); Isolated Hypercholesterolemia (Cholesterol ≥ 200 mg/L and TG < 150 mg/L); Isolated Hypertriglyceridemia (TG ≥ 150 mg/dl and Cholesterol < 200 mg/L); Isolated Low HDL-c (≤50 mg/dl in female or ≤40 mg/dl in male and Cholesterol < 200 mg/L and TG < 150 mg/L).



**Fig. 1.** Mean values of lipids by education status and health need index. High: Secondary/high school/university; Low: Without scholar degree/primary. \*Student's *t*-test,  $p < 0.05$ . Cuzick test,  $P_{\text{trend}} < 0.05$ : Total cholesterol, triglycerides, HDL-c and Non-HDL-c. Educational Level (EL) by health need index (HNI) area.

Fig. 1 shows mean lipids values in participants according to their education level. Total cholesterol value was higher in the areas with the lowest HNI, regardless of the education level. In the areas with intermediate and highest HNI, total cholesterol was higher in those with a low education level. A lower level of education was also associated with higher TG in the lowest HNI areas and with a higher Non-HDL-c in intermediate HNI areas. The mean lipid values among urban and rural residents according to the HNI of the region, higher total cholesterol, and non-HDL-C was observed in the areas with the lowest HNI. In contrast, HDL-c was lower in the areas with the intermediate and highest HNI (Supplementary material: Fig. 1a).

Table 3 shows a multivariate logistic regression model used to determine potential associations between socio-demographic characteristics, anthropometric measures and lipid abnormalities. Hypercholesterolemia was strongly and positively associated with female sex, age > 50 years, rural residence, low educational level and higher BMI, WC and WHR. Hypertriglyceridemia was associated with diabetes, hypertension, and higher BMI and WHR. Low HDL-c was associated with female gender, age > 50 years old, smoking and higher WC. High non HDL-C was associated with female gender, age > 50 years old, and higher BMI, WC and WHR.

#### 4. Discussion

The main finding of this study was the very high prevalence of dyslipidemia in the Colombian population aged between 35 and 70 years, with 87.7% of the sample having at least one type of lipid abnormality. High Non-HDL-C was the most prevalent alteration (75.3%), followed

by low HDL-c (57.1%), hypertriglyceridemia (49.7%) and total hypercholesterolemia (48.5%). We also noted large regional differences in the prevalence of some of these abnormalities, such as high TC values in the areas with the lowest HNI, and higher percentages of low HDL-c in areas with the highest HNI.

Previous studies [8–11] report a prevalence of dyslipidemia in Colombia that varies between 15.7% and 73.8%. Unfortunately, methodological differences between the few reports of lipid alterations in Colombia make comparisons with our results difficult. A study involving 2516 adults of the rural coffee-growing area [8] reported an overall prevalence of hyperlipidemia of 62.1%, which was higher in females (68.2%) than in males (56.5%). However, the type of lipid abnormality was not reported in this study. A prevalence of dyslipidemia of 35.3% was reported among 357 urban residents aged 25–50 from a small city in the central region [9], but used different cut off points ( $\geq 240$  mg/dl for TC,  $\geq 160$  for LDL-c,  $\geq 200$  for TG) than in the present study. These cut off points were also used in another urban study of 1511 residents aged 25–64 years from Bogota [10], which found a prevalence of dyslipidemia in men and women of 70% (95% CI: 66.2–73.8) and 47.7% (95% CI: 43.9–51.5), respectively. The most frequent dyslipidemia was low HDL-c followed by high triglycerides, high TC/HDL-c ratio and non-HDL-c. A cross-sectional study in a random sample of 2989 subjects 15–64 years old of the city of Bucaramanga [11] that used the same criteria as we used to define dyslipidemia showed a high prevalence of low HDL-c (30%) and a higher prevalence of elevated total cholesterol in women than men (19.7 versus 15.7%) and elevated LDL-c (23.9 versus 19.5%), but a lower prevalence of low HDL-c (22.2 versus 37.6%).

**Table 3**  
Multivariable logistic regression showing factors independently associated with dyslipidemia in all regions.

	Hypercholesterolemia		Hypertriglyceridemia		Low HDL cholesterol		High no HDL cholesterol	
	OR [95% CI] <sup>a</sup>	p value						
Female	1.25 [1.15–1.37]	<0.001	1.01 [0.94–1.10]	0.719	0.54 [0.50–0.57]	<0.001	1.06 [1.02–1.12]	0.009
Age (years)	1.015 [1.01–1.02]	<0.001	1.00 [0.99–1.01]	0.183	0.99 [0.99–0.99]	<0.001	1.006 [1.004–1.008]	<0.001
Rural	1.13 [1.06–1.21]	<0.001	1.07 [0.99–1.14]	0.053	0.96 [0.91–1.01]	0.146	1.04 [0.99–1.08]	0.056
Non study/primary	1.03 [0.96–1.11]	0.346	1.06 [0.99–1.13]	0.099	1.00 [0.95–1.06]	0.891	1.04 [0.99–1.08]	0.055
Income level (≥350 USD)	1.07 [0.98–1.14]	0.122	0.99 [0.93–1.07]	0.898	0.97 [0.92–1.03]	0.293	1.05 [1.00–1.09]	0.017
Drink alcohol n (%)	1.05 [0.99–1.11]	0.090	1.04 [0.98–1.11]	0.161	1.00 [0.96–1.05]	0.940	1.02 [0.99–1.06]	0.151
Current smoking n (%)	1.03 [0.95–1.11]	0.532	1.06 [0.99–1.15]	0.113	1.08 [1.02–1.14]	0.006	1.01 [0.96–1.06]	0.689
Physical activity								
Moderate	0.98 [0.90–1.07]	0.618	0.95 [0.88–1.03]	0.242	1.02 [0.96–1.09]	0.451	0.99 [0.95–1.04]	0.943
High	0.99 [0.92–1.08]	0.889	0.93 [0.86–0.99]	0.046	0.98 [0.92–1.04]	0.534	1.00 [0.95–1.05]	0.894
Coronary artery disease n (%)	1.01 [0.85–1.20]	0.893	1.14 [0.99–1.32]	0.066	0.95 [0.83–1.09]	0.464	0.99 [0.89–1.09]	0.841
Diabetes n (%)	0.90 [0.80–1.02]	0.115	1.16 [1.06–1.27]	0.001	1.07 [0.99–1.16]	0.095	0.95 [0.89–1.01]	0.156
Hypertension n (%)	1.04 [0.98–1.10]	0.199	1.09 [1.03–1.16]	0.002	1.01 [0.96–1.05]	0.800	1.01 [0.97–1.04]	0.648
Body mass index (BMI) kg/m <sup>2</sup>	1.02 [1.01–1.03]	<0.001	1.02 [1.01–1.03]	<0.001	1.00 [0.99–1.01]	0.834	1.02 [1.01–1.03]	<0.001
Waist circumference (WC) (cm)	0.98 [0.97–0.99]	<0.001	0.99 [0.99–1.00]	0.525	1.02 [1.01–1.02]	<0.001	0.98 [0.98–0.99]	<0.001
Waist/hip ratio (WHR)	3.06 [1.83–5.09]	<0.001	8.06 [4.98–13.0]	<0.001	1.31 [0.88–1.97]	0.199	2.46 [1.83–3.29]	<0.001
Handgrip/weight (HW)	1.00 [0.79–1.28]	0.975	0.79 [0.62–1.01]	0.056	1.16 [0.98–1.37]	0.072	0.89 [0.78–1.03]	0.124
Abdominal obesity (AO)	1.06 [0.97–1.16]	0.182	1.06 [0.97–1.15]	0.181	1.05 [0.98–1.13]	0.159	1.05 [0.99–1.10]	0.063

<sup>a</sup> Adjusted for covariates; sex, age, residential area, educational level, income, alcohol, smoker, physical activity, coronary artery disease, diabetes, hypertension, body mass index (BMI), waist circumference (WC), waist/hip ratio, handgrip/weight (HW), abdominal obesity (AO).

The alterations in the lipid profile that we and others have reported in the Colombian population support the proposal that for some as yet undefined reason, the individuals of Latin America have a higher sensitivity to present with elevated TG and Non-HDL-c, and low levels of HDL-c, as has been recently reviewed [7]. When comparing our HDL-c and TG data with reports from other countries, a higher prevalence of these alterations were reported in Colombia. The US National Survey on Nutrition and Health (NHANES 2009–2010) [23] showed a prevalence of low HDL-c of 30.1% (95% CI: 29.9–33.2%), while, a study from Murcia (Spain) reported a prevalence of low HDL-c of 27.3% (95% CI: 25.1–29.4%) [24], both substantially lower rates than we observed in Colombia (57.1%).

These data, indicating that the prevalence of low HDL-c and high TG in Colombia is higher than in other countries could have a number of explanations. In Colombia, there are a series of unique ethnic, economic and cultural characteristics that could contribute to the higher prevalence of these lipid abnormalities. Furthermore, the global PURE study demonstrated that a high carbohydrate intake was potentially associated with adverse effects on most lipid parameters [25], which varied significantly according to the level of consumption of the nutrient, suggesting that different diets might have distinct effects in populations that are undernourished compared to those that are adequately nourished or over-nourished. The PURE study showed that in low-income populations where refined carbohydrates are the main source of energy intake (>60% of energy), the most important nutritional risk factor for CVD was the high intake of carbohydrates [26], probably derived from processed food; since the intake of carbohydrates from vegetable, legume and fruit were protective in all populations [27]. Refined sugars and soft beverages are extensively consumed in

Colombia, particularly by lower income groups, since they are practical, ubiquitous and accessible [28]. Moreover, results from randomized trials have shown that reducing carbohydrate intake improves blood lipid concentrations (lower TG and increase HDL-c) [29]. Thus, the high prevalence of the specific lipid profile described in our study could be related to a high intake of processed carbohydrates. We cannot however exclude the possible influence of genetic factors present in Latin American populations, as has been previously proposed [7]. Moreover, we noted that low HDL-c values were particularly high in participants with a lower education level, lower income, and in those areas with intermediate and highest HNI. Older age, low level of education, low income, rural residence, low physical activity, overweight, abdominal obesity, hypertension, diabetes and smoking were independently associated with all classes of lipid abnormalities, and could explain the observed high prevalence of lipid abnormalities. Moreover, the disparities in the access to health services [30,31], and the low availability and affordability of cardiovascular disease medicines, particularly antihyperlipidemic drugs, could be also participating [32]. These results reinforce the importance of a global approach to management of the CV risk factors associated with increasing urbanization [33].

The study has some limitations as the inclusion of a higher number of women, and people with low education level and low income that are factors that are increasing the prevalence of lipid abnormalities. However, in the multivariate analysis, the low education level and income did not influence in the prevalence of the lipid abnormalities. Moreover, in the present study we not analyze the history or the presence of familiar hypercholesterolemia (FH), but globally [34] and in Colombia [35] the prevalence of FH is low. However, it is anticipating that further studies will be conducted with the aim to determinate if

genetic factors, and/or dietetic factors explain the high prevalence of lipid abnormalities reported in this population.

In conclusion, our analysis shows a very high prevalence of lipid abnormalities in the Colombian participants of the PURE study, recruited from 10 geographically diverse departments of the country. This suggests an urgent need to implement programs aimed at promoting healthy lifestyles, including increased participation in physical activity, a reduction in the consumption of refined carbohydrates and an improvement in the availability of effective CV medications in the Colombian population [36].

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### Conflict of interest

The authors declare no conflict of interest.

### Authorship responsibility

We confirm that this work is original and has not been published elsewhere nor is it currently under consideration for publication elsewhere. P.J.L, P.A.C, D.D.C, S.G.G, and C.C contributed to the preparation, analysis and interpretation of data for the work. S.Y designed the study, conceived and initiated the Prospective Urban Rural Epidemiology (PURE) study, supervised its conduct and data analysis. S.R coordinated the worldwide PURE study and reviewed and commented on drafts of the report. All other authors made substantial contributions to the conception, acquisition, and interpretation of data for the work. All authors have reviewed and approved this manuscript.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijcard.2018.10.090>.

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