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# Regional Subcutaneous Fat Characteristics Stratified by Sex, Age, and Obesity, and Their Relationships with Total and Visceral Fat in a Japanese Population

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**Abstract** This study aimed to clarify the sex-, age-, and obesity-level-specific regional subcutaneous fat characteristics and their relationships with total and visceral fat in 302 Japanese adults (mean age: 41.8±15.7 yr; range: 20.0 to 82.6 yr). Subcutaneous fat thickness at 14 sites (right cheek, chin, chest (2 sites), abdomen, suprailiac, triceps, subscapular, back (2 sites), thigh (2 sites), knee, and calf), percent body fat (%BF) and visceral fat area (VFA) were measured by B-mode ultrasound, dual-energy x-ray absorptiometry and computed tomography, respectively. The results of 3-way ANOVA (2 sex groups, 5 age groups, 2 obesity-level groups) for each subcutaneous fat thickness at 14 sites indicated that the characteristics of sex-specific differences differed by age groups and obesity levels, and these differences are more apparent in the obese group and the 30- to 50-year-old groups. Subcutaneous fat accumulation progressed toward the central body with increased age and obesity. The relationships between subcutaneous fat, total fat, and visceral fat differed with sex and obesity level. The significant relationship between abdominal subcutaneous fat thickness and VFA was found in the nonobese (BMI<25 kg/m$^2$) and nonviscerally obese (VFA<100 cm$^2$) groups (male: r=.474; female: r=.417), but not in the nonobese and viscerally obese males (r=−.068) and in the obese and viscerally obese subjects (males: r=.291; females: r=−.327). There may be a close relationship between subcutaneous fat accumulation capacity and visceral fat accumulation. *J Physiol Anthropol 28(5): 231–238, 2009*
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**Keywords:** body fat distribution, obesity type, visceral obesity, ultrasound

## Introduction

Obesity is one of several important risk factors for metabolic syndrome, and it is diagnosed based on criteria such as body mass index (BMI), percent body fat (%BF), visceral fat, and waist circumference. Visceral fat accumulation is closely associated with an increased risk of diabetes and cardiovascular diseases. The risk of these diseases differs by visceral obesity level even in subjects of equal obesity levels as assessed by BMI or %BF (Fujioka et al., 1987; Larsson et al., 1992), and the assessment of body fat distribution characteristics and obesity types may provide useful information in the assessment of health risk (Druet et al., 2008).

The effects of sex, age, race, and other diseases on body fat distribution have been examined. There are sex-specific differences in body fat distribution: in males, fat distribution is concentrated in the upper body, while in females, fat distribution is concentrated in the lower body. These sex-specific differences decrease in the sixth decade when many females experience menopause (Komiya et al., 1992; Shimokata et al., 1989b). However, many of these findings were obtained from studies which examined sex- and age-specific differences in waist to hip, waist to arm, and arm to thigh circumference ratios. There are limited studies of body fat distribution based on subcutaneous fat thickness measurements throughout the whole body, and there are only a very small number of studies in Japanese adults, such as a report by Komiya et al. (1992). This study measured subcutaneous fat thickness at as many as 14 sites throughout the whole body in Japanese adults, and these descriptive data are considered to be meaningful for the clarification of subcutaneous fat distribution characteristics in Japanese adults. Furthermore, a recent study reported that there was a non linear relationship between regional fat mass and visceral fat area (VFA), and these relationships differed by visceral obesity levels (Demura et al., 2008). These reports indicate that the relationships between subcutaneous, visceral and total fat may differ by obesity level and obesity type. Although subcutaneous fat thickness has been used as a simple human body composition assessment, it has not been sufficiently used in the prediction or diagnosis of health risk assessment. However, examination of its relationship with visceral and total fat, along with sex, age, obesity level, and obesity type, may provide another potential method for detecting health risks.

This study measured subcutaneous fat thickness at 14 sites, %BF, and VFA and aimed to clarify the sex-, age-, and obesity-level-specific regional subcutaneous fat characteristics and their relationships with total and visceral fat in Japanese adults.

## Methods

### *Subjects*

Subjects in this study were 302 Japanese adults (183 males and 119 females) ranging from 20 to 82 years of age. They were recruited from the general community and weight-loss programs. They all lived independently. Subjects were divided into two groups, nonobese (BMI$<$25 kg/m$^2$, NOG) and obese (BMI$\geq$25 kg/m$^2$, OG) based on the criteria for obesity in Japan (Examination Committee of Criteria for Obesity Disease in Japan, 2002). Their physical characteristics are shown in Table 1.

Anthropometric variables (height, body mass, and subcutaneous fat thicknesses at 14 sites), %BF, VFA were measured. %BF and VFA were measured by dual-energy x-ray absorptiometry (DEXA) and computed tomography (CT). All subjects were asked to complete these measurements within a week at the same time of day, as far as possible. All subjects were asked to fast for two hours prior to each measurement. Seventy-one persons among the subjects (39 males and 32 females) could not have VFA measured due to schedule conflicts. The study was approved by the Human Subject Ethical Committee of Kanazawa University, and informed consent was provided by each participant prior to participation in the study.

### *Subcutaneous fat thickness*

In keeping with previous studies (Komiya et al., 2002), subcutaneous fat thickness was measured at 14 sites with a B-mode ultrasonic instrument, EUB-200 (Hitachi Medical Co.). The sites were the right cheek, chin, chest 1 (diagonal fold just superior and lateral to the nipple), chest 2 (vertical fold on the midaxillary line at the level of the xiphoid process), abdomen, suprailiac, triceps, subscapular, back 1 (vertical fold just adjacent to and level with the vertebra prominence), back 2 (vertical fold just adjacent to the spinal column and at a level at and just below the arcus costalis), thigh 1 (vertical fold on the anterior aspect of the thigh midway between the superior aspect of the patella and anterior superior iliac spine), thigh 2 (vertical fold on the posterior aspect of the thigh), knee, and calf (vertical fold on the posterior aspect of the calf at the level of maximum circumference with the subject seated with lower leg dangling). A suitably trained tester measured the thickness of each site twice, and the mean value of these measurements was used for analysis. Intra-tester reliability (intra-class correlation coefficients) at each site was greater than 0.84.

**Table 1** Characteristics of study sample

| Variables | Male | Female |
|---|---|---|
| | Mean±SD | Mean±SD |
| | Non-obese group[a] | |
| Number | 107 | 67 |
| Age (years) | 38.5±14.5 | 40.4±17.2 |
| Height (cm) | 171.9±5.8 | 157.9±6.7 |
| Body mass (kg) | 66.0±7.5 | 53.1±6.4 |
| Body mass index (BMI, kg/m$^2$) | 19.8±4.4 | 21.2±2.6 |
| | Obese group[b] | |
| Number | 76 | 52 |
| Age (years) | 47.3±11.7 | 42.7±15.4 |
| Height (cm) | 169.5±6.1 | 156.1±6.3 |
| Body mass (kg) | 80.6±12.7 | 64.0±8.6 |
| Body mass index (BMI, kg/m$^2$) | 28.0±2.9 | 28.1±2.7 |
| | Total | |
| Number | 183 | 119 |
| Age (years) | 42.1±15.3 | 41.4±16.4 |
| Height (cm) | 170.9±6.1 | 157.1±6.6 |
| Body mass (kg) | 72.1±12.3 | 57.8±9.1 |
| Body mass index (BMI, kg/m$^2$) | 23.2±5.6 | 24.2±4.3 |

[a]: BMI$<$25 kg/m$^2$, [b]: BMI$\geq$25 kg/m$^2$

### *CT scan*

The VFA was measured at the umbilicus using CT scans (Somatom AR.C; Siemens, Erlangen, Germany) performed on subjects in a supine position. The VFA was calculated using a software program (FatScan; N2system, Osaka, Japan) (Yoshizumi et al., 1999). First, the subcutaneous fat layer was defined by tracing its contour on each scan, and then the range of CT values (in Hounsfield units) was calculated for fat tissue. Total fat area was determined by delineating the surface with a mean CT value±2 SD, and the VFA was measured by drawing a line within the muscle wall surrounding the abdominal cavity.

### *DEXA scan*

%BF was measured by DEXA (DPX-L; Lunar Radiation Corp., Madison, WI; whole body scanning, software version 1.3Z). In the DEXA measurement, a trained radiology technician performed the measurements on the subjects. DEXA measurements were performed following standard procedures, according to the manufacturer's guidelines, while the participant was lying in a supine position on a table. Whole body scanning time was 20 min, and total x-ray irradiation absorbed by a participant was 5 mrems or lower, which corresponds to 10% of a standard chest X-ray film.

### *Analyses*

#### *Relationships between subcutaneous fat distribution and sex, obesity level and aging*

To determine the relationships between subcutaneous fat distribution and sex, obesity level and age, 3-way ANOVA (2 sex groups: male and female, 2 obesity level groups: NOG and OG, and 5 age groups: 20s, 30s, 40s, 50s, and 60s and over) was applied to each subcutaneous fat thickness at 14 sites. Because this study is interested in examining sex-, age- and obesity-level differences at each area of subcutaneous fat thickness, the significance level for examining the main effect and the interaction in each area was set at $p=.05/14$ sites$=.00357$, compare with below.

*Relationships between total and visceral fat and subcutaneous fat thickness*

To examine the relationships between subcutaneous fat and total and visceral fat, the relationships between subcutaneous fat thickness and %BF and VFA were examined by Pearson's correlation coefficient for each sex and obesity level group. Compare with above, the significance level was set at $p=.05/14$ sites$=.00357$.

Furthermore, we examined the relationship between visceral fat and subcutaneous fat, considering the visceral fat level. Thus, we further divided the sample into the following four groups: nonobese (BMI$<25\,kg/m^2$) and nonviscerally obese (VFA$<100\,cm^2$) group (NO-NVOG, 45 males and 47 females), nonobese but viscerally obese (VFA$\geq 100\,cm^2$) group (NO-VOG, 24 males and 2 females), obese (BMI$\geq 25\,kg/m^2$) but nonviscerally obese (O-NVOG, 15 males and 22 females), and obese and viscerally obese (O-VOG, 60 males and 16 females). The Pearson's correlation coefficient between VFA and abdominal subcutaneous fat thickness was calculated for each group. Classifications of obesity level and visceral obesity were based on the criteria for obesity disease in Japan based on obesity-related complications (Examination Committee of Criteria for Obesity Disease in Japan, 2002).

## Results

*Relationships between subcutaneous fat distribution and Sex, Age, and Obesity Level*

Table 2 and Fig. 1 show the result of 3-way ANOVA for each subcutaneous fat thickness. There was no significant 3-way interaction (sex×obesity level×age group). Significant interactions between sex and age group and between sex and obesity level were found at all sites except for the knee.

In the NOG, significant sex differences in subcutaneous fat thickness were mainly found in the 30-year-old group, and subcutaneous fat thicknesses in the lower body were significantly greater in females than in males. In the OG, sex differences in subcutaneous fat thickness were found from 30 to 50 years of age, and subcutaneous fat thicknesses were significantly greater in females than males. Unlike the NOG, these significant sex differences were found in the entire body. Furthermore, in 20-year-old OG males, abdominal and chest 2 subcutaneous fat thicknesses were significantly greater than in females. Although significant sex differences were found in some areas (abdomen, suprailiac, chest, and triceps) in the 60s-or-older group, sex differences in subcutaneous fat thickness tended to decrease with aging.

Characteristics of obesity level differences in subcutaneous fat thicknesses differed with sex and age. In male groups, significant obesity level differences were found in the chin, chest, side chest, abdomen, suprailiac, back 1 (upper), back 2 (lower) only in the 20s and 30s age groups, and there were no significant differences in those over 40. On the other hand, in female groups, significant obesity level differences in the trunk and lower limbs were remarkably found in the 30s, 40s, and 50s, although there were no differences in the 20-year-old group.

Significant age differences were found in OG females, but not in NOG males and females. Subcutaneous fat thicknesses in the trunk significantly increased in 30-year-olds, and their increasing tendencies were not found subsequently, other than in the triceps and subscapular regions (in these areas, subcutaneous fat thickness in the 40-year-old group was significantly greater than in the 50s or 60s-or-older groups). Subcutaneous fat remarkably accumulated toward the abdomen and suprailiac.

*Relationship between subcutaneous fat thickness and %BF*

Figure 2 shows correlation coefficients between each subcutaneous fat thickness measurement and %BF for each sex and obesity level group. In NOG males, significant correlations were found in the upper body but not in the lower body except for the calf. In OG males, however, significant correlation was found only in the thigh (front), and the correlations in the upper body tended to be lower than those of the NOG. On the other hand, in the NOG females, significant correlations were found in the trunk (abdomen and subscapular) and lower limbs, but not in OG females except for the triceps and the thigh (back).

*Relationship between subcutaneous fat thickness and VFA*

Figure 3 shows correlation coefficients between each subcutaneous fat thickness and VFA for each sex and obesity level group. There were no significant correlations in both sex and obesity level groups. The correlation with abdominal subcutaneous fat thickness was highest in NOG males and females but was lowest in OG males and females.

Because this relationship differed with BMI level, this study further examined the relationship between VFA and abdominal subcutaneous fat thickness. In Japan, VFA$=100\,cm^2$ is used as a criterion for assessing visceral obesity, based on the criteria approved by the Examination Committee of Criteria for Obesity Disease in Japan (2002). We divided the study sample into the four groups by obesity level (BMI level) and obesity type (visceral obesity) as described earlier, and calculated the correlation coefficient between VFA and abdominal subcutaneous fat thickness for each group. Because the NO-VOG female sample was small ($n=2$), correlation analysis was not conducted for this group. Although significant and moderate correlation coefficients were obtained in NO-NVOG male and female groups (male: $r=.474$, $p<.00357$; female:

**Table 2** The results of 3-way (sex, age, and obesity level) ANOVA for each subcutaneous fat thickness

| 3 way-ANOVA Factor | | Cheek | Chin | Triceps | Chest 1 | Chest 2 (side) | Sub-scapla | Back 1 (upper) | Abdo-men | Suprail-iac | Back 2 (lower) | Thigh (front) | Thigh (back) | Knee | Calf |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | F (1,278) | 41.9* | 28.3* | 165.8* | 9.1* | 18.8* | 33.4* | 29.8* | 8.9* | 47.5* | 25.6* | 67.2* | 61.2* | 39.5* | 115.4* |
| | $^{\dagger}\eta^2$ | 0.131 | 0.092 | 0.374 | 0.032 | 0.063 | 0.107 | 0.097 | 0.031 | 0.146 | 0.084 | 0.195 | 0.180 | 0.124 | 0.293 |
| | $p$ | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Obesity level | F (1,278) | 2.9 | 1.1 | 5.7* | 5.0* | 1.9 | 1.8 | 3.0 | 4.6* | 5.5* | 5.2* | 1.3 | 3.2 | 4.1* | 3.6 |
| | $^{\dagger}\eta^2$ | 0.114 | 0.135 | 0.206 | 0.107 | 0.173 | 0.130 | 0.172 | 0.261 | 0.204 | 0.175 | 0.064 | 0.049 | 0.023 | 0.068 |
| | $p$ | 0.022 | 0.340 | 0.000 | 0.001 | 0.111 | 0.130 | 0.019 | 0.001 | 0.000 | 0.000 | 0.270 | 0.014 | 0.003 | 0.007 |
| Age group | F (4,278) | 35.8* | 43.3* | 72.0* | 33.3* | 58.1* | 41.7* | 57.9* | 98.3* | 71.1* | 58.8* | 19.0* | 14.4* | 6.5 | 20.2* |
| | $^{\dagger}\eta^2$ | 0.040 | 0.016 | 0.076 | 0.067 | 0.027 | 0.025 | 0.041 | 0.062 | 0.073 | 0.070 | 0.018 | 0.044 | 0.055 | 0.049 |
| | $p$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.011 | 0.000 |
| Sex×Age group# | F (4,278) | 35.8* | 43.3* | 72.0* | 33.3* | 58.1* | 41.7* | 57.9* | 98.3* | 71.1* | 58.8* | 19.0* | 14.4* | 6.5 | 20.2* |
| | $^{\dagger}\eta^2$ | 0.030 | 0.030 | 0.101 | 0.039 | 0.097 | 0.052 | 0.051 | 0.095 | 0.106 | 0.064 | 0.017 | 0.026 | 0.048 | 0.024 |
| | $p$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.011 | 0.000 |
| Sex×Obesity level# | F (1,278) | 35.8* | 43.3* | 72.0* | 33.3* | 58.1* | 41.7* | 57.9* | 98.3* | 71.1* | 58.8* | 19.0* | 14.4* | 6.5 | 20.2 |
| | $^{\dagger}\eta^2$ | 0.002 | 0.000 | 0.055 | 0.003 | 0.002 | 0.016 | 0.008 | 0.001 | 0.010 | 0.006 | 0.015 | 0.007 | 0.021 | 0.012 |
| | $p$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.011 | 0.000* |
| Obesity level×Age group# | F (4,278) | 0.6 | 0.8 | 3.7 | 2.0 | 0.8 | 1.9 | 2.3 | 1.1 | 2.3 | 0.7 | 1.2 | 1.8 | 1.9 | 1.4 |
| | $^{\dagger}\eta^2$ | 0.008 | 0.012 | 0.050 | 0.028 | 0.011 | 0.027 | 0.032 | 0.015 | 0.032 | 0.010 | 0.017 | 0.025 | 0.027 | 0.020 |
| | $p$ | 0.668 | 0.500 | 0.006 | 0.096 | 0.532 | 0.106 | 0.057 | 0.373 | 0.061 | 0.595 | 0.311 | 0.135 | 0.111 | 0.220 |
| Sex×Obesity level×Age level# | F (4,278) | 0.6 | 0.8 | 3.7 | 2.0 | 0.8 | 1.9 | 2.3 | 1.1 | 2.3 | 0.7 | 1.2 | 1.8 | 1.9 | 1.4 |
| | $^{\dagger}\eta^2$ | 0.019 | 0.014 | 0.079 | 0.013 | 0.055 | 0.035 | 0.028 | 0.086 | 0.061 | 0.029 | 0.040 | 0.009 | 0.049 | 0.019 |
| | $p$ | 0.668 | 0.500 | 0.006 | 0.096 | 0.532 | 0.106 | 0.057 | 0.373 | 0.061 | 0.595 | 0.311 | 0.135 | 0.111 | 0.220 |

Multiple comparisons

| Factor | Group | Level | Cheek | Chin | Triceps | Chest 1 | Chest 2 (side) | Sub-scapla | Back 1 (upper) | Abdo-men | Suprail-iac | Back 2 (lower) | Thigh (front) | Thigh (back) | Knee | Calf |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | NOG | 20s | | | $a_1$ | | | | | | | | $a_1$ | | | $a_1$ |
| | | 30s | | | $a_1$ | | | | | | $a_1$ | $a_1$ | $a_1$ | $a_1$ | $a_1$ | $a_1$ |
| | | 40s | | | $a_1$ | | | | | | | | | | | |
| | | 50s | | | | | | | | | $a_1$ | | | | | |
| | | 60s | | | | | | | | | | | | | | $a_1$ |
| | OG | 20s | | | | | $a_2$ | | | $a_2$ | | | | | | |
| | | 30s | $a_1$ | | $a_1$ | | | $a_1$ | $a_1$ | | | $a_1$ | $a_1$ | | $a_1$ | $a_1$ |
| | | 40s | | | $a_1$ | | $a_1$ | $a_1$ | $a_1$ | | $a_1$ | $a_1$ | $a_1$ | $a_1$ | $a_1$ | $a_1$ |
| | | 50s | $a_1$ | $a_1$ | $a_1$ | | $a_1$ | | | $a_1$ | $a_1$ | | $a_1$ | $a_1$ | $a_1$ | $a_1$ |
| | | 60s | | | $a_1$ | | $a_1$ | | | $a_1$ | $a_1$ | | | | | $a_1$ |
| Obesity level | Male | 20s | | $b_1$ | | $b_1$ | $b_1$ | | | $b_1$ | $b_1$ | | | | | |
| | | 30s | | | | $b_1$ | $b_1$ | | $b_1$ | $b_1$ | $b_1$ | $b_1$ | | | | |
| | | 40s | | | | | | | | | | | | | | |
| | | 50s | | | | | | | | | | | | | | |
| | | 60s | | | | | | | | | | | | | | |
| | Female | 20s | | | | | | | | | | | | | | |
| | | 30s | $b_1$ | | | $b_1$ | $b_1$ | | $b_1$ | | | $b_1$ | | | | |
| | | 40s | | | $b_1$ | | $b_1$ | $b_1$ | $b_1$ | | $b_1$ | $b_1$ | $b_1$ | | | |
| | | 50s | | | $b_1$ | | | $b_1$ | | | | | $b_1$ | $b_1$ | $b_1$ | |
| | | 60s | | | | | $b_1$ | | | $b_1$ | $b_1$ | | | | | |
| Age group | Female | NOG | | | | | | | | | | | | | | |
| | | OG | | | | | | | | | | | | | | |
| | Male | NOG | $c_2$ | | | | | | | | | | | | | |
| | | OG | $c_1$ | | $c_3$, $c_{10}$ | $c_1$ | $c_6$ | $c_5$,$c_9$ | $c_3$ | $c_7$ | $c_8$ | $c_1$ | | | $c_4$ | |

Significant level was set at $p=0.005/14$ sites$=0.00357$; *: $p<0.00357$; †: partial $\eta^2$; #: Interaction;
NOG: non-obese group (BMI$<$25 kg/m$^2$) OG: obesity group (BMI$\geq$25 kg/m$^2$)
$a_1$: male$<$female; $a_2$: male$>$female; $b_1$: non-obesity$<$obesity;
$c_1$: 20s$<$30s; $c_2$: 20s$<$50s; $c_3$: 20s$<$30s, 40s; $c_4$: 20s$<$30s, 50s; $c_5$: 20s$<$40s, 50s; $c_6$: 20s$<$30s, 40s, 60s; $c_7$: 20s$<$30s, 50s, 60s;
$c_8$: 20s$<$30s, 40s, 50s, 60s; $c_9$: 40s$>$60s; $c_{10}$: 40s$>$50s, 60s.

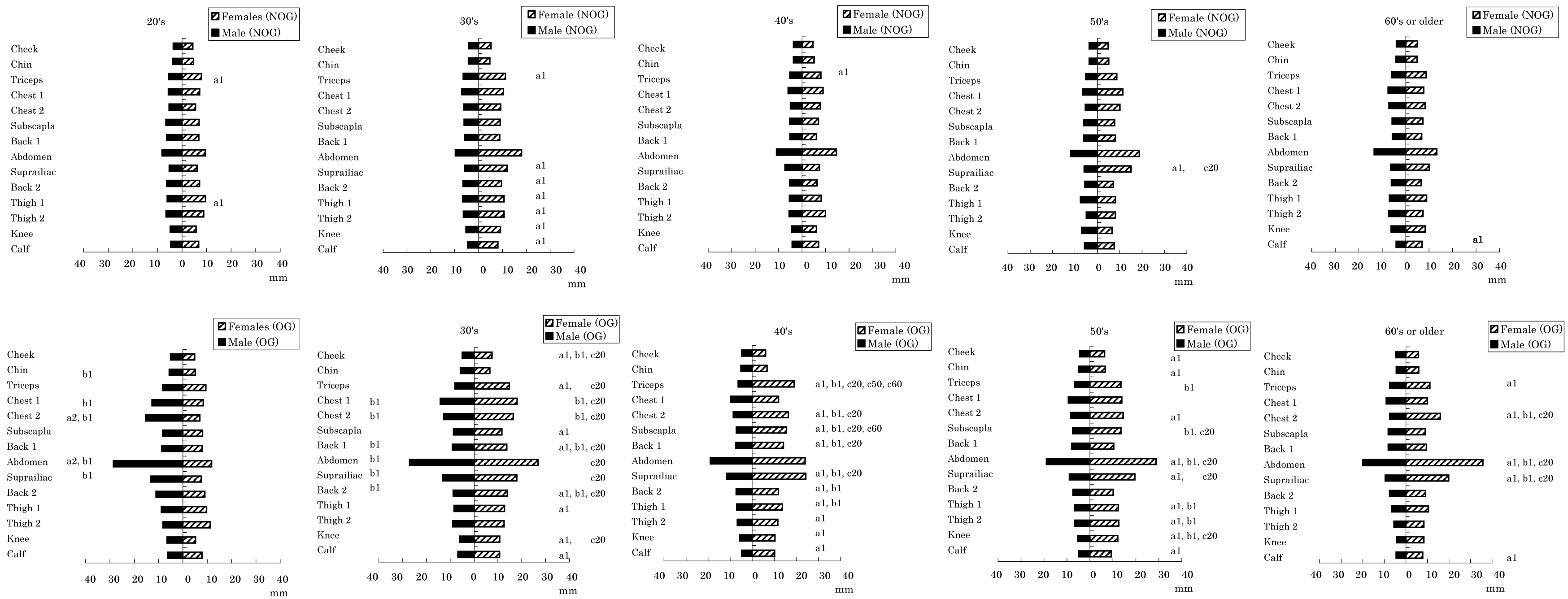


**Fig. 1** Sex, age, and obesity level differences in subcutaneous fat thickness.

$a_1$: male<female; $a_2$: male>female; $b_1$: nonobese<obese; c20, c50, c60: Subcutaneous fat thickness in the age group was significantly greater than the 20s, 50s, 60s groups, respectively.

The significant level was set at $p$=.05/14=.00357.

Sample size of each age group in nonobese subjects; males, 20s: n=41, 30s: n=23, 40s: n=14, 50s: n=12, 60s and older: n=17; females, 20s: n=23, 30s: n=13, 40s: n=8, 50s: n=13, 60s or older: n=10.

Sample size of each age group in obese subjects; males, 20s: n=8, 30s: n=14, 40s: n=16: 50s: n=23, 60s and older: n=15; females, 20s: n=13, 30s: n=10, 40s: n=8, 50s: n=13, 60s or older: n=8.

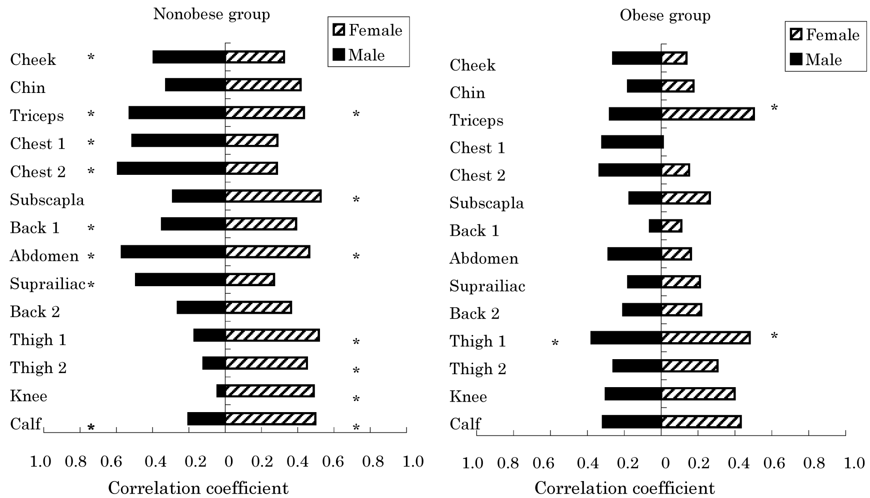


**Fig. 2** Relationships between subcutaneous fat thickness and %BF for each sex and obesity group.
This figure shows the correlation coefficients between each subcutaneous fat thickness and %BF for each sex and obesity group. *: $p<.00357$. Sample size of each group: nonobese males: n=107, nonobese females: n=67, obese males: n=76, obese females: n=52.

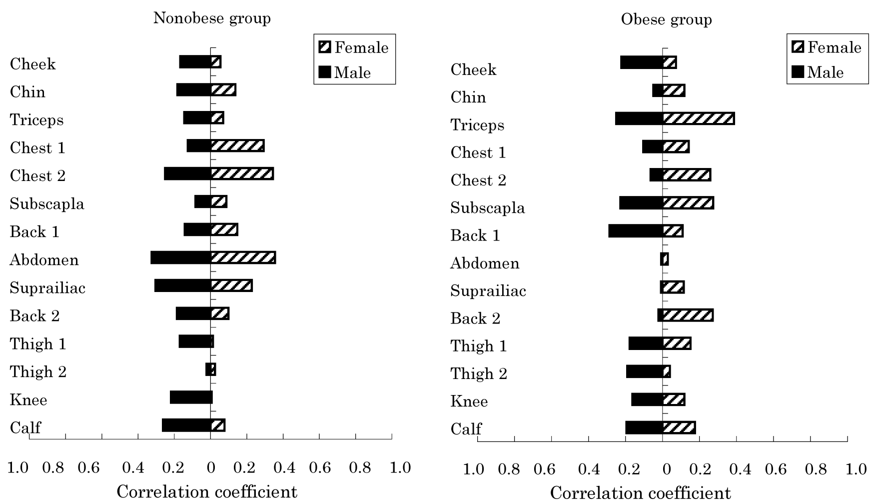


**Fig. 3** Relationships between subcutaneous fat thicknesses and VFA.
This figure shows the correlation coefficients between each subcutaneous fat thickness and VFA for each sex and obesity group. There were no significant relationship. Sample size of each group: nonobese males: n=107, nonobese females: n=67, obese males: n=76, obese females: n=52.

r=.417, $p<.00357$), there were no significant correlations in other groups. The correlations in visceral obesity groups (NO-VOG males: r=−.068, $p>.00357$; O-VOG males: r=.291, $p>.00357$; and O-VOG females: r=−.327, $p>.00357$) were less than those in the NO-NVOG.

## Discussion

This study examined sex-, age-, and obesity-level characteristics in subcutaneous fat thickness and their distribution from the measurements of whole body subcutaneous fat thicknesses at as many as 14 sites in a population with broad ranges of age and obesity levels.

Previous studies have reported that sex hormones influence sex- and age-specific characteristics in subcutaneous fat distribution (Borkan et al., 1983; Lanska et al., 1985; Refuffe-Scrive, 1986; Shimokata et al., 1989ab; Forbes, 1990; Wang et al., 1994; Wardle et al., 1996). Thus, subcutaneous fat thickness is greater in females than in males, and females have a relatively greater subcutaneous fat accumulation in the lower body. Further, there is redistribution of body fat after menopause, and body fat increases toward the upper and central body. However, this study found marked sex- and age-specific differences in subcutaneous fat thickness in the non obese population. Sex- and age-specific characteristics, such as greater subcutaneous fat accumulation in females, and subcutaneous fat accumulation toward the upper and central body with aging, were recognized in the obese population, but lower body accumulation of subcutaneous fat was only found in thirties nonobese females in their 30s. Therefore, although sex hormones influence subcutaneous fat accumulation, subcutaneous fat tends to accumulate toward the central body with increasing obesity level, irrespective of sex.

Furthermore, in this study, marked subcutaneous fat accumulation in the obese population was found until the thirties in obese males but this occurred at later ages (30s and older) in females. Previous studies have reported that the trend toward increasing central body fat distribution is especially true in Japanese adults (Forbes, 1990; Wang et al., 1994; Wardle et al., 1996). Considering these indicates that this result might relate to the sex differences in typical obesity type, "abdominal obesity" for males and "subcutaneous obesity" for females.

On the other hand, this study did not obtain detailed personal data regarding lifestyle and menopause. There is a possibility that information about menopause could provide more detailed characteristics of age differences in body fat distribution. Furthermore, although differences in lifestyle (exercise and dietary habits) influence body fat accumulation, this study could not control for lifestyle characteristics among sex and age groups. Therefore, our results should be interpreted based on these limitations. Further studies could more clearly determine sex- and age-specific characteristics in subcutaneous fat distribution by controlling these conditions.

From the results of correlation analysis between subcutaneous fat thickness and total and visceral fat, the contribution of subcutaneous fat to total body fat declines with increasing obesity level, and there is no relationship between subcutaneous and visceral fat accumulation. However, there was little relationship between abdominal subcutaneous fat and VFA in the viscerally obese population rather than the non viscerally obese population. This may suggest the following possibility. Although subcutaneous and visceral fat increase with increasing obesity level, there may be a limitation in the capacity for subcutaneous fat accumulation which is dependent on sex and race, and accumulation of visceral fat may progress more when this capacity is exceeded. Demura and Sato (2008) reported a nonlinear relationship between VFA and fat mass in the trunk, and subcutaneous fat increases with visceral fat at low obesity levels. However, accumulation of subcutaneous fat is suppressed and that of visceral fat is advanced when subcutaneous fat progresses to a certain level. Other previous studies reported that there are many noninsulin-dependent diabetic patients among Japanese-Americans (Bergstrom et al., 1990; Kato-Palmer et al., 1988) though the BMI criterion for obesity is lower in Japanese than Westerners (Examination Committee of Criteria for Obesity Disease in Japan, 2002). Furthermore, Asian women are known to have a larger amount of abdominal fat for the same level of BMI compared with Caucasian and African-American women (Hwang et al., 2008). Thus, the Japanese population may differ in the capacity for subcutaneous fat accumulation compared to Westerners, and the Japanese population may have metabolic characteristics where visceral fat accumulates easily at lower obesity levels.

Subcutaneous fat thickness has been mainly used as a simple predictor of body density or %BF. However, according to one assumption, there is a capacity for subcutaneous fat accumulation and this capacity closely relates to visceral fat accumulation. This suggests another potential for subcutaneous fat assessment in health risk assessment, by proposing an indicator of subcutaneous fat (such as abdominal subcutaneous fat, total subcutaneous fat, or subcutaneous fat in the trunk) when visceral fat accumulation progresses. However, our study included only two participants who weighed over 100 kg, and the sample size of viscerally obese females was also small. Therefore, application of these results is limited to the clarification of the relationship between subcutaneous and visceral fat accumulation. Further examinations of more obese Japanese participants and other races are necessary.

## Conclusion

Subcutaneous fat in Japanese adults accumulates toward the central body with increasing obesity level irrespective of sex. This trend is remarkable until the thirties in males but occurs at later ages (30s or older) in females. This difference may relate to the sex differences in obesity type. On the other hand, it is possible that there may be a limitation in the capacity for subcutaneous fat accumulation which is dependent on sex and race, and the capacity may closely relate to visceral fat accumulation. These findings may suggest another potential method for the evaluation of subcutaneous fat in health risk assessment.

## References

Bergstrom RW, Newell-Morris LL, Leonetti DL, Shuman WP, Wahl PW, Fujimoto WY (1990) Association of elevated fasting C-peptide level and increased intra-abdominal fat distribution with development of NIDDM in Japanese–American men. Diabetes 39: 104–111

Borkan GA, Hults DE, Gerzof SG, Robbins AH, Silbert CK (1983) Age changes in body composition revealed by computed tomography. J Gerontol 38: 673–677

Demura S, Sato S (2008) Nonlinear relationships between visceral fat area and percent regional fat mass in the trunk and the lower limbs in Japanese adults. Eur J Clin Nutr 62: 1395–1404 [Epub 2007 Sep 5]

Druet C, Baltakse V, Chevenne D, Dorgeret S, Zaccaria I, Wang Y, Levy-Marchal C (2008) Independent effect of visceral adipose tissue on metabolic syndrome in obese adolescents. Horm Res 70: 22–28

Examination Committee of Criteria for 'Obesity Disease' in Japan, Japan Society for the Study of Obesity (2002) New Criteria for 'Obesity Disease' in Japan. Circ J 66: 987–992

Forbes GB (1990) The abdomen: hip ratio. Normative data and observation on selected patients. Int J Obes 14: 149–157

Fujioka S, Matsuzawa Y, Tokunaga K, Tarui S (1987) Contribution of intra-abdominal fat accumulation to the impairment of glucose and lipid metabolism in human obesity. Metabolism 36: 54–59

Hwang MJ, Chung WS, Gallagher D, Kim DY, Shin HD, Song MY (2008) How useful is waist circumference for assessment of abdominal obesity in Korean pre-menopausal women during weight loss? Asia Pac J Clin Nutr 17: 229–234

Kato-Palmer S, Madison RE, Lipson LG. (1988) Diabetes in older Japanese Americans. Gerontologist 28: 234A

Komiya S, Eto C, Otoki K, Teramoto K, Shimizu F, Shimamoto H (2002) Gender differences in body fat of low- and high-body-mass children: relationship with body mass index. Eur J Appl Physiol 82: 16–23

Komiya S, Muraoka Y, Zhang FS, Masuda T (1992) Age-related changes in body fat distribution in middle-aged and elderly Japanese. J Anthropol Soc Nippon 100: 161–169

Lanska DJ, Lanska MJ, Hartz AJ, Rimm AA (1985) Factors influencing anatomic location of fat tissue in 52,953 women. Int J Obes 9: 29–38

Larsson B, Bengtsson C, Björntorp P, Lapidus L, Sjöström L, Svärdsudd K, Tibblin G, Wedel H, Welin L, Wilhelmsen L (1992) Is abdominal body fat distribution a major explanation for the sex difference in the incidence of myocardial infarction? The study of men born in 1913 and the study of women, Göteborg, Sweden. Am J Epidemiol 135: 266–273

Rebuffe-Scrive M, Eldh J, Hafstrom L-O, Bjorntorp P (1986) Metabolism of mammary, abdominal and femoral adipocytes in women before and after menopause. Metabolism 35: 792–797

Shimokata H, Andres R, Coon PJ, Elahi D, Muller D, Tobin JD (1989a) Studies in the distribution of body fat. II. Longitudinal effects of change in weight. Int J Obes 13: 455–464

Shimokata H, Tobin JD, Muller DC, Elahi D, Coon PJ, Andres R (1989b) Studies in the distribution of body fat. I. Effects of age, sex, and obesity. J Gerontol 44: M66–73

Wang J, Thornton J C, Russell M, Burastero S, Heymsfield S, Pierson RN (1994) Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. Am J Clin Nutr 60: 23–28

Wardle J, Wrightson K, Gibson L (1996) Body fat distribution in South Asian women and children. Int J Obes 20: 267–271

Yoshizumi T, Nakamura T, Yamane M, Islam AH, Menju M, Yamasaki K, Arai T, Kotani K, Funahashi T, Yamashita S, Matsuzawa Y (1999) Abdominal fat: standardized technique for measurement at CT. Radiology 211: 283–286

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