

Original Article

Associations between the Serum 25(OH)D Concentration and Lipid Profiles in Japanese Men

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Aim: Low circulating 25-hydroxyvitamin D [25(OH)D] concentration has been linked to a high prevalence of cardiovascular disease. One explanation for this phenomenon is that there is an association between the serum 25(OH)D level and lipid profiles. However, studies examining this relationship are limited and have yielded inconsistent results. We thus aimed to evaluate the association between the serum 25(OH)D concentration and lipid profiles in Japanese men taking into consideration confounding factors, including the visceral fat area (VFA) and cardiorespiratory fitness.

Methods: A total of 136 men (age range: 20-79 years) participated in our study. Fasting blood samples were analyzed to determine the 25(OH)D, oxidized low-density lipoprotein (oxLDL), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), triglyceride (TG), apolipoprotein (Apo)A-1 and ApoB levels. The VFA was evaluated on magnetic resonance imaging (MRI), and cardiorespiratory fitness was assessed by measuring the peak oxygen uptake ($\dot{V}O_2$ peak).

Results: The median 25(OH)D concentration was 35.6 nmol/L, and the prevalence of 25(OH)D deficiency was 78.7%. A multiple linear regression analysis revealed that the serum 25(OH)D concentration was inversely related to the LDL-C/HDL-C, TG, ApoB and ApoB/ApoA-1 values, even after adjusting for age, season, smoking status, alcohol consumption, medication use, vitamin D intake, calcium intake, VFA and cardiorespiratory fitness.

Conclusions: Serum 25(OH)D level is inversely correlated with the LDL-C/HDL-C, TG, ApoB and ApoB/ApoA-1 values in Japanese men, independent of the VFA and cardiorespiratory fitness.

J Atheroscler Thromb, 2015; 22: 355-362.

Key words: Vitamin D, Lipids, Visceral fat, Cardiorespiratory fitness

Introduction

Low vitamin D concentration is prevalent in many populations and has become a common public health problem worldwide¹. In addition to its role in maintaining bone health, a high serum vitamin D level,

as assessed according to the circulating 25-hydroxyvitamin D [25(OH)D] concentration, has been reported to be associated with improved cardiovascular outcomes and immune function parameters in addition to a low risk of developing type 2 diabetes mellitus, metabolic syndrome and cardiovascular disease (CVD)²⁻⁵. The main cause of CVD is atherosclerosis, a condition in which the artery wall becomes thick and hard as a result of the accumulation of plaque^{6,7}. Disorders of lipid metabolism, such as increased levels of triglycerides (TG), low-density lipoprotein cholesterol (LDL-C) and apolipoprotein (Apo)B and

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Received: May 11, 2014

Accepted for publication: August 28, 2014

decreased levels of high-density lipoprotein cholesterol (HDL-C) and ApoA-1, have been identified to be contributing factors to the pathogenesis of atherosclerosis and CVD⁸⁻¹¹).

Recent studies in humans suggest that 25(OH)D has beneficial effects on the cardiovascular system, partly via its actions against blood lipids^{12, 13}. However, data regarding the relationships between the 25(OH)D level and lipid profiles in healthy adults are limited, and the results of previous studies are inconsistent¹⁴⁻¹⁸. Some investigations have reported that the 25(OH)D concentration is positively correlated with the HDL-C or ApoA-1 levels¹⁶⁻¹⁸, whereas others have not found the 25(OH)D concentration to correlate with HDL-C or ApoA-1¹⁵, but rather be inversely correlated with the LDL-C, ApoB and TG levels^{14, 15}. Although previous studies have considered the confounding effects of total and/or abdominal fat by assessing simple anthropometric measurements, such as body mass index (BMI) and waist circumference (WC), recent studies have revealed that reductions in the visceral fat area (VFA) may occur in the absence of changes in WC or BMI^{19, 20}. Magnetic resonance imaging (MRI) permits the reliable and non-invasive characterization of the VFA, which appears to be more strongly related to dyslipidemia and other cardiovascular risk factors than WC or BMI²¹⁻²³. Furthermore, considerable evidence suggests that a high level of cardiorespiratory fitness can reduce the risk of developing CVD, in part by improving the blood lipid profiles^{25, 26}, and recent studies suggest that increased cardiorespiratory fitness is significantly associated with high 25(OH)D concentration in adults²⁴. However, no previous reports have investigated the potential confounding effects of cardiorespiratory fitness on the relationships between the 25(OH)D concentration and lipid profiles. Therefore, the use of simple obesity indicators and failing to take into consideration the effects of cardiorespiratory fitness may account for the discrepancies in previous studies investigating the relationships between the 25(OH)D level and lipid profiles. Finally, all previous studies were conducted among European and American populations. Hence, it is unclear whether these findings are comparable in Asian individuals.

Aim

The purpose of this study was to evaluate the associations between the serum 25(OH)D concentration and lipid profiles in Japanese men. We also sought to investigate whether these associations are independent of the VFA, as a reliable marker of

abdominal fat, and parameters of cardiorespiratory fitness.

Methods

Subjects

A total of 136 healthy Japanese men 20-79 years of age participated in the present study. All procedures were conducted at T Campus, W University (35°N latitude). The health status of each subject was confirmed using medical questionnaires and blood pressure measurements obtained by accredited nurses and doctors. None of the subjects had been diagnosed with cardiac disease, diabetes or chronic renal failure. We excluded individuals on lipid-lowering medications or drugs that could affect the study variables (i.e., vitamin D supplements, vitamin D analogues, calcium or any agents that could affect bone or mineral metabolism, including bisphosphonates). The purpose, procedures and risks of the study were explained to each participant prior to inclusion, and all subjects were enrolled after obtaining written informed consent. All procedures were reviewed and approved by the Ethics Committee of Waseda University.

Anthropometric Measurements

Height (without shoes) was measured to the nearest millimeter using a stadiometer (YL-65, Yagami Inc., Nagoya, Japan). Body mass was determined using an electronic scale with the subject wearing light clothing and no shoes and rounded to the nearest 0.1 kg (Inner Scan BC-600, Tanita Co., Tokyo, Japan). The BMI was calculated by dividing the body mass in kilograms by the square of the height in meters (kg/m²). WC was measured at the umbilical region using inelastic measuring tape at the end of normal expiration to the nearest 0.1 cm. The VFA was measured on MRI (Signa 1.5T, General Electric Co., Milwaukee, Wisconsin, USA). The MRI examinations were performed by two coauthors qualified to operate the equipment. The imaging conditions included a T1-weighted spin-echo and axial-plane sequence with a slice thickness of 10 mm, repetition time (TR) of 140 ms and echo time of 12.3 ms. Cross-sectional images were scanned at the umbilical region²². The magnetic resonance images were transferred to a personal computer in the Digital Imaging and Communications in Medicine (DICOM) file format, and the cross-sectional area of the VFA at the umbilical region was determined using an image-analysis software program (Slice-o-matic 4.3 for Windows, Tomovision, Montreal, Canada). All scans and analyses were performed by the same investigators in order to minimize

interobserver variation, and the coefficient of variation for the cross-sectional area at the umbilical level was 0.4%.

Brachial Arterial Blood Pressure

The resting systolic and diastolic blood pressure (SBP and DBP) values were measured using a semi-automated device (VaSera VS-1500) over the brachial and dorsalis pedis arteries according to the oscillometric method²⁷. The recordings were made in duplicate with the participant in the supine position.

Cardiorespiratory Fitness Parameters

Cardiorespiratory fitness was assessed according to a maximal graded exercise test using a cycle ergometer (Ergonomic 828E; Monark, Varberg, Sweden) and quantified as the $\dot{V}O_2$ peak. The graded cycle exercise began at a workload of 45-90 W and was increased by 15 W/min until the subject could no longer maintain the required pedaling frequency of 60 rpm. The heart rate and level of perceived exertion were monitored each minute during the exercise. Expired gas was collected from the subject in the incremental portion of the exercise test. The O_2 and CO_2 concentrations were measured and averaged over 30-s intervals using an automated gas analyzer (Aeromonitor AE-300; Minato Medical Science, Tokyo, Japan). The highest value of $\dot{V}O_2$ recorded during the exercise test was considered to be the $\dot{V}O_2$ peak (mL/kg/min).

Blood Sample Analysis

Blood samples were collected between 08:30 and 10:00 AM by accredited nurses and doctors after a 12-hour overnight fast and centrifuged at 3,000 $\times g$ for 15 minutes at 4°C. The blood glucose, glycated hemoglobin (HbA1c), total-C, HDL-C, LDL-C, TG, ApoA-1, ApoB and free fatty acid (FFA) levels were directly measured from fresh blood samples by BML, Inc. (Tokyo, Japan). The remaining serum and plasma samples were transferred to separate tubes and immediately stored at -80°C. No repeatedly freeze-thawed samples were used for oxLDL or 25(OH)D quantification. The serum 25(OH)D and plasma oxLDL concentrations were measured in duplicate using commercially available enzyme-linked immunosorbent assay (ELISA) kits (25(OH)D: Immunodiagnostic AG, Bensheim, Germany; oxLDL: Mercodia AB, Uppsala, Sweden) according to the manufacturer's instructions. The intra- and inter-assay coefficients of variation were 8.9% and 10.6% for 25(OH)D and 2.8% and 6.4% for oxLDL, respectively.

Lifestyle Variables

Information regarding the levels of vitamin D and calcium intake and alcohol consumption was obtained using a brief self-administered diet history questionnaire (BDHQ)^{28, 29}. The smoking status and medications were also assessed using questionnaires. The smoking status was classified as never or former/current smoker, and medication use was classified as user or non-user.

Statistical Analysis

All statistical analyses were performed using the SPSS software package, version 21.0 (SPSS, Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was performed to assess the normality of the data distribution. The 25(OH)D values were square root transformed, the HDL-C values are expressed as the reciprocal of the square root transformed values and the SBP, TG, FFA, ApoA-1, cardiorespiratory fitness, calcium and vitamin D intake values were log transformed to obtain their normal distributions prior to the analysis. Student's *t*-test (for normally distributed variables), Mann-Whitney *U*-test (for non-normally distributed variables) and chi-square test (for categorical variables) were used to evaluate the differences in these parameters according to the 25(OH)D concentration (25(OH)D < 50 nmol/L vs 25(OH)D \geq 50 nmol/L). Partial Pearson's correlation coefficients were computed between the serum 25(OH)D level and the subject characteristics and controlled for age. Multiple linear regression analyses were performed to assess the associations between the serum 25(OH)D concentration (independent variable) and lipid profiles (dependent variables), adjusted for age, season, smoking status, alcohol consumption, medication use, vitamin D and calcium intake and VFA, then further adjusted for cardiorespiratory fitness. All measurements and calculated values are presented as the mean (SD) (for normally distributed variables) or median (interquartile range; IQR) (for non-normally distributed variables). The level of statistical significance was set at $p < 0.05$.

Results

The subject characteristics and blood parameters according to the 25(OH)D concentration are presented in **Table 1**. The median 25 (OH)D concentration was 35.6 (26.0-48.2) nmol/L. In addition, 78.7% of the subjects were 25 (OH)D-deficient (< 50 nmol/L), while 14.0% had an insufficient 25(OH)D concentration (50-75 nmol/L). The 25(OH)D-deficient participants had significantly ($p < 0.05$) lower HDL-C, ApoA-1 and calcium and vitamin D intake levels

Table 1. Subject characteristics

Variables	All	25(OH)D < 50 nmol/L	25(OH)D ≥ 50 nmol/L	<i>p</i>
<i>n</i>	136	107	29	
Age (year)	63.5 (45.3-69.0)	62.0 (39.0-69.0)	65.0 (63.0-71.0)	0.007
Height (cm)	170.1 (6.7)	169.8 (6.9)	171.4 (5.8)	0.234
Weight (kg)	67.9 (9.5)	67.8 (9.9)	68.7 (8.0)	0.648
BMI (kg/m ²)	23.4 (2.5)	23.4 (2.6)	23.3 (2.1)	0.822
WC (cm)	83.0 (7.5)	82.9 (7.8)	83.5 (6.5)	0.703
VFA (cm ²)	97.6 (52.2)	99.4 (54.7)	91.2 (42.2)	0.455
FG (mg/dL)	95.8 (10.2)	95.4 (10.7)	97.1 (7.8)	0.449
HbA1c (%)	5.0 (0.3)	5.0 (0.3)	5.0 (0.2)	0.815
SBP (mm Hg)	139.0 (129.5-153.9)	138.0 (127.0-152.0)	141.5 (132.3-155.8)	0.278
DBP (mm Hg)	90.3 (11.5)	90.2 (11.6)	90.9 (10.9)	0.753
Total-C (mg/dL)	205.7 (35.2)	203.1 (35.9)	215.4 (30.8)	0.095
HDL-C (mg/dL)	59.0 (51.3-67.0)	56.0 (50.0-65.0)	66.0 (62.0-75.5)	< 0.001
LDL-C (mg/dL)	117.4 (30.2)	117.3 (31.1)	117.8 (27.3)	0.940
LDL-C/HDL-C	2.04 (0.70)	2.11 (0.69)	1.77 (0.70)	0.018
TG (mg/dL)	85.0 (62.0-117.0)	92.0 (65.0-118.0)	66.0 (53.5-92.5)	0.021
FFA (mEq/L)	0.51 (0.40-0.71)	0.51 (0.40-0.73)	0.51 (0.40-0.70)	0.841
oxLDL (U/mL)	43.2 (11.9)	43.4 (12.5)	42.1 (9.3)	0.596
ApoA-1 (mg/dL)	147.0 (132.0-162.0)	142.0 (131.0-158.0)	159.0 (150.0-178.0)	< 0.001
ApoB (mg/dL)	95.1 (23.5)	95.8 (24.4)	92.5 (20.2)	0.517
ApoB/ApoA-1	0.66 (0.20)	0.68 (0.20)	0.57 (0.18)	0.010
25(OH)D (nmol/L)	35.6 (26.0-48.2)	30.4 (23.0-37.8)	68.6 (58.0-78.4)	< 0.001
Cardiorespiratory fitness (mL/kg/min)	33.3 (28.3-39.7)	33.0 (27.7-40.2)	33.8 (32.6-39.6)	0.295
Calcium intake (mg/day)	647.2 (428.1-820.5)	619.6 (410.1-759.2)	681.9 (507.7-954.1)	0.048
Vitamin D intake (μg/day)	13.5 (8.9-23.0)	12.3 (8.8-18.9)	18.8 (12.5-28.3)	0.003
Alcohol consumption (g/day)	17.1 (1.2-40.8)	15.7 (1.0-38.6)	23.0 (7.4-49.4)	0.348
Current or former smoking status (%)	43.4	43.9	41.4	0.806
Medication use (%)	23.5	20.6	34.5	0.129

The data are expressed as the mean (SD) or median (IQR). 25(OH)D, 25-hydroxyvitamin D; BMI, body mass index; WC, waist circumference; VFA, visceral fat area; FG, fasting glucose; HbA1c, glycated hemoglobin; SBP, systolic blood pressure; DBP, diastolic blood pressure; Total-C, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; FFA, free fatty acids; Apo, apolipoprotein; oxLDL, oxidized low-density lipoprotein.

and significantly ($p < 0.05$) higher LDL-C/HDL-C, ApoB/ApoA-1 and TG values than the participants with insufficient and sufficient levels.

The age-adjusted relationships between the serum 25(OH)D concentration and the subjects' characteristics are shown in **Table 2**. The serum 25(OH)D concentration was found to be negatively correlated with the TG, LDL-C/HDL-C, VFA, ApoB/ApoA-1, ApoB and oxLDL values ($p < 0.05$) and positively associated with the HDL-C, ApoA-1, cardiorespiratory fitness and calcium and vitamin D intake values ($p < 0.05$).

In order to investigate whether the serum 25(OH)D concentration was independently related to the blood lipid profiles, multivariate linear regression analyses using blood lipids as the dependent variable were performed (**Table 3**). As shown in Model 1, the

25(OH)D concentration correlated positively with the HDL-C and ApoA-1 levels ($p < 0.05$) and negatively with the LDL-C/HDL-C ($p < 0.01$), ApoB/ApoA-1 ($p < 0.01$), TG ($p < 0.01$) and ApoB ($p < 0.05$) values after adjusting for age, season, smoking status, alcohol consumption, medication use and vitamin D and calcium intake. However, the associations between the serum 25(OH)D concentration and the ApoA-1 ($p = 0.06$) and ApoB ($p = 0.06$) levels were of borderline statistical significance when further adjusted for the VFA, with a limited effect on the other lipid profiles. Following further adjustment for cardiorespiratory fitness, similar results were obtained for the relationships between the serum 25(OH)D concentration and the TG, LDL-C/HDL-C and ApoB/ApoA-1 values. In contrast, the associations between the 25(OH)D con-

centration and the HDL-C and ApoA-1 levels were no longer significant after adjustment, whereas the relationship between the serum 25(OH)D concentration and the ApoB level achieved statistical significance ($p < 0.05$).

Discussion

This cross-sectional study was performed to examine whether the serum 25(OH)D concentration is associated with the circulating lipid profiles in Japanese men 20-79 years of age. Our results showed that the serum 25(OH)D concentration correlated inversely with the LDL-C/HDL-C, TG, ApoB and ApoB/ApoA-1 levels, even after controlling for potential confounding factors, such as age, season, smoking status, alcohol consumption, medication use, vitamin D and calcium intake, VFA and cardiorespiratory fitness.

Limited studies have examined the influence of vitamin D on the levels of blood lipids in healthy adults, and the findings are inconsistent. Auwerx *et al.*¹⁷ and Carbone *et al.*¹⁸ found the serum 25(OH)D concentration to be positively correlated with the HDL-C and ApoA-1 levels, but not the TG, LDL-C, ApoB or ApoB/ApoA-1 levels, without considering factors of obesity in middle-aged men and women. Moreover, John *et al.*¹⁶ documented that the serum 25(OH)D concentration positively correlated with the ApoA-1, but not HDL-C levels following adjustment for BMI in 170 adults 35-65 years of age. Conversely, Jorde *et al.*¹⁴ and Karhapaa *et al.*¹⁵ found the serum 25(OH)D concentration to be negatively correlated with the TG, LDL-C, LDL-C/HDL-C and ApoB levels, but not the HDL-C or ApoA-1 levels, in adults, after taking into account BMI and WC¹⁵. Additionally, all previous studies were conducted in American and European adults. To the best of our knowledge, the present study is the first to investigate the relationships between 25(OH)D and blood lipids in Japanese men (20 to 79 years of age). Consequently, the partial Pearson's correlation analyses clearly showed that the serum 25(OH)D concentration was robustly associated with the VFA ($p < 0.01$), but not other measurements of adiposity, such as BMI and WC. Hence, a better obesity indicator, VFA, was controlled for in this study. Furthermore, our observations support the findings of previous studies showing that a high serum 25(OH)D concentration is associated with a desirable lipid profile, including low TG, LDL-C/HDL-C and ApoB/ApoA-1 levels and a high HDL-C level, even after adjusting for VFA in Japanese men. Meanwhile, we also observed significant associations between the 25(OH)D concentration and the ApoA-1 and ApoB

Table 2. Age-adjusted relationships between the serum 25(OH)D levels and the subjects' characteristics ($n = 136$)

	<i>r</i>	<i>p</i>
BMI	-0.039	0.654
WC	-0.097	0.265
VFA	-0.258	0.003
SBP	-0.037	0.667
DBP	-0.129	0.136
FG	0.001	0.991
HbA1c (%)	-0.048	0.579
HDL-C*	-0.290	0.001
LDL-C	-0.123	0.156
TG	-0.319	<0.001
LDL-C/HDL-C	-0.278	0.001
ApoA-1	0.237	0.006
ApoB	-0.202	0.019
ApoB/ApoA-1	-0.289	0.001
OxLDL	-0.175	0.042
Cardiorespiratory fitness	0.361	<0.001
Calcium intake	0.298	<0.001
Vitamin D intake	0.359	<0.001

The data are presented as partial Pearson's correlation coefficients. 25(OH)D, 25-hydroxyvitamin D; BMI: body mass index; WC, waist circumference; VFA, visceral fat area; FG, fasting glucose; HbA1c, glycated hemoglobin; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; Apo, apolipoprotein; oxLDL, oxidized low-density lipoprotein. The 25(OH)D level was square root transformed; HDL-C* is the reciprocal of the square root transformed value. The SBP, TG, ApoA-1, cardiorespiratory fitness, calcium and vitamin D intake parameters were log transformed for the analysis.

levels after controlling for BMI and WC (data not shown), consistent with previous results^{15,16}. However, when the potential confounding factors and obesity indicators BMI and WC were replaced with VFA, the positive relationships between the serum 25(OH)D concentration and the ApoA-1 or ApoB levels exhibited borderline significance.

Previous studies have found that high levels of cardiorespiratory fitness are linked to beneficial blood lipid profiles and high circulating 25(OH)D concentration²⁴⁻²⁶. However, none of these previous studies considered the importance of the potentially confounding effects of cardiorespiratory fitness in the context of the relationship between the serum 25(OH)D concentration and lipid profiles. In the present study, following further adjustment for cardiorespiratory fitness, the inverse relationships between the 25(OH)D concentration and the TG, ApoB, ApoB/ApoA-1 and LDL-C/HDL-C levels remained statisti-

Table 3. Multiple regression analysis of the associations between the serum 25(OH)D concentrations and the lipid profiles ($n=136$)

Variables	Model 1				Model 2				Model 3			
	<i>B</i>	β	<i>p</i>	<i>R</i> ²	<i>B</i>	β	<i>p</i>	<i>R</i> ²	<i>B</i>	β	<i>p</i>	<i>R</i> ²
HDL-C*	-0.002	-0.268	0.040	0.115	-0.002	-0.210	0.019	0.185	-0.001	-0.143	0.115	0.219
LDL-C/HDL-C	-0.121	-0.280	0.003	0.077	-0.098	-0.228	0.014	0.130	-0.101	-0.234	0.016	0.124
TG	-0.040	-0.306	0.001	0.115	-0.031	-0.235	0.007	0.220	-0.032	-0.248	0.007	0.216
oxLDL	-1.011	-0.138	0.135	0.088	-0.668	-0.091	0.320	0.130	-1.004	-0.137	0.151	0.142
ApoA-1	0.010	0.212	0.020	0.119	0.008	0.173	0.058	0.146	0.004	0.095	0.302	0.194
ApoB	-2.996	-0.206	0.024	0.113	-2.483	-0.171	0.063	0.134	-3.244	-0.223	0.019	0.152
ApoB/ApoA-1	-0.036	-0.293	0.002	0.080	-0.030	-0.245	0.008	0.123	-0.030	-0.247	0.011	0.116

25(OH)D, 25-hydroxyvitamin D; HDL-C, high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglycerides; oxLDL, oxidized low-density lipoprotein; Apo, apolipoprotein. *B*, unstandardized regression coefficients; β , standardized regression coefficients. The 25(OH)D level was square root transformed. HDL-C* is the reciprocal of the square root transformed value. The TG, ApoA-1 and cardiorespiratory fitness parameters were log transformed for the analysis. Model 1: adjusted for age, season, smoking status, alcohol consumption, medication use, vitamin D and calcium intake; Model 2: as in model 1 plus VFA; Model 3: as in model 2 plus cardiorespiratory fitness.

cally significant, whereas the positive associations between the 25(OH)D concentration and the HDL-C and ApoA-1 levels disappeared. Moreover, in our population of Japanese men, we found that the associations between the 25(OH)D concentration and the ApoA-1 and HDL-C values were significantly influenced by the level of cardiorespiratory fitness, rather than the body fat distribution, and the serum 25(OH)D concentration was found to be inversely associated with the ApoB, TG, LDL-C/HDL-C and ApoB/ApoA-1 values, regardless of the fat distribution and level of cardiorespiratory fitness. In addition, although vitamin D metabolism is closely correlated with cholesterol, the multiple regression analysis indicated that the serum 25(OH)D concentration was negatively correlated with the ratio of LDL-C/HDL-C and level of ApoB, a key structural component of LDL-C, as well as the level of TG, with similar regression coefficients. Therefore, these data suggest that a high serum 25(OH)D concentration has a beneficial effect on both the TG level and cholesterol metabolism, independent of the visceral fat area and degree of cardiorespiratory fitness in Japanese men.

oxLDL is known to be involved in the critical early stages of atherogenesis in addition to foam cell and thrombus formation³⁰⁻³². Furthermore, recent studies have revealed that, in addition to LDL-C and HDL-C, the oxLDL level is a strong independent predictor of CVD in healthy participants³³. Recently, Gradinaru *et al.*³⁴ found the 25(OH)D concentration to be inversely correlated with the oxLDL levels in elderly subjects with impaired fasting glucose and diabetes. However, the relationship between the serum 25(OH)D and oxLDL levels has not yet been deter-

mined in healthy adults. In the present study, we observed a negative relationship between the serum 25(OH)D and oxLDL levels after adjusting for age, although this relationship was lost following further adjustment. Nevertheless, due to the limited amount of data, no definitive conclusions can be drawn, and further investigation is warranted.

The present study is associated with several limitations. First, this study used a cross-sectional design and therefore cannot provide causal evidence regarding the association between the serum 25(OH)D concentration and lipid profiles. Second, the study population included only Japanese men. It remains unknown whether the same associations exist in people of other ethnicities, as vitamin D metabolism and the circulating 25(OH)D concentration vary substantially by race³⁵. Further understanding of this issue in other populations is therefore needed. Third, because we only investigated men in the present study, our results should be interpreted with caution and confirmed in further cohorts of women. Despite these limitations, the present analysis has some strengths, including the reliable characterization of abdominal fat and precise and objective measurements of fitness. Most importantly, this is the first study to focus on the relationship between the 25(OH)D concentration and lipid profiles in an Asian population.

Conclusion

In conclusion, the present study revealed that the serum 25(OH)D level is inversely associated with the TG, ApoB, LDL-C/HDL-C and ApoB/ApoA-1 values, independent of abdominal fat and cardiorespira-

tory fitness in Japanese men.

Acknowledgements

We would like to thank the subjects who participated in this study. Additionally, we wish to thank our laboratory members (Hiroshi Kawano, Yuko Gando, Ryoko Kawakami, Takafumi Ando and Taishi Susa) who provided support for the data collection. This study was supported in part by a Grant-in-Aid for the Global COE (Sport Sciences for the Promotion of Active Life to Waseda University) from the Ministry of Education, Culture, Sports, Science and Technology of Japan (to M.H.) and Grants-in-Aid for Scientific Research (C) from the Ministry of Education, Culture, Sports, Science and Technology of Japan (to Z.B.C.).

Conflicts of Interest

The authors have no conflicts of interest to declare.

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