International Journal of Scientific Research and Management (IJSRM)
||Volume||10||Issue||12||Pages||MP-2022-740-763||2022||
Website: www.ijsrm.in ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v10i12.mp02

Correlation between Levels of Remnant Cholesterol versus LDL, A Cross-Sectional study

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Abstract

Background: High levels of LDL cholesterol were directly related to the risk of atherosclerosis, metabolic diseases and cardiovascular complications. However, in some groups of patients with low level, they were also found. Lead to the risk of other lipid components, including Remnant cholesterol. Recent study found related to cardiovascular risk as well. Currently, no direct comparison between Remnant cholesterol and LDL cholesterol level.

Objective: To study the correlation between Remnant cholesterol and LDL levels both in fasting and non-fasting state with the medical conditions that increases the risk of cardiovascular disease.

Materials and methods: To determine the association between remnant cholesterol and LDL. 200 cases of Thai begins at the age of 18 years old were tested for total cholesterol, LDL, HDL and TG level both in the fasting and non-fasting states. The obtained values were calculated for Remnant cholesterol levels and analysed for a direct correlation between the two levels, also includes a comparative analysis. The AUC was used to assess the prognostic accuracy of lipid level to diagnose the condition that poses cardiovascular risks.

Results: In the sample of 200 patients tested for lipid. At a mean age of 64.5 years, 42 percent were female and 76.5 percent received statins. We found that remnant cholesterol had poorly correlation with LDL levels when compared among the fasting conditions (r=0.164, 0.119), as well as among the statin used or not (r=0.118, 0.293). The analysis found that remnant cholesterol does well correlate with TG levels (r=0.770). Also, the predictive value of Remnant cholesterol over LDL levels for detect diabetes mellitus, coronary artery disease and overweight (AUC=0.610, 0.588, 0.593).

Conclusion: In this study. We found that remnant cholesterol does correlate poorly with LDL in any fasting state. Prediction of the incidence of diabetes mellitus, coronary heart disease and overweight has seemed better with remnant cholesterol. More studies may need for decreasing the knowledge gap and provide a better guide for disease prevention.

Keywords: Cholesterol; Remnant cholesterol; Lipoprotein; LDL; Statin; Prevention

Introduction

High LDL cholesterol levels do related to cardiovascular diseases and complications among patients at risk or having atherosclerosis. Data came from several studies has been established as widely adopted for current clinical practice [1-4]. However, some patients with low LDL cholesterol still had atherosclerosis and came up with complications, especially coronary heart disease [5,6]. Lead to a study to find out the association of other lipid components with these diseases such as HDL [7-11], triglyceride [12-15], Non-HDL [16-18] and including with remnant cholesterol [19]. Remnant cholesterol is the remainder of all cholesterol, neither HDL nor LDL, which represents IDL (Intermediate density lipoprotein), VLDL (Very low-density lipoprotein) and TRL (triglyceride-rich lipoprotein). Studies have shown that high remnant cholesterol levels increasing the risk of coronary artery disease and myocardial infarction. Also, it indicates residual risk after a cardiovascular event or statin used. Statin use may contribute to lowering remnant cholesterol. Even though LDL levels are low, remnant cholesterol levels may still be high in some populations. However, no studies conclude exactly how remnant cholesterol relates to LDL cholesterol levels when classified in each population group with different risks. This study aims to find the relationships and the consistency of calculated remnant cholesterol

to LDL cholesterol. We tested the hypothesis that remnant cholesterol levels do correlate in both fasting and non-fasting states. We explored in detail the association with cardiovascular risks and diseases. The information obtained may be assessing the risk of patients that lead to guiding prevention and cares for those at risk of cardiovascular disease effectively.

Materials and Methods

Participants and protocol: First, recruit retrospective electronic data from patients who visit Bhumibol Adulyadej Hospital and perform lipid profile testing (Including TC, LDL, HDL and TG measurement) from Jan to June 2019. Second, a sampling of 200 patients for another detailed analysis. Eligibility requirements include Thai patients who begin at 18 years old agree to perform lipid profile blood testing in 12 hours fasting and non-fasting states. Exclusion criteria include those who deny participating in this study and cannot do the blood test. Written ethical consent with baseline information received from each participant. The study was carried out and approved by the ethics committee of an institutional review board of the royal Thai air force medical department.

Laboratory analysis: Lipid profiles consist of TC, LDL, HDL and TG were measured both in fasting and non-fasting states. Remnant cholesterol was calculated using standardized formula (Remnant cholesterol=Total cholesterol-(HDL+LDL)). LDL cholesterol was measured directly.

Statistical analysis: It is a pilot study. Retrospective data analysed for the correlation between remnant cholesterol and LDL cholesterol levels. The sample of 200 tested a correlate of remnant cholesterol either any fasting conditions or between the two lipids. It was graphed as a scatter plot with a fitted correlation line from a linear correlation of direct measured LDL on calculated remnant cholesterol. We also examined pairwise correlations between the lipid values using the Pearson correlation coefficient. Baseline descriptive categorical data presented in percentage and were analysed using the Pearson chi-square, while continuous data were using independent sample T-test and reported in mean ± standard deviation. We used a paired sample T-test for lipid profile data. The area under the receiver operating characteristic curve (AUC) was used to assess the prognostic accuracy of lipid levels to diagnose the condition that poses cardiovascular risks. We divided the patients into four groups using remnant cholesterol and LDL levels (using the cut point of 130 mg/dl for LDL [1-4] and the mean value for Remnant cholesterol). Also, looking for the differences of each group. Baseline descriptive categorical data were analysed using Analysis of Variance (ANOVA). The continuous data were analysed and reported in mean ± standard deviation, which f and p-value calculated, with a level of significance set at 0.05. IBM SPSS Statistics version 25 (IBM Corp, Armonk, NY, USA) was used in the data analysis.

Table 1 Baseline Characteristics (n=200)

Age – years	64.53 ± 13.95
Female sex – no. (%)	84 (42)
BMI – kg/m^2	24.62 ± 4.73
SBP (mmHg)	129.67 ± 19.19
Any history of smoking	71 (35.5)
Any statin used – no. (%)	153 (76.5)
High intensity statin used*	121 (60.5)
Underlying diseases	
Congestive heart failure – no. (%)	67 (33.5)

Had undergone echocardiography. – no. (%)	138 (69)
LVEF – %**	52.25 ± 18.06
Diabetes mellitus – no. (%)	66 (33)
Hypertension – no. (%)	167 (83.5)
Dyslipidemia – no. (%)	156 (78)
Prior stroke/TIA – no. (%)	18 (9)
Chronic kidney disease – no. (%)	77 (38.5)
eGFR – ml/min/1.73 m^2 (CKD-EPI)	65.51 ± 28.57
Coronary artery disease – no. (%)	125 (62.5)
Atrial fibrillation	28 (14)
Overweight – no. (%)***	80 (40)
Obesity – no. (%)***	24 (12)
10 years Thai CV risk (%)	16.05 ± 9.82

BMI, body mass index; SBP, systolic blood pressure; TIA, transient ischemic attack; eGFR, estimated glomerular filtration rate; LVEF, left ventricular ejection fraction; CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration

*Based on intensity of statin definition **Mean of 138 patients.

*** Overweight as ≥ 25 kg/m^2, Obesity as ≥ 30 kg/m^2

Table 2 Comparing measure lipid profiles in fasting and non-fasting state (mg/dl).

Lipid components	Fasting	Non-fasting	p-value	95% CI of the difference	Pearson r
Total cholesterol	163.49 ± 50.28	161.06 ± 49.31	0.072	(- 0.216) - 5.076	0.928
Triglyceride	133.12 ± 81.51	136.05 ± 75.54	0.490	(- 11.29) - 5.434	0.711
LDL	108.87 ± 45.2	105.15 ± 44.46	<0.001*	1.512 - 5.928	0.938
HDL	43.77 ± 13.91	43.47 ± 13.62	0.452	(- 0.485) - 1.085	0.917
Remnant cholesterol**	10.86 ± 12.26	12.45 ± 11.34	0.013*	(- 2.835) - (- 0.345)	0.716
Non-HDL cholesterol***	119.72 ± 48.74	117.59 ± 47.17	0.082	(- 0.276) - 4.536	0.936

LDL, low density lipoprotein; HDL, high density lipoprotein *Significant at p <0.05

**Using standardized formula (Remnant cholesterol = Total cholesterol - (HDL + LDL)) [22] ***Using simple formula non HDL = TC – HDL [22]

Results

From January to June 2019, 19,038 patients visited the hospital and were received blood tests for lipid profiles (Total cholesterol, LDL, HDL and TG) regardless of the fasting state. Baseline characteristics of patients are shown in the supplementary appendix. Direct LDL measurement does positively correlate with those calculated. We found that remnant cholesterol does correlate poorly with LDL (r=-0.196) as shown in Supplemental Figure S17. However, it does well correlate positively with TG levels. In the sample of 200 populations, patients tested for lipid profiles in both fasting and non-fasting states. Baseline characteristics of patients are showing in Table 1. At a mean age of 64.5 years, 42 percent were female. A little overweight in this population, as the mean BMI is around 24.62 kg/m2. According to the Thai national health examination survey we use the cut point at 25 kg/m2 and 30 kg/m2 for overweight and obesity respectively. 80 patients (40%) had overweight and 24 of them (12%) were obese. The baseline of high normal blood pressure was observed (129.67± 19.19 mmHg). About 35.5 percent had any history of smoking. Most of the patients were statin users (76.5%) and around 60.5 percent coming with high intensity. Sixty-seven patients (33.5%) had a history of congestive heart failure. Unfortunately, only 138 patients (69%) had undergone echocardiography which means Left Ejection Fraction (LVEF) is around 52.25 ± 18.06 percent. Thirty-three percent were Diabetes mellitus. Most of them were diagnosed with hypertension (83.5%) and coronary artery disease (62.5%). Chronic kidney disease was found in 77 patients (38.5%), which mean eGFR is around 65.51 ± 28.57 ml/min/1.73 m2. Also, a trace of the population comes with atrial fibrillation (14%) or any history of prior stroke (9%). Moderate risk in ten years base on the Thai Cardiovascular (CV) risk score was observed among this population (16.05 ± 9.82%).

Measure lipid profiles of the patients described in Table 2. Compare between fasting and non-fasting states, found that LDL levels were a bit higher in the fasting state (mean 108.87 ± 45.2 mg/dl, p <0.001), conversely with Remnant cholesterol that was lower (mean 10.86 ± 12.26 mg/dl, p=0.013). No difference between other lipid components was observed, including triglyceride, HDL, non-HDL, also with total cholesterol levels. The analysis was done with a moderate to strongly positive correlation within all lipid components in any fasting state, including Remnant cholesterol (r=0.716) shown in Figure 1, so we use the fasting lipid profiles to test the hypothesis.

We conducted the correlational analysis between fasting remnant cholesterol and other lipids components. The finding suggests that remnant cholesterol was correlated poorly with LDL either in fasting (r=0.164, Figure 2) or not (r=0.119, Supplemental Figure S3), same with HDL, non-HDL and TC. However, it does well correlated positively with TG (r=0.77, Figure 3).

Most of the patients in this study were statin users, so we conducted a correlational analysis of cholesterol in either group of statin use or not, as for the intensity of statin. The type of statin use is showing in Supplemental Table S2. Results were consistent in both groups which Remnant cholesterol was correlated poorly with LDL.

We try to test the hypothesis that Remnant cholesterol can use to predict clinical outcomes. On the current knowledge, we know that LDL cholesterol can predict cardiovascular events [1-4] and had used for calculated ten years risks. We found that Remnant cholesterol correlates poorly with the Thai cardiovascular risk score. Also, consistency of this finding was found in other lipid components (TC, HDL and LDL) that were used to calculate Thai cardiovascular risk score.

To determine the prognostic accuracy of lipid components to detect cardiovascular risks, we used the area under the receiver operating curve (AUC). Primary focus on remnant cholesterol and LDL levels. Remnant cholesterol may have a prognostic accuracy over LDL levels for predicting diabetes mellitus (AUC was 0.610 (95% CI 0.528-0.691), coronary artery disease (AUC was 0.588 (95% CI 0.507–0.669)), and also overweight (BMI cut off at 25 kg/m2 ; AUC was 0.593 (95% CI 0.514–0.672)). Unfortunately, no prognostic significance for other cardiovascular risk factors, the summary of diagnostic performance was described in Supplemental Table S3.

We divided the patient into four categories depending on the mean of lipid levels. The mean value of remnant cholesterol is 10.86 mg/dl and LDL is 108.87 mg/dl. According to the standard cut point of normal LDL in the population is 130 mg/dl [1-3], we used LDL cut point at 130 mg/dl rather than 108.87 mg/dl. Classified the patient into four groups, either both high and low or mixing of lipid levels. The summary of baseline characteristics shown in Supplemental Table S7. The Group of patients with both the low level of LDL and

remnant cholesterol was founded oldest (67.29 ± 13.96 years). The highest prevalence of obesity presented in a group which high levels in both of these two lipids (28%). No significant difference among other risk factors. Also, we use the higher lipid level above this cut point to check the accuracy to detect diabetes mellitus, coronary artery disease and overweight, as shown in Supplemental Table S4. Remnant cholesterol provided better sensitivity to detect these diseases in exchange with lower specificity than LDL cholesterol (50%, 45.6% and 43.8% to detect diabetes mellitus, coronary artery disease and overweight, respectively). The highest specificity showed when using these two lipids in combination 89.6%, 85.3% and 90% to detect diabetes mellitus, coronary artery disease and overweight, respectively.

Figure 1 Correlational analysis between fasting and non-fasting Remnant cholesterol (mg/dl) (n= 200)

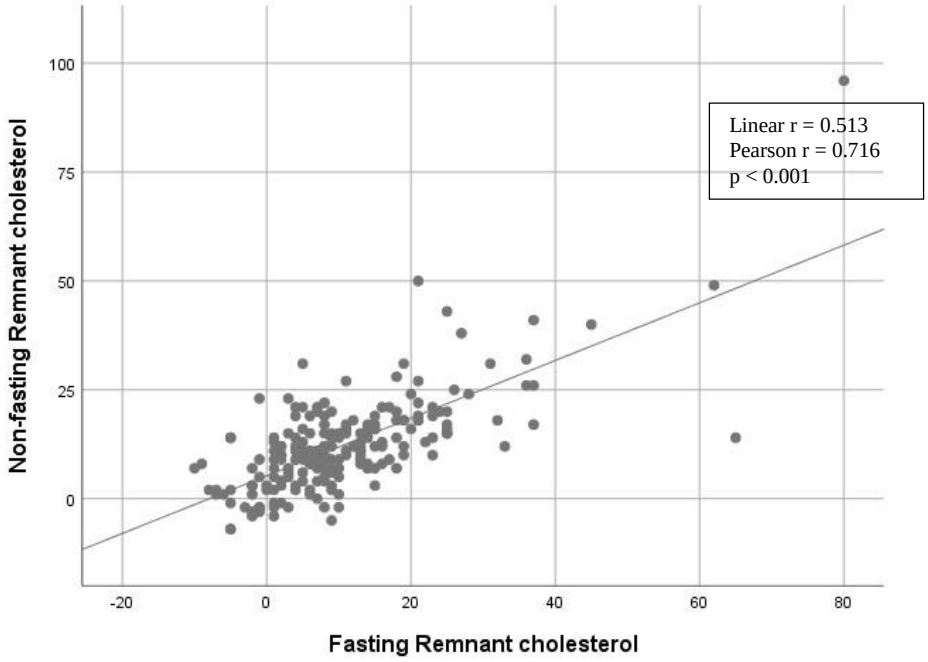


Figure 2 Correlational analysis between fasting Remnant cholesterol and LDL (mg/dl) (n = 200)

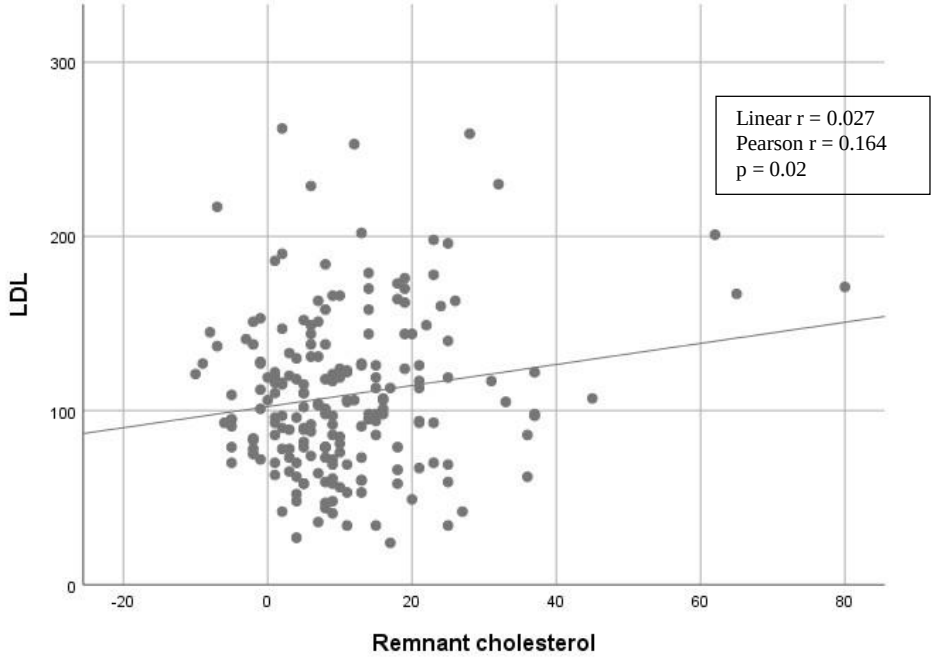
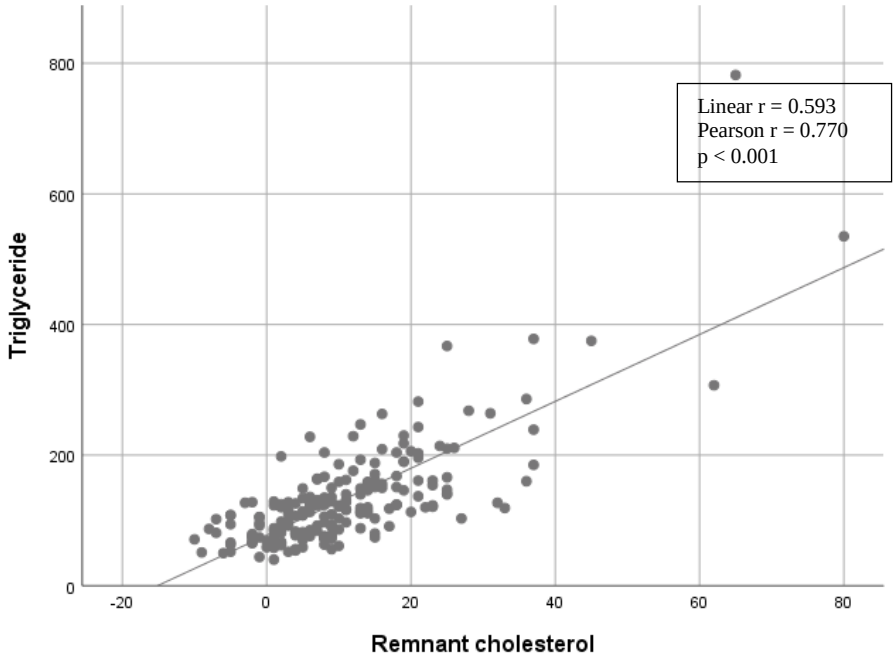


Figure 3 Correlational analysis between fasting Remnant cholesterol and Triglyceride (mg/dl) (n = 200)



Discussion

In our cross-sectional study among Thai patients, calculated remnant cholesterol does correlate poorly with directed LDL cholesterol measurement, either in any fasting or statin used state and the Thai CV risk score. Otherwise, remnant cholesterol had a moderate positive correlation with triglyceride. Remnant cholesterol can measure in any fasting condition. Also, we found the predictive value of LDL cholesterol to detect diabetes mellitus, coronary artery disease and overweight. Currently, we know that high LDL levels do correlate with cardiovascular disease. The standard LDL cholesterol measurement was used widely, based on the clinical practice guidelines [1-4]. Some patients with low or normal LDL cholesterol carried the residual cardiovascular risks, so the concept of remnant cholesterol as a cardiovascular risk factor was showing in many studies [20]. A recent study found that remnant cholesterol was associated with the risk of ischemic heart disease, myocardial infarction and increased all-cause mortality. We used calculated remnant cholesterol instead of directly measured because it is feasible, cheap and well correlated with that direct measured [20]. We found that remnant cholesterol does poorly correlate with LDL cholesterol. Based on the 2014 Thai EGAT sub analytic study with a sampling of 1847 patients (baseline characteristic as shown in Supplemental Table S5 with permission, the result of correlation among LDL cholesterol and calculated remnant cholesterol was the same as compared with our study Supplemental Figure S18 with permission. So, we can conclude that remnant cholesterol had poorly correlated with LDL cholesterol. This remnant cholesterol had a moderately positive correlation with triglyceride levels. It may be partly explained by the hypothesis that components of remnant cholesterol may consist of intermediate, very low density and triglyceride rich lipoprotein [16]. However, the proportion of these components still unknown, showing the gap of knowledge that needs more study in the future.

The remnant cholesterol may add predictive value to detect diabetes mellitus, coronary artery disease and overweight, especially among those with a low level of LDL. Proved the concept that remnant cholesterol is a remnant of residual risks. The finding that remnant cholesterol had correlated with overweight was the same as in previous study. However, patients in our study were in the high risk group (33% had diabetes mellitus, 83.5% had hypertension, 62.5% had coronary artery disease and 40% had overweight) and also most of them were statin used that may interfere with lipid measurement. We should interpret these results cautiously when using them among the general population [21].

No standard cut-off level for remnant cholesterol in the general population currently. A previous study has used 15 mg/dl as the cut point for remnant cholesterol among those with risk factors. However, it does not accept the standard clinical practice [22]. Instead, we used the mean remnant cholesterol of our study (10.86 mg/dl, as shown in (Table 2). In subgroup analysis, we found a significant age difference and the unequal of obesity prevalence, especially among those with low levels of remnant cholesterol and LDL or both high levels of these two. We try to use this cut point to determine the prognostic accuracy of remnant cholesterol to detect diabetes mellitus, coronary artery disease and overweight. It had low sensitivity but high specificity to detect these diseases, especially when combined with LDL cholesterol level. These results warrant further study to define prognostic accuracy and standard cut point among a population with these lipids [23].
Our study has several limitations. First, this is a cross-sectional with a limited time to study. It may be underestimating the risk [24]. Second, the population in this study with low sample size and had a higher risk than the general population because of COVID-19 spreading that we can collect the sampling only from cardiology out-patient clinic and in-patient ward. Third, this is an open study for those interested to participate without randomization, so it may carry some risk of bias. Need for further studies among the general population, to confirm the results of this study and for decreasing the gap of knowledge [25].

Conclusions

We found that remnant cholesterol does correlate poorly with LDL cholesterol levels, both in fasting and non-fasting states. Prediction of the incidence of diabetes mellitus, coronary heart disease and overweight has seemed better with remnant cholesterol than LDL cholesterol levels. Further studies are needed to predict long-term cardiovascular outcomes and provide a better guide for cardiovascular disease prevention.

Acknowledgement

This study would not be possible without assistance and encouragement from all cardiology staff at Bhumibol Adulyadej Hospital (BAH), especially my advisor, doctor Krisada Sastravaha, who always understands and provides invaluable suggestions. Thanks, doctor Prin Vathesatogkit for additional help and provide some data from the Thai EGAT study to alleviate this study analysis. Also, I would like to express my gratitude to all BAH and Ramathibodi's (EGAT study team) staff who always persevere with me to have this study finished. Lastly, I would like to thanks all participants who understand and confide in me to enrol them in the study.

Supplementary Materials

See the supplemental table S1-S7 and Figure S1-S20 for more detail.

Ethics approval and consent to participate

This study had an approval for human data collection, basis on open Thai PDPA. (Director and editorial board committee of Bhumibol Adulyadej hospital, RTAF; Ministry of health, Thailand.)

Conflicts of Interest

The author declare that there is no conflict of interest regarding the publication of this paper.

Funding Statement

No funding support.

Authors' contributions

SR analysed and interpreted the patient data, and was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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Supplementary Appendix

Table S1 2019 BAH (January - June) baseline characteristics (n = 19,038)

Age – years	64.16 ± 13.44
Female sex – no. (%)	10,801 (56.7)
Underlying diseases	
Diabetes mellitus – no. (%)	2,345 (12.3)
Hypertension – no. (%)	5,215 (27.3)
Dyslipidemia – no. (%)	1766 (9.2)
Prior stroke/TIA – no. (%)	876 (4.6)
Chronic kidney disease – no. (%)	457 (2.4)
Coronary artery disease – no. (%)	794 (4.2)
Atrial fibrillation	210 (1.1)
Lipid profiles (mg/dl)	
Total cholesterol	180.79 ± 41.69
Triglyceride	135.5 ± 81.41
LDL (direct measurement)	121.87 ± 40.52
LDL (calculated)*	97.90 ± 36.30
HDL	55.79 ± 15.50
Remnant cholesterol	3.14 ± 14.17
Non-HDL cholesterol**	125 ± 40.21

TIA, transient ischemic attack; LDL, low density lipoprotein; HDL, high density lipoprotein

*Using Friedwald equation (LDL = TC – (TG/5) – HDL) **Using simple formula non HDL = TC – HDL

Table S2 Type of statin used in this study (n = 153)

Atorvastatin – no. (%)	121 (79)
- 10 mg	2 (1.3)
- 20 mg	2 (1.3)
- 40 mg*	117 (76.4)
Rosuvastatin – no. (%)	7 (4.6)
- 10 mg	3 (2)
- 20 mg*	4 (2.6)
Simvastatin – no. (%)	19 (12.5)
- 10 mg	10 (6.5)
- 40 mg	9 (6)
Pravastatin 40 mg – no.(%)	2 (1.3)
Pitavastatin 2 mg – no. (%)	4 (2.6)

*High intensity statin

Table S3 Summary of diagnostic performance of Remnant cholesterol and LDL levels using AUC.

	AUC – median (95% CI)	
	Remnant cholesterol	LDL
Hypertension	0.542 (0.433 – 0.650)*	0.400 (0.299 – 0.500)
Diabetes mellitus	0.610 (0.528 – 0.691)	0.478 (0.392 – 0.563)
Dyslipidemia	0.550 (0.449 – 0.651)*	0.483 (0.387 – 0.578)
Chronic kidney disease	0.515 (0.432 – 0.598)*	0.417 (0.336 – 0.499)
Coronary artery disease	0.588 (0.507 – 0.669)	0.417 (0.336 – 0.497)
Atrial fibrillation	0.445 (0.340 – 0.550)	0.338 (0.224 – 0.452)
Congestive heart failure	0.475 (0.385 – 0.564)	0.418 (0.336 – 0.501)
Cerebrovascular disease	0.402 (0.484 – 0.764)	0.624 (0.484 – 0.764)*
Overweight**	0.593 (0.514 – 0.672)	0.504 (0.421 – 0.587)*
Obesity**	0.605 (0.494 – 0.716)*	0.556 (0.418 – 0.693)*

*Without asymptotic significant; **Based on Thai NHES ; AUC, Area under receiver-operating curve.

Table S4 Prognostic accuracy of Remnant cholesterol and LDL levels* to detect diabetes mellitus, CAD and overweight (n = 200)

	Diabetes Mellitus			Coronary artery disease			Overweight		
Measure of accuracy	RC	LDL	Mix	RC	LDL	Mix	RC	LDL	Mix
False positive – no.	49	36	14	25	23	11	47	30	12
False negative – no.	33	50	55	68	96	111	45	58	67
Sensitivity - %	50	24.2	16.7	45.6	23.2	11.2	43.8	27.5	16.3
Specificity - %	63.4	73.1	89.6	66.7	69.3	85.3	60.8	75	90
PPV - %	40.2	30.8	44	69.5	55.8	56	42.7	42.3	52
NPV - %	72	66.2	68.6	42.4	35.1	36.6	61.9	60.8	61.7

*Using cut point at 10.86 mg/dl for Remnant cholesterol and 130 mg/dl for LDL; LDL, low density lipoprotein; RC, Remnant cholesterol

Table S5 the 2014 EGAT study baseline characteristics (n = 1,847) *Used with permission.

Age – years	50.78 ± 6.9
Female sex – no. (%)	583 (31.6)
BMI – kg/m^2	24.67 ± 3.79
SBP (mmHg)	132.17 ± 16.96
Underlying diseases	
Diabetes mellitus – no. (%)	172 (9.3)
Hypertension – no. (%)	428 (23.2)
Dyslipidemia – no. (%)	590 (31.9)
Prior stroke/TIA – no. (%)	13 (0.7)
Chronic kidney disease – no. (%)	17 (0.9)
Coronary artery disease – no. (%)	28 (1.5)
Fasting lipid profiles (mg/dl)	
Total cholesterol	212.8 ± 40.87
Triglyceride	135.22 ± 104.05
LDL (direct measurement)	145.2 ± 37.68
HDL	56.32 ± 14.67
Remnant cholesterol	11.28 ± 17.23
Non-HDL cholesterol*	156.48 ± 40.22

BMI, body mass index; SBP, systolic blood pressure; TIA, transient ischemic attack;
LDL, low density lipoprotein; HDL, high density lipoprotein; EGAT, Electricity Generating Authority of Thailand
*Using simple formula non HDL = TC – HDL

Table S6 Comparison of baseline characteristics between the 2014 EGAT study and our study.

	EGAT study n = 1847	Our study n = 200	p-value
Age – years	50.78 ± 6.9	64.53 ± 13.95	<0.001*
Female sex – no. (%)	583 (31.6)	84 (42)	0.003*
BMI – kg/m^2	24.67 ± 3.79	24.62 ± 4.73	0.861
SBP (mmHg)	132.17 ± 16.96	129.67 ± 19.19	0.079
Underlying diseases			
Diabetes mellitus – no. (%)	172 (9.3)	66 (33)	<0.001*
Hypertension – no. (%)	428 (23.2)	167 (83.5)	<0.001*
Dyslipidemia – no. (%)	590 (31.9)	156 (78)	<0.001*
Prior stroke/TIA – no. (%)	13 (0.7)	18 (9)	<0.001*
Chronic kidney disease – no. (%)	17 (0.9)	77 (38.5)	<0.001*
Coronary artery disease – no. (%)	28 (1.5)	125 (62.5)	<0.001*
Fasting lipid profiles (mg/dl)			
Total cholesterol	212.8 ± 40.87	163.49 ± 50.28	<0.001*
Triglyceride	135.22 ± 104.05	133.12 ± 81.51	0.781
LDL (direct measurement)	145.2 ± 37.68	108.87 ± 45.2	<0.001*
HDL	56.32 ± 14.67	43.77 ± 13.91	<0.001*
Remnant cholesterol	11.28 ± 17.23	10.86 ± 12.26	0.733
Non-HDL	156.48 ± 40.22	119.72 ± 48.74	<0.001*

BMI, body mass index; SBP, systolic blood pressure; TIA, transient ischemic attack;
LDL, low density lipoprotein; HDL, high density lipoprotein; EGAT, Electricity Generating Authority of Thailand
*Significant at p <0.05 **Using simple formula non HDL = TC – HDL

Table S7 Baseline Characteristics define categorized by lipid levels (LDL and Remnant cholesterol).

	High LDL with low Remnant cholesterol N = 27	Both of high LDL and Remnant cholesterol N = 25	Both of low LDL and Remnant cholesterol N = 31	Low LDL with high Remnant cholesterol N = 57	ANOVA p	F
Age – years	65.04 ± 14.41	59.76 ± 12.85	67.29 ± 13.96	61.98 ± 13.49	0.037*	2.883
Female – no. (%)	11 (40.7)	12 (48)	35 (38.5)	26 (45.6)	0.767	0.381
BMI	23.83 ± 3.88	26.21 ± 4.53	24.55 ± 4.68	24.8 ± 4.18	1.360	0.256
SBP	128.78 ± 20.32	130.32 ± 15.14	128.96 ± 20.36	130.95 ± 18.7	0.153	0.928
Any history of smoking – no. (%)	10 (37)	8 (32)	31 (34.1)	22 (38.6)	0.925	0.158
Any Statin used – no. (%)	20 (74.1)	18 (72)	70 (76.9)	45 (78.9)	0.906	0.186
High intensity statin used – no. (%)	15 (55.6)	16 (64)	50 (54.9)	40 (70.2)	0.286	1.270
Diabetes Mellitus – no. (%)	5 (18.5)	11 (44)	28 (30.8)	22 (38.6)	0.178	1.655
Dyslipidemia – no. (%)	19 (70.4)	20 (80)	70 (76.9)	47 (82.5)	0.643	0.559
Prior stroke/TIA – no. (%)	4 (14.8)	3 (12)	9 (9.9)	2 (3.5)	0.315	1.189
Chronic kidney disease – no. (%)	11 (40.7)	7 (28)	34 (37.4)	25 (43.9)	0.585	0.647
eGFR – ml/min/1.73 m^2 (CKD-EPI)	67.78 ± 25.03	69.48 ± 28.67	65.48 ± 26.48	62.75 ± 33.36	0.760	0.391
CAD – no. (%)	15 (55.6)	14 (56)	53 (58.2)	43 (75.4)	0.124	1.945

Atrial fibrillation – no. (%)	2 (7.4)	2 (8)	19 (20.9)	5 (8.8)	0.086	2.227
CHF – no. (%)	5 (18.5)	6 (24)	35 (38.5)	21 (36.8)	0.172	1.684
LVEF – %**	58 ± 14.34	54.83 ± 17.6	51.33 ± 19.25	50.29 ± 17.74	0.424	0.939
Overweight	9 (33.3)	13 (52)	36 (39.6)	22 (38.6)	0.566	0.678
Obesity	2 (7.4)	7 (28)	11 (12.1)	4 (7)	0.047*	2.701
10 years Thai CV risk (%)	14.35 ± 11.28	16.25 ± 10.92	16.1 ± 9.26	16.68 ± 9.64	0.792	0.347

Using cut point at 10.86 mg/dl for Remnant cholesterol and 130 mg/dl for LDL.

*Significant at p <0.05 **138 patients were done with an echocardiogram; BMI, body mass index;

SBP, systolic blood pressure; TIA, transient ischemic attack;

eGFR, estimated glomerular filtration rate; LVEF, left ventricular ejection fraction; CKD-EPI, Chronic Kidney Disease Epidemiology Collaboration

Figure S1 Correlational analysis between calculated and direct LDL cholesterol measurement (mg/dl) (n = 19,038)

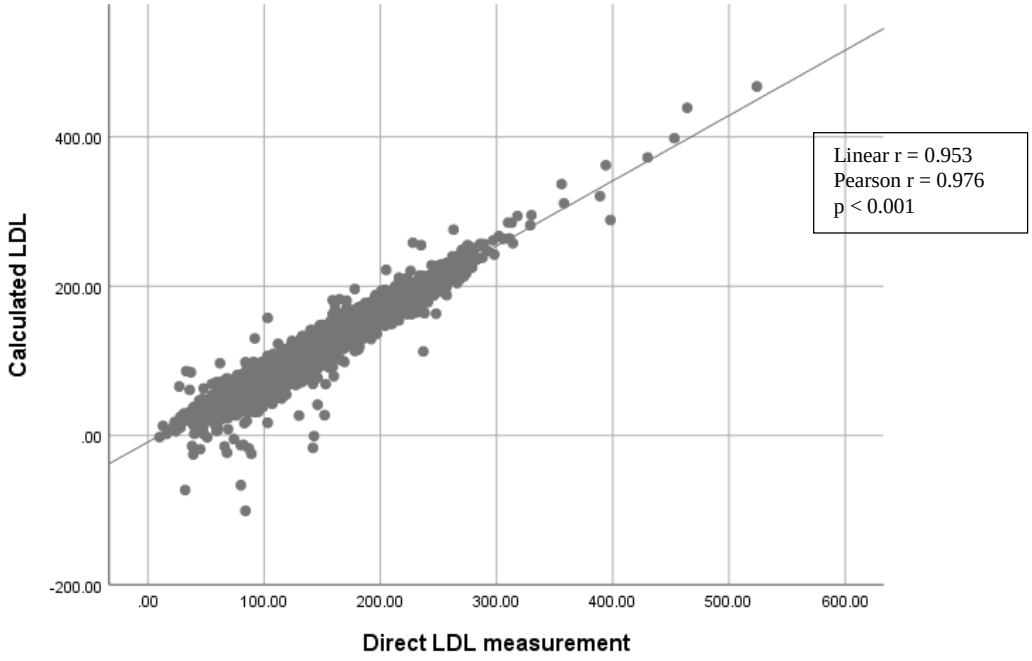


Figure S2 Correlational analysis between Remnant cholesterol and Triglyceride (mg/dl) (n = 19,038)

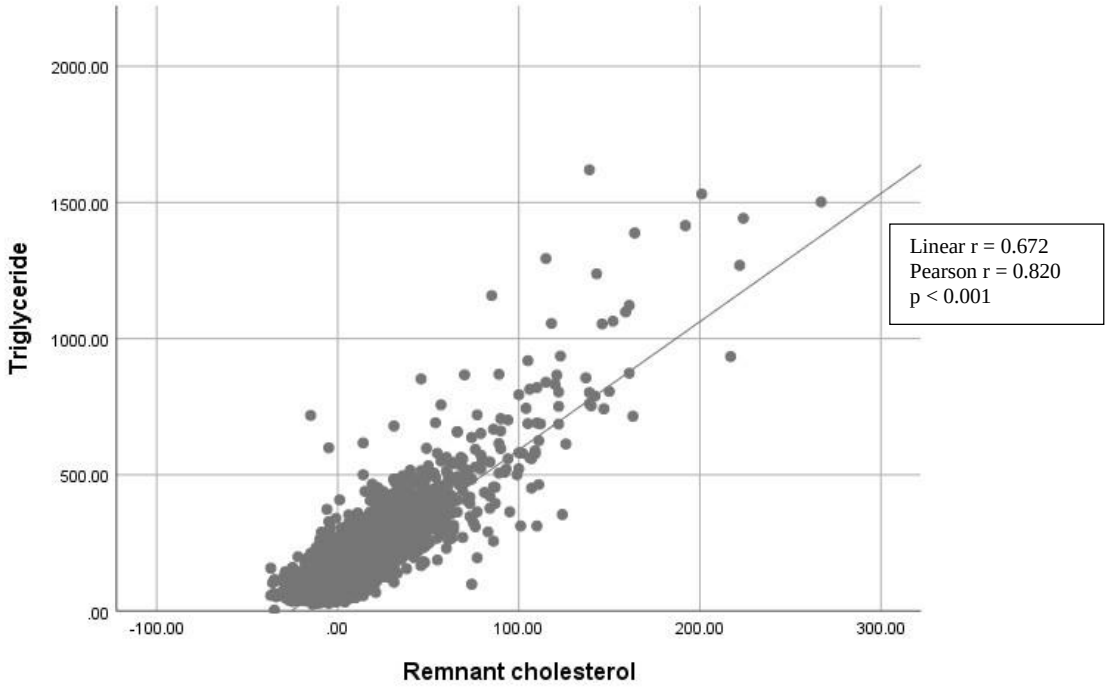


Figure S3 Correlational analysis between non-fasting Remnant cholesterol and LDL (mg/dl) (n = 200)

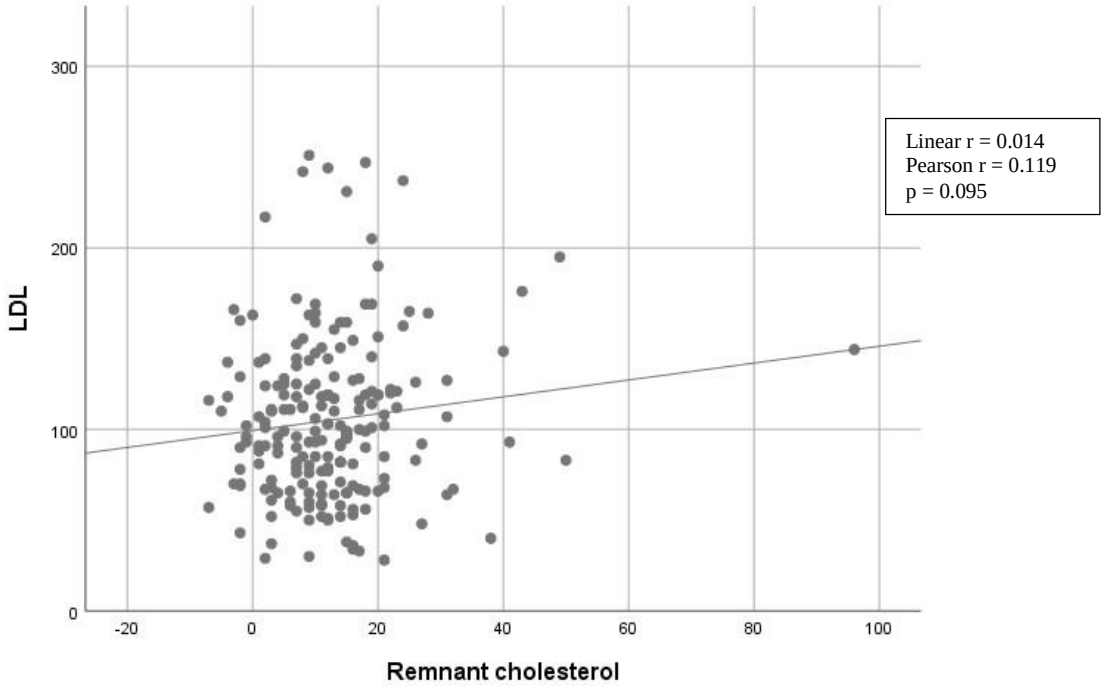


Figure S4 Correlational analysis between fasting Remnant cholesterol and HDL (mg/dl) (n = 200)

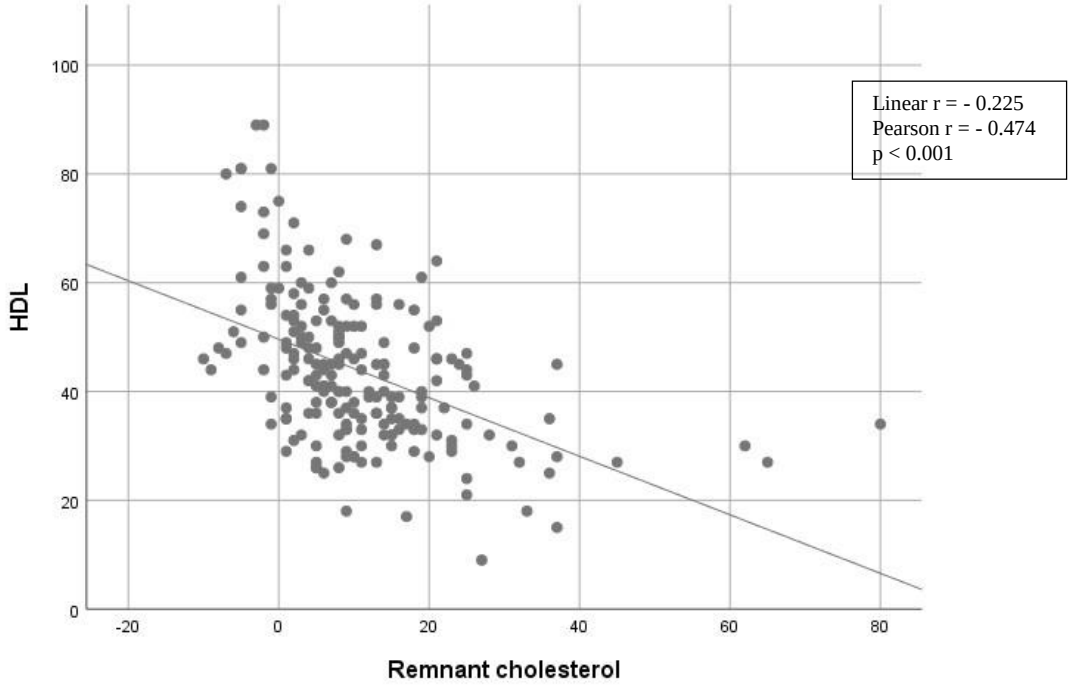


Figure S5 Correlational analysis between fasting Remnant cholesterol and non-HDL cholesterol (mg/dl) (n = 200)

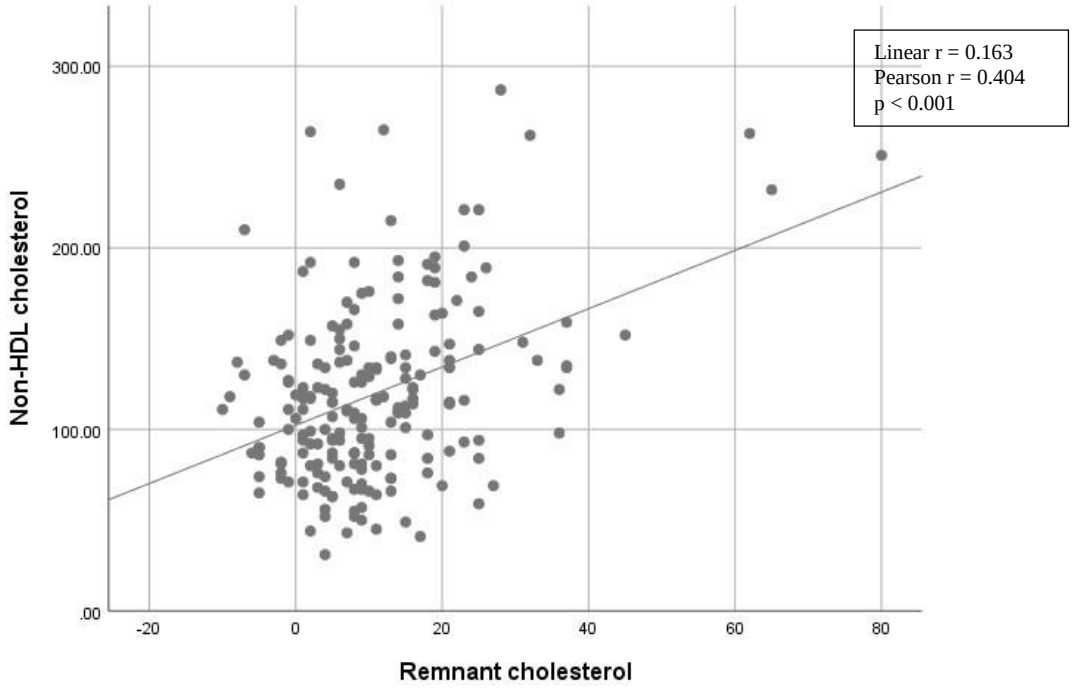


Figure S6 Correlational analysis between fasting Remnant cholesterol and total cholesterol (mg/dl) (n = 200)

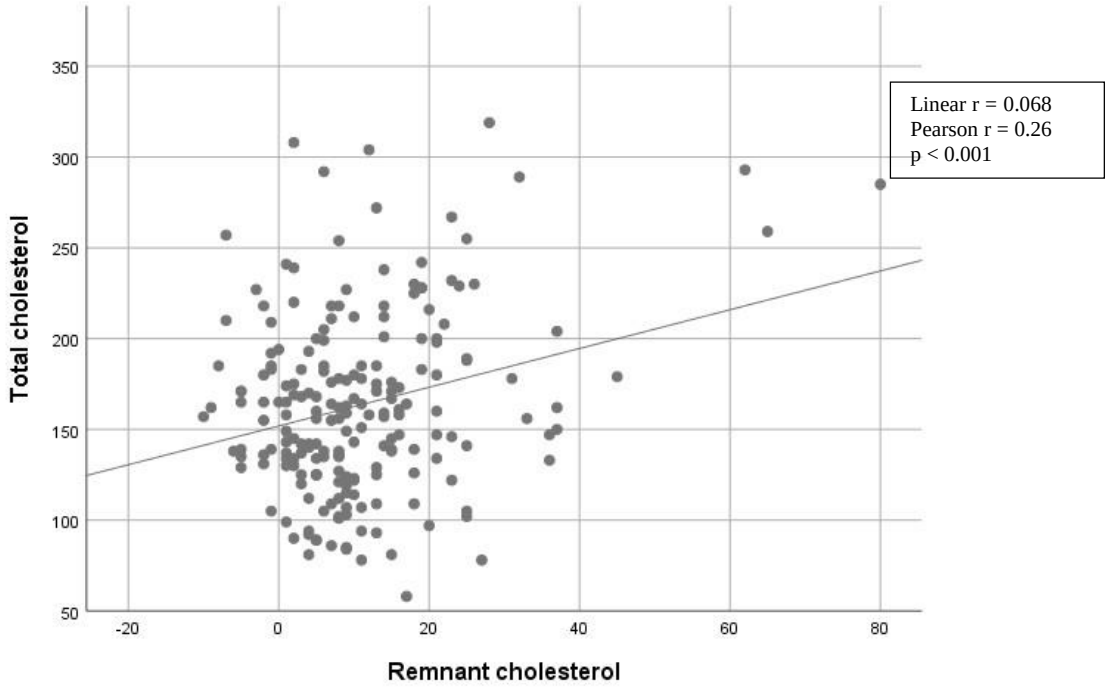


Figure S7 Correlational analysis between fasting Remnant cholesterol and LDL among any statin users (mg/dl) (n = 153)

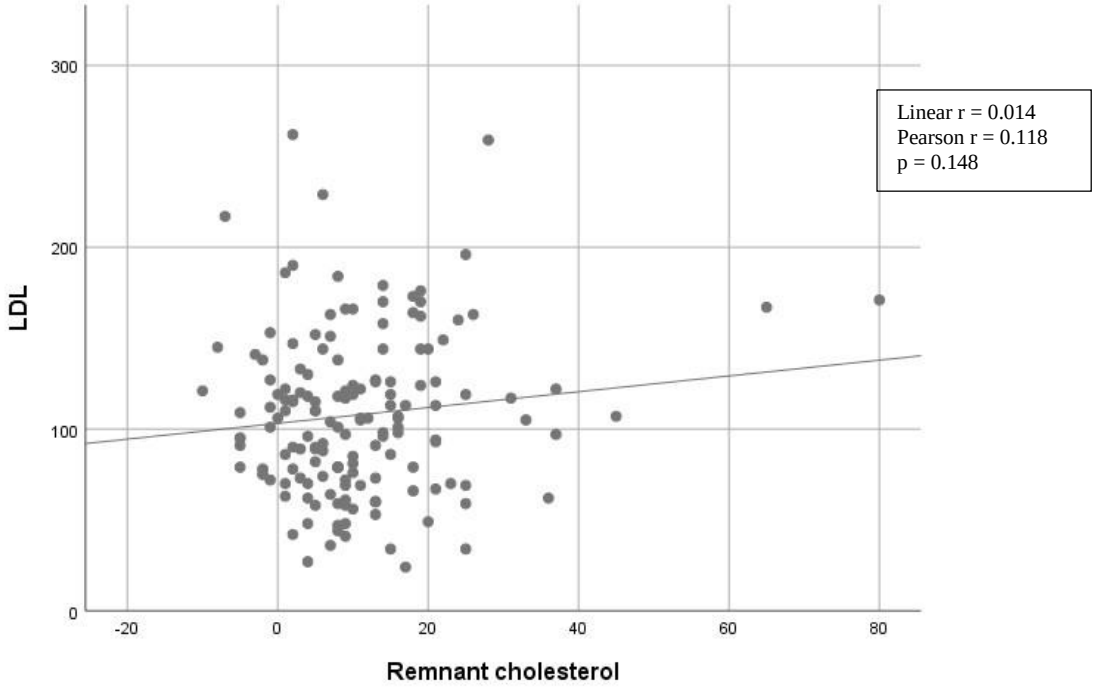


Figure S8 Correlational analysis between fasting Remnant cholesterol and LDL among non-statin users (mg/dl) (n = 47)

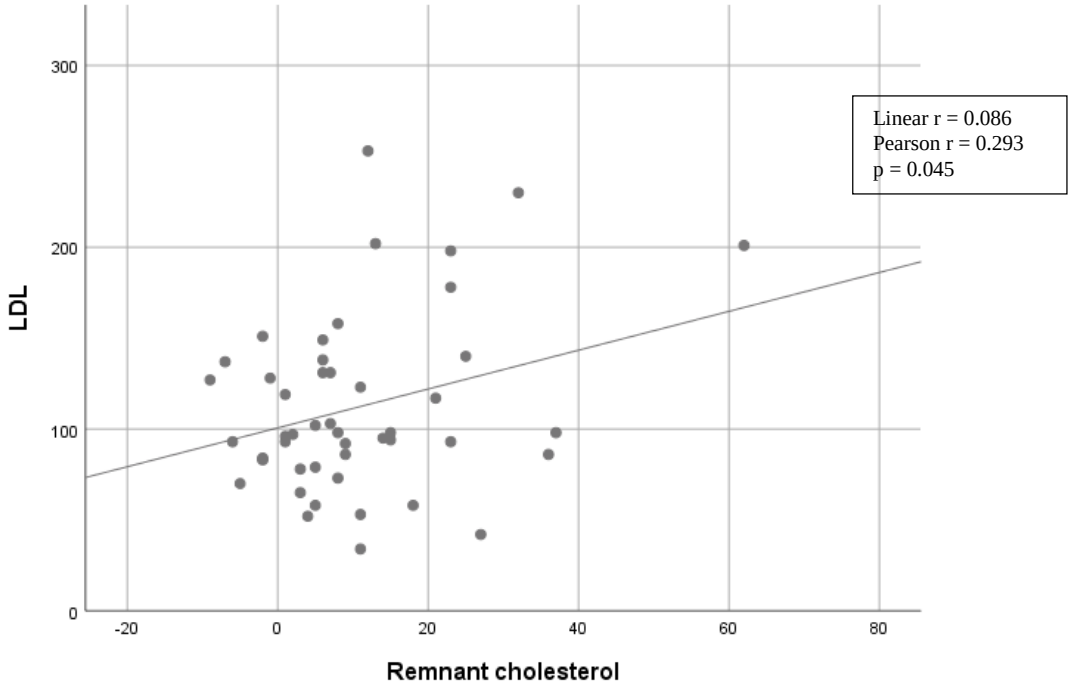


Figure S9 Correlational analysis between fasting Remnant cholesterol and LDL among high-intensity statin users (mg/dl) (n = 121)

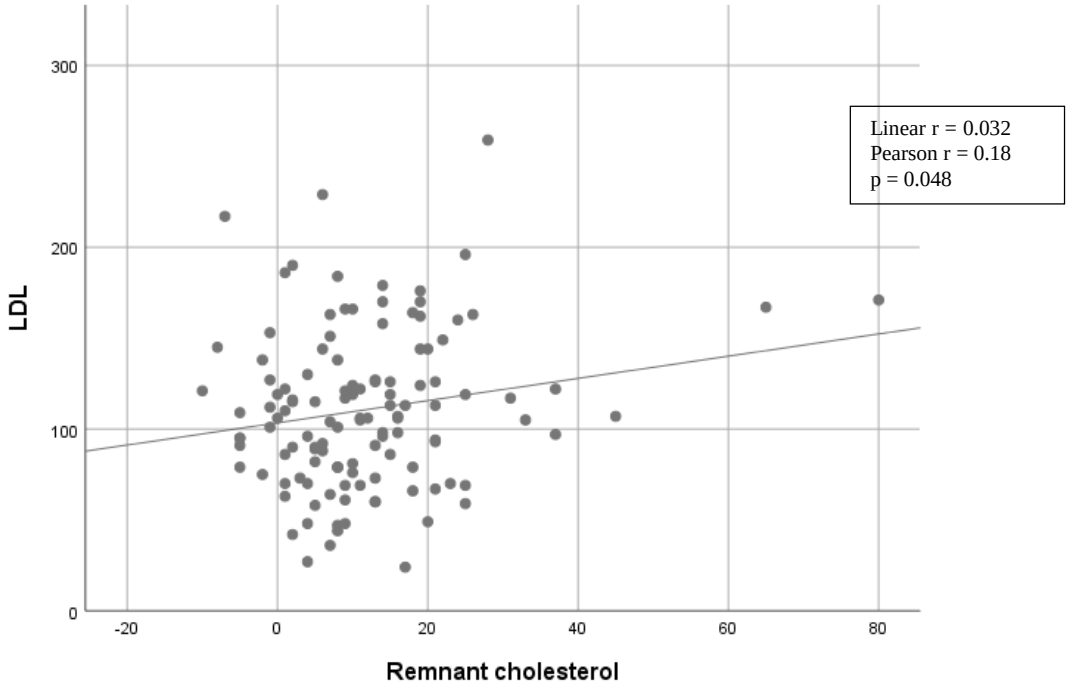


Figure S10 Correlational analysis between fasting Remnant cholesterol and LDL among patients without high-intensity statin (mg/dl) (n = 79)

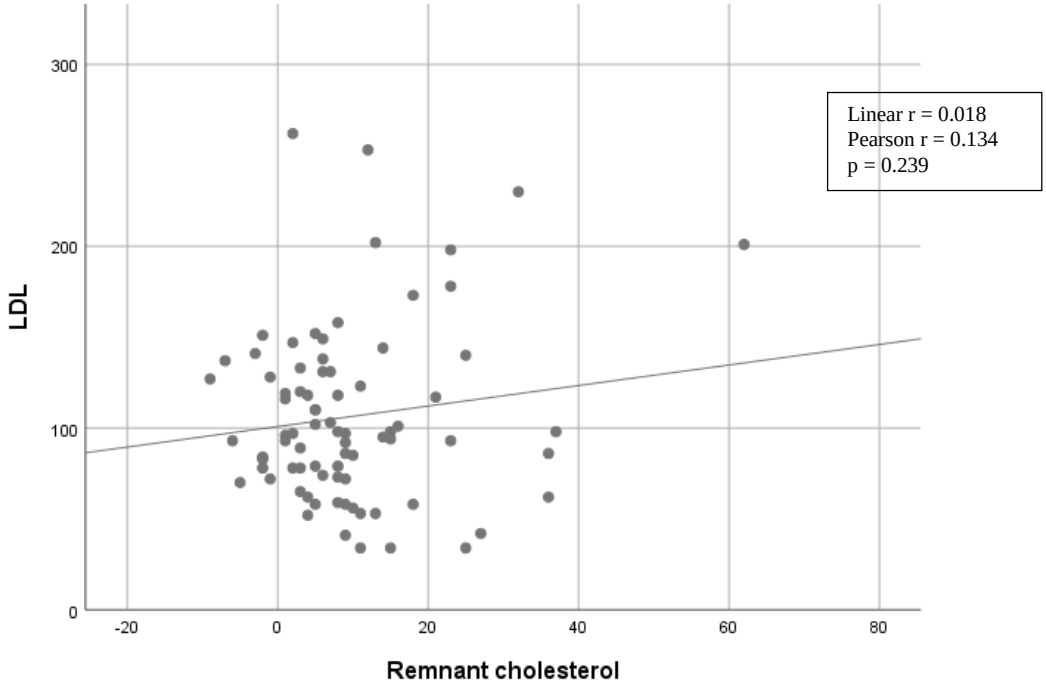


Figure S11 Correlational analysis between fasting Remnant cholesterol and LDL among patients with low to moderate intensity statin (mg/dl) (n = 32)

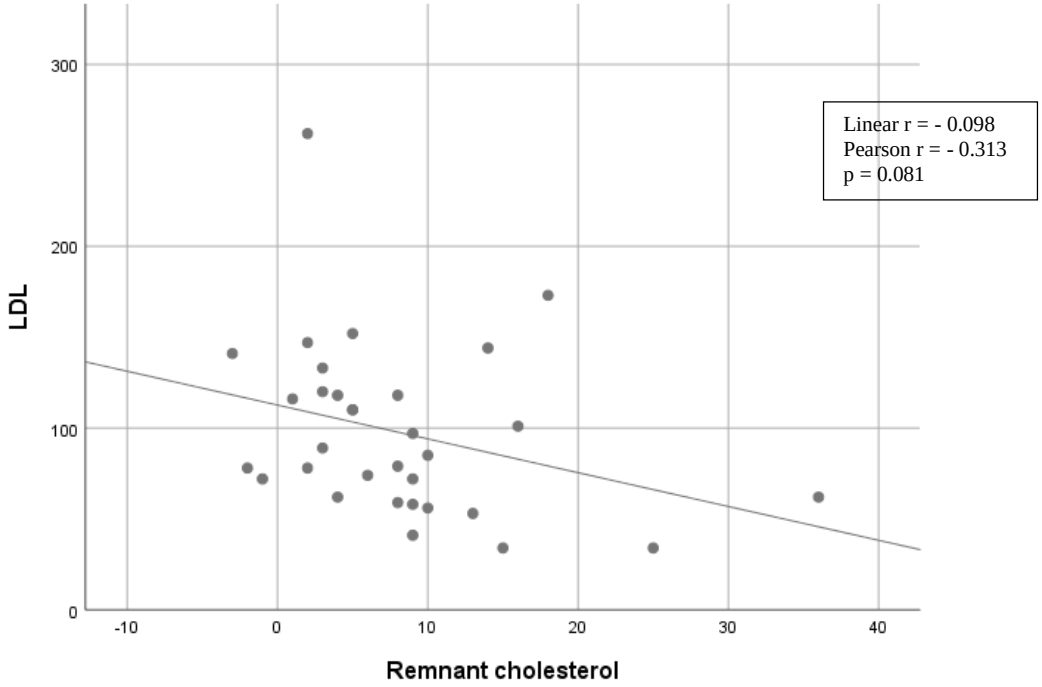


Figure S12 Correlational analysis between fasting Remnant cholesterol and 10 years Thai cardiovascular risk score (n = 200)

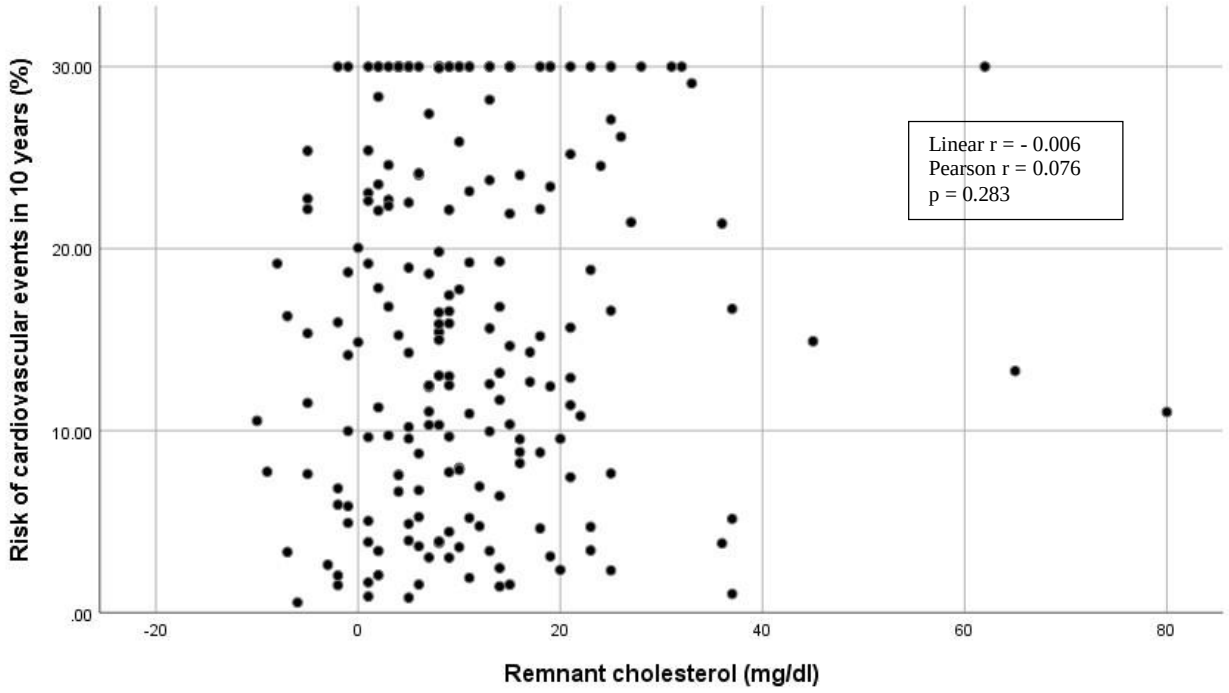


Figure S13 Correlational analysis between fasting LDL cholesterol and 10 years Thai cardiovascular risk score (n = 200)

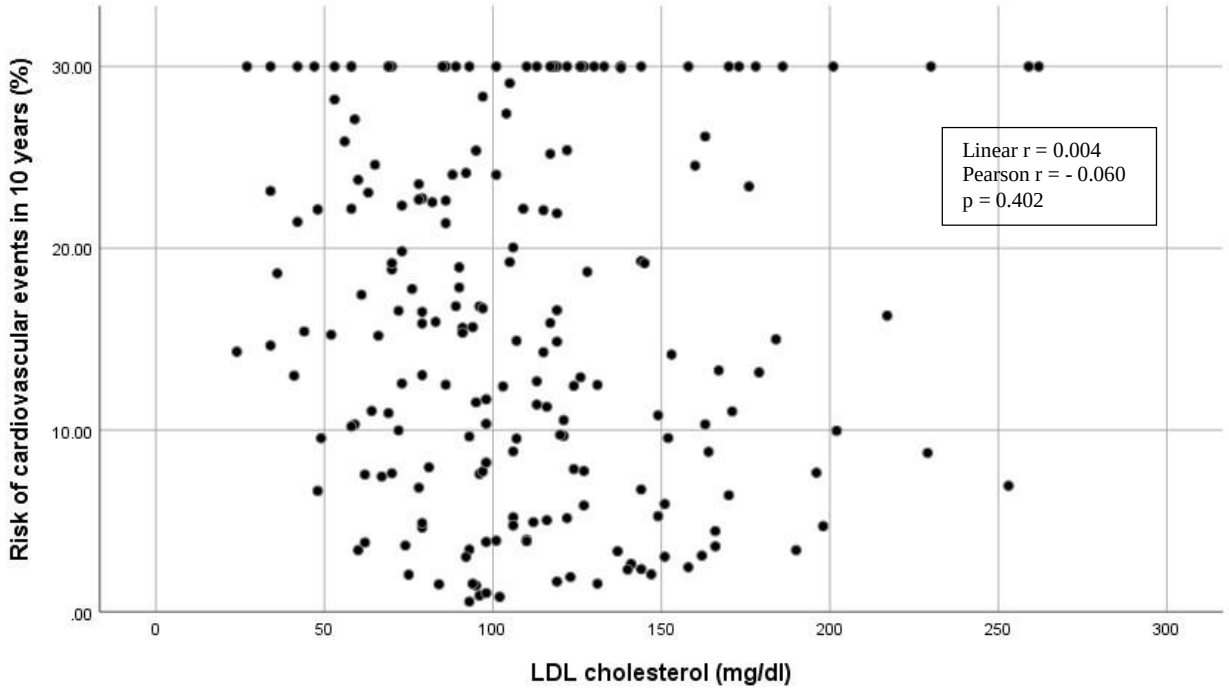


Figure S14 Correlational analysis between fasting HDL cholesterol and 10 years Thai cardiovascular risk score (n = 200)

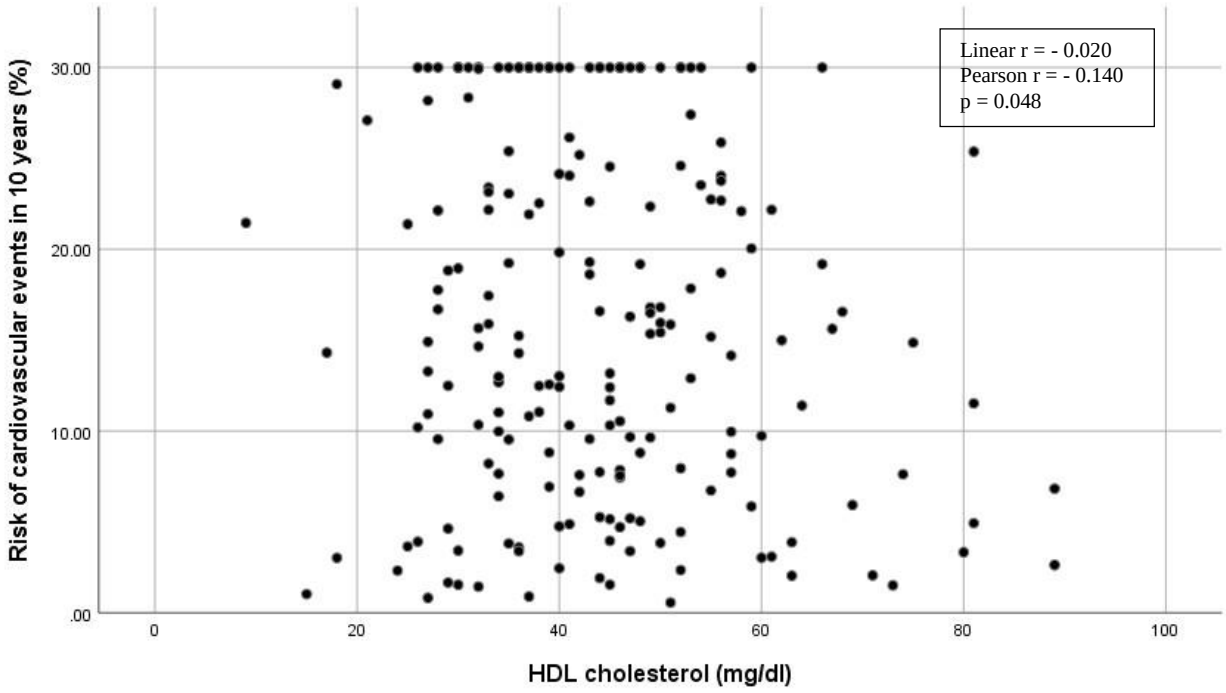


Figure S15 Correlational analysis between fasting total cholesterol and 10 years Thai cardiovascular risk score (n = 200)

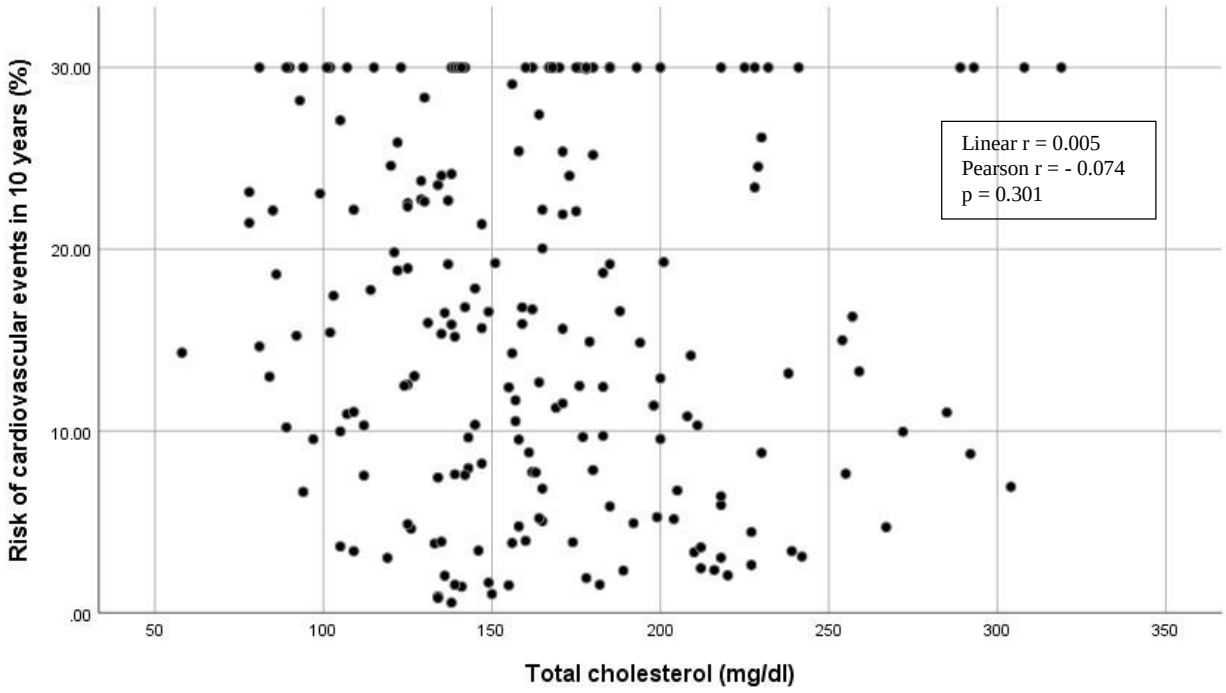


Figure S16 Correlational analysis between Remnant cholesterol and directed LDL measurement. Based on the 2014 EGAT study (n = 1,847) *Used with permission.

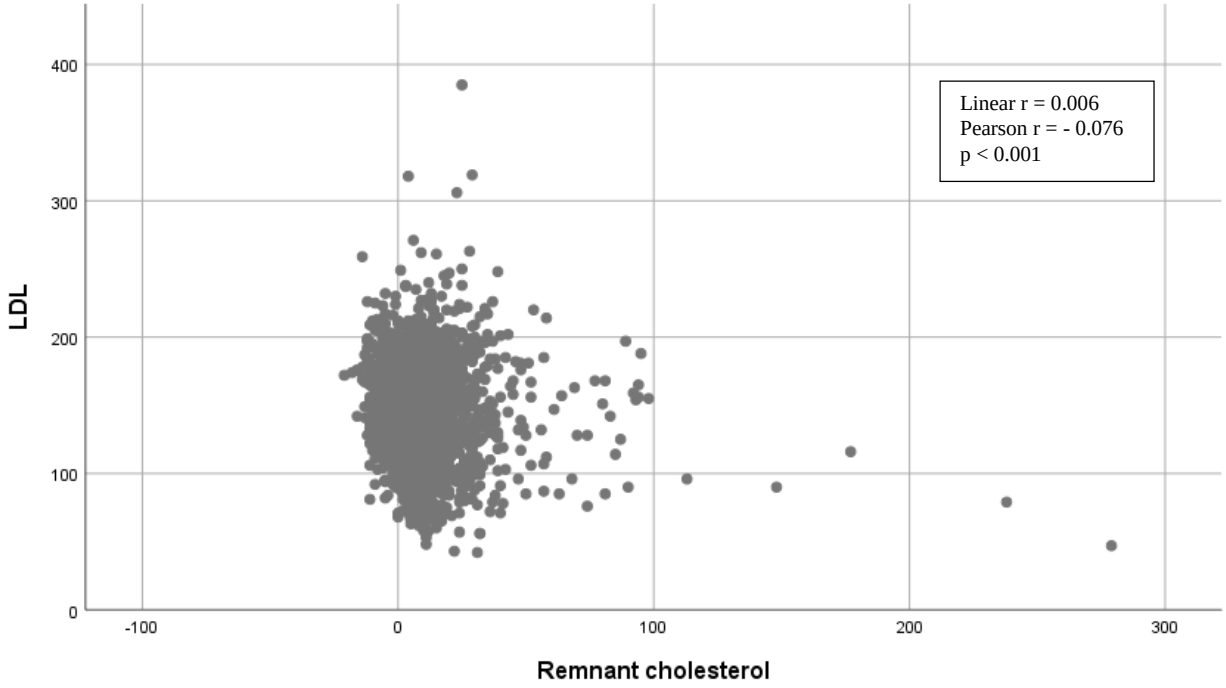


Figure S17 Correlational analysis between Remnant cholesterol and LDL, regardless of the fasting state. (mg/dl) (n = 19,038)

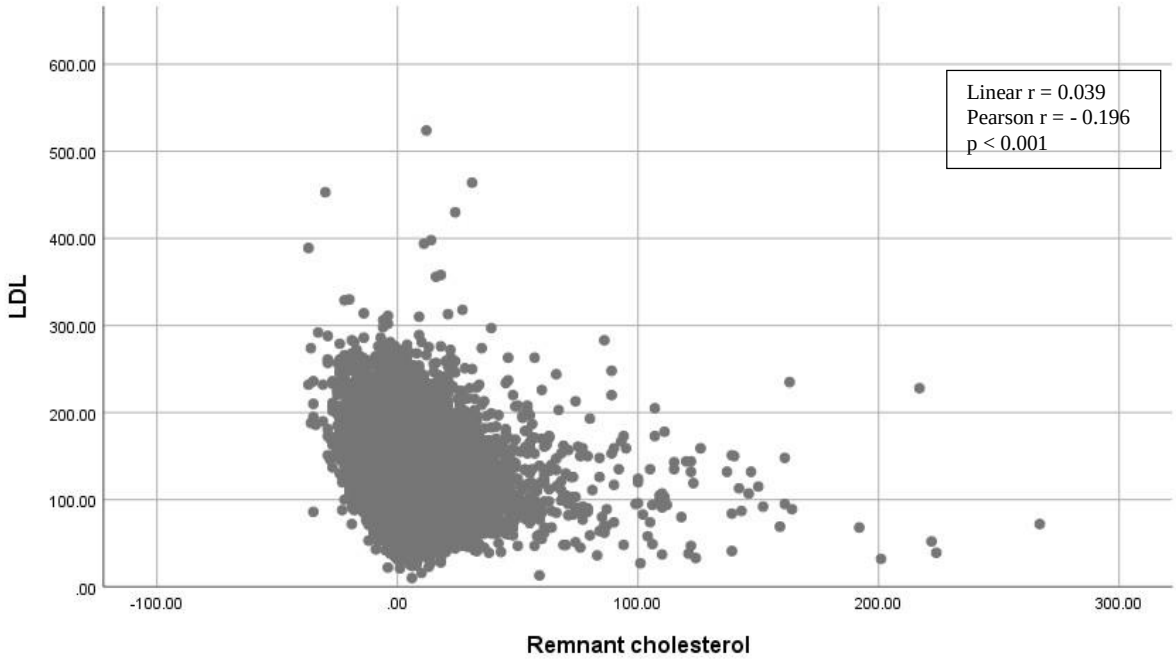


Figure S18 Patient-based analysis for predicting diabetes mellitus, using Remnant cholesterol or LDL levels.

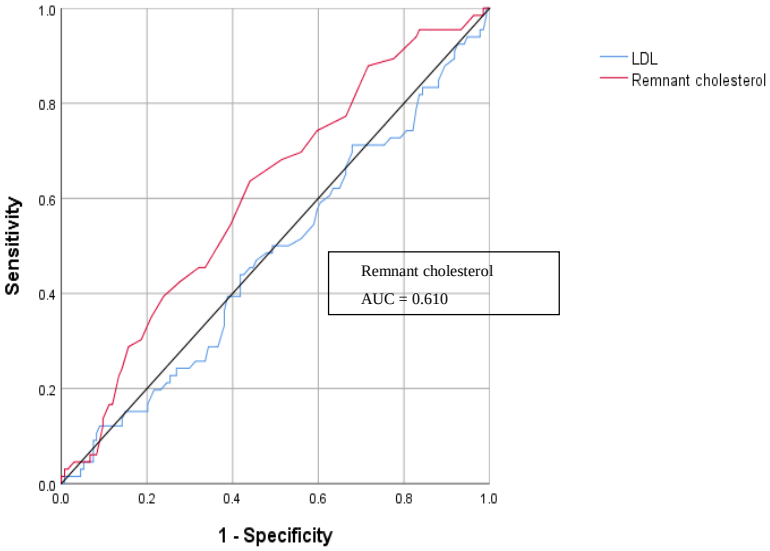


Figure S19 Patient-based analysis for predicting coronary artery disease, using Remnant cholesterol or LDL levels.

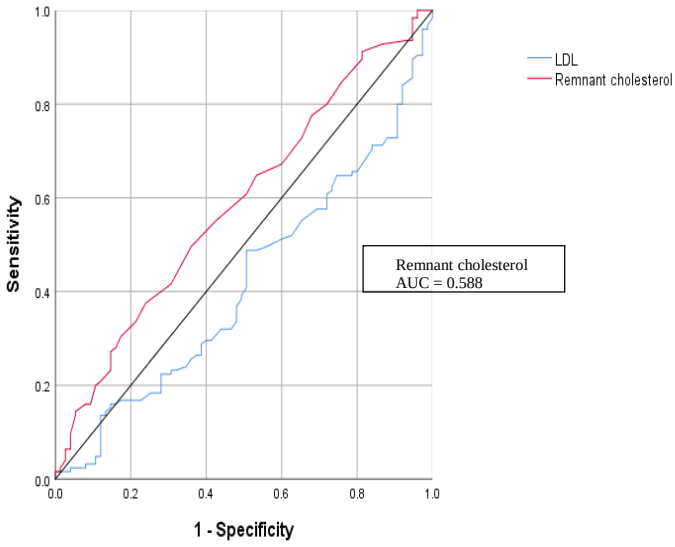
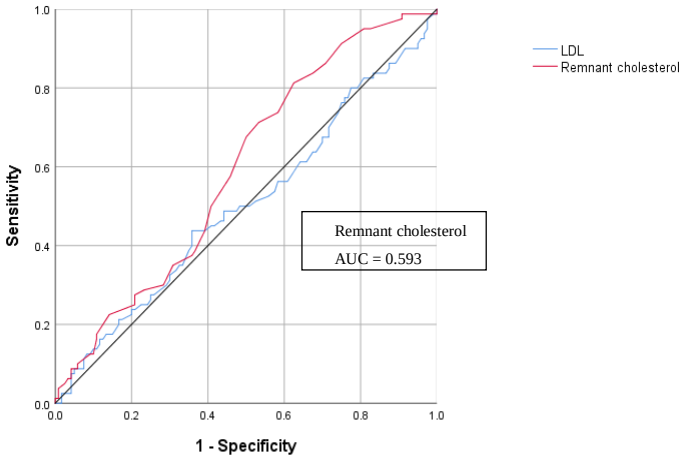


Figure S20 Patient-based analysis for predicting overweight (BMI cut off at 25 kg/m2) using Remnant cholesterol or LDL levels.



Additional Details on Method