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

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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. 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 national cross-sectional study of the risk factors of non-Communicable disease (STEPs) performed in 2016, through multi-stage random sampling, were analyzed. Because of clustered, hierarchical and skewed form of the data, factors related to total Cholesterol (TC), Triglycerides (TG), LDL-C, HDL-C, TG/HDL-C, TC/HDL-C, 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, BMI, waist circumference, 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.

Conclusion

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.

Background

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, LDL, HDL and triglycerides are each independent risk factors for coronary heart disease [3].

The ratio of triglycerides to high density lipoprotein (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. And 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 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 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 non-Communicable diseases 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 (fig. 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 here

Data Collection and Measurements

Following the WHO STEPwise approach to risk factor Surveillance, demographic data , life styles 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), blood pressure, pulse rate, and individuals' pedometer information were measured; participants were without shoes but with light clothing. Body Mass Index (BMI) was calculated by dividing weight by square meter of height [5]. Physical activity was calculated based on Global Physical Activity Questionnaire, GPAQ [17]. Metabolic Equivalents (METs) was 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. Systolic (SBP) and diastolic blood pressures (DBP) were measured 3 times using the device Beurer GmbH, Germany, with 5 minutes intervals, and mean values of second and third measurements were used for analysis. High blood pressure was defined as $SBP \geq 140$ or $DBP \geq 90$ mmHg or taking antihypertensive medication at the time of data collection or if a health specialist has previously told the participant that s/he has hypertension.

Fasting blood samples were taken and centrifuged, immediately and were transferred to the NCD research center, the coordinating center of this study in Tehran in cold chain conditions. Fasting plasma glucose, TC, HDL-C and TG were measured by an autoanalyzer (Cobas C311 Hitachi High–Technologies Corporation, Japan) [18]. LDL-C was estimated using Chen formula [19]. Diabetes was defined as fasting plasma glucose, 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

After filtering and confirming the validity and reliability of the data, the process of analysis was performed. Multiple imputation method was used for missing data. The data were weighted according to age and sex distribution and provincial population based on 2016 national census conducted by the statistical center of Iran (SCI). Continuous variables were reported using mean $\pm$ 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 total Cholesterol (TC), Triglycerides (TG), LDL-C, HDL-C, TG/HDL-C, TC/HDL-C, 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. Parameters of the model were estimated for 10th, 25th, 50th, 75th and 90th centiles. On the other hand, because of the clustered and hierarchical nature of the STEPs data, a multilevel modeling approach was applied. Random effects of the province as well as urban or rural area of residence were taken into account. 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 analysis 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 ordinary least square 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.

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. Body Mass Index 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 total cholesterol 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. Waist circumference 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. Akaike information criterion indicated that the three-level quantile regression model had better fit compared to the OLS regression (Tables 2 and 3).

Body mass index, waist circumference 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. 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 to S10.

Akaike information criterion indicated that the three-level quantile regression model had a better fit compared to the OLS regression. 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.

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 account using multilevel modeling. In addition association of factors with different indices of the lipids distribution was studied by the aim 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 shows 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. 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 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. reported that the presence of nicotine in cigarette smoke increased levels of TG, cholesterol, VLDL and decreased HDL-C levels [33]. In a cross-sectional study on adult men in North West of China village, Li *et al.* 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 [34]. 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%), VLDL (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.* found that there was a significant relationship between higher physical activity and lower level of TG and also higher level of HDL-C [38]. In study of Li Qi *et al.* a general inverse relationship between regular physical activity and lipid disorder was found [27].

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 sub-national 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 modelling and random effects, and also analysis of the whole domain of lipids distribution using quantile regression are strengths of this research.

Conclusion

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.

Declarations

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Authors' contributions

PM analyzed and drafted the manuscript. DKh reviewed the study, advised on data structure and edited the manuscript. ShD reviewed the study and edited the manuscript. FF involved in STEPs planning and

design. YM was the study supervisor, designed the study, advised on analyses and edited the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available from Non-Communicable Disease Research Center (NCDRC), Tehran, Iran. The data are available at a reasonable request from Professor Farshad Farzadfar, E-mail: farzadfar3@yahoo.com

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.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Tables

Table1 Descriptive characteristics of participants by gender [*mean ± SD*, n (%)]

Variable	Men (n = 7584)	Women (n = 9173)	P_ Value
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	165.9 ± 36.4	< 0.001
HDL-C (mg/dL)	37.5 ± 9.9	43.8 ± 11.4	< 0.001
LDL-C (mg/dL)	96.9 ± 28.3	97.8 ± 29.3	0.041
TG (mg/dL)	139.3 ± 91.0	120.2 ± 75.6	< 0.001
TC/HDL-C	4.5 ± 1.4	4.0 ± 1.3	< 0.001
TG/HDL-C	4.2 ± 3.9	3.1 ± 2.9	< 0.001
LDL-C/HDL-C	2.7 ± 1.0	2.3 ± 0.9	< 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

BMI: body mass index, WC: waist circumference

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						
ICC	63.08 0.02	24.60 0.01	18.24 0.01	45.67 0.02	103.23 0.02	
Province						
ICC	49.52 0.01 2916	21.37 0.01 1810.50	17.88 0.01 1397.26	35.43 0.01 2186.49	37.92 - 4183.50	
AIC	77309.96	75740.71	75462.01	77186.76	80076.4	75667.4

Entries show $\beta \pm SE$ (p - value) 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, : Random effect variance, ; Error variance.

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 (<0.001)	0.76 ± 0.05 (<0.001)	0.89 ± 0.04 (<0.001)	0.95 ± 0.04 (<0.001)	0.99 ± 0.10 (<0.001)	0.80 ± 0.04 (<0.001)
BMI(kg/m ²)	1.07 ± 0.20 (<0.001)	0.94 ± 0.15 (<0.001)	0.81 ± 0.13 (<0.001)	0.81 ± 0.18 (<0.001)	0.94 ± 0.22 (<0.001)	0.76 ± 0.11 (<0.001)
WC (cm)	0.15 ± 0.06 (0.02)	0.04 ± 0.05 (0.45)	0.02 ± 0.05 (0.71)	0.12 ± 0.07 (0.11)	0.21 ± 0.08 (0.01)	0.08 ± 0.04 (0.05)
Diabetes	-6.86 ± 1.70 (<0.001)	-3.27 ± 1.72 (0.06)	-1.33 ± 1.48 (0.36)	1.59 ± 1.70 (0.35)	5.17 ± 2.88 (0.07)	-0.64 ± 1.14 (0.57)
Hypertension	-0.71 ± 0.97 (0.46)	-1.29 ± 1.05 (0.22)	1.88 ± 0.97 (0.05)	3.32 ± 1.27 (0.01)	1.77 ± 1.37 (0.20)	1.55 ± 0.89 (0.08)
Education Level						
1-6	2.15 ± 1.86 (0.02)	2.42 ± 1.74 (0.16)	2.15 ± 1.48 (0.14)	0.24 ± 1.75 (0.88)	1.73 ± 2.34 (0.46)	1.27 ± 1.24 (0.30)
7-12	6.01 ± 1.99 (0.003)	3.92 ± 1.94 (0.04)	4.02 ± 1.75 (0.02)	2.07 ± 1.91 (0.28)	4.02 ± 2.94 (0.17)	3.70 ± 1.28 (0.003)
>12	6.33 ± 2.09 (0.003)	3.97 ± 2.04 (0.05)	5.43 ± 1.56 (<0.001)	5.09 ± 1.76 (0.004)	7.12 ± 2.07 (<0.001)	5.87 ± 1.43 (<0.001)
Residence						
ICC	37.54 0.01	27.93 0.01	31.50 0.02	55.13 0.02	107 0.02	
Province						
ICC	34.20 0.01	25.45 -	19.87 0.06	39.77 0.01	91.80 0.02	
	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 $\beta \pm SE$ (p - value) 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, : Random effect variance, , Error variance.

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

Entries show $\beta \pm SE$ (p - value) 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, : Random effect variance, , Error variance.

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 (0.03)	0.005 ± 0.001 (<0.001)	0.008 ± 0.001 (<0.001)	0.01 ± 0.004 (0.005)	0.01 ± 0.007 (0.02)	0.008 ± 0.003 (0.006)
BMI(kg/m ²)	0.02 ± 0.003 (<0.001)	0.03 ± 0.003 (<0.001)	0.05 ± 0.006 (<0.001)	0.06 ± 0.01 (<0.001)	0.09 ± 0.02 (<0.001)	0.03 ± 0.008 (<0.001)
WC (cm)	0.007 ± 0.001 (<0.001)	0.01 ± 0.001 (<0.001)	0.01 ± 0.002 (<0.001)	0.03 ± 0.006 (<0.001)	0.04 ± 0.01 (<0.001)	0.02 ± 0.003 (<0.001)
Diabetes	0.19 ± 0.05 (0.001)	0.35 ± 0.06 (<0.001)	0.58 ± 0.11 (<0.001)	1.05 ± 0.19 (<0.001)	1.90 ± 0.32 (<0.001)	0.95 ± 0.09 (<0.001)
Hypertension	0.05 ± 0.03 (0.13)	0.10 ± 0.03 (0.002)	0.16 ± 0.04 (<0.001)	0.27 ± 0.09 (0.004)	0.36 ± 0.14 (0.01)	0.27 ± 0.07 (<0.001)
Smoking	0.12 ± 0.10 (0.22)	0.06 ± 0.12 (0.60)	0.33 ± 0.18 (0.05)	0.15 ± 0.33 (0.63)	1.29 ± 2.16 (0.55)	0.15 ± 0.38 (0.69)
Physical Activity						
Moderate	0.03 ± 0.02 (0.20)	0.05 ± 0.03 (0.07)	0.03 ± 0.05 (0.14)	-0.02 ± 0.09 (0.76)	-0.13 ± 0.18 (0.47)	-0.01 ± 0.07 (0.82)
High	-0.05 ± 0.03 (0.11)	-0.09 ± 0.04 (0.02)	-0.14 ± 0.04 (0.002)	-0.24 ± 0.08 (0.006)	-0.27 ± 0.21 (0.20)	-0.22 ± 0.08 (0.005)
Residence						
ICC	0.74	0.97	0.02	0.19	0.56	
Province	0.13	0.19	-	0.01	0.01	
ICC	0.57	1.34	13.47	0.04	0.22	
	0.10	0.24	0.74	-	-	
	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 $\beta \pm SE$ (p - value) 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, : Random effect variance, , Error varianc

Figures

Figure 1

Flowchart of the participant in the study

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