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Association between dyslipidemia and risk of type 2 diabetes mellitus in middle-aged and older Chinese adults: a secondary analysis of a nationwide cohort

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ABSTRACT

Aims To evaluate the type 2 diabetes mellitus (T2DM) risk of individuals with different types of dyslipidaemia and compare the predictive value of distinct lipid parameters in predicting T2DM.

Methods We conducted a secondary analysis of data from the China Health and Retirement Longitudinal Study (CHARLS). 17 708 individuals over 45 years old were interviewed, and 11 847 blood samples were collected at the baseline survey (2011–2012). Outcome of T2DM was confirmed during two follow-up surveys (2013–2014 and 2015–2016). The HRs and 95% CI of T2DM associated with dyslipidaemia were estimated by Cox proportional hazards regressions model. The discriminatory value of eight lipid parameters were compared by the area under the receiver operating characteristic (ROC) curve (AUC).

Results A total of 7329 participants were enrolled in our analysis; during the mean follow-up time of 3.4 years, 387 (5.28%) participants developed new-onset diabetes. Compared with participants in normal lipid levels, the T2DM risk of those with hypercholesterolaemia, hypertriglyceridaemia and low high-density lipoprotein cholesterol (HDL-C) were significantly increased (HRs (95% CI) were 1.48 (1.11 to 1.96), 1.92 (1.49 to 2.46) and 1.67 (1.35 to 2.07), respectively). The AUCs of non-HDL-C (0.685, 95% CI 0.659 to 0.711), triglyceride (TG) (0.684, 95% CI 0.658 to 0.710), total cholesterol (TC)/HDL-C (0.685, 95% CI 0.659 to 0.712) and TG/HDL-C (0.680, 95% CI 0.654 to 0.706) were significantly (p<0.005) larger than that of other lipid parameters.

Conclusion Middle-aged and elderly adults with hypertriglyceridaemia, hypercholesterolaemia and low HDL-C were at higher risk for developing diabetes. Non-HDL-C, TG, TC/HDL and TG/HDL have greater performance than other lipid parameters in predicting T2DM incidence.

Strengths and limitations of this study

► This study systematically compared the predictive power among different lipid profiles in forecasting type 2 diabetes mellitus.
► The study's subjects were obtained by multistage probability sampling from 28 provinces of China; our findings could apply to the general middle-aged and elderly Chinese population.
► The primary limitation of this study was that case of diabetes was defined by interviewee's self-report; lacking of clinical evaluation may lead to discrepancy with the actual situation.

expenditure is spent on diabetic care, and four out of five people with diabetes live in low-income and middle-income countries, especially like China, which has the largest number of adult patients with diabetes.[3]

Dyslipidaemia has recently been recognised as a risk factor for T2DM. A large prospective study among middle-aged adults conducted in the USA has shown the low levels of high-density lipoprotein cholesterol (HDL-C) and elevated triglyceride (TG) levels were significantly related to the development with diabetes.[4] A cohort study drawn from the Korean population found that the elevated concentration of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and TG were independent risk factors for development of new-onset T2DM.[5] Moreover, increasing number of studies recently demonstrated that combined lipid parameters such as non-HDL-C, TG/HDL-C, LDL-C/HDL-C and TC/HDL-C were associated with T2DM[6 7] and have superiority value in predicting the incident of T2DM.[8 9] However, contradictory results about the relationship between dyslipidaemia and diabetes existed in different studies.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is an important problem for public health with 1 in 11 adults (463 million) has lived with diabetes in 2019.[1] If the dramatical increase in its prevalence continues, 700 million more people of 20–79 years old will have T2DM in 2045.[2] It is reported that 12% of global health

Although the important role of combined lipid profiles in predicting T2DM has been gradually recognised, a systematic comparison on the predictive value of lipid parameter for T2DM has not been performed. Therefore, in this study, we aimed to: (1) estimate the T2DM risk of the middle-aged and older Chinese adults with different types of dyslipidaemia; (2) compare the predictive valuer of individual and combined lipid parameters in forecasting T2MD incidence.

MATERIALS AND METHODS
Data source
The study used the China Health and Retirement Longitudinal Study (CHARLS),[10] a national representative research database from China. Considering regional and socioeconomic diversity across China, the CHARLS obtained a sample of the Chinese aged 45 years and older by multistage probability sampling from 28 provinces. The national baseline survey of CHARLS was commenced from 2011 and followed biennially at 2013 and 2015. The CHARLS database consisted participants' demographics background, health status and functioning, healthcare and insurance, work, retirement and pension, as well as anthropometric measurements. Informed consent was obtained from all participants.

Study population
A total of 17 708 individuals were interviewed in the main CHARLS baseline survey, and 11 847 blood samples were successfully collected. Among those with available serum lipid measurements, we first excluded subjects who self-reported a history of diabetes. Then, we excluded those who had incomplete decisive confounding variables, such as demographic information, anthropometric or biomarker records, individuals who had an undefined diabetic outcome due to lost to follow-up or data missing in 2013 or 2015.

Estimating T2DM incidence
An incident case of T2DM was defined as self-reported of doctor-diagnosed diabetes. Participants were required to answer the question, 'Have you been diagnosed with diabetes by a doctor?' during the follow-up. In addition, investigators would confirm the situation in the next interview through the question, 'Our records from your last interview show that you have had/not had diabetes, is this right?'. Individuals who at least once self-reported have been diagnosed with diabetes in 2013 or 2015 were defined as new-onset diabetes.

Assessment of dyslipidaemia
Concentrations of four classical serum lipid indices, including TC, TG, LDL-C and HDL-C, were tested from blood samples stored in the freezer by using the standard enzymatic colorimetric method. Dyslipidaemia was defined according to criterion published by the 2016 Chinese guidelines for the management of dyslipidaemia

in adults.[11] Dyslipidaemia was determined as a TC of 240 mg/dL (6.2 mmol/L) or greater, TG level of 200 mg/dL (2.3 mmol/L) or greater, LDL-C level of 160 mg/dL (4.1 mmol/L) or greater and HDL-C level of 40 mg/dL (1 mmol/L) or less. Borderline high were defined if TC was 200–239 mg/dL, TG was 150–199 mg/dL and LDL-C was 130–159 mg/dL.

Patient and public involvement
Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Statistical analysis
Baseline characteristics of participants were described according to the diabetes status. Mean (SD) or median (IQR) were presented for normally and non-normally distributed continuous variables, respectively. Groups were compared using the independent t-test, and non-normally distributed variables were compared after logarithmic transformation.

T-tests or Wilcoxon rank-sum test were used to analyse differences between different groups based on normality of distribution. Proportions were reported for categorical variables and compared with the help of the χ^2 test or Fisher's exact test.

Model building procedures
Cox proportional hazards regression was used to estimate the risk of incident T2DM for participants with dyslipidaemia by calculating the HRs and 95% CIs in the crude models. Potential confounding factors were stepwise added into the adjusted models. Age, gender, education level and marriage status were controlled in the minimally models. The final models further adjusted for waist circumference, body mass index (BMI), systolic blood pressure, diastolic blood pressure, C reactive protein, plasma glucose, cigarette smoking and alcohol drinking. Moreover, stratified analysis was performed to examine the robustness of our research findings. Potential effect modification by stratifying variables were calculated by including cross-product term of the stratifying variable and the exposure into the fully adjusted model, and the likelihood ratio test was conducted to compare the models with or without a cross-product term.

Comparing predictors performance
We estimated the discriminatory value of eight parameters by computing the area under the receiver operating characteristic (ROC) curve (AUC) of multivariable-adjusted logistic models. Each regression model contained one lipid parameter and conventional risk factors. Lipid profiles included four classical lipid measures (TC, TG, HDL-C and LDL-C) and four combined lipid profiles (non-HDL-C, TC/HDL-C, TG/HDL-C and LDL-C/HDL-C). The conventional risk factors included age, gender, waist circumference, BMI, systolic blood pressure, diastolic blood pressure, cigarette smoking and alcohol consumption. The statistic differences in AUCs were
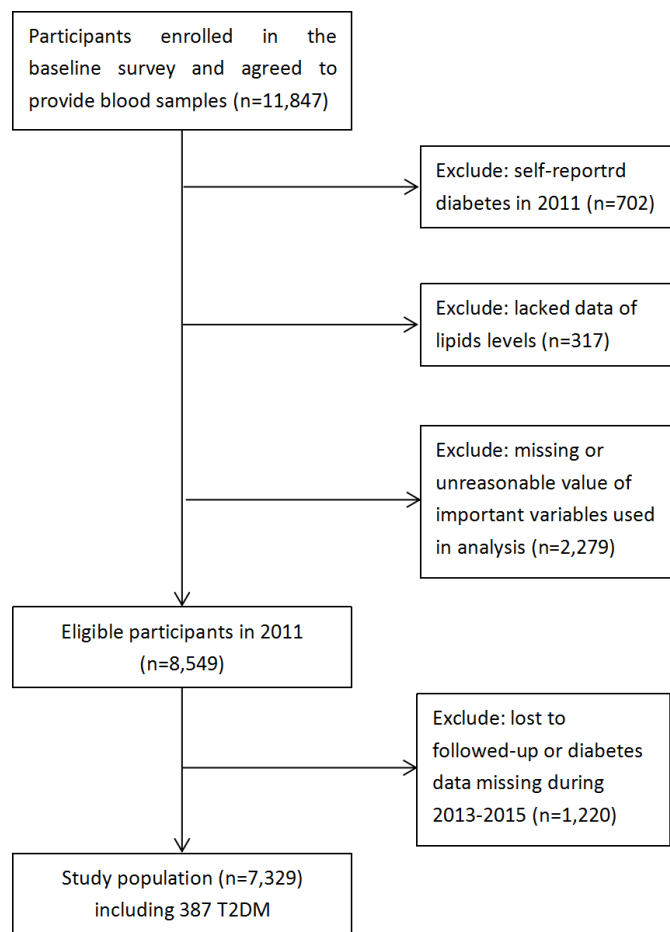
Figure 1 Flow chart of the study population according to inclusion and exclusion criteria.

compared by using an algorithm developed by DeLong *et al.*[12]

Stata V.15 (StataCorp, College Station, Texas, USA) was used to perform all analyses. All tests were two sided, and statistical significance was defined as p values <0.05.

RESULTS
Baseline characteristics
A total of 7329 participants were included in our analysis. A flow chart of the study population is given in figure 1. During the mean follow-up time of 3.4 years, 387 participants had been diagnosed as diabetes, and the incidence rate of diabetes was 5.74%. The mean (SD) age of all individuals at baseline was 58.77 (9.40) years. There were 3455 men account for 47.14%. A total of 819 (11.17%) participants defined as hypercholesterolaemia. The median (IQR) of TC, TG, LDL-C, HDL-C levels at baseline were 190.98 (167.40–215.34) mg/dL, 104.43 (74.34–152.22) mg/dL, 114.43 (93.17–136.86) mg/dL and 49.87 (40.59–60.31) mg/dL, respectively. The mean ratios (SD) of TC to HDL-C, TG to HDL-C and LDL-C to HDL-C were 4.06 (1.45), 3.14 (4.09) and 2.42 (0.94), respectively. The baseline characteristics of all participants and a characteristics comparison of individuals with different

TC classifications presented in table 1. Participants with hypercholesterolaemia at baseline survey had a disposition to be female and revealed higher age, BMI, waist circumference, blood pressure and fasting blood glucose.

The T2DM risk of dyslipidaemia
Table 2 presents the unadjusted and multivariable-adjusted HRs and 95% CI for diabetes according to dyslipidaemia status. At the primary models without any cofounding factors, all types of dyslipidaemia were associated with significantly increased T2DM risk. Compared with the normal subgroup, the HRs (95% CI) of T2DM in the hypercholesterolaemia (TC ≥240 mg/dL), hypertriglyceridaemia (TG ≥200 mg/dL), elevated LDL-C (LDL-C ≥160 mg/dL) and low HDL-C (HDL-C <40 mg/dL) subgroups were 1.77 (1.34–2.33), 2.56 (2.03–3.23), 1.55 (1.17–2.05) and 1.94(1.59–2.38), respectively. After gradually adjusting for potential influence factors, the associations were modestly attenuated but still statistically significant. The HRs (95% CI) were 1.48 (1.11 to 1.96), 1.92 (1.49 to 2.46) and 1.67 (1.353to 2.07) in the fully adjusted models, respectively. However, the statistically significant association between elevated LDL-C level and diabetes did not remain at further adjusted model (HR 0.93, 94% CI 0.62 to 1.41). Baseline borderline high TG was associated with a 58% (HR 1.58, 95% CI 1.21 to 2.07) increase in the risk of T2DM after adjusting for potential confounders. In addition, no statistically significant heterogeneity was observed for the associations between dyslipidaemia and diabetes in subgroups stratified by different impact factors including age, gender, waist circumference, systolic blood pressure, diastolic blood pressure, education level, cigarette smoking, alcohol consumption and BMI. The results were presented by forest plot figures in online supplemental figures 1–4.

The performance of lipid parameters in predicting T2DM
As listed in table 3, after the same adjustment for potential confounding factors, levels of non-HDL-C, TC, TG, ratios of TC to HDL-C, TG to HDL-C and LDL-C to HDL-C were positive significantly associated with incidence of T2DM (p<0.05). HDL-C and T2DM shown a significantly negative relationship (p=0.001). The statistically significant association between LDL-C and T2DM was not observed in our study (p=0.396). The AUCs that indicate the predictive performance of models are shown in table 3. The AUCs were compared between models including various lipid parameters respectively in addition to conventional risk factors and the reference model including only conventional risk factors. The AUCs for models of non HCL-C (AUC 0.685, 95% CI 0.659 to 0.711), TG (AUC 0.684, 95% CI 0.658 to 0.710), ratio of TC to HDL-C (AUC 0.685, 95% CI 0.659 to 0.712) and ratio of TG to HDL-C (AUC 0.680, 95% CI 0.654 to 0.706) combined with conventional factors were significantly larger than that of model that only contained conventional factors (AUC 0.672, 95% CI 0.646 to 0.700). The ROC curves of four parameters that significantly increased the AUC

Table 1 Characteristics of study participants at baseline in the China Health and Retirement Longitudinal Study (CHARLS), 2011

Baseline characteristics	All participants, N (%) or mean±SD	Classifications of each lipid parameter, N (%)			
TC	190.98 (167.40–215.34)*	Normal (<200 mg/dL)	Borderline high (200–240 mg/dL)	Hypercholesterolaemia (≥240 mg/d)	
N (%)	7329 (100)	4431 (60.46)	2079 (28.37)	819 (11.17)	
TG	104.43 (74.34–152.22)*	Normal (<150 mg/dL)	Borderline high (150–200 mg/dL)	Hypertriglyceridaemia (≥200 mg/dL)	
N (%)	7329 (100)	5445 (74.29)	883 (12.05)	1001 (13.66)	
LDL-C	114.43 (93.17–136.86)*	Normal (<130 mg/dL)	Borderline high (130–160 mg/dL)	Elevated LDL-C (≥160 mg/dL)	
N (%)	7329 (100)	5010 (68.36)	1528 (21.12)	771 (10.52)	
HDL-C	49.87 (40.59–60.31)*	Normal (≥40 mg/dL)	Low HDL-C (<40 mg/dL)		
N (%)	7329 (100)	5625 (76.75)	1704 (23.25)		
		Characteristics based on classifications of total cholesterol			P
Age (years)	58.77±9.40	58.40±9.57	59.25±9.16	59.66±8.84	<0.001
BMI (kg/m^2)	23.40±3.72	23.18±3.64	23.65±3.81	24.09±3.84	<0.001
Waist circumference (cm)	83.93±12.28	83.15±12.31	85.02±11.76	85.52±13.03	<0.001
SBP (mm Hg)	129.51±21.22	128.15±20.99	130.84±21.55	133.69±20.92	<0.001
DBP (mm Hg)	75.41±12.11	74.66±12.09	76.17±12.02	77.63±12.13	<0.001
C reactive protein (mg/L)	0.99 (0.54–2.09)*	0.92 (0.51–2.06)*	1.04 (0.56–1.99)*	1.18 (0.65–2.36)*	<0.001
Plasma glucose (mg/dL)	102.24 (94.32–112.68)*	100.8 (93.42–110.70)*	103.5 (95.22–113.94)*	106.20 (97.20–120.24)*	0.004
Gender, n (%)					<0.001
Male	3455 (47.14)	2292 (51.73)	880 (42.33)	283 (34.55)	
Female	3874 (52.86)	2139 (48.27)	1199 (57.67)	536 (65.45)	
Education level, n (%)					<0.001
Illiterate	2163 (29.51)	1384 (31.23)	583 (28.04)	196 (23.93)	
Primary or above	5166 (70.49)	3047 (68.77)	1496 (71.96)	623 (76.07)	
Marital Status, n (%)					0.003
Married/ cohabitation	6499 (88.68)	3938 (88.87)	1858 (89.37)	703 (85.84)	
Single/divorced	830 (11.32)	493 (11.13)	221 (10.63)	116 (14.16)	
Cigarette smoking, n (%)					<0.001
Never smoke	4473 (61.03)	2572 (58.05)	1241 (64.50)	560 (68.38)	
Used to smoke	593 (8.09)	338 (7.63)	186 (8.95)	69 (8.42)	
Still have	2263 (30.88)	1521 (34.33)	552 (26.55)	190 (23.20)	
Alcohol drinking, n (%)					0.021
Never drink	4848 (66.15)	2916 (65.81)	1358 (65.32)	574 (70.09)	
Used to drinking	576 (7.86)	387 (8.73)	144 (6.93)	45 (5.49)	
Still have	1905 (25.99)	1128 (25.46)	577 (27.75)	200 (24.42)	

*Variables are presented as median (IQR).
BMI, body mass index; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride.

Table 2 HR (95% CI) for diabetes in relation to total cholesterol, triglycerides, low-density lipoprotein cholesterol and high-density lipoprotein cholesterol concentration (CHARLS 2011–2015)

	Model 1	Model 2	Model 3
TC			
Normal (<200 mg/dL)	1	1	1
bBorderline high (200–240 mg/dL)	1.33 (1.08–1.65)	1.27 (1.03–1.58)	1.19 (0.95–1.48)
Hypercholesterolaemia (≥240 mg/dL)	1.77 (1.34–2.33)	1.64 (1.22–2.17)	1.48 (1.11–1.96)
TG			
Normal (<150 mg/dL)	1	1	1
Borderline high (150–200 mg/dL)	2.00 (1.55–2.61)	1.91 (1.46–2.48)	1.58 (1.21–2.07)
Hypertriglyceridaemia (≥200 mg/dL)	2.56 (2.03–3.23)	2.46 (1.93–3.13)	1.92 (1.49–2.46)
LDL-C			
Normal (<130 mg/dL)	1	1	1
Borderline high (130–160 mg/dL)	1.14 (0.90–1.40)	0.91 (0.69–1.20)	0.86 (0.65–1.14)
Elevated LDL-C (≥160 mg/dL)	1.55 (1.17–2.05)	0.99 (0.66–1.85)	0.93 (0.62–1.41)
HDL-C			
Normal (≥40 mg/dL)	1	1	1
Low HDL-C (<40 mg/dL)	1.94 (1.59–2.38)	2.15 (1.75–2.63)	1.67 (1.35–2.07)

Model 1: not adjusted.
Model 2: model 1 adjusted for age (continuous, years), gender (male and female), education (illiterate, primary or above) and marital status (married/cohabitation, single/divorced).
Model 3: model 2 adjusted for waist circumference (continuous, cm), body mass index (continuous, kg/m^2), diastolic blood pressure (continuous, mm Hg), systolic blood pressure (continuous, mm Hg), C reactive protein (mg/L), plasma glucose (mg/dL), cigarette smoking (never smoke, used to smoke or still have) and alcohol drinking (never drink, used to drinking or still have).
BMI, body mass index; CHARLS, China Health and Retirement Longitudinal Study; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

when added into the reference model were presented in the online supplemental figure 5.

DISCUSSION

This current study aimed to compare the predictive power of different lipid profiles in forecasting T2DM. Meanwhile, we assess the T2DM risk among individuals with four different types of dyslipidaemia in a population-representative cohort in China. There were several important findings. Participants with borderline high TG, hypercholesterolaemia, hypertriglyceridaemia and low HDL-C suffered a higher T2DM risks through our 5-year national longitudinal study. Furthermore, non-HDL-C, TG, ratio of TC to HDL-C and ratio of TG to HDL-C provide better performance for T2DM prediction than other lipid panels. Our findings add the current evidence demonstrating that TC, TG and low HDL-C are risk factors for diabetes and emphasise that serum TG and combined lipid parameters were more efficient predictor factor for diabetes versus other lipid profiles.

In the present study, participants with hypercholesterolaemia, hypertriglyceridaemia and low HDL-C were 1.48, 1.92 and 1.67, respectively, times more likely to develop T2DM compared with those without, which is accordant with some previously reported studies

conducted in western country and Asian. A 5-year follow-up of 3951 initially non-diabetic participants from the Insulin Resistance Atherosclerosis Study showed that participants with high TGs (>1.68 mmol/L) and low level of HDL-C (<1.06 mmol/L) were at increased risk developing diabetes (relative risk 2.27, 95% CI 1.59 to 3.25 and RR 2.07, 95% CI 1.45 to 3.13).[13] A prospective 8-year follow-up of the Tianjin General Hospital cohort of 7241 participants without prior diabetes or cardiovascular disease showed that high TG level (TG ≥2.26 mmol/L) was correlated with an increased risk of developing T2DM (HR 1.54, 95% CI 1.24 to 1.90).[14] During 10-year follow-up, individuals with dyslipidaemia were 1.7 times more likely to develop T2DM than those with normal serum lipid measures (OR 1.70, 95% CI 1.23 to 2.34).[15] The fifth Framingham Offspring study revealed that, compared with participants with normal lipid profiles, men with HDL-C level <40 mg/dL or women with HDL-C <50 mg/dL had 2.55 times risk of progressing to diabetes, and participants with TG level ≥150 mg/dL had 1.75 times risk of progressing to diabetes.[4] On the whole, individuals with dyslipidaemia were at higher risk of incident T2DM; dyslipidaemia may be a risk factor for T2DM.

Even though LDL-C was generally acknowledged as a key factor of cardiovascular diseases, it is still controversial

Table 3 Receiver operating characteristic analysis of lipid parameters in the prediction of diabetes mellitus during follow-up

	β	95% CI	AUC (95% CI)	Cut-off point	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Reference model			0.672 (0.646 to 0.700)	0.055	59.21	66.89	9.07	96.71
TC/HDL-C	0.14	0.08 to 0.20	0.685 (0.659 to 0.712)*	0.043	76.23	52.52	8.19	97.51
Non-HDL (mg/dL)	1.72	0.94×10^{-3} to 2.51×10^{-3}	0.685 (0.659 to 0.711)*	0.058	57.44	70.28	9.73	96.73
TG (mg/dL)	1.75×10^{-3}	0.92×10^{-3} to 2.58×10^{-3}	0.684 (0.658 to 0.710)*	0.045	74.42	54.33	8.32	97.44
TG/HDL-C	0.03	0.01 to 0.05	0.680 (0.654 to 0.706)*	0.045	73.45	54.24	8.20	97.34
LDL-C/HDL-C	0.20	0.09 to 0.31	0.680 (0.654 to 0.707)	0.046	72.91	55.21	8.32	97.34
HDL-C (mg/dL)	−13.37	-0.02 to -5.29×10^{-3}	0.679 (0.652 to 0.705)	0.046	72.63	54.32	8.14	97.26
TC (mg/dL)	2.91×10^{-3}	0.23×10^{-3} to 5.61×10^{-3}	0.674 (0.647 to 0.701)	0.052	64.32	62.91	8.81	96.93
LDL-C (mg/dL)	1.27×10^{-3}	-1.66×10^{-3} to 4.19×10^{-3}	0.672 (0.646 to 0.699)	0.048	68.51	58.04	8.33	97.06

β (95% CI) were tested in multivariable logistic regression models that added lipid parameter into the reference model that contained conventional risk factors (age, gender, waist circumference, body mass index, systolic blood pressure, diastolic blood pressure, C reactive protein, plasma glucose, cigarette smoking and alcohol drinking). The AUCs were compared between the reference model and multivariable regression models of each lipid parameters.

*P<0.05.

AUC, the area under the receiver operating characteristic curve; HDL–C, high density lipoprotein cholesterol; LDL–C, low density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

whether high or low LDL-C level would affect diabetes development. In our study, elevated LDL-C (≥160 mg/dL) did not arise a significant increase of T2DM. However, genetic researches shown reduced LDL-C may be a protective factor for T2DM. A 1-SD genetically instrumented elevation in LDL-C levels (equivalent to 38 mg/dL) was associated with a lower risk of diabetes (OR 0.79, 95% CI 0.71 to 0.88).[16] Another genetic meta-analysis illustrated that LDL-C lowering genetic variants in or near NPC1L1 were associated with a higher risk of T2DM.[17] Further investigations are needed to identify the relationship between LDL-C and diabetes.

Blood lipid profiles are indexes in predicting risk of T2DM. Our study suggested that non-HDL-C, TG, TG/HDL-C and TC/HDL-C were better marker among all lipid profiles for predicting the future incident of diabetes. Current US and European guidelines recommend the assessment of non-HDL-C calculated as TC minus HDL cholesterol for cardiovascular risk estimation.[11 18] The role of non-HDL-C in predicting incident T2DM was also emphasised recently by other three studies.[19–21] The discrimination ability of TG was equivalent to other well-known T2DM risk factors, such as fasting plasma glucose and waist circumference for predicting T2DM at follow-up.[7] Numerous studies have provided consistent evidence that TG/HDL-C ratio may be a favourable predictor of future incident of T2DM. A meta-analysis showed that lg (TG/HDL-C) has better ability to reflect the risk of T2DM with standardised mean difference of 1.78 (95% CI 1.04 to 2.52) than other methodology including TG, HDL-C and LDL-C.[22] A cross-sectional study found that TC/HDL-C (AUC 0.684, 95% CI 0.663 to 0.705) was the best predictor among lipid profiles which followed by TG/HDL-C (AUC 0.666, 95% CI 0.643 to 0.688) and non-HDL-C (AUC 0.656, 95% CI 0.634 to 0.679).[20]

Some studies have shown that lipoproteins will have some effects on β-cell insulin secretion and glucose metabolism, which indirectly indicated that dyslipidaemia plays a role in the development of diabetes. A cohort study stated that the decrease of insulin secretory capacity may due to increased serum TC level.[23] An experimental study on Min6 cells and primary islets discovered the function of HDL-C to promote the insulin secretion of pancreatic beta-cells and to enhance the glucose uptake by skeletal muscle, which elevates the potentiality that the low HDL-C concentration may exacerbate blood glucose control or accelerate the progression of pre-diabetes to diabetes mellitus.[24] A systematic review concluded hypercholesterolaemia and low HDL-C levels may accelerate the development of beta-cell dysfunction under available evidence. This review proposed that cholesterol efflux obstructed by defective HDL could bring about accumulation of cholesterol in beta-cells, induce hyperglycaemic, damaged insulin secretion and β-cell apoptosis.[25]

Strengths of our study included the following: (1) the data we used derived from a nationally representative survey with a large-scale sample size; (2) notwithstanding a relatively long follow-up term, the rate of lost to follow-up was low; (3) previous studies usually focused on one cholesterol component; however, our study analysed the predictive effects of eight different lipid profiles on diabetes. Several limitations should also be acknowledged. Firstly, previous studies indicated that family history of diabetes and environmental factors including physical inactivity and caloric excess play a key role in the development of the disease.[26 27] Hence, there is no control over family history of diabetes and environmental factors that may have an influence on our results. Secondly, the biochemical indicators levels only be detected once at baseline survey, and the biochemical parameters during the follow-up were absent because the blood samples were not collected during the subsequent follow-up. It needs further investigation in this filed. Third, in our study, cases of diabetes mellitus were defined if interviewees self-reported that they had been diagnosed with diabetes during the follow-up period. Lacking of clinical evaluation may lead to discrepancy with the actual situation. Nevertheless, we performed the sensitivity analysis by removing the individuals who reported diabetes mellitus in 2013 to confirm the association and found a similar association between dyslipidaemia symptom and diabetes. The result indicates the association is stable in Chinese middle-aged and elderly adults.

CONCLUSION

In conclusion, our prospective cohort study identifies distinct relationships of major lipid fractions and risk of development to T2DM. Middle-aged and elderly adults with hypertriglyceridaemia, hypercholesterolaemia and low HDL-C are at higher risk for diabetes. Non-HDL-C, TG, TC/HDL and TG/HDL have superior value than other lipid profiles in predicting diabetes incidence. These findings provide detailed data for the future more effective prevention of T2DM to support.

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