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Relationship between thigh intermuscular adipose tissue accumulation and number of metabolic syndrome risk factors in middle-aged and older Japanese adults

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ABSTRACT

Background: To evaluate the association between thigh intermuscular adipose tissue accumulation and number of metabolic syndrome risk factors in middle-aged and older Japanese adults.
Methods: Thigh muscle cross-sectional area, subcutaneous adipose tissue, thigh intermuscular adipose tissue, abdominal subcutaneous adipose tissue, and visceral adipose tissue were measured in 166 middle-aged and older (mean age, 69 years) Japanese adults using magnetic resonance imaging. Daily physical activity was calculated using pedometers, and energy intake per day was evaluated using 3-day dietary records. Multiple linear regression analysis was used to assess the association between intermuscular adipose tissue and the number of metabolic syndrome risk factors.
Results: Multiple regression analysis indicated that intermuscular adipose tissue was significantly associated with the number of metabolic syndrome risk factors, after adjusting for age, sex, body mass index, daily physical activity, energy intake, thigh muscle cross-sectional area, and visceral adipose tissue ($p < 0.05$).
Conclusions: Thigh intermuscular adipose tissue accumulation was significantly associated with the number of metabolic syndrome risk factors in middle-aged and older Japanese adults, independent of age, sex, body mass index, daily physical activity, energy intake, thigh muscle cross-sectional area, and visceral adipose tissue.

1. Introduction

Age-related loss of skeletal muscle mass, termed sarcopenia (Rosenberg, 1997), is related to mobility disorders, impaired activities of daily living, and decreased quality of life in older adults (Janssen et al., 2002; Doherty, 2003). Sarcopenia has also been reported as associated with metabolic diseases, such as diabetes (Morley, 2008; Kim et al., 2010) and metabolic syndrome (MetS) (Yum et al., 2012). Furthermore, sarcopenic obesity, defined as having low skeletal muscle mass in the presence of obesity (Baumgartner et al., 2004), is reportedly more closely associated with MetS than either sarcopenia or obesity alone (Lim et al., 2010).

Intermuscular adipose tissue (IMAT) has been observed in the skeletal muscles of older adults with sarcopenia. Recent studies have demonstrated that patients with metabolic diseases, such as type 2 diabetes (Goodpaster et al., 2000; Hilton et al., 2008; Gallagher et al., 2009) or stroke (Ryan et al., 2002, 2011), have a greater amount of IMAT compared with healthy individuals. These observations indicate that increased IMAT contributes to the pathogenesis of metabolic disease. However, few reports have examined the relationship between IMAT and metabolic abnormalities in older adults without severe disease.

MetS represents a cluster of cardiovascular risk factors that includes abdominal obesity, hypertension, dyslipidemia, and hyperglycemia (Reaven, 1988). The incidence of lifestyle-related diseases reportedly increases with increasing numbers of MetS risk factors, even if they are mild risk factors (Nakamura et al., 2001).

Therefore, there is a clinical need to determine the effects of IMAT on metabolic abnormalities in terms of MetS risk factors for the prevention of lifestyle-related disease. To date, only two previous studies have reported that IMAT is independently associated with the incidence of MetS in men or women without severe disease (Goodpaster et al., 2003; Therkelsen et al., 2013). Despite reporting an association between IMAT and MetS, neither of these studies focused on the number of MetS risk factors or measured physical activity or energy intake. The influence of IMAT on MetS risk factors is likely to differ according to the race (Yim et al., 2007); however, to the best of our knowledge, no studies have been conducted on middle-aged and older Japanese adults.

Therefore, the present study aimed to determine the association between thigh IMAT accumulation and the number of MetS risk factors in middle-aged and older Japanese adults, independent of sex and objectively measured physical activity and energy intake.

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2. Methods

2.1. Participants

The present study included 166 middle-aged and older Japanese adults without exercise habits or severe metabolic disease (mean age, 68.9 ± 5.5 years; 53 men, 113 women). Participants were recruited through advertisements in the local community. All participants provided informed written consent. The Ethical Committee of the Institute of Health and Sport Sciences and the Institute of Clinical Medicine at the University of Tsukuba approved the present study protocol.

2.2. Anthropometric measurements

Anthropometric measurements were performed on barefoot participants wearing light clothing. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Body weight was measured to the nearest 0.1 kg using a digital scale (TBF-551; Omron Healthcare Co., Ltd., Kyoto, Japan). Body mass index (BMI) was calculated as body weight/height^2 (kg/m^2).

2.3. Thigh muscle and abdominal cross-sectional area (CSA)

Thigh muscle and abdominal CSA measurements were obtained by magnetic resonance imaging (MRI) at the University of Tsukuba. Participants were placed in the supine position with extended knee joints on a 0.25-T scanner (AIRIS mate; Hitachi Medical Co., Tokyo, Japan). Thigh cross-sectional images were obtained using a conventional T1-weighted spin-echo sequence (10-mm slice thickness, 20-mm intersection interval, TR 360 ms, TE 28 ms, 256 × 256 matrix, FOV 240 mm, FA 90°). Abdominal cross-sectional images were obtained between L4 and L5 vertebrae using a conventional T1-weighted spin-echo sequence (10-mm slice thickness, 20-mm intersection interval, TR 510 ms, TE 30 ms, 256 × 256 matrix, FOV 320 mm, FA 90°).

Total area, thigh muscle, thigh subcutaneous adipose tissue (TSAT), and thigh IMAT were measured from a single cross-sectional image at 50% of the right femur length. In the present study, IMAT was defined as adipose tissue area visible between muscle groups and beneath the muscle fascia (Ruan et al., 2007). Abdominal subcutaneous adipose tissue (ASAT) and visceral adipose tissue (VAT) were measured from a single cross-sectional image between the L4 and L5 vertebrae. All cross-sectional images were analyzed by a single trained investigator using SliceOmatic 5.0 image analysis software (Tomovision, Montreal, Canada). The coefficient of variation for thigh muscle, TSAT, and IMAT were ±0.24%, ±0.45%, and ±0.53%, respectively, whereas those for ASAT and VAT were ±0.40% and ±0.57%, respectively.

2.4. MetS components and risk factor

MetS risk factors were determined according to the Japanese Diagnosis Criteria (Matsuzawa, 2005) as follows: (1) abdominal obesity, waist circumference of ≥85 cm in men and ≥90 cm in women; (2) hypertension, systolic blood pressure (SBP) of ≥130 mm Hg and/or diastolic blood pressure (DBP) of ≥85 mm Hg; (3) dyslipidemia, triglyceride (TG) levels of ≥150 mg/dL and/or high-density lipoprotein cholesterol (HDL-C) levels of <40 mg/dL; and (4) hyperglycemia, fasting glucose (FG) levels of ≥110 mg/dL. Additional MetS risk factor criteria included those receiving drug treatments for hypertension, dyslipidemia, or hyperglycemia.

Waist circumference was measured three times to the nearest 0.1 cm at the midpoint between the lower costal margin and iliac crest using a calibrated measuring tape. Blood pressure was measured twice using an electronic digital blood pressure monitor (HEM-780, Omron Healthcare Co., Ltd., Kyoto, Japan) with individuals in a seated position after a 10-min rest period. Fasting TG, HDL-C, and FG levels were obtained from blood samples drawn after an overnight fast.

2.5. Covariates

Daily physical activity was measured using a pedometer (HJ-730IT, Omron Healthcare Co., Ltd., Kyoto, Japan). Participants were directed to wear the pedometer on a belt around the waist from waking up in the morning until going to bed at night for 14 days, except during sleeping and bathing. In addition, participants were asked to record their physical activity in detail using a physical activity diary to exclude unusual physical activity, such as travel or business trips, from daily physical activity. The number of steps recorded daily was calculated from the average number of steps per day measured by the pedometer and the physical activity diary.

Daily intake of total energy, in addition to carbohydrates, fat, and protein, were assessed using 3-day dietary records. Dietary intake data were analyzed by a nutritionist using Eiyoukun Ver 4.0 software (Kenpakusya Co., Ltd., Tokyo, Japan). Estimated energy requirement (EER) values were calculated for each participant based on height, weight, and physical activity levels (Sasaki, 2008). Total energy intake was evaluated to determine the EER usage ratio as the total energy intake per EER. Participants also completed a postmenopausal health questionnaire. All female participants were postmenopausal and were not receiving hormone replacement therapy during the present study period.

2.6. Statistical analysis

Patients were divided into quartiles according to IMAT (Q1, <2.7 cm^2; Q2, 2.7–3.7 cm^2; Q3, 3.8–5.5 cm^2; Q4, >5.5 cm^2) to examine the number of MetS risk factors in each IMAT quartile. The mean differences in continuous variables between IMAT quartiles were tested using one-way analyses of variance, and categorical variables were tested using the χ^2 test. Relationships between IMAT accumulation and number of MetS risk factor were determined using partial correlation coefficients adjusted for age and sex. Multiple regression analysis models were used to determine whether IMAT was independently associated with the number of MetS risk factors. Analyses were adjusted for age, sex, physical activity, energy intake, and thigh muscle CSA (Model 1), and further adjusted for BMI (Model 2) and VAT (Model 3), as these variables have been shown to be strongly associated with MetS in several previous studies as well as the present study. All statistical analyses were performed using SPSS 21.0 software (SPSS Inc., Tokyo, Japan); p values <0.05 were considered statistically significant.

3. Results

Participant characteristics according to IMAT quartiles are shown in Table 1. Overall, 31.9% participants were men. No significant differences in age or height were observed between quartiles; however, body weight and BMI were significantly higher in Q4 than in Q1 and Q2. Moreover, thigh muscle and abdominal CSA values, except for TSAT, were significant greater in Q4 than in Q1–Q3. No significant differences in physical activity or dietary intake were observed between quartiles.

The number of MetS risk factors and components according to IMAT quartiles are shown in Table 2. The number of MetS risk factors was significantly higher in Q4 than in Q1 ($p < 0.001$). IMAT quartiles were significantly associated with the frequency of abdominal obesity ($p < 0.001$) and hyperglycemia ($p < 0.01$); however, no significant difference in frequencies of hypertension and dyslipidemia were observed between IMAT quartiles. In addition, among the components of MetS, IMAT quartiles were significantly positively associated with waist circumference ($p < 0.001$) and FG ($p < 0.05$). No significant difference in SBP, DBP, TG, and HDL-C were observed between IMAT quartiles (Table 2).

Table 3 shows the partial correlation, controlled for age and sex, between body composition variables, physical activity, energy intake, and MetS components. IMAT was significantly correlated with the number