

Effect of Longitudinal Changes in Visceral Fat Area and Other Anthropometric Indices to the Changes in Metabolic Risk Factors in Japanese Men

The Hitachi Health Study

YUMI MATSUSHITA, PHD¹
TORU NAKAGAWA, MD, PHD²
SHUICHIRO YAMAMOTO, MD, PHD²
YOSHIHIKO TAKAHASHI, MD, PHD³

TETSUJI YOKOYAMA, MD, PHD⁴
TETSUYA MIZOUE, MD, PHD⁵
MITSUHIKO NODA, MD, PHD³

OBJECTIVE—The effects of longitudinal changes in the visceral fat area (VFA), and other anthropometric indices, on the risk factors of metabolic syndrome were not studied. We calculated the changes in metabolic risk factors in relation to changes in certain anthropometric indices in a large-scale study of Japanese men.

RESEARCH DESIGN AND METHODS—The subjects were 1,106 men participating in the Hitachi Health Study who received a computed tomography examination in both 2004 and 2007. VFA, subcutaneous fat area (SFA), and waist circumference were measured using the computed tomography. We examined how longitudinal changes in each anthropometric index over a 3-year period influenced the value of each metabolic risk factor.

RESULTS—Changes (Δ) over a 3-year period in body weight, SFA, and waist circumference strongly correlated, while the changes in body weight and VFA were weakly correlated. Changes in the VFA were associated with changes in metabolic risk factors, especially changes in triglyceride and HDL; we found these changes to be independent of the Δ body weight and Δ waist circumference.

CONCLUSIONS—Change in body weight is not a precise surrogate marker of Δ VFA, and repeated VFA measurements over time are useful. Adopting a lifestyle that does not increase the VFA is important in preventing metabolic syndrome.

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Cardiovascular disease (CVD) is one of the leading causes of morbidity and mortality in the world (1). Previous reports have shown that obesity plays a significant role in increasing cardiovascular risk (2). Certain indicators of obesity, such as the visceral fat area (VFA), or visceral adipose tissue, are more strongly associated with the risk of CVD than other indicators of obesity,

such as waist circumference, BMI (3), or the subcutaneous fat area (SFA) (2). A large VFA is strongly related to a higher prevalence of impaired fasting glucose levels (4,5), diabetes (4,6,7), insulin resistance (4,8–10), hypertension (11,12), abnormality of lipid metabolism (13–16), and metabolic risk factors (14,17,18). Previous studies have examined the relationship between baseline VFA and

metabolic risk factors. In a previous intervention study of 54 postmenopausal women, an increase in VFA strongly correlated with changes in triglyceride and HDL cholesterol levels compared with changes in the blood pressure and fasting blood glucose levels (19). In the current study, we examined the relationships between changes in the VFA, SFA, body weight, and waist circumference and changes in CVD risk factors to determine the relative contributions of the longitudinal changes in these anthropometric indices to the changes in metabolic risk factors over a 3-year period. Determining the relationships between the anthropometric indices and metabolic risk factors would be useful for preventing CVD in clinical settings.

RESEARCH DESIGN AND METHODS

Overall, a total of 13,971 male employees and their spouses, after ≥ 12 h of fasting, underwent health check-ups during a baseline survey performed in 2004 and 2005 at the Hitachi Health Care Center in Ibaraki Prefecture. Of these, 2,655 men received a computed tomography scan. The final analysis involved 1,106 men from the initial study who participated in a 3-year follow-up survey performed in 2007 and 2008 (aged 30–72 years in the baseline survey). The mean age of the men for whom follow-up data were available was younger than that of the men for whom follow-up data were not available. In addition, the mean age of the men who received a computed tomography examination in the baseline survey was greater than the mean age of the men who did not receive the computed tomography examination. No significant differences were seen between the other characteristics when age-adjusted comparisons were performed. Self-reporting questionnaires were used to investigate whether the subjects were currently receiving medical treatment for hyperlipidemia, hypertension, or diabetes

From the ¹Department of Clinical Research Coordination, National Center for Global Health and Medicine, Tokyo, Japan; the ²Hitachi Health Care Center, Hitachi, Ltd., Ibaraki, Japan; the ³Department of Diabetes and Metabolic Medicine and Diabetes Research Center, National Center for Global Health and Medicine, Tokyo, Japan; the ⁴Department of Health Promotion, National Institute of Public Health, Saitama, Japan; and the ⁵Department of Epidemiology and Prevention, National Center for Global Health and Medicine, Tokyo, Japan.

Corresponding author: Yumi Matsushita, ymatsushita@ri.ncgm.go.jp.

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Changes in VFA and incidence of CVD risk

at the time of both surveys. Body height and weight were measured using an automated scale (BF-220; Tanita), and the BMI was defined as the weight in kilograms divided by the square of the height in meters. VFA, SFA, and waist circumference were measured using a computed tomography scanner and protocols previously described (20). In brief, single-slice imaging was performed at the umbilical level in a spine position using a Redix turbo CT machine (Hitachi Medico). The imaging conditions were 120 kV, 50 mA, and a slice thickness of 5 mm. VFA, SFA, and waist circumference were calculated using fatPointer software (Hitachi Medico). Triglyceride and HDL cholesterol levels were measured using the oxygen method with a Hitachi 7600 device (Sekisui Medical). Blood glucose levels were measured using the glucose electrode technique with an ADAMS glucose GA-1170 device (Arkrey). Blood pressure was measured using an oscillometric method with a Kentaro ADVANCE BP-203RV III A/B device (Colin) while the patient was in a sitting position and after the patient had rested for 3 min. Informed consent was obtained from each examinee regarding the use of his or her data for research purposes. The current study was approved by the ethics review committee of the National Center for Global Health and Medicine.

Definition of the state of risk factor clustering

Subjects with two or more of the following four factors, defined by the National Cholesterol Education Program's Adult Treatment Panel III guidelines (21), with the exception of waist circumference, were defined to have clustering of metabolic risk factors: 1) triglyceride ≥ 150

Table 1—Anthropometric and CVD risk variables at baseline and changes during the 3-year follow-up period (n = 1,106)

	Baseline		Changes in 3-year period		P*
	Mean	SD	Mean	SD	
Height (cm)	169.0	6.1	0.3	0.5	<0.001
Weight (kg)	67.6	9.4	0.0	3.1	0.61
BMI (kg/m ²)	23.6	2.7	0.1	1.1	0.018
VFA (cm ²)	120.0	52.2	0.0	32.5	0.99
SFA (cm ²)	122.6	52.2	4.2	24.7	<0.001
VFA/SFA	1.03	0.54	-0.03	0.48	0.055
WC (cm)	85.6	8.1	-0.2	4.6	0.088
SBP (mmHg)	121.5	11.7	-1.1	10.8	0.001
DBP (mmHg)	76.9	8.2	-0.1	7.1	0.62
TG (mg/dL)	137.6	92.6	-9.0	80.0	<0.001
HDL cholesterol (mg/dL)	56.4	14.2	-1.8	7.9	<0.001
Fasting glucose (mg/dL)	105.2	13.0	-1.5	8.7	<0.001

TG, triglyceride; WC, waist circumference. *Paired *t* test between values at baseline and at the 3-year follow-up.

mg/dL (1.69 mmol/L), 2) HDL cholesterol <40 mg/dL (1.03 mmol/L), 3) systolic blood pressure (SBP) ≥ 130 mmHg or diastolic blood pressure (DBP) ≥ 85 mmHg, or 4) fasting plasma glucose ≥ 110 mg/dL (6.11 mmol/L). Subjects currently receiving treatment for hyperlipidemia, hypertension, or diabetes were deemed as having the respective risk factor, regardless of the biochemical value.

Statistical analyses

The baseline data and the 3-year changes (Δ) in CVD risk-related variables (i.e., BMI, VFA, SFA, VFA/SFA, waist circumference, SBP, DBP, triglyceride, HDL cholesterol, and glucose) were calculated for subjects who had not received a medical treatment in both surveys. The *P* value between baseline and the 3-year follow-up period was calculated using a paired

t test. Pearson correlation coefficients for the changes in the anthropometric and CVD risk variables were calculated. To establish the independent contribution of each anthropometric variable, multiple linear regression analyses were used to obtain the standardized partial regression coefficients, where the change in the CVD risk variable was the dependent variable and the changes in the anthropometric indices were the independent variables; a stepwise procedure was used to select significant variables. All analyses were performed using SPSS (version 15.0; SPSS, Chicago, IL).

RESULTS—The anthropometric and CVD risk variables at the baseline survey and changes at the 3-year follow-up period are shown in Table 1. The mean (SD) age of the subjects was 52.7 (8.4)

Table 2—Pearson correlation coefficients among changes in anthropometric and CVD risk variables (n = 1,106)

	Δ VFA	Δ SFA	Δ Body weight	Δ Waist circumference	Δ BMI	Δ SBP	Δ DBP	Δ Fasting glucose	Δ Log triglycerides	Δ HDL
Δ VFA	1	0.632	0.672	0.756	0.671	0.138	0.162	0.188	0.197	-0.234
Δ SFA	0.632	1	0.738	0.765	0.738	0.174	0.177	0.187	0.171	-0.238
Δ Body weight	0.672	0.738	1	0.722	0.989	0.155	0.210	0.203	0.222	-0.252
Δ Waist circumference	0.756	0.765	0.722	1	0.718	0.140	0.156	0.168	0.196	-0.233
Δ BMI	0.671	0.738	0.989	0.718	1	0.150	0.203	0.204	0.225	-0.253
Δ SBP	0.138	0.174	0.155	0.140	0.150	1	0.627	0.055	0.096	-0.003
Δ DBP	0.162	0.177	0.210	0.156	0.203	0.627	1	0.093	0.097	-0.004
Δ Fasting glucose	0.188	0.187	0.203	0.168	0.204	0.055	0.093	1	0.039	0.041
Δ Log triglycerides	0.288	0.280	0.350	0.295	0.353	0.109	0.117	0.079	1	-0.288
Δ HDL cholesterol	-0.234	-0.238	-0.252	-0.233	-0.253	-0.003	-0.004	0.041	-0.250	1

The absolute value of a correlation coefficient >0.06 was statistically significant at *P* < 0.05. The correlation coefficients were essentially unchanged after adjustments for age (data not shown).

years at baseline. The mean BMI was 23.6 (2.7) kg/m², the mean VFA was 120.0 (52.2) cm², and the mean waist circumference was 85.6 (8.1) cm at baseline. The 3-year changes in each of these parameters were relatively small.

Pearson correlation coefficients for the changes in the anthropometric measurements and CVD risk variables are shown in Table 2. Strong correlations among the changes in the four adiposity indices were observed, with a colinearity observed among the indices. Correlations among the Δ body weight, Δ SFA, and Δ waist circumference were also strong, but the correlation between the Δ body weight and Δ VFA was weak. These findings suggested that the Δ body weight was not an exact surrogate marker of Δ VFA. We also analyzed correlations among the changes in anthropometric measurements and CVD risk variables. Significant correlations between the Δ log triglyceride and Δ VFA, the Δ log triglyceride and Δ body weight, the Δ SBP and Δ SFA, the Δ SBP and Δ body weight, and the Δ glucose and Δ body weight were observed. The correlation coefficients were essentially unchanged after adjustments for age (data not shown).

Multiple linear regression analyses showed that the changes in VFA, SFA, body weight, and waist circumference were independently associated with the changes in CVD risk factors during the 3-year follow-up period (Table 3). The Δ DBP, Δ glucose, Δ log triglyceride, and Δ HDL cholesterol were significantly affected by both the Δ VFA and Δ SFA. In contrast, the Δ SBP was only significantly affected by the Δ SFA. The Δ log triglyceride and Δ HDL cholesterol values were more strongly affected by the Δ VFA than by the Δ SFA. These results suggest that the Δ VFA and Δ SFA contribute differently to the Δ CVD risk variables. A multiple regression analysis showed that the Δ VFA were significantly related to the Δ log triglyceride and Δ HDL cholesterol and were independent of the Δ body weight and Δ waist circumference.

CONCLUSIONS—This study investigated the change in metabolic risk factors between a baseline examination and a 3-year follow-up examination, measured using computed tomography. The changes in body weight, SFA, and waist circumference strongly correlated. The changes in body weight and VFA showed weak correlation, suggesting that changes in body weight are not an exact surrogate marker

Table 3—Independent associations of changes in VFA, SFA, body weight, and waist circumference with changes in the CVD risk factors during the 3-year follow-up period according to multiple linear regression analyses

Dependent variable	Independent variables	Model 1		Model 2	
		Standardized partial β	P	Standardized partial β	P
Δ SBP	Δ VFA	0.056	0.115	—	—
	Δ SFA	0.161	<0.001	0.194	<0.001
	Age	0.034	0.216	—	—
Δ DBP	Δ VFA	0.093	0.008	0.093	0.008
	Δ SFA	0.135	<0.001	0.135	<0.001
	Age	−0.105	<0.001	−0.105	<0.001
Δ Fasting glucose	Δ VFA	0.100	0.002	0.100	0.002
	Δ SFA	0.127	<0.001	0.127	<0.001
	Age	−0.071	0.005	−0.071	0.005
Δ Log triglycerides	Δ VFA	0.207	<0.001	0.206	<0.001
	Δ SFA	0.141	<0.001	0.143	<0.001
	Age	−0.026	0.295	—	—
Δ HDL cholesterol	Δ VFA	−0.154	<0.001	−0.154	<0.001
	Δ SFA	−0.134	<0.001	−0.134	<0.001
	Age	−0.082	0.001	0.082	0.001
Δ SBP	Δ VFA	0.031	0.480	—	—
	Δ SFA	0.121	0.011	0.128	0.002
	Δ Body weight	0.084	0.067	0.089	0.031
	Δ Waist	−0.009	0.866	—	—
	Age	0.041	0.142	—	—
Δ DBP	Δ VFA	0.055	0.203	—	—
	Δ SFA	0.070	0.139	—	—
	Δ Body weight	0.157	0.001	0.220	<0.001
	Δ Waist	−0.035	0.507	—	—
	Age	−0.092	0.001	−0.088	0.001
Δ Fasting glucose	Δ VFA	0.080	0.040	—	—
	Δ SFA	0.085	0.045	—	—
	Δ Body weight	0.158	<0.001	0.223	<0.001
	Δ Waist	−0.082	0.070	—	—
	Age	−0.053	0.037	—	—
Δ Log triglycerides	Δ VFA	0.112	0.003	0.127	<0.001
	Δ SFA	0.008	0.846	—	—
	Δ Body weight	0.229	0.000	0.248	<0.001
	Δ Waist	0.031	0.483	—	—
	Age	−0.006	0.813	—	—
Δ HDL cholesterol	Δ VFA	−0.105	0.004	−0.112	0.001
	Δ SFA	−0.065	0.106	−0.073	0.043
	Δ Body weight	−0.116	0.003	—	—
	Δ Waist	−0.017	0.684	−0.119	0.002
	Age	−0.092	<0.001	−0.093	<0.001

Model 1: All independent variables were entered into the model. Model 2: Significant variables were selected using the stepwise method. β , regression coefficient.

of changes in VFA. A multiple regression analysis showed that the Δ VFA was significantly related to Δ triglyceride and Δ HDL cholesterol independently of Δ body weight and Δ waist circumference, suggesting the importance of monitoring VFA over time.

In previous cross-sectional studies, positive correlations between VFA and SBP and between VFA and serum triglyceride

were reported to be significant when VFA was measured by computed tomography (14). In previous longitudinal studies, the effects of changes in BMI (22), weight (23), and waist circumference (24,25) on metabolic risk factors were examined. One such report showed a strong linear trend between increasing BMI and a worsening of various variables of metabolic risk factors, including blood pressure and lipid

profiles (24). Likewise, another report showed that weight changes were linearly related to all measurements of each component of the metabolic risk factors (23). Other studies have shown that a reduction in the waist circumference and the VFA achieved through lifestyle modifications is closely linked to an improvement in metabolic risk factors (19,25). These studies suggest that the changes in BMI, weight, waist circumference, and VFA are related to risk factors for CVD. However, the impact of the change in the VFA (measured twice in the same person), which is regarded as the strongest indicator of CVD risk among the anthropometric variables, has remained uncertain. To our knowledge, this is the first study to analyze the relationships between changes in VFA and changes in metabolic risk factors, compared with other anthropometric variables, in a large population. Our findings clearly showed that the Δ VFA were significantly related to the Δ log triglyceride and Δ HDL cholesterol and were independent of the Δ body weight and Δ waist circumference.

In previous studies (22), the mean value of each component of metabolic risk factors or the prevalence of metabolic risk factors and its components were compared according to changes in BMI, body weight, and waist circumference. This is the first study that compared the strength of the association of metabolic risk factors with the change in VFA in a large population.

The current study has the following strengths: the study had a longitudinal design and examined the relationships between metabolic risk factors and the change in VFA using computed tomography scans performed twice on the same subject. The number of subjects was relatively large, with >1,000 subjects being followed over a 3-year period. Our study is thought to have a small measurement bias because VFA and SFA were measured using the same computed tomography machine, in the same region, and at the same state of expiration during both the baseline examination and the 3-year follow-up examination. A random measurement error could have diluted the relationship between Δ VFA and the metabolic risk factors. Thus, the real relationship may be stronger than the observed one. Nevertheless, the current study also has a limitation. The study subjects were limited to men, and further studies in women are needed.

In conclusion, the current study of Japanese men showed that changes in the

VFA were associated with changes in metabolic risk factors. The Δ VFA was significantly related to Δ log triglyceride and Δ HDL cholesterol and was independent of Δ body weight and Δ waist circumference, suggesting the importance of measuring the VFA repeatedly over time. The adoption of a lifestyle that does not result in an increase in VFA is important in preventing metabolic syndrome.

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No potential conflicts of interest relevant to this article were reported.

Y.M. was the principal investigator, researched data, contributed to discussions, wrote the manuscript, and reviewed and edited the manuscript. T.N. researched data, contributed to discussions, and reviewed and edited the manuscript. S.Y. researched data and reviewed and edited the manuscript. Y.T. contributed to discussions. T.Y., T.M., and M.N. contributed to discussions and reviewed and edited the manuscript. Y.M. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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