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Subcutaneous Fat Mass in Japanese Young Children

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Abstract

The risk of excess fat appears to be greater in individuals who have larger subcutaneous fat measurements during childhood. However, the development of a subcutaneous fat mass (SFM) is difficult to define because it is generally difficult to measure directly. The purpose of this study was to investigate SFM in young children by measurement of anthropometric variables. The objectives of the study were to examine the differences in SFM between boys and girls, and the interrelationships between SFM and other anthropometric indices (e.g. skin-folds and skin-fold ratios) or total body fat mass (TBFM), in a homogeneous group of healthy young children. SFM was determined from anthropometric measurements, and TBFM by bioelectrical impedance analysis, in a sample of 141 boys and 139 girls, aged between 3 - 6 years. For each sex, the "normal-weight" group was defined based on a body mass index lying between the 25th and 75th percentiles. Sixty-nine boys (weighing 17.2 ± 2.6 kg) and 70 girls (weighing 16.7 ± 1.9 kg) were designated as being in the normal-weight groups. The normal-weight girls had significantly thicker skin-fold than the normal-weight boys: extremity skin-fold (37.9 ± 5.2 vs. 35.0 ± 6.0 mm, $p < 0.01$) and trunk skin-fold (19.3 ± 4.1 vs. 17.1 ± 3.2 mm, $p < 0.001$). Absolute SFM was higher in normal-weight girls than in normal-weight boys (1.4 ± 0.4 vs. 1.2 ± 0.4 kg, $p < 0.01$). Of all the anthropometric variables, the extremity skin-fold showed the strongest correlation with SFM for the normal-weight boys ($r = 0.819$, $p < 0.001$), while the trunk skin-fold showed the strongest correlation for the normal-weight girls ($r = 0.807$, $p < 0.001$). The SFM was related independently to TBFM after controlling for each anthropometric variable. The regression slopes between SFM and TBFM were not statistically different (0.251 kg SFM/kg TBFM in boys and 0.290 kg SFM/kg TBFM in girls) for either sex. It can be concluded that there are no differences in TBFM or internal fat mass between normal-weight boys and girls, whereas, in contrast, sex differences in SFM are evident. The rate of increase in SFM relative to TBFM appears to be similar for both groups.

Key words: body mass index, anthropometrics, skin-fold, subcutaneous fat mass

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Introduction

There is considerable interest in the ontogeny of "fat patterning", because a "centripetal" distribution of subcutaneous adipose tissue, in which skin-fold thickness on the trunk is relatively

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greater than that on the limbs, is associated with an increased risk of diabetes, cardiovascular disease and hypertension in adulthood[1][2][3][4][5].

The risk of excess fat appears to be greater in individuals who have larger subcutaneous fat measurements during childhood[6]. Several reports have appeared correlating serial measurements of skin-fold thickness in individuals from childhood to maturity[7][8]. Skin-folds at the subscapular and suprailiac sites were found to increase in thickness relative to the skin-fold thickness at the triceps in each sex in late childhood, possibly coincident with pubescence or with maturation of the adrenal gland[9]. These increases occurred at a younger age in girls than in boys[10]. However, little is known regarding patterns of change in the distribution of adipose tissue within individuals , particularly with respect to maturation events such as puberty and the menopause. Cross-sectional analyses indicate that adipose tissue is distributed peripherally in most children, irrespective of sex, prior to adolescence[10].

The fat in adipose tissue is highly labile and large changes may occur over a short period of time. These changes are associated with diet, level of exercise and emotional state. With an obese child, the main problem is to estimate the fat content and distribution accurately, and to determine whether it poses a health risk. Simple weight excess evaluation, as well as the commonly used anthropometric indices (body mass index, BMI; waist to hip ratio, WHR), do not seem to be accurate enough for this purpose in children[11]. Moreover, errors in the measurement of skin-fold thickness using calipers can be large and may increase with increasing levels of adiposity[12]. The development of subcutaneous adipose tissue in young children is difficult to define because it is generally difficult to measure directly by computed tomography (CT) or magnetic resonance imaging (MRI). As a result, patterns of change in adipose tissue distribution may be complex and difficult to measure accurately. Current information on the link between fat distribution in childhood and health problems later in life is limited to the measurement of fat distribution using crude anthropometric indices. Previous studies are limited by a lack of understanding of the relationship between subcutaneous adipose tissue content and anthropometric indices.

The objectives of this study were to examine gender differences in subcutaneous fat mass (SFM), and the interrelationships between SFM and other anthropometric indices (e.g. skin-fold thickness and skin-fold ratios) or total body fat mass (TBFM) in a homogeneous group of healthy young children.

Subjects and methods

Subjects

During October and November 1998, 280 healthy children (141 boys and 139 girls) attending three kindergartens in different parts of Fukuoka were examined. For each sex, the "normal-weight" group was defined based on a BMI between the 25th and 75th percentiles. Sixty-nine (48.9%) boys and 70 (50.4%) girls were designated as belonging to the "normal-weight groups", respectively. All parents of the children gave their written informed consent to participate in the study after receiving a detailed explanation of the purpose and risks involved.

Measurement of anthropometry and total body composition by bioelectrical impedance analysis (BIA)

Height was measured to the nearest 0.1 cm. Body weight was measured to the nearest 0.02 kg on a calibrated balance-beam scale with subjects wearing light underwear. BMI was calculated as weight/height^2, where weight is expressed in kg and height in m. Abdominal and hip circumferences were measured with a metric plastic tape while the children stood upright. Abdominal circumference was measured at the level of the umbilicus, and hip circumference was recorded at the maximum gluteal protuberance of the buttocks. The WHR was calculated as waist circumference/hip circumference. Skin-fold measurements were obtained using Harpenden skin-fold calipers (British Indicators, England) at the right cheek, chest 1 (diagonal fold just superior and lateral to the nipple), chest 2 (vertical fold on the mid-axillary line at the level of the xiphoid process), abdomen, suprailiac, triceps, scapula, back 1 (vertical fold just adjacent to, and level with, the vertebra prominens), back 2 (vertical fold just adjacent to the spinal column and level with, 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, calf (vertical fold on the posterior aspect of the calf at the level of maximum circumference, subject seated with lower leg dangling) and chin sites (those used by Komiya and others, 1992[13]). All anthropometric measurements were performed by the same researcher and are presented here as the mean of three measurements.

TBFM and lean body mass (LBM) were estimated from total body resistance measured with a tetrapolar bioelectrical-impedance analyser (TP-95K, Toyo Physical, Inc., Fukuoka, Japan) as described previously[14]. Since bioelectrical-impedance analysis (BIA) and total body water (TBW by $H_2{}^{18}O$ dilution) data showed a very close correlation in 4- to 6-year-old children[15], we feel justified in taking BIA data as a measure of body composition in children. Goran and others (1993)[15] suggested that the Kushner equation (1992)[16] for TBW can be transformed into an equation for LBM by using published age- and gender-specific constants for the hydration of LBM in children[17]: hydration of LBM = 76.9 − 0.25 age (yr) − 1.9 gender where girls equals 0 and boys equals 1. The equation provides an estimate for LBM :

$$\text{LBM (kg)} = [(ht^2/R)*0.59 + (wt*0.065) + 0.04] / [0.769 - (0.0025*age) - (0.019*gender)]$$

where ht is the subject's height (cm), R is the body's resistance (ohm), wt is the subject's body weight (kg), age in years, and gender is 0 for girls and 1 for boys. TBFM was obtained by subtracting LBM from total body weight. The percentage body fat (%fat) was calculated from the TBFM by dividing by total body weight.

Measurement of SFM and internal fat mass

SFM was calculated by measuring skin-fold thickness at 14 sites and using a modification of the equation derived by Skerjl and others (1953)[18] and Davies and others (1986)[19]. The main modifications of the equation in the present study were the introduction of (1) mean thickness of adipose tissue over body surface / 2 and (2) skin weight.

$$\text{SFM (g)} = [\text{mean thickness of adipose tissue over body surface (cm)} / 2 * \text{body surface area (cm}^2) * \text{density of fat (g/cm}^3)] - \text{skin weight (g)}$$

Body surface area was calculated using the equation of Fujimoto and others (1968)[20]. The density of fat was taken as 0.900 g/cm^3 [21]. Skin weight was calculated from body weight using the equation of Satake and Ozaki (1991)[22]. Subcutaneous fat distribution was estimated from the ratio of trunk skin-fold (sum of chest 1, chest 2 and abdomen) to extremity skin-fold (triceps, thigh 1 and calf). Internal fat mass (IFM) was calculated as the difference between TBFM and SFM.

Statistical analyses

All statistical analyses (calculation of percentiles, regression analyses, statistics) were performed using Excel 98 and StatView J-4.5. Variables are presented as means ± standard deviations. Sex-related differences between variables were tested by Student's *t*-test for unpaired data after analysis of variance. Pearson correlation and partial correlation coefficients were used to assess the relationship between SFM and various anthropometric indices (e.g. BMI, TBFM, IFM and skin-folds). Differences with *p* values less than 0.05 were considered significant.

Results

The physical characteristics and body composition data for all boys ($n = 141$) and girls ($n = 139$) in the study, and boys ($n = 69$) and girls ($n = 70$) based on a BMI between the 25th and 75th percentile (normal-weight groups), are shown in Table 1. There were no significant differences between the boys and girls in this study for any of the variables listed in Table 1. The %fat was significantly higher for the girls in the normal-weight group, although the BMI was significantly lower in this group. The normal-weight girls had significantly thicker skin-fold than normal-weight boys: extremity skin-fold (37.9 ± 5.2 vs. 35.0 ± 6.0 mm, $p < 0.01$) and trunk skin-fold (19.3 ± 4.1 vs. 17.1 ± 3.2 mm, $p < 0.001$). Absolute SFM was higher in normal-weight girls than in normal-weight boys (1.4 ± 0.4 vs. 1.2 ± 0.4 kg, $p < 0.01$).

There were no significant differences in the TBFM, IFM or trunk-to-extremity skin-fold ratio. In addition, abdominal circumference, hip circumference and WHR were similar in both groups.

SFM correlated strongly with TBFM in normal-weight boys ($r = 0.506$, $p < 0.001$) and in normal-weight girls ($r = 0.546$, $p < 0.001$), and SFM and %fat in normal-weight girls also correlated ($r = 0.352$, $p < 0.01$), as shown in Table 2. However, the correlation coefficients between SFM and IFM were not significant for either group.

The correlation coefficients for SFM or TBFM and simple anthropometric variables, and the partial correlation coefficients between SFM and TBFM after adjustment for each anthropometric variable, are shown in Table 3. SFM correlated with all of the anthropometric variables except WHR for both sexes, and with trunk/extremity skin-fold ratio in normal-weight boys. Of all the anthropometric variables measured for normal-weight boys, the extremity skin-fold showed the strongest correlation with SFM ($r = 0.819$, $p < 0.001$), while the trunk skin-fold showed the strongest correlation for normal-weight girls ($r = 0.807$, $p < 0.001$). Furthermore, the index of body fat distribution in common use, trunk/extremity skin-fold ratio, was only related to SFM for normal-weight girls ($r =$

Table 1. Physical characteristics, body composition and body fat distribution for total children and children based on BMI mached between 25 and 75%ile.

	Total		25～75%ile		
	Boys N=141 Mean ±S.D.	Girls N=139 Mean ±S.D.	Boys n=69 Mean ±S.D.	Girls n=70 Mean ±S.D.	P value
Age, yr	5.0 ±0.9	5.0 ±0.9	4.9 ±0.9	4.8 ±0.8	
Height, cm	106.0 ±07.1	105.5 ±6.6	105.2 ±7.5	104.4 ±6.3	
Weight, kg	17.6 ±3.1	17.2 ±2.6	17.2 ±2.6	16.7 ±1.9	
BMI, kg/m^2	15.6 ±1.3	15.4 ±1.2	15.4 ±0.4	15.2 ±0.4	0.0128
Abdominal circumference, cm	48.6 ±3.9	48.9 ±3.3	48.2 ±2.7	48.2 ±2.1	
Hip circumference, cm	54.4 ±4.3	54.8 ±3.9	53.8 ±3.2	53.9 ±2.7	
WHR	0.90 ±0.04	0.89 ±0.04	0.90 ±0.04	0.89 ±0.03	
Trunk skinfold, mm	18.5 ±6.9	20.4 ±6.4	17.1 ±3.2	19.3 ±4.1	0.0007
Extremity skinfold, mm	36.6 ±9.4	39.3 ±7.2	35.0 ±6.0	37.9 ±5.2	0.0035
Trunk/extremity skinfold ratio	0.50 ±0.09	0.52 ±0.10	0.50 ±0.08	0.51 ±0.09	
Total body fat mass by BIA, kg	3.1 ±1.3	3.4 ±1.2	2.9 ±0.9	3.1 ±0.8	
Subcutaneous fat mass, kg	1.3 ±0.9	1.5 ±0.7	1.2 ±0.4	1.4 ±0.4	0.0051
Internal fat mass, kg	1.8 ±0.8	1.8 ±0.8	1.7 ±0.7	1.7 ±0.7	
%Fat	17.5 ±5.2	19.4 ±5.4	16.8 ±4.3	18.5 ±4.4	0.0245

There are no significant differences by t-test between the total boys and girls.

Table 2. Correlation coefficients among the four adiposity indices in children based on BMI machedbetween 25 and 75%ile.

	Subcutaneous fat mass	*Internal fat mass*	*Total body fat mass*	*Percentage of body fat*
SFM	—	*0.023*	*0.506****	*0.162*
IFM	*0.019*	—	*0.872****	*0.882****
TBFM	*0.546****	*0.846****	—	*0.834***
%Fat	*0.352***	*0.835****	*0.888****	—

*upper; Boys, lower; Girls **p<0.01, ***p<0.001*

Table 3. Correlations between SFM or TBFM and simple anthropometric variables, and partial correlations between SFM and TBFM after adjustment for each anthropomentric variable for children based on BMI machedbetween 25 and 75%ile.

	Correlation with SFM		*Correlation with TBFM*		*Partial Correlation between SFM and TBFM Adjusted for Anthropometric Variables*	
	Boys	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
Age	*0.512****	*0.308***	*0.357***	*0.120*	*0.403****	*0.539****
Height	*0.619****	*0.392***	*0.409****	*0.306**	*0.353***	*0.487****
Weight	*0.677****	*0.472****	*0.424****	*0.347***	*0.328***	*0.462****
BMI	*0.483****	*0.271**	*0.165*	*0.119*	*0.493****	*0.538****
Abdominal circumference	*0.622****	*0.536****	*0.392****	*0.369***	*0.364***	*0.443****
Hip circumference	*0.585****	*0.561****	*0.360***	*0.505***	*0.390***	*0.368***
WHR	*0.010*	*0.116*	*0.010*	*0.220*	*0.506****	*0.537****
Chest1 skinfold	*0.555****	*0.698****	*0.215*	*0.202*	*0.476****	*0.578****
Chest2 skinfold	*0.666****	*0.722****	*0.264**	*0.389***	*0.459****	*0.415****
Abdominal skinfold	*0.637****	*0.679****	*0.338***	*0.229*	*0.401****	*0.547****
Triceps skinfold	*0.542****	*0.538****	*0.162*	*0.243**	*0.504****	*0.507****
Thigh1 skinfold	*0.777****	*0.718****	*0.387***	*0.411****	*0.353***	*0.396****
Calf skinfold	*0.673****	*0.449****	*0.331***	*0.193*	*0.405****	*0.523****
Trunk skinfold	*0.735****	*0.807****	*0.331***	*0.303**	*0.411****	*0.535****
Extremity skinfold	*0.819****	*0.769****	*0.382***	*0.385***	*0.364***	*0.424****
Trunk / extremity skinfold ratio	*0.077*	*0.348***	*0.083*	*0.081*	*0.503****	*0.555****

** p<0.05, ** p<0.01, *** p<0.001*

0.348, p <0.01). For both groups, age correlated significantly with SFM but was not related to TBFM for the girls ($r = 0.120$, $p > 0.05$). The BMI, WHR, chest 1 skin-fold and trunk/extremity skin-fold ratio did not correlate significantly with TBFM in either sex. In general, the associations between SFM and anthropometric variables were stronger than those observed for TBFM. In addition, SFM was related independently to TBFM after controlling for each simple anthropometric variable.

The regression slope for SFM vs. TBFM is shown in Figure 1. A high correlation was observed in both normal-weight boys and

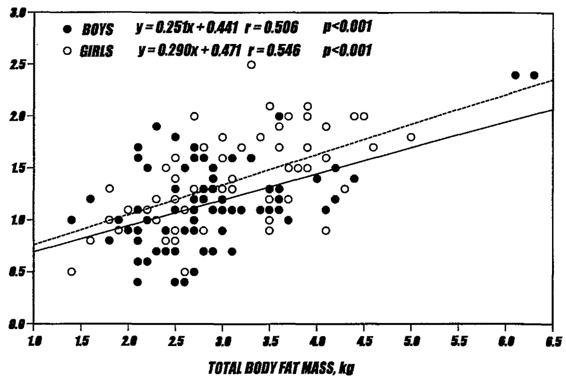

Fig. 1. Relationship between subcuraneous fat mass (SFM) and total body fat mass (TBFM) in normal weight boys (solid line) and normal weight girls (dotted line).

normal-weight girls, although the slopes were not statistically different (0.251 kg SFM/kg TBFM and 0.290 kg SFM/kg TBFM).

Discussion

A number of studies have reported a stability in the fatness ranking between early infancy and childhood[23) 24) 25)]. The evidence, based on group data, suggests that subcutaneous adipose tissue does not track well from birth to about 5 or 6 years of age, and that subcutaneous adipose tissue, therefore, appears to be highly labile during infancy and early childhood[10)]. Conversely, sex differences in body fat distribution has been the topic of several investigations[26) 27) 28)]. More than 50 years ago, Vague (1947)[29)] documented the metabolic implications of regional peripheral adipose tissue distribution and was first to emphasise the health hazards related to an android fat pattern, although consistent associations have not been found during childhood[30) 31)]. The risk of excess fat appears to be greater in those who have larger subcutaneous fat measurements during childhood[6)]. Given the importance of subcutaneous fat in the development of obesity, the availability of a noninvasive method for measuring subcutaneous fat mass would be a significant advance. However, there is little information on the factors accounting for differences in fat distribution in Japanese children and the normal developmental changes in subcutaneous fat stores are unknown. Therefore, from a clinical perspective it is becoming more important to identify good diagnostic tools for estimating subcutaneous adipose tissue that do not rely primarily on expensive and heavily used clinical equipment with radiation exposure. In addition, more accurate estimates of SFM may be obtained by including regional measurements of body fat by CT and dual-energy X-ray absorptiometry (DXA). For example, the use of CT in healthy Caucasian and Mohawk Indian children (4.4–8.8-years-old), in a single slice at the level of the umbilicus, revealed a mean abdominal subcutaneous adipose tissue area of 65.3 ± 44.8 cm^2, and a mean intra-abdominal adipose tissue area of 8.3 ± 5.8 cm^2 [32)]. In another study on children aged 7.7 ± 1.6 years, DXA measurements provided strong evidence of sex differences in absolute subcutaneous abdominal adipose tissue (SAAT): the SAAT was 65 ± 67 cm^2 and 172 ± 102 cm^2 in white boys and girls, respectively[33)]. Although CT can be used to measure regional body fat, this technique cannot resolve total body subcutaneous adipose tissue from the whole body. We propose that SFM determined from anthropometric variables could be used as an index of subcutaneous fat accumulation that is independent of the various anthropometric variables. Use of this index allows the examination of gender differences in SFM in young children. However, there have been no studies of age-related changes and sex differences in body fat distribution (i.e. the relative proportions of SFM and IFM), a parameter that varies with ethnicity and illness. Age-related changes and sex differences in body fat distribution are an important aspect of health related to nutritional status. Unfortunately there is little evidence regarding the precision of anthropometric measures of SFM in whole-body.

The main objective of this study was to compare the relationship between SFM and TBFM in young boys and girls. The results demonstrate that the accumulation of TBFM is proportionally similar in both sexes. However, girls presented significantly higher amounts of SFM than boys. The rate of increase in SFM relative to TBFM has also been shown to be similar in both sexes. Finally, the results suggest that SFM is related independently to TBFM after controlling for each anthropometric variable. These preliminary data provide the framework for further studies examining the determinants of biological variability in subcutaneous adipose tissue during growth and development, and the relationship between subcutaneous adipose tissue early in life and later health outcome.

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