Original Article

Identifying Factors Related to Serum Lipids Using Multilevel Quantile Model: Analysis of Nationwide STEPs Survey 2016

Abstract

Background: Lipid disorder is a modifiable risk factor for diseases related to plaque formation in arteries such as heart attack, stroke, and peripheral vascular diseases. Identifying related factors and diagnosis and treatment in time reduces the incidence of non-communicable diseases (NCDs). The aim of this study was to determine factors associated with lipids based on a national survey data. **Methods:** Data of 16757 individuals aged 25–64 years obtained from the Iranian STEPwise approach to NCD risk factor surveillance (STEPs) performed in 2016, through multistage random sampling, were analyzed. Because of clustered, hierarchical, and skewed form of the data, factors related to total holesterol (TC), triglycerides (TG), low-density lipoprotein-cholesterol) (LDL-C), high-density lipoprotein-cholesterol) (HDL-C), TG/HDL-C, TC/HDL-C, and LDL-C/HDL-C were determined applying multilevel quantile mixed model. Parameters of the model were estimated on the basis of random effect of the province as well as urban or rural area for 10th, 25th, 50th, 75th, and 90th quantiles. Statistical analyses were performed by R software version 4.0.2. **Results:** Significant relationship was found between age, body mass index (BMI), waist circumference (WC), diabetes, hypertension, smoking, physical activity, education level, and marital status with TC, LDL-C, HDL-C, LDL-C, and LDL-C/HDL-C. With increasing BMI and WC, subjects had higher levels of serum lipids, especially in higher quantiles of lipid levels. Lipid levels were significantly increased among smokers and those with diabetes or hypertension. The random effects were also significant showing that there is a correlation between the level of lipids in provincial habitants as well as urban and rural areas. **Conclusions:** This study showed that the effect of each factor varies depending on the centiles of the lipids. Significant relationship was found between sociodemographic, behaviors, and anthropometric indices with lipid parameters.

Keywords: *Multilevel analysis, serum lipids, STEPs study, quantile mixed model*

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Introduction

Cardiovascular disease is recognized as a major cause of global mortality and one of the most serious health problems worldwide.[1] The association between lipids and coronary heart disease (CHD) is well established.[2] The results of a meta-analysis show that total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), and triglycerides (TG) are each independent risk factors for CHD.[3]

The ratio of TG to HDL-C (TG/HDL-C) independently predicts cardiovascular events[4,5] and is associated with glucose intolerance, diabetes mellitus, atherogenic dyslipidemia, and metabolic syndrome especially in obese and diabetic patients.[6,7] Studies showed that TG/HDL-C is better than TG per se and increases risk prediction more than TG. Considering the complex metabolic interaction between TG and cholesterol-rich lipoproteins, the simultaneous use of these parameters seems to provide more accurate information.[3,5]

In fact, lipid disorder is a modifiable risk factor for diseases related to plaque formation in arteries such as heart attack, stroke, and peripheral vascular diseases.[8,9] Different factors such as age, sex, lifestyle change due to industrialization, undesirable diet, low physical activity, and smoking lead to increased incidence of lipid disorders.[10,11]

Many studies have analyzed factors associated with dyslipidemia using ordinary least squares (OLS) regression analysis which can only measure the influence of independent variables only on the

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center (mean) of the dependent variable distribution. Since lipid variables usually follow a right skewed distribution, one will ignore and lose some important information when focusing only on average via OLS regression.[12,13] This model also requires some assumptions such as the normality of the response variable which is not always true especially for lipid profile. In this study, we are interested in the effect of risk factors on all parts of the lipids distributions.

The quantile regression model without having the limitations of OLS regression assumptions has high flexibility in modeling data with the heterogeneous conditional distribution. It is able to provide an accurate and comprehensive view of the involvement of independent variables in all parts of the response variable, especially in the primary and end sequences.[14,15] Since the impairment of lipids is a silent threat to people's health, it is important to estimate the factors associated with them in order to plan interventions for reducing related risk factors. In this research, factors related to serum lipids were studied based on national data of World Health Organization (WHO) STEPwise approach to non-communicable disease (NCD) risk factor surveillance (STEPs) survey using multilevel quantile mixed model.

Methods

Participants

The data for this research was acquired from the cross-sectional STEPs survey which was conducted to determine the risk factors of NCDs risk factors among the population of >=18 years old in 2016. In STEPs study, individuals have been selected by multistage cluster random sampling across all provinces of Iran. The foundation of the survey design has been reported elsewhere.[16] Laboratory measurements were performed for individuals over 25 years old. In this research, data of 16757 subjects aged 25–64 were investigated [Figure 1]. In the STEPs study, all procedures were done according to predetermined instructions, and written informed consent has been collected from all participants.

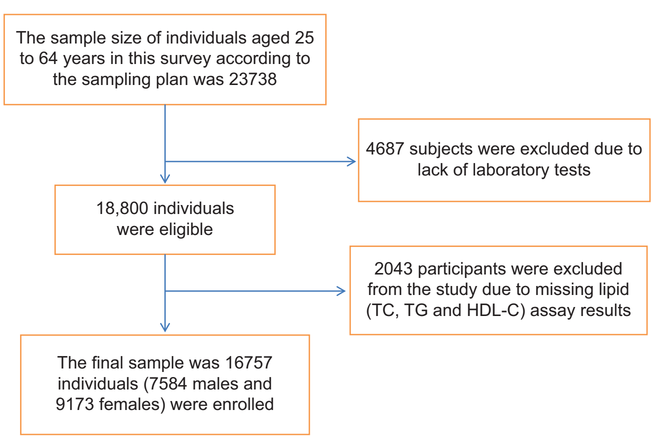

Figure 1: Flowchart of the participant in the study

Data Collection and Measurements

Following the WHO STEPwise approach to risk factor surveillance, demographic data, lifestyles, and risk factors such as smoking, diet, physical activity, history of hypertension, and diabetes were collected through a questionnaire by trained interviewers.[16]

Consistent with WHO protocols, anthropometric variables (height, weight, hip and waist circumference (WC)), blood pressure, pulse rate, and individuals' pedometer information of participants were measured; participants were without shoes but with light clothing. Body mass index (BMI) was calculated by dividing weight by square meter of height.[16] Physical activity was calculated based on Global Physical Activity Questionnaire, GPAQ.[17] Metabolic equivalent of tasks (METs) were used to show the intensity of physical activity based on GPAQ analysis. After calculating METS, individuals were divided into three groups with low, medium, and high physical activity. Physical activity was categorized in three levels: (1) high: vigorous-intensity activity, on at least 3 days a week, achieving a minimum of at least 1500 MET minutes per week, or 7 days of any combination of walking and moderate- or vigorous-intensity activities, achieving a minimum of at least 3000 MET minutes per week; (2) moderate: three or more days of vigorous-intensity activity of at least 20 minutes per day, or five or more days of moderate-intensity activity, including walking, of at least 30 minutes per day, or five or more days of any combination of walking, moderate- or vigorous intensity activities, achieving a minimum of at least 600 MET minutes per week; and (3) low: not meeting any of the above-mentioned criteria. Systolic (SBP) and diastolic blood pressures (DBP) were measured three times using the device Beurer GmbH, Germany, with 5-minute intervals, and mean values of second and third measurements were used for analysis. High blood pressure was defined as SBP ≥140 or DBP ≥90 mmHg or taking antihypertensive medication at the time of data collection or if a health specialist has previously told the participant that he/she has hypertension.

Fasting blood samples were taken and centrifuged immediately and were transferred to the NCDRC research center, the coordinating center of this study in Tehran in cold chain conditions. Fasting plasma glucose (FPG), TC, HDL-C, and TG were measured by an auto-analyzer (Cobas C311 Hitachi High–Technologies Corporation, Japan).[18] LDL-C was estimated using Chen formula.[19] Diabetes was defined as FPG ≥126 mg/dL, using glucose lowering medications or if a health specialist has previously told the participant is diabetic and evaluating the history of drugs' consumption. Lipid profiles were considered as quantitative variables. Tobacco use includes people who were smoking daily. Fruits, vegetables, and dairy consumption has been measured as the unit consumed per day.

Statistical analyses

Continuous variables were reported using mean ± standard deviation (SD) and categorical variables with number and percentage. The baseline characteristics were compared using t-test and Chi-square.

Because of the skewed form of the distribution of the dependent variables, factors related to TC, TG, LDL-C, HDL-C, TG/HDL-C, TC/HDL-C, and LDL-C/HDL-C were determined by applying quantile regression. In this model, the effect of independent variables is determined on different percentiles of the dependent variables rather than their center only. Quantile regression, introduced by Koenker and Bassett in 1987, is a regression-based method for modeling different parts especially extreme points of the response variable distribution conditional on the covariates. In linear regression, we focus on the center of the distribution so the coefficients are estimated by least square technique to minimize the sum of squared deviations. But in quantile regression, several quantiles of the conditional distribution are modeled as a linear function of subject characteristics. In this study, parameters of the model were estimated for 10^{th}, 25^{th}, (lower) 50^{th} (median), 75^{th}, and 90^{th} (higher) centiles.

On the other hand, because of the clustered and hierarchical nature of the STEPs data, a multilevel modeling approach was applied. A number of sampling designs such as multilevel, longitudinal, and cluster sampling typically require statistical methods taking into account the correlation between observations that belong to a unit or cluster. By applying multilevel or hierarchical mixed effect model, we are able to estimate between-cluster variability. They provide a modeling structure for estimating the intra-class correlation coefficients (ICCs). In this research, random effects of the province as well as urban or rural area of residency and individuals were taken into account in a three-level model. Therefore, linear quantile mixed model (LQMM) was fitted to the data. Independent variables for the model were selected based on existing literature and then using univariate analysis. Variables with a P value < 0.25 in univariate analyses were evaluated in the multivariate stage. Also, variables that were significant ($p < 0.05$) at least at one quantile were kept in final models. In addition, the OLS regression model was fitted for comparison. Appropriate models were selected based on the smaller value of Akaike information criterion (AIC). Statistical analyses were performed using R software version 4.0.2, Package "lqmm".

Results

Data of 16757 participants aged 25–64 with mean age 42.93 ± 10.94 years were analyzed; of them, 7584 (45.3%) were male and 9173 (54.7%) female. BMI in women was significantly higher than in men ($p < 0.001$). There was a significant difference between males and females in terms of education, marital status, smoking, hypertension, diabetes, eating habits, and physical activity ($p < 0.001$). Lipid profiles were different between males and females ($p < 0.001$). Women had higher TC but lower ratios of TC, TG, and LDL-C to HDL-C [Table 1].

The distributions of lipids were statistically significant between males and females, so three-level quantile regression model with mixed effect was performed separately for each gender. Because of a large number of tables, we present results for TC and TG/HDL-C models here, and other findings are presented in supplementary tables.

Age and BMI showed a positive and significant relation with all levels of TC in all quantiles with an increasing trend in male participants. This means that the effect of age and BMI on TC is higher for people with higher TC than those with lower TC. WC at median quantiles and high blood pressure at high quantiles (P75- P90) were positively associated with TC. Diabetes at low quantiles showed a reverse relation with TC level so that with increasing TC level, the effect of diabetes was positive and increasing. Men with high education level had higher TC compared to illiterates. Married men had higher TC compared to single males. Similarly, age, BMI, diabetes, education level, and marital status in females had similar effects as those in males. High blood pressure in females in median quantiles (P50-P75) was positively associated with TC. AIC indicated that the three-level quantile regression model had better fit compared to the OLS regression [Tables 2 and 3].

BMI, WC, and diabetes in both genders were positively correlated with all levels of TG/HDL-C at all studied centiles; quantile regression coefficients had an increasing trend at the right tail of the distribution. Men's age had a negative relation with TG/HDL-C ratio in median quantiles. There was a positive significant correlation between high blood pressure and TG/HDL-C ratio in higher quantiles of male and female participants. High and moderate physical activity decreases TG/HDL-C ratio, especially at upper quantiles. In high school- and university-educated men, TG/HDL-C had an increasing trend from lower to upper percentiles. A similar trend can be seen in smoker men; however, in females, smoking was significant in the median ratio only. Female's age showed a significant positive relation with TG/HDL-C ratio in all quantiles [Tables 4 and 5].

The rest of the results are based on the supplementary tables S1–S10. BMI, WC, diabetes, and hypertension in both genders were significantly correlated with all levels of TG in all quantiles with an increasing trend. High physical activity significantly decreased the high levels of TG. In other words, the higher the TG, the more effective was intensive physical activity. Having higher education level showed a positive relationship with TG in many quantiles. Daily smoking significantly affects the level of TG in most

Table 1: Descriptive characteristics of participants by gender [mean±SD, Median (IQR), *n* (%)]

Variable	Men (*n*=7584)	Women (*n*=9173)	*P*
Age (year)	43.2±11.0	42.7±10.9	0.003
BMI (kg/m^2)	25.9±4.4	27.9±5.3	< 0.001
WC (cm)	91.9±12.9	91.4±13.6	0.01
TC (mg/dL)	160.7±35.4 (158.0 (136-182))	165.9±36.4 (163.0 (141-187))	< 0.001
HDL-C (mg/dL)	37.5±9.9 (36.2 (30.7-43))	43.8±11.4 (42.5 (35.8-50.5))	
LDL-C (mg/dL)	96.9±28.3 (95.1 (77.3-114))	97.8±29.3 (95.1 (77.3-115.2))	0.041
TG (mg/dL)	139.3±91.0 (115.3 (80-171))	120.2±75.6 (101.0 (71-147))	< 0.001
TC/HDL-C	4.5±1.4 (4.3 (3.4-5.3))	4.0±1.3 (3.7 (3.0-4.6))	< 0.001
TG/HDL-C	4.2±3.9 (3.1 (1.9-5.2))	3.1±2.9 (2.3 (1.5-3.7))	< 0.001
LDL-C/HDL-C	2.7±1.0 (2.6 (1.9-3.3))	2.3±0.9 (2.2 (1.7-2.9))	< 0.001
Diabetes	821 (10.9%)	1265 (14.0%)	<0.001
Hypertension	2115 (28.5%)	2892 (32.1%)	<0.001
Smoking	1589 (21%)	60 (0.7%)	< 0.001
Residence			0.55
Rural	2626 (34.6%)	3136 (34.2%)	
Urban	4958 (65.4%)	6037 (65.8%)	
Physical activity			<0.001
Low	3314 (44.8%)	5810 (64.4%)	
Moderate	1298 (17.5%)	1729 (19.2%)	
High	2785 (37.7%)	1483 (16.4%)	
Education (years)			< 0.001
0	537 (7.1%)	1496 (16.3%)	
1-6	2047 (27%)	2895 (31.6%)	
6-12	3433 (45.3%)	3242 (35.3%)	
>12	1567 (20.7%)	1540 (16.8%)	
Marital status			< 0.001
Single	679 (9.1%)	774 (8.6%)	
Married	6686 (89.9%)	7361 (81.8%)	
Divorced/Widow	74 (10.0%)	860 (9.6%)	
Fast -Food Consumption	1023 (13.8%)	937 (10.4%)	< 0.001
Cooking oil type			0.23
Liquid	4632 (62.3%)	5529 (61.3%)	
Solid	2643 (35.6%)	3312 (36.8%)	
Other	156 (2.1%)	173 (1.9%)	
Fruits Consumption) unit per day	1.6±1.1	1.5±1.0	0.01
Vegetables Consumption) unit per day	1.2±1.0	1.2±1.0	< 0.001
Dairy Consumption) unit per day	1.9±0.9	1.7±0.9	< 0.001

Entries are mean and sd for continuous variables and count (percentages) for categorical variables. Median (IQR) is reported for lipid profiles reported in 2nd line. BMI: body mass index, WC: waist circumference

percentiles. Married men had a higher level of TG in many quantiles, compared to singles. In females, the effect of age on TG was positive so that higher levels of TG were elevated as people getting older [Tables S1 and S2].

Age and BMI in both genders were positively correlated with all levels of LDL-C at all studied centiles, and diabetes in low quantiles had negative association with LDL-C levels. Married individuals had higher LDL-C levels than single individuals. In men, WC at quantiles of P25-P90 and hypertension at the high quantile had positive association with LDL-C levels. LDL-C of men with high level of physical activity was reduced. High blood pressure was negatively correlated in the low quantile of LDL-C and positively related at upper quantiles, in females. Daily smoking increased females' LDL-C levels in percentiles 10 and 25. Similar results can be seen in higher educated women [Tables S3 and S4].

In male and female participants, age had a positive and significant relationship with all quantiles of HDL-C levels and showed an increasing trend. On the other hand, BMI and WC showed significant negative relation with HDL-C levels in all quantiles. Diabetes had a negative association with HDL-C levels. In individuals with high level of physical activity, HDL-C has increased compared to those with less physical activity. In men, daily smoking was significantly and negatively correlated

Table 2: Three-level quantile regression coefficients for male participants' total cholesterol in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.19±0.05 **(<0.001)**	0.32±0.04 **(<0.001)**	0.37±0.03 **(<0.001)**	0.50±0.04 **(<0.001)**	0.53±0.08 **(<0.001)**	0.31±0.04 **(<0.001)**
BMI (kg/m^2)	0.99±0.24 **(<0.001)**	0.82±0.20 **(<0.001)**	0.91±0.23 **(<0.001)**	1.13±0.21 **(<0.001)**	1.47±0.37 **(<0.001)**	0.98±0.14 **(<0.001)**
WC (cm)	0.03±0.10 (0.77)	0.13±0.08 (0.11)	0.27±0.08 **(0.001)**	0.26±0.08 **(0.001)**	0.19±0.16 (0.21)	0.20±0.05 **(<0.001)**
Diabetes	-14.00±2.06 **(<0.001)**	-9.21±2.22 **(<0.001)**	-5.37±1.68 **(0.001)**	1.33±1.77 (0.45)	5.53±2.99 (0.06)	-4.10±1.37 **(0.002)**
Hypertension	-0.72±0.05 (0.66)	-0.31±1.12 (0.78)	1.10±1.20 (0.35)	2.82±1.33 **(0.03)**	4.31±1.89 **(0.02)**	2.28±0.97 **(0.01)**
Education Level						
1-6	0.53±2.52 (0.83)	-1.01±1.88 (0.59)	0.67±1.80 (0.70)	-0.61±2.14 (0.77)	-0.59±2.81 (0.83)	-2.02±1.85 (0.27)
7-12	2.75±2.46 (0.26)	0.85±1.79 (0.63)	2.10±1.73 (0.22)	1.89±2.07 (0.36)	3.82±3.36 (0.25)	0.30±1.82 (0.86)
>12	4.58±2.86 (0.11)	2.66±2.06 (0.20)	4.60±2.33 **(0.05)**	5.21±2.51 **(0.04)**	6.05±3.10 **(0.05)**	2.99±1.94 (0.12)
Marital Status						
Married	4.16±1.80 **(0.02)**	1.08±1.57 (0.49)	3.37±1.44 **(0.02)**	1.10±2.18 (0.61)	-3.57±2.98 (0.23)	1.94±1.35 (0.15)
Divorced/ Widowed	1.39±4.49 (0.75)	-5.54±4.07 (0.17)	1.75±6.25 (0.78)	5.34±5.43 (0.32)	-3.02±9.34 (0.74)	0.81±4.06 (0.84)
Residence						
σ_b^2	63.08	24.60	18.24	45.67	103.23	
ICC	0.02	0.01	0.01	0.02	0.02	
Province						
σ_b^2	49.52	21.37	17.88	35.43	37.92	
ICC	0.01	0.01	0.01	0.01	-	
σ_e^2	2916	1810.50	1397.26	2186.49	4183.50	
AIC	77309.96	75740.71	75462.01	77186.76	80076.4	75667.4

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th, and 90th percentiles of total cholesterol. Significant coefficients are shown in bold. AIC: Akaike information criterion, ICC: Intraclass correlation coefficient, σ_b^2 : Random effect variance, σ_e^2 : Error variance

with HDL-C levels in all quantiles (Except P_{10}). Females with high level of education had higher HDL-C than illiterates, but the level of HDL-C was reduced in married women [Tables S5 and S6].

According to Tables S7 and S8, BMI and WC in both genders were significantly correlated with TC-C/HDL-C ratio in all quantiles. In addition, daily smoking was positively correlated with men's TC/HDL-C ratio at all quantiles. Diabetes is meaningful in first quantile (P10) and last quantile (P90); first it had a negative correlation with TC/HDL-C ratio, but in last quantile, it showed a positive correlation and increased TC/HDL-C ratio. High physical activity in men decreased TC/HDL-C ratio in all quantiles compared to low physical activity levels. TC/HDL-C ratio was increased in married men and those with higher education. However, in females, a positive association was observed for age at all quantiles and diabetes and hypertension in upper quantiles.

BMI and WC in both genders were significantly correlated with LDL-C/HDL-C ratio in all quantiles. But diabetes was negatively correlated in lower quantiles and positively at upper ones. Smoking in men had a positive correlation with LDL-C/HDL-C ratio so that regression coefficients tend to increase at high quantiles. High physical activity decreased LDL-C/HDL-C ratio at all quantiles. This ratio was increased in married and also university-educated men [Tables S9 and S10].

The AIC indicated that the three-level quantile regression model had a better fit compared to the OLS regression. The variances of the random effects were also considerable showing that there is association between the level of lipids in provincial habitants as well as urban and rural areas [Tables 2-5].

Discussion

In this study, lipid parameters as quantitative variables were studied based on a nationwide random sampling data for adults 25–64 years old. Random effects resulting from the clustering design of the samples from provinces and areas of residence as rural and urban were taken into

Table 3: Three-level quantile regression coefficients for female participants' total cholesterol in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.68±0.06	0.76±0.05	0.89±0.04	0.95±0.04	0.99±0.10	0.80±0.04
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
BMI (kg/m^2)	1.07±0.20	0.94±0.15	0.81±0.13	0.81±0.18	0.94±0.22	0.76±0.11
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.15±0.06	0.04±0.05	0.02±0.05	0.12±0.07	0.21±0.08	0.08±0.04
	(0.02)	(0.45)	(0.71)	(0.11)	**(0.01)**	**(0.05)**
Diabetes	-6.86±1.70	-3.27±1.72	-1.33±1.48	1.59±1.70	5.17±2.88	-0.64±1.14
	(<0.001)	(0.06)	(0.36)	(0.35)	(0.07)	(0.57)
Hypertension	-0.71±0.97	-1.29±1.05	1.88±0.97	3.32±1.27	1.77±1.37	1.55±0.89
	(0.46)	(0.22)	**(0.05)**	**(0.01)**	(0.20)	(0.08)
Education Level						
1-6	2.15±1.86	2.42±1.74	2.15±1.48	0.24±1.75	1.73±2.34	1.27±1.24
	(0.02)	(0.16)	(0.14)	(0.88)	(0.46)	(0.30)
7-12	6.01±1.99	3.92±1.94	4.02±1.75	2.07±1.91	4.02±2.94	3.70±1.28
	(0.003)	**(0.04)**	**(0.02)**	(0.28)	(0.17)	**(0.003)**
>12	6.33±2.09	3.97±2.04	5.43±1.56	5.09±1.76	7.12±2.07	5.87±1.43
	(0.003)	**(0.05)**	**(<0.001)**	**(0.004)**	**(<0.001)**	**(<0.001)**
Residence						
σ_b^2	37.54	27.93	31.50	55.13	107	
ICC	0.01	0.01	0.02	0.02	0.02	
Province						
σ_b^2	34.20	25.45	19.87	39.77	91.80	
ICC	0.01	-	0.06	0.01	0.02	
σ_e^2	2821.73	1785.90	1390.54	2226.89	4463.57	
AIC	93186.8	91458.7	91209.9	93491.2	97401.0	91826.1

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th, and 90th percentiles of total cholesterol. Significant coefficients are shown in bold. AIC: Akaike information criterion, ICC: Intraclass correlation coefficient, σ_b^2 : Random effect variance, σ_e^2 : Error variance

account using multilevel modeling. In addition, association of factors with different indices of the lipids distribution was studied by the aid of the quantile regression model.

Results showed a significant relationship between age, BMI, WC, diabetes, hypertension, smoking, physical activity, education level, and marital status with lipid parameters. Age was positively associated with TC and LDL-C in both genders and with TG and TG/HDL-C in females at all quantiles. This is in accordance with previous cross-sectional and longitudinal studies.[20,21] In a study on the Japanese population, Wakabayashi also showed an increase in TG/HDL-C ratio in the older females compared to the young females.[22]

Results of a study in China show that TC and LDL-C levels in females over 50 were significantly higher than that of males at the same age[23]; but according to Taiwanese paper, TG, LDL-C, and TC increased with age among those under 50 years old, and it was higher in men. This gender gap decreased as age increased, so that after the age of 50, lipid levels were significantly higher in women compared to men. Similar trend is generally seen in Asian and the Pacific population in terms of age and gender.[24] Our study showed that anthropometric indices such as BMI and waist circumference were positively correlated with TC, TG, LDL-C, TC/HDL-C, LDL-C/HDL-C in their most quantiles and negatively related with HDL-C. These findings suggest that by elevating lipids to their higher centiles, they will be more sensitive to increased BMI and WC. Previous studies also have demonstrated that higher BMI and WC are more likely to be associated with higher levels of lipids.[10,25,26] However, the difference is that our research has explored the relationship in five quantiles of lipids distributions rather than mean point only. The latter is the way that is usually done in other studies. It is believed that obesity reduces lipoprotein lipase activity and can also increase small, dense, and atherogenic lipoprotein of LDL and increase the level of apolipoprotein B.[13,27] The study by Miralles showed that overweight subjects had higher levels of TG/HDL-C.[28]

Diabetes is another factor related to lipid parameters, especially with the level of TG and TG/HDL-C ratio. Its effect was meaningful in all quantiles, and the coefficients were increased moving from lower to upper quantiles. This means that with increasing these lipids to higher levels, the relationship between diabetes and TG and TG/HDL ratio increases. In addition, total cholesterol had negative

Table 4: Three-level quantile regression coefficients for male participants' TG/HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.00±0.002	0.00±0.002	-0.008±0.003	-0.01±0.005	-0.04±0.01	-0.02±0.004
	(0.72)	(0.52)	**(0.01)**	**(0.008)**	(0.06)	**(<0.001)**
BMI (kg/m²)	0.04±0.008	0.09±0.01	0.14±0.01	0.25±0.02	0.31±0.03	0.17±0.01
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.01±0.003	0.01±0.004	0.02±0.005	0.02±0.007	0.04±0.01	0.02±0.005
	(0.001)	**(0.005)**	**(<0.001)**	**(0.001)**	**(0.002)**	**(<0.001)**
Diabetes	0.19±0.10	0.38±0.10	0.74±0.12	1.05±0.19	1.79±0.51	0.95±0.15
	(0.05)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Hypertension	0.05±0.05	0.08±0.04	0.20±0.09	0.38±0.15	0.71±0.26	0.29±0.10
	(0.28)	(0.08)	**(0.03)**	**(0.01)**	**(0.007)**	**(0.006)**
Smoking	0.15±0.04	0.28±0.05	0.45±0.05	0.63±0.10	1.10±0.27	0.58±0.11
	(0.002)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Physical Activity						
Moderate	-0.06±0.05	-0.07±0.06	-0.14±0.09	-0.49±0.20	-0.74±0.31	-0.38±0.11
	(0.21)	(0.29)	(0.10)	**(0.01)**	**(0.02)**	**(0.001)**
High	-0.11±0.04	-0.20±0.03	-0.30±0.05	-0.51±0.12	-0.93±0.22	-0.49±0.09
	(0.09)	(0.20)	**(<0.001)**	**(<0.001)**	**(0.05)**	**(<0.001)**
Education Level						
1-6	0.14±0.08	0.15±0.11	0.29±0.11	0.36±0.15	0.15±0.36	0.35±0.20
	(0.09)	(0.20)	**(0.01)**	**(0.01)**	(0.66)	(0.08)
7-12	0.31±0.09	0.30±0.11	0.47±0.13	0.59±0.15	0.77±0.40	0.68±0.20
	(0.001)	**(0.01)**	**(<0.001)**	**(<0.001)**	**(0.05)**	**(<0.001)**
>12	0.33±0.09	0.36±0.11	0.59±0.15	0.68±0.20	0.84±0.38	0.78±0.21
	(<0.001)	**(0.001)**	**(<0.001)**	**(0.001)**	**(0.03)**	**(<0.001)**
Marital Status						
Married	0.07±0.05	0.06±0.07	0.26±0.08	0.35±0.16	0.94±0.33	0.52±0.14
	(0.23)	(0.38)	**(0.003)**	**(0.03)**	**(0.005)**	**(<0.001)**
Divorced/ Widowed	0.17±0.20	0.08±0.17	-0.01±0.25	0.49±0.63	1.34±0.91	0.28±0.44
	(0.40)	(0.63)	(0.95)	(0.43)	(0.14)	(0.51)
Residence						
σ_b^2	6.91	4.72	0.11	0.46	1.30	
ICC	0.41	0.36	0.01	0.02	0.02	
Province						
σ_b^2	1.39	0.01	0.04	0.24	1.53	
ICC	0.12	-	-	0.01	0.02	
σ_e^2	9.58	8.06	9.00	20.97	61.93	
AIC	34228.1	34718.1	37220.3	41966.8	48148.1	42203.5

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th, and 90th percentiles of TG/HDL-C. Significant coefficients are shown in bold. AIC: Akaike information criterion, ICC: Intraclass correlation coefficient, σ_b^2: Random effect variance, σ_e^2: Error variance

relation with diabetes at its lower quantiles. The specific mechanism of association between lipid ratios and diabetes is not now known. According to a pathophysiological model, lipids are deposited improperly in non-fat tissues such as the liver, skeletal muscle, and Beta pancreas cells.[29] These inappropriate lipid deposits are related to lipotoxicity, including pressure of endoplasmic reticulum, disruption of mitochondrial function, oxidative stress, and inflammation, which in turn leads to insulin resistance and finally a decrease in β-galactosidase function.[30] Insulin resistance can alter systemic lipid metabolism, leading to dyslipidemia and the well-known lipid triad, high levels of plasma triglycerides, low levels of high-density lipoprotein, and the appearance of small dense low-density lipoproteins.[31]

A study of the general Korean population found that there was a linear association between the TG/HDL-C ratio and insulin resistance.[32]

We also found that hypertension was significantly associated with lipid parameters (TC, TG, LDL-C, TC/HDL-C, and LDL-C/HDL-C) in some quantiles; this relationship was different in men and women. The relationship was strong for TG and TG/HDL-C ratio. However, no significant

Table 5: Three-level quantile regression coefficients for female participants' TG/HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.003±0.001	0.005±0.001	0.008±0.001	0.01±0.004	0.01±0.007	0.008±0.003
	(0.03)	**(<0.001)**	**(<0.001)**	**(0.005)**	**(0.02)**	**(0.006)**
BMI (kg/m²)	0.02±0.003	0.03±0.003	0.05±0.006	0.06±0.01	0.09±0.02	0.03±0.008
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.007±0.001	0.01±0.001	0.01±0.002	0.03±0.006	0.04±0.01	0.02±0.003
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Diabetes	0.19±0.05	0.35±0.06	0.58±0.11	1.05±0.19	1.90±0.32	0.95±0.09
	(0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Hypertension	0.05±0.03	0.10±0.03	0.16±0.04	0.27±0.09	0.36±0.14	0.27±0.07
	(0.13)	**(0.002)**	**(<0.001)**	**(0.004)**	**(0.01)**	**(<0.001)**
Smoking	0.12±0.10	0.06±0.12	0.33±0.18	0.15±0.33	1.29±2.16	0.15±0.38
	(0.22)	(0.60)	**(0.05)**	(0.63)	(0.55)	(0.69)
Physical Activity						
Moderate	0.03±0.02	0.05±0.03	0.03±0.05	-0.02±0.09	-0.13±0.18	-0.01±0.07
	(0.20)	(0.07)	(0.14)	(0.76)	(0.47)	(0.82)
High	-0.05±0.03	-0.09±0.04	-0.14±0.04	-0.24±0.08	-0.27±0.21	-0.22±0.08
	(0.11)	**(0.02)**	**(0.002)**	**(0.006)**	(0.20)	**(0.005)**
Residence						
σ_b^2	0.74	0.97	0.02	0.19	0.56	
ICC	0.13	0.19	-	0.01	0.01	
Province						
σ_b^2	0.57	1.34	13.47	0.04	0.22	
ICC	0.10	0.24	0.74	-	-	
σ_e^2	4.92	4.12	4.57	11.02	33.75	
AIC	34996.9	35768.1	38838.6	44788.7	52585.6	45427.1

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th, and 90th percentiles of TG/HDL-C. Significant coefficients are shown in bold. AIC: Akaike information criterion, ICC: Intraclass correlation coefficient, σ_b^2 : Random effect variance, σ_e^2 : Error

relation was seen between high blood pressure and HDL-C levels. This finding suggests that control of blood pressure should be considered by increasing TG and TG/HDL-C ratio and in turn can be used as an important factor in predicting hypertension.

Generally, smoking is a risk factor for dyslipidemia. In our study, relationship between lipid parameters and smoking was different in men and women. There was a positive and significant correlation between smoking in men and TC/HDL-C, TG/HDL-C, LDL-C/HDL-C, and negative association with HDL-C ratios in all quantiles compared to non-smokers. Quantile regression coefficients tended to increase in higher quantiles. Gamit *et al.*[33] reported that the presence of nicotine in cigarette smoke increased levels of TG, cholesterol, VLDL, and decreased HDL-C levels. In a cross-sectional study on adult men in North West of China village, Li *et al.*[34] concluded that TC/HDL-C, TG/HDL-C, and LDL-C/HDL-C ratios were significantly higher in smokers than non-smokers, whereas HDL-C was lower in smokers. In a meta-analysis, Craig and colleagues analyzed the association between smoking in adults and lipids' concentration. The results of 54 published studies revealed that smokers had higher levels of TC (3.0%), TG (9.1%), very low-density lipoprotein-cholesterol (VLDL-C) (10.4%), LDL-C (1.7%), and lower level of HDL-C (5.7%) compared to non-smokers. In addition, significant dose-dependent relationships were reported for TC, TG, and LDL-C findings.[35]

We observed significant association between high physical activity and lipid parameters; this association in males was higher than females. In men, there was a positive relationship between high level of physical activity and HDL-C in all quantiles so that intensive body activity increased the HDL-C levels. The results of the study showed that the duration, amount, and the intensity of exercise all related to the effect size of exercise on blood lipids. HDL-C is the most sensitive factor to exercise. The mechanism of fat changes resulting from exercise is unclear, but the exercise itself may lead to reduction of lipids.[36,37] Truthmann *et al.*[38] found that there was a significant relationship between higher physical activity and lower level of TG and also higher level of HDL-C. In study of Li Qi *et al.*,[27] a general inverse relationship between regular physical activity and lipid disorder was found.

Other factors affecting lipid parameters were education and marital status, those with higher education level compared to the illiterates and married people compared to unmarried had higher level of lipids. This relationship was stronger in men. A study in China among people of 18 years old and above showed a positive association between the level of education and the prevalence of dyslipidemia in a multivariate analysis, which may be related to a better economic level along with excessive nutrition in people with high education.[27]

Our results are expected to help policymakers for developing appropriate prevention and control strategies for modifiable risk factors of dyslipidemia in order to decrease the overall non-communicable disease mortality and morbidity.

Like any other study, our research had some limitations. Since the STEPs data have been gathered in a cross-sectional study, causality between factors and lipid disorders could not be inferred. In this study, we did not include the data of health behaviors and eating habits of the participants in analyses which can be regarded as a limitation. However, the main strength of this research is its representativeness on national and subnational levels and data quality based on the comprehensive standard protocol and regulatory guidelines for execution and monitoring. On the other hand, the present report has benefitted the advantages of sophisticated statistical modeling. Taking into account of cluster effects by applying multilevel modeling and random effects and also analysis of the whole domain of lipids distribution using quantile regression are strengths of this research.

Conclusions

In this study, the method used showed that the effect of each factor on lipid profiles varies depending on the centiles of TC, TG/HDL-C, and also TG, LDL-C, HDL-C, TC/HDL-C, and LDL-C/HDL-C. There was a significant relationship between age, BMI, WC, diabetes, hypertension, smoking, physical activity, education, and marital status with lipid parameters. In females, lipid parameters increased with age, so middle and old-aged females should pay more attention to their level of lipids.

Ethics approval and consent to participate

This article is adapted from a master's thesis in epidemiology. This research has also been reviewed and approved by the ethics committee of the Shahid Beheshti University of Medical Sciences with code: IR.SBMU.PHNS.REC.1399.059. Individuals who were willing to participate completed the written informed consent forms.

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Conflicts of interest

There are no conflicts of interest.

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References

1. Amini M, Zayeri F, Salehi M. Trend analysis of cardiovascular disease mortality, incidence, and mortality-to-incidence ratio: Results from global burden of disease study 2017. BMC Public Health 2021;21:401.
2. Tohidi M, Mohebi R, Cheraghi L, Hajsheikholeslami F, Aref S, Nouri S, *et al*. Lipid profile components and incident cerebrovascular events versus coronary heart disease; The result of 9 years follow-up in Tehran lipid and glucose study. Clin Biochem 2013;46:716-21.
3. A Comparison of lipid variables as predictors of cardiovascular disease in the asia pacific region. Ann Epidemiol 2005;15:405-13.
4. Quispe R, Manalac RJ, Faridi KF, Blaha MJ, Toth PP, Kulkarni KR, *et al*. Relationship of the triglyceride to high-density lipoprotein cholesterol (TG/HDL-C) ratio to the remainder of the lipid profile: The Very Large Database of Lipids-4 (VLDL-4) study. Atherosclerosis 2015;242:243-50.
5. Hadaegh F, Khalili D, Ghasemi A, Tohidi M, Sheikholeslami F, Azizi F. Triglyceride/HDL-cholesterol ratio is an independent predictor for coronary heart disease in a population of Iranian men. Nutr Metab Cardiovasc Dis 2009;19:401-8.
6. Eeg-Olofsson K, Gudbjörnsdottir S, Eliasson B, Zethelius B, Cederholm J. The triglycerides-to-HDL-cholesterol ratio and cardiovascular disease risk in obese patients with type 2 diabetes: An observational study from the Swedish National Diabetes Register (NDR). Diabetes Res Clin Pract 2014;106:136-44.
7. Hajian-Tilaki K, Heidari B, Bakhtiari A. Triglyceride to high-density lipoprotein cholesterol and low-density lipoprotein cholestrol to high-density lipoprotein cholesterol ratios are predictors of cardiovascular risk in Iranian adults: Evidence from a population-based cross-sectional study. Caspian J Intern Med 2020;11:53-61.
8. Narindrarangkura P, Bosl W, Rangsin R, Hatthachote P. Prevalence of dyslipidemia associated with complications in diabetic patients: A nationwide study in Thailand. Lipids Health Dis 2019;18:90.
9. He H, Yu YQ, Li Y, Kou CG, Li B, Tao YC, *et al*. Dyslipidemia awareness, treatment, control and influence factors among adults in the Jilin province in China: A cross-sectional study. Lipids Health Dis 2014;13:122.
10. Opoku S, Gan Y, Fu W, Chen D, Addo-Yobo E, Trofimovitch D, *et al*. Prevalence and risk factors for dyslipidemia among adults in rural and urban China: Findings from the China National Stroke Screening and prevention project (CNSSPP). BMC Public Health 2019;19:1500.
11. Gao H, Wang H, Shan G, Liu R, Chen H, Sun S, *et al*. Prevalence

of dyslipidemia and associated risk factors among adult residents of Shenmu City, China. PLoS One 2021;16:e0250573.

12. Zhang X, Shen L, Wang Y, Guo X, Dou J, Lv Y, *et al*. The influencing factors of serum lipids among middle-aged women in Northeast China. Iran J Public Health 2018;47:1660-6.
13. Zhang A, Yao Y, Xue Z, Guo X, Dou J, Lv Y, *et al*. A study on the factors influencing triglyceride levels among adults in northeast China. Sci Rep 2018;8:6388.
14. Biganeh E, Mehrabi Y, Mirmiran P, Khadem Maboudi A, Nazeri P. Application of quantile regression model in assessment of urine iodine related factors in Tehran population. Iran J Endocrinol Metab 2013;15:33-40.
15. Hosseinzadeh Z, Bakhshi E, Jashni Motlagh A, Biglarian A. Application of quantile regression to identify of risk factors in infant's growth parameters. RJMS 2018;24:85-95.
16. Djalalinia S, Modirian M, Sheidaei A, Yoosefi M, Zokaiee H, Damirchilu B, *et al*. Protocol design for large-scale cross-sectional studies of surveillance of risk factors of non-communicable diseases in Iran: STEPs 2016. Arch Iran Med 2017;20:608-16.
17. Available from: https://www.who.int/ncds/surveillance/steps/GPAQ/en/.
18. Aryan Z, Mahmoudi N, Sheidaei A, Rezaei S, Mahmoudi Z, Gohari K, *et al*. The prevalence, awareness, and treatment of lipid abnormalities in Iranian adults: Surveillance of risk factors of noncommunicable diseases in Iran 2016. J Clin Lipidol 2018;12:1471-81.e4.
19. Chen Y, Zhang X, Pan B, Jin X, Yao H, Chen B, *et al*. A modified formula for calculating low-density lipoprotein cholesterol values. Lipids Health Dis 2010;9:52.
20. Gostynski M, Gutzwiller F, Kuulasmaa K, Döring A, Ferrario M, Grafnetter D, *et al*. Analysis of the relationship between total cholesterol, age, body mass index among males and females in the WHO MONICA Project. Int J Obes Relat Metab Disord 2004;28:1082-90.
21. Veghari G, Sedaghat M, Joshghani H, Niknezad F, Angizeh A, Tazik E, *et al*. Plasma total cholesterol level and some related factors in northern Iranian people. J Nat Sci Biol Med 2013;4:359-63.
22. Wakabayashi I. Influence of age and gender on triglycerides-to-HDL-cholesterol ratio (TG/HDL ratio) and its association with adiposity index. Arch Gerontol Geriatr 2012;55:729-34.
23. Pan L, Yang Z, Wu Y, Yin RX, Liao Y, Wang J, *et al*. The prevalence, awareness, treatment and control of dyslipidemia among adults in China. Atherosclerosis 2016;248:2-9.
24. Lin CF, Chang YH, Chien SC, Lin YH, Yeh HY. Epidemiology of dyslipidemia in the Asia Pacific region. Int J Gerontol 2018;12:2-6.
25. Shen Z, Munker S, Wang C, Xu L, Ye H, Chen H, *et al*. Association between alcohol intake, overweight, and serum lipid levels and the risk analysis associated with the development of dyslipidemia. J Clin Lipidol 2014;8:273-8.
26. Feingold KR. Obesity and dyslipidemia. In: Feingold KR, Anawalt B, Blackman M, Boyce A, Chrousos G, de Herder WW, *et al.,* edotext. South Dartmouth (MA): MDText.com, 2000-2020, PubMed PMID: 26247088.
27. Qi L, Ding X, Tang W, Li Q, Mao D, Wang Y. Prevalence and risk factors associated with dyslipidemia in Chongqing, China. Int J Environ Res Public Health 2015;12:13455-65.
28. Weiler Miralles CS, Wollinger LM, Marin D, Genro JP, Contini V, Morelo Dal Bosco S. Waist-to-height ratio (WHtR) and triglyceride to HDL-C ratio (TG/HDL-c) as predictors of cardiometabolic risk. Nutr Hosp 2015;31:2115-21.
29. Seo MH, Bae JC, Park SE, Rhee EJ, Park CY, Oh KW, *et al*. Association of lipid and lipoprotein profiles with future development of type 2 diabetes in nondiabetic Korean subjects: A 4-year retrospective, longitudinal study. J Clin Endocrinol Metab 2011;96:E2050-4.
30. Yu Y, Bao H, Cheng X. Association between different lipid ratios and diabetes in Chinese adults with H-type hypertension. 2020. doi: 10.21203/rs. 3.rs-124308/v1.
31. Ormazabal V, Nair S, Elfeky O, Aguayo C, Salomon C, Zuñiga FA. Association between insulin resistance and the development of cardiovascular disease. Cardiovasc Diabetol 2018;17:122.
32. Kim JS, Kang HT, Shim JY, Lee HR. The association between the triglyceride to high-density lipoprotein cholesterol ratio with insulin resistance (HOMA-IR) in the general Korean population: Based on the National Health and Nutrition Examination Survey in 2007–2009. Diabetes Res Clin Pract 2012;97:132-8.
33. Gamit KS, Nanavati MG, Gohel PM, Gonsai R. Effects of smoking on lipids profile. Int J Curr Res Rev 2013;5:36-42.
34. Li XX, Zhao Y, Huang LX, Xu HX, Liu XY, Yang JJ, *et al*. Effects of smoking and alcohol consumption on lipid profile in male adults in northwest rural China. Public Health 2018;157:7-13.
35. Craig WY, Palomaki GE, Haddow JE. Cigarette smoking and serum lipid and lipoprotein concentrations: An analysis of published data. BMJ 1989;298:784-8.
36. Wang Y, Xu D. Effects of aerobic exercise on lipids and lipoproteins. Lipids Health Dis 2017;16:132.
37. Koh-Banerjee P, Chu NF, Spiegelman D, Rosner B, Colditz G, Willett W, *et al*. Prospective study of the association of changes in dietary intake, physical activity, alcohol consumption, and smoking with 9-y gain in waist circumference among 16 587 US men. Am J Clin Nutr 2003;78:719-27.
38. Truthmann J, Schienkiewitz A, Busch MA, Mensink GB, Du Y, Bosy-Westphal A, *et al*. Changes in mean serum lipids among adults in Germany: Results from National Health Surveys 1997-99 and 2008-11. BMC Public Health 2016;16:240.

Table S1: Three-level Quantile regression coefficients for male participants' TG in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.08±0.06	0.04±0.07	0.05±0.09	-0.41±0.13	-0.53±0.28	-0.33±0.11
	(0.17)	(0.56)	(0.57)	**(0.003)**	(0.07)	**(0.003)**
BMI (kg/m²)	1.47±0.23	2.49±0.39	3.96±0.50	6.46±0.52	8.15±0.90	4.37±0.37
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.34±0.07	0.42±0.11	0.46±0.13	0.56±0.16	0.86±0.27	0.63±0.12
	(<0.001)	**(<0.001)**	**(<0.001)**	**(0.001)**	**(0.002)**	**(<0.001)**
Diabetes	5.40±3.40	9.40±2.21	19.42±3.96	27.29±4.83	35.14±12.55	23.68±3.47
	(0.11)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.006)**	**(<0.001)**
Hypertension	2.54±1.09	3.53±1.30	7.46±2.55	11.57±3.95	18.24±6.90	9.22±2.47
	(0.02)	**(0.008)**	**(0.004)**	**(0.004)**	**(0.009)**	**(<0.001)**
Smoking	5.18±1.40	6.29±1.22	6.87±1.74	12.53±2.92	9.23±6.46	9.17±2.54
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	(0.15)	**(<0.001)**
Physical Activity						
Moderate	-1.43±1.65	-2.53±1.65	-4.31±3.13	-8.06±4.69	-12.79±6.73	-9.14±2.74
	(0.38)	(0.12)	(0.17)	(0.08)	(0.06)	(0.17)
High	-2.00±1.14	-6.11±1.44	-6.70±1.60	-11.32±3.22	-12.23±6.40	-10.57±2.27
	(0.08)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.05)**	**(<0.001)**
Education Level						
1-6	4.93±2.21	5.18±2.74	7.38±2.72	8.62±4.01	12.15±8.31	8.53±4.69
	(0.02)	(0.06)	**(0.007)**	**(0.03)**	(0.14)	(0.06)
7-12	8.26±2.30	8.70±2.55	14.11±2.72	15.63±4.23	27.76±9.79	18.62±4.62
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.005)**	**(<0.001)**
>12	11.06±2.45	12.72±2.79	16.62±3.36	19.89±5.70	25.54±9.51	22.01±4.95
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.008)**	**(<0.001)**
Marital Status						
Married	0.89±1.68	3.26±2.25	8.94±2.77	9.84±4.67	18.64±8.94	12.21±3.43
	(0.59)	(0.15)	(0.001)	(0.03)	(0.03)	(<0.001)
Divorced/ Widowed	3.60±7.04	3.97±5.58	0.14±11.73	16.88±16.91	22.29±22.55	8.35±10.30
	(0.61)	(0.47)	(0.99)	(0.32)	(0.32)	(0.41)
Residence						
σ_b^2	4.59	15.18	100.82	272.20	-	
ICC	-	-	0.01	0.02	-	
Province						
σ_b^2	3.92	-	21.65	159.6	2469.09	
ICC	-	-	-	0.01	0.06	
σ_e^2	7334.20	5803.39	5959.84	12588.84	33819.21	
AIC	84235.9	84523.4	86445.5	90448.6	95925.8	89759.5

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of TG. Significant coefficients are shown in Bold. AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2: Error variance

Table S2: Three-level Quantile regression coefficients for female participants' TG in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear regression
Age (year)	0.41±0.04	0.55±0.04	0.66±0.06	0.79±0.11	1.00±0.24	0.65±0.08
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
BMI (kg/m^2)	0.71±0.12	0.93±0.12	1.48±0.20	2.27±0.45	2.82±0.71	1.37±022
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.30±0.06	0.42±0.06	0.55±0.10	0.82±0.20	1.06±0.26	0.76±0.08
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Diabetes	6.53±1.82	10.11±1.90	20.43±3.10	35.21±4.59	57.41±7.79	27.97±2.31
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Hypertension	3.15±1.21	4.15±1.42	6.39±1.30	9.45±2.50	10.70±3.43	7.48±1.80
	(0.01)	**(0.004)**	**(<0.001)**	**(<0.001)**	**(0.002)**	**(<0.001)**
Physical Activity						
Moderate	2.20±0.99	2.10±1.04	1.70±1.68	-1.39±2.73	-3.69±4.29	-1.25±1.89
	(0.08)	(0.10)	(0.31)	(0.60)	(0.39)	(0.50)
High	-0.35±1.04	-2.10±1.25	-4.90±1.68	-7.08±2.30	-6.07±5.67	-4.55±2.06
	(0.73)	(0.09)	**(0.004)**	**(0.002)**	(0.28)	**(0.02)**
Education Level						
1-6	2.08±1.31	2.23±1.64	2.26±1.54	6.00±3.42	8.37±4.76	2.26±2.52
	(0.11)	(0.17)	(0.14)	(0.08)	(0.08)	(0.36)
7-12	2.47±1.54	4.28±1.93	5.99±2.00	9.32±3.58	12.09±6.93	8.03±2.59
	(0.11)	**(0.02)**	**(0.003)**	**(0.01)**	(0.08)	**(0.001)**
>12	2.84±1.58	2.68±2.20	2.36±1.58	6.69±3.76	9.48±6.17	5.64±2.90
	(0.07)	(0.22)	(0.13)	**(0.05)**	(0.12)	**(0.05)**
Residence						
σ_b^2	13.59	25.98	39.61	133.29	765.9	
ICC	-	-	-	0.01	0.03	
Province						
σ_b^2	4.32	13.25	10.81	38.67	289.8	
ICC	-	-	-	-	0.01	
σ_e^2	4893.00	3875.06	4039.87	8712.35	23073.61	
AIC	98180.7	98540.9	100960.8	105984.7	112469	104733.5

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of TG. Significant coefficients are shown in Bold. AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2:Random effect variance, σ_e^2:Error variance

Table S3: Three-level Quantile regression coefficients for male participants' LDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear regression
Age (year)	0.12±0.04	0.20±0.03	0.30±0.03	0.39±0.03	0.39±0.07	0.24±0.03
	(0.01)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
BMI (kg/m^2)	0.82±0.17	0.60±0.13	0.84±0.17	0.87±0.21	1.34±0.27	0.78±0.11
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.11±0.07	0.24±0.04	0.20±0.06	0.24±0.08	0.09±0.11	0.19±0.04
	(0.15)	**(<0.001)**	**(0.002)**	**(0.005)**	(0.41)	**(<0.001)**
Diabetes	-12.15±1.99	-9.80±1.74	-4.01±1.72	-1.76±1.73	2.67±2.52	-4.83±1.09
	(<0.001)	**(<0.001)**	**(0.02)**	(0.31)	(0.27)	**(<0.001)**
Hypertension	-2.02±1.31	-0.97±0.91	0.46±0.99	1.19±0.89	2.30±1.19	0.90±0.77
	(0.12)	(0.29)	(0.64)	(0.18)	**(0.05)**	(0.24)
Physical Activity						
Moderate	-1.50±1.22	-1.98±1.07	-3.32±1.15	-3.35±1.23	-1.58±2.23	-2.36±0.85
	(0.22)	(0.06)	**(0.004)**	**(0.009)**	(0.47)	**(0.005)**
High	-1.30±0.81	-1.56±0.76	-1.77±1.58	-2.41±0.77	-3.68±1.01	-1.91±0.70
	(0.11)	**(0.04)**	**(0.002)**	**(0.002)**	**(<0.001)**	**(0.006)**
Marital Status						
Married	2.43±1.11	2.28±0.90	1.33±0.81	0.75±1.36	-2.13±2.48	0.50±1.06
	(0.03)	**(0.01)**	(0.10)	(0.68)	(0.39)	(0.63)
Divorced/ Widowed	2.50±2.95	-1.88±3.73	0.84±5.16	0.88±5.38	-1.68±8.29	0.25±3.22
	(0.39)	(0.61)	(0.87)	(0.87)	(0.83)	(0.93)
Residence						
σ_b^2	12.90	11.69	11.49	40.49	107.29	
ICC	-	-	0.01	0.02	0.03	
Province						
σ_b^2	8.30	5.38	10.67	30.57	31.98	
ICC	-	-	0.01	0.02	0.01	
σ_e^2	1867.10	1157.36	894.01	1392.78	2658.43	
AIC	73899.6	72321.1	72061.1	73765.7	76636.8	72191

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of LDL-cholesterol. Significant coefficients are shown in Bold.
AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2:Error variance

Table S4: Three-level Quantile regression coefficients for female participants' LDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear regression
Age (year)	0.43±0.04	0.51±0.04	0.61±0.03	0.79±0.04	0.86±0.07	0.56±0.03
	(<0.001)	**(<0.001)**	**(<0.001)**	**(0.01)**	**(<0.001)**	**(<0.001)**
BMI (kg/m^2)	1.06±0.16	0.93±0.09	0.79±0.11	0.74±0.16	0.78±0.18	0.71±0.09
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	-0.10±0.05	-0.009±0.04	0.04±0.03	0.08±0.06	0.13±0.07	0.09±0.05
	(0.10)	(0.84)	**(0.05)**	(0.14)	(0.10)	**(0.008)**
Diabetes	-6.73±1.54	-3.60±1.29	-2.23±0.96	-0.19±1.26	-0.42±2.65	-2.19±0.92
	(<0.001)	**(0.006)**	**(0.02)**	(0.78)	(0.87)	**(0.01)**
Hypertension	-1.77±0.84	-0.59±1.03	1.22±0.59	2.45±1.05	1.71±1.03	1.07±0.72
	(0.03)	(0.57)	**(0.04)**	**(0.02)**	(0.10)	(0.13)
Smoking	9.76±3.88	7.72±3.94	4.15±2.71	5.23±4.52	-4.89±5.81	3.96±3.88
	(0.01)	**(0.05)**	(0.12)	(0.24)	(0.40)	(0.30)
Education Level						
1-6	0.45±1.45	1.57±1.42	1.31±1.18	1.25±1.35	1.50±2.10	0.56±1.00
	(0.75)	(0.27)	(0.26)	(0.35)	(0.47)	(0.57)
7-12	3.53±1.56	2.97±1.40	2.11±1.39	2.35±1.52	3.47±2.35	2.02±1.03
	(0.02)	**(0.03)**	(0.13)	(0.12)	(0.14)	**(0.05)**
>12	2.64±1.70	2.76±1.34	2.08±1.35	3.68±1.69	4.73±1.99	3.43±1.16
	(0.12)	**(0.04)**	(0.12)	**(0.03)**	**(0.01)**	**(0.003)**
Marital Status						
Married	-1.44±1.06	1.13±0.81	1. 35±1.00	0.77±1.60	0.90±2.50	2.49±1.03
	(0.17)	(0.16)	(0.17)	(0.62)	(0.71)	**(0.01)**
Divorced/ Widowed	1.27±1.40	1.77±1.44	2.38±1.21	0.73±1.84	1.61±3.33	3.29±1.43
	(0.86)	(0.22)	**(0.05)**	(0.69)	(0.62)	**(0.02)**
Residence						
σ_b^2	18.61	10.17	16.69	20.78	48.93	
ICC	0.01	-	0.01	0.01	0.01	
Province						
σ_b^2	12.21	9.27	19.79	31.62	61.14	
ICC	-	-	0.02	0.02	0.02	
σ_e^2	1817.31	1156	906.61	1456.94	2890.13	
AIC	89145.1	87460.4	87301.7	89608.7	93420.6	87894.4

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of LDL-cholesterol. Significant coefficients are shown in Bold.
AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2: Error variance

Table S5: Three-level Quantile regression coefficients for male participants' HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.05±0.01	0.04±0.01	0.06±0.01	0.07±0.01	0.10±0.03	0.06±0.01
	(0.003)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.001)**	**(<0.001)**
BMI (kg/m^2)	-0.30±0.07	-0.37±0.06	-0.35±0.05	-0.41±0.06	-0.42±0.10	-0.39±0.04
	(<0.001)	**(<0.001))**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	-0.07±0.02	-0.06±0.02	-0.08±0.02	-0.09±0.02	-0.11±0.03	-0.07±0.01
	(0.006)	**(0.007)**	**(<0.001)**	**(<0.001)**	**(0.003)**	**(<0.001)**
Diabetes	-1.26±0.40	-1.30±0.30	-1.22±0.29	-1.37±0.42	-1.05±1.04	-1.20±0.37
	(0.002)	**(<0.001)**	**(<0.001)**	**(0.001)**	(0.31)	(0.001)
Smoking	2.12±0.27	-2.02±0.21	-2.22±0.31	-2.15±0.43	-2.41±0.73	-2.14±0.27
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.001)**	**(<0.001)**
Physical Activity						
Moderate	0.63±0.41	0.78±0.35	0.49±0.38	0.07±0.52	0.27±0.91	0.46±0.29
	(0.13)	**(0.02)**	(0.20)	(0.79)	(0.76)	(0.12)
High	1.02±0.34	1.35±0.22	1.43±0.24	1.55±0.35	1.89±0.53	1.62±0.24
	(0.003)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Residence						
σ_b^2	2.18	1.55	2.41	2.87	4.60	
ICC	0.01	0.01	0.02	0.01	0.01	
Province						
σ_b^2	1.59	1.69	3.49	4.09	3.88	
ICC	-	0.01	0.03	0.02	0.01	
σ_e^2	185.23	121	101.60	175.03	367.48	
AIC	56404.7	55209.7	55595.4	58025.6	61595.4	56164.0

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of HDL-cholesterol. Significant coefficients are shown in Bold.
AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2: Error variance

Table S6: Three-level Quantile regression coefficients for female participants' HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.04±0.02	0.08±0.02	0.09±0.01	0.10±0.01	0.14±0.03	0.08±0.01
	(0.03)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
BMI (kg/m²)	-0.08±0.07	-0.15±0.06	-0.14±0.04	-0.24±0.07	-0.24±0.08	-0.18±0.03
	(0.28)	**(0.01)**	**(0.004)**	**(<0.001)**	**(0.003)**	**(0.004)**
WC (cm)	-0.09±0.02	- 0.10±0.02	-0.12±0.01	-0.10±0.02	-0.12±0.03	-0.10±0.01
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Diabetes	-1.51±0.37	-1.31±0.42	-1.60±0.41	-1.94±0.52	-1.76±0.81 **(0.03)**	-1.45±0.36
	(<0.001)	**(0.002)**	**(<0.001)**	**(<0.001)**		**(<0.001)**
Physical Activity						
Moderate	-0.42±0.49	-0.61±0.42	0.01±0.42	0.34±0.51	0.13±0.84	0.06±0.30
	(0.38)	(0.14)	(0.97)	(0.51)	(0.87)	(0.98)
High	1.21±0.35	0.45±0.33	0.78±0.35	0.98±0.64	1.14±0.81	1.20±0.32
	(<0.001)	(0.17)	**(0.02)**	(0.13)	(0.16)	**(<0.001)**
Education Level						
1-6	0.80±0.57	0.40±0.50	0.46±0.40	0.42±0.64	0.43±0.95 (0.65)	0.53±0.40
	(0.16)	(0.43)	(0.25)	(0.51)		(0.18)
7-12	0.83±0.61	0.69±0.54	0.64±0.57	0.87±0.65	1.48±1.02	0.67±0.41
	(0.17)	(0.20)	(0.26)	(0.18)	(0.14)	(0.10)
>12	1.63±0.75	1.45±0.56	2.14±0.58	2.17±0.87	2.84±1.28	1.93±0.46
	(0.03)	**(0.01)**	**(<0.001)**	**(0.01)**	**(0.02)**	**(<0.001)**
Marital Status						
Married	-0.15±0.58	-1.09±0.49	-1.13±0.50	-1.52±0.58	1.81-± 0.92	-0.60±0.41
	(0.78)	**(0.03)**	**(0.02)**	**(0.01)**	**(0.05)**	(0.14)
Divorced/ Widowed	-0.32±0.80	-0.86±0.72	-1.13±0.49	-1.64±0.70	-2.75±1.18	-0.68±0.57
	(0.68)	(0.23)	**(0.02)**	**(0.02)**	**(0.02)**	(0.22)
Residence						
σ_b^2	4.32	1.28	0.95	0.87	5.23	
ICC	0.01	-	0.006	0.003	0.01	
Province						
σ_b^2	65.88	1.46	2.13	2.56	5.72	
ICC	0.003	0.008	0.01	0.01	0.01	
σ_e^2	278.89	178.75	146.89	244.29	494.17	
AIC	71988.8	70341.4	70572.4	73190	77199.9	71079.2

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of HDL-cholesterol. Significant coefficients are shown in Bold.
AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2:Random effect variance, σ_e^2:Error variance

Table S7: Three-level Quantile regression coefficients for male participants' TC/HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.00±0.002	0.001±0.001	0.001±0.001	0.004±0.002	0.004±0.003	0.00±0.001
	(0.88)	(0.45)	(0.32)	(0.12)	(0.24)	(0.57)
BMI (kg/m²)	0.04±0.008	0.05±0.008	0.08±0.01	0.10±0.01	0.12±0.01	0.07±0.005
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.01±0.002	0.01±0.002	0.01±0.004	0.009±0.005	0.01±0.005	0.01±0.002
	(<0.001)	**(<0.001)**	**(0.001)**	**(0.05)**	**(0.002)**	**(<0.001)**
Diabetes	-0.15±0.06	-0.08±0.06	-0.04±0.07	0.13±0.10	0.48±0.13	0.04±0.05
	(0.02)	(0.17)	(0.49)	(0.19)	**(<0.001)**	(0.38)
Smoking	0.13±0.03	0.21±0.04	0.31±0.04	0.34±0.05	0.56±0.09	0.32±0.03
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Physical Activity						
Moderate	-0.13±0.04	-0.10±0.05	-0.16±0.04	-0.15±0.09	-0.19±0.10	-0.16±0.04
	(0.004)	(0.07)	**(0.001)**	(0.10)	(0.06)	**(0.001)**
High	-0.13±0.03	-0.17±0.03	-0.22±0.04	-0.27±0.05	-0.29±0.09	-0.22±0.03
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.002)**	**(<0.001)**
Education Level						
1-6	0.03±0.07	0.05±0.07	0.10±0.06	0.06±0.11	-0.12±0.18	0.02±0.07
	(0.64)	(0.43)	(0.11)	(0.61)	(0.51)	(0.77)
7-12	0.11±0.06	0.16±0.06	0.19±0.06	0.17±0.12	0.15±0.19	0.13±0.07
	(0.10)	**(0.01)**	**(0.007)**	(0.16)	(0.42)	**(0.05)**
>12	0.19±0.06	0.26±0.08	0.27±0.08	0.29±0.13	0.22±0.17	0.20±0.07
	(0.006)	**(0.001)**	**(0.001)**	**(0.03)**	(0.21)	**(0.007)**
Marital Status						
Married	0.09±0.05	0.10±0.04	0.13±0.05	0.11±0.08	0.18±0.10	0.14±0.05
	(0.10)	**(0.01)**	**(0.009)**	(0.18)	(0.07)	**(0.008)**
Divorced/ Widowed	0.16±0.15	-0.09±0.16	0.03±0.26	0.04±0.36	0.47±0.30	0.08±0.16
	(0.29)	(0.57)	(0.90)	(0.90)	(0.12)	(0.59)
Residence						
σ_b^2	0.56	0.01	4.88	0.03	0.12	
ICC	0.13	-	0.70	0.01	0.01	
Province						
σ_b^2	3.26	34.15	0.01	4.41	0.22	
ICC	0.47	0.93	-	0.55	0.02	
σ_e^2	3.64	2.46	2.07	3.57	7.34	
AIC	26680.7	25730.9	26129.7	28511.2	31995.4	26766.1

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of total cholesterol/LDL. Significant coefficients are shown in Bold.
AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2: Error variance

Table S8: Three-level Quantile regression coefficients for female participants' TC/HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.005±0.001	0.005±0.001	0.01±0.001	0.01±0.001	0.01±0.002	0.01±0.001
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
BMI (kg/m^2)	0.02±0.004	0.03±0.004	0.03±0.005	0.04±0.008	0.05±0.01	0.03±0.003
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
WC (cm)	0.006±0.001	0.009±0.002	0.01±0.002	0.01±0.003	0.01±0.005	0.01±0.001
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.02)**	**(<0.001)**
Diabetes	-0.01±0.05	0.04±0.04	0.08±0.05	0.22±0.06	0.37±0.09	0.15±0.04
	(0.75)	(0.35)	(0.14)	**(0.001)**	**(<0.001)**	(0.14)
Hypertension	-0.02±0.03	0.03±0.03	0.06±0.04	0.07±0.04	0.20±0.05	0.09±0.03
	(0.43)	(0.22)	(0.10)	(0.12)	**(<0.001)**	**(0.003)**
Residence						
σ_b^2	7.59	1.65	-	0.02	0.18	
ICC	0.73	0.46	-	-	0.02	
Province						
σ_b^2	0.49	0.15	-	7.40	0.04	
ICC	0.15	0.07	-	0.70	-	
σ_e^2	2.72	1.90	1.69	3.02	6.45	
AIC	29486.3	28699.1	29593.6	32928.8	37449.5	30561.6

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of total cholesterol/HDL. Significant coefficients are shown in Bold.
AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2:Error variance

Table S9: Three-level Quantile regression coefficients for male participants' LDL-C/HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.00±0.001 (0.75)	0.001±0.001 (0.31)	0.001±0.002 **(0.04)**	0.005±0.002 **(0.01)**	0.006±0.002 **(0.01)**	0.002±0.001 **(0.04)**
BMI (kg/m²)	0.03±0.006 **(<0.001)**	0.03±0.007 **(<0.001)**	0.006±0.008 **(<0.001)**	0.06±0.009 **(<0.001)**	0.07±0.009 **(<0.001)**	0.04±0.004 **(<0.001)**
WC (cm)	0.006±0.001 **(0.001)**	0.01±0.002 **(<0.001)**	0.01±0.001 **(<0.001)**	0.009±0.004 **(0.01)**	0.01±0.003 **(0.001)**	0.01±0.001 **(<0.001)**
Diabetes	-0.18±0.05 (0.002)	-0.14±0.06 (0.01)	-0.02±0.05 (0.09)	-0.03±0.07 (0.63)	0.27±0.07 **(<0.001)**	-0.05±0.03 (0.20)
Smoking	0.10±0.03 **(0.001)**	0.16±0.03 **(<0.001)**	0.20±0.02 **(<0.001)**	0.25±0.04 **(<0.001)**	0.41±0.06 **(<0.001)**	0.23±0.02 **(<0.001)**
Physical Activity						
Moderate	-0.07±0.03 **(0.05)**	-0.11±0.04 **(0.01)**	-0.11±0.02 **(0.003)**	-0.08±0.06 (0.17)	-0.07±0.06 (0.24)	-0.10±0.03 **(<0.001)**
High	-0.08±0.03 **(0.01)**	-0.12±0.02 **(<0.001)**	-1.48±2.89 **(<0.001)**	-0.19±0.04 **(<0.001)**	-0.20±0.05 **(<0.001)**	-0.15±0.02 **(<0.001)**
Education Level						
1-6	0.05±0.05 (0.33)	0.06±0.06 (0.37)	0.04±0.05 (0.09)	0.03±0.08 (0.71)	-0.03±0.11 (0.75)	-0.01±0.05 (0.77)
7-12	0.11±0.05 **(0.04)**	0.12±0.06 **(0.05)**	0.11±0.05 (0.10)	0.09±0.08 (0.27)	0.08±0.12 (0.49)	0.05±0.05 (0.26)
>12	0.13±0.05 **(0.02)**	0.18±0.08 **(0.02)**	0.18±0.07 **(<0.001)**	0.19±0.09 **(0.03)**	0.12±0.12 (0.30)	0.11±0.05 **(0.04)**
Marital Status						
Married	0.06±0.04 (0.13)	0.09±0.03 **(0.009)**	0.10±0.03 **(0.01)**	0.10±0.06 (0.08)	0.06±0.08 (0.44)	0.07±0.03 **(0.04)**
Divorced/ Widowed	0.06±0.10 (0.57)	0.07±0.16 (0.66)	0.10±0.11 (0.86)	0.19±0.28 (0.48)	0.48±0.22 **(0.03)**	0.05±0.11 (0.66)
Residence						
σ_b^2	0.68	-	0.01	0.02	0.03	
ICC	0.24	-	0.01	0.01	-	
Province						
σ_b^2	0.65	0	0.01	0.78	0.03	
ICC	0.23	-	0.01	0.29	-	
σ_e^2	2.13	1.39	1.12	1.87	3.72	
AIC	22647.4	21453.6	21544.7	23668.5	26818.4	21927.2

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of LDL-C/HDL-C. Significant coefficients are shown in Bold.
AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2: Error variance

Table S10: Three-level Quantile regression coefficients for female participants' LDL-C/HDL-C in 2016 National STEPs study

Factors	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	Linear Regression
Age (year)	0.009±0.001	0.009±0.001	0.01±0.001	0.01±0.001	0.01±0.002	0.01±0.001
	(<0.001)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
BMI (kg/m²)	0.01±0.004	0.01±0.004	0.01±0.005	0.01±0.006	0.02±0.006	0.01±0.003
	(0.001)	**(<0.001)**	**(0.001)**	**(0.004)**	**(0.001)**	**(<0.001)**
WC (cm)	0.004±0.002	0.008±0.001	0.009±0.002	0.009±0.002	0.01±0.003	0.01±0.001
	(0.03)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(0.001)**	**(<0.001)**
Diabetes	0.06±0.05	0.09±0.06	0.21±0.04	0.35±0.07	0.51±0.10	0.37±0.04
	(0.26)	(0.16)	**(<0.001)**	**(<0.001)**	**(<0.001)**	**(<0.001)**
Hypertension	0.09±0.03	0.10±0.03	0.10±0.03	0.07±0.03	0.11±0.05	0.17±0.03
	(0.007)	**(0.001)**	**(0.005)**	**(0.03)**	**(0.02)**	**(<0.001)**
Physical Activity						
Moderate	-0.01±0.04	-0.01±0.03	0.005±0.03	-0.01±0.03	-0.04±0.04	-0.04±0.03
	(0.74)	(0.73)	(0.84)	(0.71)	(0.36)	(0.13)
High	-0.07±0.04	-0.07±0.03	-0.04±0.03	-0.04±0.03	-0.07±0.06	-0.04±0.03
	(0.07)	**(0.04)**	(0.18)	(0.17)	(0.24)	(0.18)
Residence						
σ_b^2	9.21	7.81	2.05	0.04	0.08	
ICC	0.78	0.82	0.58	0.01	0.01	
Province						
σ_b^2	0.06	0.11	0.19	0.13	0.52	
ICC	0.02	0.06	0.11	0.04	0.07	
σ_e^2	2.52	1.69	1.44	2.52	6.00	
AIC	30748.3	29373.1	29996.6	33382.2	39137	36785.9

Entries show β ± SE (*P*) for 10th, 25th, 50th, 75th and 90th percentiles of LDL-C/HDL-C. Significant coefficients are shown in Bold. AIC: Akaike Information Criterion, ICC: Intraclass Correlation Coefficient, σ_b^2: Random effect variance, σ_e^2: Error variance