INTERNAL MEDICINE

□ ORIGINAL ARTICLE □

Association between Hemoglobin and Diabetes in Relation to the Triglycerides-to-High-Density Lipoprotein Cholesterol (TG-HDL) Ratio in Japanese Individuals: The Nagasaki Islands Study

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Abstract

Objective Our previous study reported that categorizing diabetes patients according to the serum triglycerides-to-high-density lipoprotein cholesterol (TG-HDL) ratio is useful for estimating the risk of atherosclerosis, as a high TG-HDL ratio in patients with diabetes constitutes risk factors for atherosclerosis. Another study showed that a high hemoglobin level is associated with the risk of atherosclerosis. However, no previous studies have examined the association between the hemoglobin level and diabetes categorized by the TG-HDL ratio. In order to investigate these associations, we conducted a cross-sectional study of 3,733 (1,299 men and 2,434 women) Japanese participants 30-89 years of age undergoing a general health checkup.
Methods We investigated the association between the hemoglobin levels and the incidence of diabetes in all subjects, who were divided into tertiles according to the TG-HDL ratio. Diabetes was defined as an HbA1c (NGSP) level of ≥6.5% and/or the initiation of glucose-lowering or insulin therapy.
Results Of the 265 diabetes patients identified in this study, 116 had a high TG-HDL ratio (high TG-HDL diabetes) and 71 had a low TG-HDL ratio (low TG-HDL diabetes). Independent from classical cardiovascular risk factors, the multivariate odds ratio of a 1 SD (standard deviation) increment in hemoglobin (1.30 g/dL for men, 1.16 g/dL for women) was 1.04 (95% confidence intervals (CI): 0.88-1.22) for all patients with diabetes, 1.44 (95%CI: 1.17-1.77) for the patients with high TG-HDL diabetes and 0.67 (95%CI: 0.54-0.83) for the patients with low TG-HDL diabetes.
Conclusion The hemoglobin level is positively associated with high TG-HDL diabetes and inversely associated with low TG-HDL diabetes. These findings suggest that measuring the hemoglobin level is clinically relevant for estimating the risk of atherosclerosis in patients with diabetes categorized according to the TG-HDL ratio.

Key words: hemoglobin, TG-HDL, diabetes, cross-sectional study, Japanese

(Intern Med 53: 837-843, 2014)
(DOI: 10.2169/internalmedicine.53.1423)

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Received for publication July 22, 2013; Accepted for publication November 10, 2013
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Introduction

An elevated insulin concentration is reportedly inversely associated with the serum high-density lipoprotein (HDL) cholesterol concentration (1) and positively associated with the serum triglyceride (TG) concentration (2). Furthermore, a high triglycerides-to-high-density lipoprotein cholesterol (TG-HDL) ratio has been found to indicate insulin resistance in the general population (3), overweight individuals (4, 5) and type 2 diabetes patients (6). The classification of diabetes in our study population according to tertiles of the TG-HDL ratio (Shimizu's diabetes classification) (7) was therefore based on the assumption that, in patients with a high TG-HDL ratio, diabetes is primarily caused by insulin resistance with a reduced compensatory β-cell function, while that observed in patients with a low TG-HDL ratio is primarily caused by complete β-cell dysfunction.

Moreover, our previous study found that categorizing patients with diabetes in terms of the TG-HDL ratio is useful for estimating the risk of atherosclerosis assessed by means of both the cardio ankle vascular index (CAVI) and carotid intima media thickness (CIMT). Diabetes patients with a high TG-HDL ratio are identified as being at risk of atherosclerosis, while those with a low TG-HDL ratio are not (7). Another study reported that the hemoglobin level is associated with the development of atherosclerosis assessed by means of the pulse wave velocity (PWV) (8). However, no studies reported thus far have examined the association between the hemoglobin level and the incidence of diabetes categorized according to the TG-HDL ratio.

We therefore conducted a cross-sectional study of 3,733 Japanese individuals 30-89 years of age undergoing general health checkups between 2005 and 2012.

Materials and Methods

Subjects

Written consent forms were available in Japanese to ensure comprehensive understanding of the study objectives, and the informed consent form was signed or confirmed with a thumbprint by each participant. This study was approved by the Ethics Committee for the Use of Humans at Nagasaki University (project registration number: 0501120073).

The survey population comprised 4,269 participants 30 to 89 years of age, all residents of the western rural community of the Goto Islands, who participated in this study between 2005 and 2012. A total of 229 individuals with missing data and 307 patients with a history of cardiovascular disease were excluded, leaving 3,733 participants (1,299 men and 2,434 women) for enrollment in this study. There were no differences in cardiovascular risk factors between the participants with and without available data for serum measurements.

The mean age of the study population was 63.8 years (± 11.1 standard deviation (SD); range 30-89) (64.9±10.6 SD, range 30-89 for men and 63.2±11.3 SD, range 30-89 for women). Trained interviewers obtained information regarding the smoking status, drinking status, medical history and use of antihypertensive agents or medications for diabetes mellitus.

Anthropometric measurements

Body weight and height were measured with an automatic body composition analyzer (BF-220, Tanita, Tokyo, Japan) at the time of blood drawing.

Biochemical measurements

Fasting blood samples were collected in EDTA-2K and siliconized tubes. The samples collected in the siliconized tubes were used to separate the serum via centrifugation following blood coagulation. The samples collected in the EDTA-2K tubes were used to measure the hemoglobin concentration using the sodium lauryl sulfate (SLS)-hemoglobin method. The levels of serum triglycerides, serum HDL cholesterol, serum aspartate aminotransferase (AST), serum γ-glutamyltranspeptidase (γ-GTP), HbA1c and serum creatinine were measured using standard laboratory procedures.

The glomerular filtration rate (GFR) was estimated using an established method with three variations recently proposed by a working group of the Japanese Chronic Kidney Disease Initiative (9). According to this adaptation, GFR ($mL/min/1.73\ m^2$) = 194 × (serum creatinine (enzyme method))$^{-1.094}$ × (age)$^{-0.287}$ × (0.739 for women).

Definition of diabetes and its subtypes

The HbA1c level (as defined by the National Glycohemoglobin Standardization Program (NGSP)) was calculated using the following equation, which was recently proposed by a working group of the Japanese Diabetes Society (JDS): HbA1c (NGSP) = HbA1c (JDS) + 0.4% (10). The presence of diabetes was defined as an HbA1c (NGSP) level of ≥6.5% and/or the initiation of glucose-lowering or insulin therapy (11). We further defined subtypes of diabetes by calculating tertiles of the TG-HDL ratio for all participants: low-TG-HDL diabetes (median TG-HDL ratio: 1.27 for men, 0.85 for women), intermediate-TG-HDL diabetes (2.13 for men, 1.76 for women) and high-TG-HDL diabetes (4.49 for men, 3.65 for women), as in our previous study (7). Written consent forms were available in Japanese to ensure comprehensive understanding of the study objectives, and an informed consent form was signed by each participant.

Statistical analysis

After the sex-specific tertiles of the hemoglobin level were calculated, the sex-and age-adjusted clinical characteristics were expressed in relation to the hemoglobin level for the purpose of this study, and the TG-HDL categories for all subjects were established according to sex-specific tertiles of the TG-HDL ratio. In diabetic patients, differences in the

Table 1. Sex-and Age-adjusted Distributions of Characteristics by Hemoglobin Level Tertiles

	Hemoglobin tertiles			
	T1 (low)	T2	T3 (high)	p
No. at risk	1,229	1,223	1,281	
Age, years	63.2 ± 12.0	63.2 ± 10.6	62.6 ± 10.4	
Male, %	34	38	33	0.031
Systolic blood pressure, mmHg	138	140	145	<0.001
Diastolic blood pressure, mmHg	80	83	86	<0.001
Antihypertensive medication use, %	25	28	31	0.005
Body mass index, kg/m^2	22.5	23.3	23.9	<0.001
Current drinker, %	22	28	26	0.003
Current smoker, %	10	11	14	0.009
Never smoker, %	78	73	73	0.008
Former smoker, %	13	16	13	0.018
Serum triglycerides (TG), mg/dL	107	120	134	<0.001
Serum HDL-cholesterol (HDL), mg/dL	60.0	59.1	58.7	0.098
TG-to-HDL ratio	2.05	2.31	2.63	<0.001
Serum aspartate aminotransferase (AST), IU/L	22.6	23.2	23.8	0.005
Serum γ-glutamyltranspeptidase (γ-GTP), IU/L	27	32	35	<0.001
Serum creatinine, mg/dL	0.77	0.77	0.76	0.903
Glomerular Filtration Rate (GFR), mL/min/1.73m^2	70.4	69.5	68.7	0.009

Hemoglobin level tertiles: <14.0g/dL, 14.0-15.0g/dL, and >15.0g/dL for men and <12.6g/dL, 12.6-13.3g/dL, and >13.3g/dL for women. p: p factor

sex-and age-adjusted mean values of diabetic risk factors according to the TG-HDL category were analyzed using covariance or general linear models, while logistic regression models were used to calculate the odds ratios (ORs) and 95% confidence intervals (CIs) of diabetes in order to determine the association with the hemoglobin level in relation to the TG-HDL ratio.

Two different approaches were used to make adjustments for confounding factors. First, the data were adjusted for sex and age only. Second, other possible confounding factors were included, that is, the smoking status (never smoker, former smoker, current smoker), alcohol consumption [non-drinker, current light to moderate drinker (1-6 times/week), current heavy drinker (every day)], systolic blood pressure (mmHg), antihypertensive medication use (no, yes), body mass index [BMI (kg/m^2)], AST (IU/L), γ-GTP (IU/L) and estimated GFR (mL/min/1.73 m^2).

All statistical analyses were performed using the SAS system for Windows (version 9.3; SAS Inc., Cary, USA). All p-values for the statistical tests were two-tailed, and values of <0.05 were regarded as being statistically significant.

Results

Study population

The clinical characteristics of the study population are summarized in Table 1. Systolic blood pressure, diastolic blood pressure, antihypertensive medication use, BMI, current drinker, current smoker, TG, TG-HDL, AST and γ-GTP were positively associated with the hemoglobin level while never smoker and GFR were inversely associated with the hemoglobin level. Of the total 3,733 men and women, 265 were diagnosed with diabetes, 71 of whom had low TG-HDL, 78 had intermediate TG-HDL and 116 had high TG-HDL. As part of our study, we conducted a further investigation of CAVI data for 3,612 subjects, which showed a significant positive association between the hemoglobin level and mean CAVI. The sex-and age-adjusted values of CAVI for the three hemoglobin tertiles were 8.04 for the low tertile (<14.0 g/dL for men and <12.6 g/dL for women), 8.06 for the intermediate tertile (14.0-15.0 g/dL for men and 12.6-13.3 g/dL for women) and 8.19 for the high tertile (>15.0 g/dL for men and >13.3 g/dL for women) (p=0.006).

We also found significant positive associations between the hemoglobin level, TG-HDL and increased arterial stiffness (CAVI ≥9). The multivariable-adjusted OR and 95%CI of increased arterial stiffness per increment of 1 SD (standard deviation) in the hemoglobin level (1.30 g/dL for men, 1.16 g/dL for women) were 1.20 (1.09-1.33) for the total subjects, 1.28 (1.10-1.49) for men and 1.15 (1.01-1.31) for women, while those for a 1 SD increment in TG-HDL (2.23 for men, 1.75 for women) were 1.19 (1.08-1.30), 1.23 (1.06-1.43) and 1.15 (1.02-1.30), respectively.

Characteristics of the diabetes participants categorized according to the TG-HDL ratio

Table 2 shows the sex-and age-adjusted characteristics of the patients divided into diabetes categories according to the TG-HDL tertiles for all subjects. The TG-HDL ratio was found to be positively associated with systolic blood pressure, diastolic blood pressure, BMI, hemoglobin and serum creatinine and inversely associated with GFR.

Association between the hemoglobin level and diabetes

OR and 95% CI for diabetes in relation to the hemoglobin levels are shown in Table 3. We found no significant as-

Table 2. Relationship between Sex-and Age-adjusted Mean Values and TG-HDL Categories for Diabetic Patients

	Categories of TG-HDL ratios			
	Low TG-HDL diabetes	Intermediate TG-HDL diabetes	High TG-HDL diabetes	p
No. at risk	71	78	116	
Age, year	69.0 ± 8.3	69.3 ± 9.4	66.6 ± 8.4	
Male, %	61	42	44	
Systolic blood pressure, mmHg	141	146	151	0.010
Diastolic blood pressure, mmHg	79	83	87	<0.001
Antihypertensive medication use, %	41	45	35	0.400
Body mass index, kg/m^2	22.7	24.4	25.5	<0.001
Current drinker, %	30	28	23	0.505
Current smoker, %	10	12	13	0.806
Hemoglobin (Hb), g/dL	13.0	13.6	14.1	<0.001
Serum aspartate aminotransferase (AST), IU/L	26	24	26	0.562
Serum γ-glutamyltranspeptidase (γ-GTP), IU/L	35	34	43	0.177
Serum creatinine, mg/dL	0.72	0.74	0.81	0.005
Glomerular Filtration Rate (GFR), mL/min/1.73m^2	74.7	73.7	67.7	0.020

Age: mean values of age. TG-HDL ratio: Triglycerides / HDL-cholesterol ratio. Categories of TG-HDL ratios were categorized by tertiles of TG-HDL values for all subjects. Medican values of TG-HDL for each categoies were 1.27, 2.13, and 4.49 for men and 0.85, 1.76, and 3.65 for women. p for trend: Trends for TG-HDL categories for diabetes. p: trends for diabetes categories

Table 3. Odds Ratios (OR) and 95% Confidence Intervals (CI) for Diabetes in Relation to Hemoglobin Levels

	Hemoglobin tertiles				1 SD increment in
	T1 (low)	T2	T3 (high)	p for trend	hemoglobin
No. at risk (percentage of men)	1,229 (34)	1,223 (38)	1,281 (33)		
Diabetes					
No. of cases (percentage)	82 (6.7)	92 (7.5)	91 (7.1)		
Sex-and age-adjusted OR	1.00	1.28 (0.93-1.75)	1.28 (0.93-1.75)	0.136	1.10 (0.96-1.25)
Multivariable OR	1.00	1.20 (0.87-1.65)	1.08 (0.78-1.49)	0.671	1.04 (0.88-1.22)

Multivariable OR: adjusted further for age and sex,systolic blood pressure, antihypertensive medication use, body mass index, smoking, alcohol intake,serum aspartate aminotransferase (AST), serum γ-glutamyltranspeptidase (γ-GTP) and glomerular filtration rate (GFR). Hemoglobin leves tertiles: <14.0g/dL, 14.0-15.0g/dL, and >15.0g/dL for men and <12.6g/dL, 12.6-13.3g/dL, and >13.3g/dL for women

Table 4. Odds Ratios (OR) and 95% Confidence Intervals (CI) for Subtypes of Diabetes by Hemoglobin Levels

	Hemoglobin tertiles				1 SD increment in
	T1 (low)	T2	T3 (high)	p for trend	hemoglobin
No. at risk (percentage of men)	1,229 (34)	1,223 (38)	1,281 (33)		
High TG-HDL diabetes					
No. of cases (percentage)	22 (1.8)	40 (3.3)	54 (4.2)		
Sex-and age-adjusted OR	1.00	2.01 (1.18-3.43)	2.73 (1.64-4.55)	<0.001	1.64 (1.34-2.01)
Multivariable OR	1.00	1.83 (1.07-3.13)	2.05 (1.22-3.46)	0.009	1.44 (1.17-1.77)
Intermediate TG-HDL diabetes					
No. of cases (percentage)	24 (2.0)	27 (2.2)	27 (2.1)		
Sex-and age-adjusted OR	1.00	1.33 (0.76-2.34)	1.34 (0.76-2.36)	0.314	1.07 (0.85-1.35)
Multivariable OR	1.00	1.31 (0.74-2.32)	1.22 (0.68-2.18)	0.507	1.03 (0.81-1.31)
Low TG-HDL diabetes					
No. of cases (percentage)	36 (2.9)	25 (2.0)	10 (0.8)		
Sex-and age-adjusted OR	1.00	0.76 (0.45-1.29)	0.31 (0.15-0.64)	0.001	0.66 (0.53-0.81)
Multivariable OR	1.00	0.80 (0.47-1.37)	0.34 (0.16-0.70)	0.004	0.67 (0.54-0.83)

Multivariable OR: adjusted further for age and sex,systolic blood pressure, antihypertensive medication use, body mass index, smoking, alcoholintake,serum aspartate aminotransferase (AST), serum γ-glutamyltranspeptidase (γ-GTP) and glomerular filtration rate (GFR). Hemoglobin level tertiles: <14.0g/dL, 14.0-15.0g/dL, and >15.0g/dL for men and <12.6g/dL, 12.6-13.3g/dL, and >13.3g/dL for women

sociations between the hemoglobin level and diabetes.

An analysis of the association between the hemoglobin level and diabetes categorized according to the TG-HDL ratio disclosed a significant positive association for high TG-HDL diabetes and a significant inverse association for low TG-HDL diabetes (Table 4).

Furthermore, in a sex-specific analysis of these associations, essentially the same associations were observed for both men and women. The multivariable-OR of a 1 SD increment in hemoglobin for high, intermediate and low TG-HDL diabetes was 1.59 (1.16-2.17), 1.00 (0.70-1.44) and 0.69 (0.51-0.94) for men and 1.35 (1.02-1.78), 1.09 (0.79-1.50) and 0.64 (0.46-0.87) for women, respectively.

Associations between BMI, hemoglobin and the TG-HDL ratio

BMI was found to be positively associated with both the hemoglobin level and TG-HDL ratio. The results of a sex- and age-adjusted linear regression analysis of the hemoglobin levels and TG-HDL ratios per 1 SD increment in BMI (3.1 kg/m^2 for men and 3.4 kg/m^2 for women) showed regression coefficients of β=0.21 (0.18, 0.25; p<0.001) and β= 0.38 (0.34, 0.42; p<0.001), respectively. While similar associations were observed for participants with a BMI of <25 kg/m^2, the association between BMI and the hemoglobin level was no longer significant in the patients with a BMI of ≥25 kg/m^2, although a slightly positive association was observed for the TG-HDL ratio. Among the participants with a BMI of <25 kg/m^2, the adjusted linear regression analysis of the hemoglobin levels and TG-HDL ratios per 1 SD increment of BMI yielded β=0.12 (0.09, 0.15; p<0.001) and β= 0.21 (0.81, 0.24; p<0.001), respectively. Among the participants with a BMI of ≥25 kg/m^2, the corresponding values were β= -0.009 (-0.06, 0.04; p=0.737) and β=0.08 (0.02, 0.13; p=0.006), respectively.

Association between hemoglobin and high TG-HDL (sex-specific highest TG-HDL tertile) in relation to BMI

We also investigated the association between the highest tertile of TG-HDL (high TG-HDL) and a 1 SD increment in the hemoglobin level in relation to the BMI status because the hemoglobin levels and TG-HDL ratios were significantly associated in the participants with a BMI of <25 kg/m^2 but not those with a BMI of ≥25 kg/m^2. We also found that significant positive associations were restricted to the participants with a BMI of <25 kg/m^2. The sex-and age-adjusted OR of high TG-HDL in relation to a 1 SD increment in hemoglobin was 1.30 (1.21-1.39) for the total subjects, 1.32 (1.21-1.45) for the participants with a BMI of <25 kg/m^2 and 1.08 (0.96-1.45) for the participants with a BMI of ≥25 kg/m^2 (P for interaction = 0.026).

Association between the hemoglobin level and diabetes in the participants with a BMI of ≥25 kg/m^2

Due to the limitation of significant positive associations between high TG-HDL and hemoglobin to participants with a BMI of ≥25 kg/m^2, we performed further analyses of these study subjects only. A significant positive association was detected for high TG-HDL diabetes, while a significant inverse association was detected for low TG-HDL diabetes. The multivariable ORs for a 1 SD increment in hemoglobin for high, intermediate and low TG-HDL diabetes were 1.53 (1.14-2.06), 1.20 (0.81-1.78) and 0.63 (0.40-0.99), respectively.

Associations between high TG-HDL, high TG-HDL diabetes and increased arterial stiffness limited to participants with a BMI of ≥25 kg/m^2

As part of our study of 1,015 subjects with a BMI of ≥25 kg/m^2 whose CAVI data were available, we observed that high TG-HDL as such is not a risk factor for increased arterial stiffness, while diabetes with high TG-HDL constitutes a significant risk factor. The multivariable ORs of increased arterial stiffness for high TG-HDL and high TG-HDL diabetes were 1.19 (0.85-1.68) and 2.30 (1.23-4.32), respectively.

Discussion

The major finding of our study is that the hemoglobin level was positively associated with high TG-HDL diabetes and inversely associated with low TG-HDL diabetes.

Our previous study of 1,344 men found that diabetic patients with high TG-HDL, but not intermediate or low TG-HDL, were at a significant risk for atherosclerosis (diagnosed as CIMT ≥1.1 mm) and increased arterial stiffness (diagnosed as CAVI ≥8.0) (7).

On the other hand, another Japanese study of 120 men and 223 women who participated in general health examinations reported a sex-differentiated association between the hemoglobin level and arterial stiffness assessed by means of the brachial-ankle PWV. The PWV in men was not found to be related to the hemoglobin level (r=0.013, p=0.886), while that in women increased significantly and progressively in association with an increase in the hemoglobin level (r= 0.276, p=<0.001) (8).

In our current study, we found further evidence that, although no significant associations were observed between the hemoglobin level and diabetes, categorizing diabetes patients according to the TG-HDL ratio disclosed a significant positive association for high TG-HDL diabetes and a significant inverse association for low TG-HDL diabetes.

The mechanisms explaining why the hemoglobin level was positively associated with high TG-HDL diabetes and inversely associated with low TG-HDL diabetes have not yet been elucidated.

A higher hemoglobin level may indicate a higher risk of atherosclerosis (8), and atherosclerosis is also positively associated with high TG-HDL diabetes (7). Furthermore, even when the HbA1c level is regarded as a cardiovascular risk marker (12), the value is expressed as a ratio, the ratio of glycated hemoglobin to total hemoglobin. This implies that, on an individual basis, the total amount of glycated hemoglobin is strongly influenced by the total hemoglobin level. In fact, the HbA1c levels in this study were high, even among the participants with rather low hemoglobin levels, whose total glycated hemoglobin values may not be high. Such mechanisms suggest that diabetes accompanied by a high hemoglobin level represents a higher risk of atherosclerosis, while diabetes associated with a low hemoglobin level does not.

BMI can be a determining factor in the association between the hemoglobin level and diabetes categorized according to the TG-HDL ratio. Subjects with metabolic syndrome reportedly have elevated hemoglobin levels (13, 14), while an Ethiopian study reported finding a positive association between the hemoglobin level and BMI among men (14). This is compatible with the finding in our current study that the hemoglobin level is positively associated with BMI (15). Upon further investigation, we found that, compared to non-diabetic participants, the low TG-HDL diabetes patients exhibited lower BMI values, while the intermediate and high TG-HDL diabetes patients demonstrated higher BMI values. The sex-and age-adjusted BMI was 22.5 kg/m^2 for low TG-HDL diabetes, 23.2 kg/m^2 for non-diabetes, 24.3 kg/m^2 for intermediate TG-HDL diabetes and 25.5 kg/m^2 for high TG-HDL diabetes ($p<0.001$). However, further investigation revealed a significantly positive association to exist between the hemoglobin level and BMI, as well as a significant association between high TG-HDL ratios and the hemoglobin levels only in the participants with a BMI of <25 kg/m^2. Since the human production of hemoglobin may have reached its maximum level in subjects with a high BMI, a BMI of ≥25 kg/m^2 may act as a confounding factor for these associations. The findings of our previous study of a positive association between the hemoglobin levels that was also restricted to participants with a BMI of <25 kg/m^2 (15) appear to support the present results. Furthermore, when we limited the analysis of the association between hemoglobin and diabetes categorized according to the TG-HDL ratio to participants with a BMI of ≥25 kg/m^2, we also detected a significant positive association for high TG-HDL diabetes and a significant inverse association for low TG-HDL diabetes. As part of our study of subjects with a BMI of ≥25 kg/m^2 whose CAVI data were available, we also found that high TG-HDL itself was not a risk factor for increased arterial stiffness, although high TG-HDL diabetes is a significant risk factor.

Some potential limitations in this study warrant consideration. First, the limited number of diabetes patients (five men and five women with low TG-HDL diabetes among the highest tertile of the hemoglobin level) made it difficult to perform a sex-specific analysis. However, when we analyzed the association between increments of 1 SD and diabetes categorized according to the TG-HDL ratio, we found a significant inverse association for low TG-HDL diabetes among both men and women. Second, we did not have access to data on the menstrual or menopausal status, which has a strong influence on the hemoglobin levels in women. However, our sex-specific analysis showed essentially the same associations for both men and women. Third, since data regarding exercise were not available, we could not make adjustments for the influence of exercise. The lack of fasting serum glucose data and serum insulin data also prevented us from evaluating associations between hemoglobin and insulin resistance. Finally, because this study was a cross-sectional study, we could not establish any causal relationships.

Conclusion

In conclusion, we found that the hemoglobin levels in a Japanese population were positively associated with high TG-HDL diabetes and inversely associated with low TG-HDL diabetes. These findings suggest that measuring the hemoglobin level is clinically relevant for estimating the risk of atherosclerosis in patients with diabetes categorized according to the TG-HDL ratio.

The authors state that they have no Conflict of Interest (COI).

Acknowledgement

This work was supported financially by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (No. 25291107). We are grateful to the staff of Goto City Hall for their outstanding support.

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