Body composition of Japanese children

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Abstract There is limited information about total and regional body composition in children at the organ tissue level. The purpose of this review is to take note of the current body of knowledge regarding body composition research in Japanese children on the basis of recent data centering on fat mass and skeletal muscle (SM) mass. According to the author's recent findings of fat mass, 1) the value of % fat in overweight boys and girls was over 35% using DXA measurement; 2) about 50% of the difference in whole body fat mass, between overweight and normal weight children, may be attributable to incremental increases in trunk fat mass in both boys and girls; and 3) equations using skinfold calipers and ultrasound seem to be more useful field methods in estimating fat mass specifically for children at the present time. Moreover, the author's new studies of SM mass indicate that 1) whole body SM mass dramatically increases from prepubertal (9.2 kg for boys, 10.8 kg for girls) to adolescent stages (20.0 kg for boys, 14.6 kg for girls), which is similar to adults (22.3 kg for males, 13.5 kg for females); 2) the increase in SM mass, during each growth stage, seems to be fairly constant on the extremities and trunk area in both boys and girls; and 3) the adult ultrasound-derived prediction equations for SM mass are applicable for adolescents near 14 years of age, but are not valid for prepubertal children. Future research will involve the development of equations for estimating fat mass and SM mass for prepubertal children and adolescents.

Keywords : Skeletal muscle mass, fat mass, MRI, Children, Prediction equation

Current knowledge of body composition research in children

Body composition in children is greatly influenced by nutritional intake and physical activity levels during daily living. Therefore, research on body composition in children is linked to a comprehensive estimation of lifestyle. Although body composition studies have been developed for more than 30 years, based on a two-compartment model which classifies body weight as fat mass and fat free mass, there is limited information about total and regional body composition in children at the organ-tissue level. Organ-tissue level body composition studies for children have only reported the proportional contributions of adipose tissue, skeletal muscle (SM), brain, liver, heart and kidneys to body weight and fat free mass¹⁾; there is still much unknown research in the area of organ-tissue level body composition in children. The purpose of this review is to take note of the current body of knowledge of body composition research in children in conjunction with the author's recent data centered on fat mass and SM mass.

Fat mass in Japanese children

Although the prevalence of obesity in primary school children has increased in Japan, there has only been limited information about fat mass and fat distribution using precise, reliable and safe measurement tools. According to our recent research using dual-energy X-ray absorptiometry (DXA: Delphi A-QDR, Hologic Inc., Bedford, MA, USA; Version 12.4:3 Pediatric Whole body) for normal weight children (62 boys and 38 girls) and overweight children based on body mass index (BMI) (15 boys and 13 girls) aged 6-13 years²⁾, total fat mass in overweight boys and girls was higher than in normal weight boys and girls, respectively (Table 1). In addition, the difference in average total body fat mass between overweight and normal weight children was 9.2 kg in boys and 6.8 kg in girls (Table 1).

Arm, leg and trunk fat mass in overweight children was also higher compared with normal weight children, respectively (Table 1). The difference in arm, leg and trunk fat mass between overweight and normal weight children was 1.5 kg (16% of the difference of average total body fat mass), 3.3 kg (36%) and 4.4 kg (48%) in boys, and 1.0 kg (15%), 2.4 kg (35%) and 3.4 kg (50%) in girls, respectively. These results indicated that 1) the value of % fat in overweight boys and girls was over 35% using DXA

Table 1. Fat mass in normal weight and overweight children.

	Boys		Girls	
	Normal weight (n = 62)	Overweight (n = 15)	Normal weight (n = 38)	Overweight (n = 13)
Age (year)	10 ± 2	9 ± 2	9 ± 2	9 ± 2
Standing height (cm)	137.0 ± 11.7	139.3 ± 12.8	135.0 ± 13.0	138.2 ± 12.3
Body mass (kg)	32.4 ± 7.8	45.1 ± 13.5 **	30.5 ± 8.3	41.6 ± 10.1 **
BMI (kg/m ²)	16.5 ± 1.7	22.3 ± 3.0 **	16.1 ± 2.1	21.0 ± 1.6 **
%fat (%)	21.6 ± 5.8	35.8 ± 5.9 **	25.1 ± 5.3	35.0 ± 4.5 **
Fat mass (kg)				
Total body	7.2 ± 3.4	16.4 ± 6.0 **	7.7 ± 3.0	14.5 ± 3.7 **
Arms	0.8 ± 0.5	2.3 ± 0.9 **	0.9 ± 0.4	1.9 ± 0.5 **
Legs	3.1 ± 1.4	6.4 ± 2.4 **	3.4 ± 1.3	5.8 ± 1.3 **
Trunk	3.3 ± 1.6	7.7 ± 2.9 **	3.4 ± 1.4	6.8 ± 2.1 **

The data presented as mean ± SD.

Body mass, % fat and fat mass measured by DXA.

Arm: the area distal to the line connecting the axilla and the glenohumeral joint space, leg: the area distal to the line tangent to the ischium and the upper edge of the greater trochanter, and trunk: the remaining area.

** $p < 0.01$, p value for unpaired t -tests: normal weight vs. overweight. (Statistical analyses were performed using SPSS for Windows (version 19.0; SPSS Inc, Chicago, IL)).

measurement (even though normal weight boys and girls were about 20% and 25% fat, respectively), and 2) about 50% of this difference in whole body fat mass may be attributable to incremental increases in trunk fat mass in both boys and girls. In the near future, it will be necessary to establish the cardiovascular risk factors associated with the current levels of fat in Japanese children.

Until now, there were very few simple, effective, and affordable field methods to accurately and non-invasively estimate total and regional fat mass in children. The representative equations for estimating fat mass in children were based on body density as the criterion measure obtained from underwater weighing that is largely affected by human body water composition and an accurate measurement of residual lung volume. Because of this, we have carefully developed and verified prediction equations for total body fat mass in both boys and girls using skinfold thickness by skinfold calipers using DXA to provide reference data³⁾. However, one major problem with the skinfold method is that the error of estimation increases as body fat increases⁴⁾. As a solution to this problem, we developed prediction equations for evaluating total and regional fat mass in children using B-mode ultrasound⁵⁾. Even though the ultrasound technique is much more expensive than the hand-held skinfold caliper, ultrasound can be used in a field setting with comparably much greater accuracy, reliability, and validity for determining total and regional fat mass in a variety of body types and ages. When using these prediction equations, it is necessary to recognize this bias and use both calipers and ultrasound techniques. As a result, these equations seem to be a more useful field method for estimating body composition, especially for children at the present time.

Skeletal muscle mass in Japanese children

Since SM is the source of power for play and sport activities in children, SM mass has the potential of being a very important index for predicting exercise performance and estimating nutritional status during different growth stages. However, previous research has provided only a limited amount of information about whole body SM mass. According to our research using magnetic resonance imaging (MRI: General Electric Signa 1.5 Tesler scanner), which provided precise, reliable, and safe measurements of whole body SM mass in children and adults, and does so in a relatively short period of time (i.e. 20-30 min), whole body SM mass dramatically increases from the prepubertal to adolescent stages (Table 2)⁶⁾. It has been pointed out that this increase in SM mass is attributable to the growth in height⁶⁾. Moreover, it was observed that whole body SM in adolescents is similar to that in adults (Table 2)^{6,7)}.

Currently, it is unknown if the distribution of SM mass in children is a miniature representation of the distribution of SM mass in adults. The percentage of regional to whole body SM mass was about 9% for arm, 43% for trunk, 37% for thigh and 12% for lower leg in prepubertal children, adolescents and adults (Table 2). Moreover, the author's recent longitudinal data for prepubertal boys indicated that arm, leg and trunk SM mass over a one year period increased by about 10%, respectively. (Table 3). These results suggest that the increase in SM mass during each growth stage is at a fairly constant speed for the extremities and trunk area in both boys and girls. Furthermore, it is very interesting that about half of the difference in fat free mass (1.6 kg) between the first and second measurements was attributable to an incremental increase in SM mass (0.9 kg).

Table 2. Total and regional skeletal muscle mass in prepubertal children, adolescents and adults.

	Prepubertal children				Adolescents				Adults			
	Boys (n = 6)		Girls (n = 4)		Boys (n = 11)		Girls (n = 10)		Males (n = 10)		Females (n = 10)	
Age (year)	9	± 0	10	± 1	14	± 0	14	± 1	21	± 2	22	± 1
Standing height (cm)	131.6	± 3.0	139.8	± 6.9	165.5	± 9.2	154.8	± 3.1	171.7	± 6.1	160.2	± 5.1
Weight (kg)	28.4	± 2.0	32.5	± 2.1	55.0	± 8.6	46.9	± 5.1	63.5	± 5.5	55.6	± 6.2
Skeletal muscle mass (kg)												
Total body	9.2	± 0.9	10.8	± 1.7	20.0	± 3.1	14.6	± 1.8	22.3	± 3.0	13.5	± 2.0
Arms	0.8	± 0.1	0.9	± 0.1	1.8	± 0.3	1.2	± 0.2	2.3	± 0.3	1.2	± 0.2
Trunk	4.0	± 0.5	4.8	± 0.7	8.4	± 1.3	6.1	± 1.0	9.7	± 1.6	5.5	± 1.0
Thigh	3.4	± 0.4	3.8	± 0.7	7.6	± 1.4	5.5	± 0.5	8.0	± 1.1	5.0	± 0.6
Lower leg	1.0	± 0.1	1.3	± 0.2	2.2	± 0.4	1.7	± 0.2	2.4	± 0.3	1.8	± 0.3

The data presented as mean ± SD.

Prepubertal children: Tanner stage 1 and not approaching peak height velocity, adolescents: over Tanner stage 2.

The data of prepubertal children and adolescents for Midorikawa et al., 2009, and adults for Abe et al., 2003.

Arm: the axillary fossa to the styloid process of the radius, thigh: the femoral neck to the articular surface of the medial condyle, lower leg: the articular surface of the medial condyle to the malleolus lateralis, and trunk: the first cervicales vertebra to the femoral neck.

Table 3. Skeletal muscle mass for first and second measurement in boys.

	Boys (n = 23)	
	First measurement	Second measurement
Age (year)	9 ± 2	10 ± 1 **
Standing height (cm)	134.6 ± 9.1	139.6 ± 9.4 **
Weight (kg)	29.4 ± 5.1	32.2 ± 5.9 **
BMI (kg/m ²)	16.1 ± 1.4	16.4 ± 1.7 **
%fat (%)	20.6 ± 5.4	22.2 ± 6.0 **
Fat mass (kg)	6.2 ± 2.5	7.4 ± 3.1 **
Fat-free mass (kg)	23.2 ± 3.4	24.8 ± 3.6 **
Skeletal muscle mass (kg)		
Total body	8.6 ± 1.7	9.5 ± 1.8 **
Arms	0.8 ± 0.1	0.9 ± 0.2 **
Legs	4.7 ± 0.9	5.2 ± 1.0 **
Trunk	3.1 ± 0.6	3.5 ± 0.7 **

The data presented as mean ± SD.

Percentage (%) fat and fat mass measured by DXA.

Arm: the axillary fossa to the styloid process of the radius, leg: the femoral neck to the malleolus lateralis, and trunk: the first cervicales vertebra to the femoral neck.

** p < 0.01, p value for paired t-tests : first vs. second measurement (Statistical analyses were performed using SPSS for Windows (version 19.0; SPSS Inc, Chicago, IL)).

There are very few effective methods to accurately and non-invasively estimate SM mass in both children and adults. Under these conditions, we have developed ultrasound-derived prediction equations for estimating total and regional (i.e. arm, trunk, thigh and lower leg) SM mass in adult males and females⁸). These adult ultrasound-derived prediction equations appear to be applicable to adolescents from about age 14 years, which is over Tanner stage 2 and at peak height velocity, but not valid for prepubertal children⁶). Future research will focus on developing prediction equations for skeletal muscle mass in children using skinfold calipers, B-mode ultrasound and bio-electrical impedance methods.

Research project plan

Future research will involve the development of equations for estimating fat mass and SM mass for prepubertal children and adolescents. Moreover, since information about internal organs has only been reported from anatomical data⁹), future research will also focus on the relationships between internal organs and resting energy expenditure in children.

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References

- 1) Hsu A, Heshka S, Janumala I, Song MY, Horlick M, Krasnow N, Gallagher D. 2003. Larger mass of high-metabolic-rate organs does not explain higher resting energy expenditure in children. *Am J Clin Nutr* 77: 1506-1511.
- 2) Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 320: 1240-1243.
- 3) Midorikawa T, Ohta M, Hikiyama Y, Torii S, Bembien MG, Sakamoto S. 2011. Predicting total fat mass from skinfold thicknesses in Japanese prepubertal children: A cross-sectional and longitudinal validation. *Asia Pac J Clin Nutr* 20: 426-431.
- 4) Semiz S, Ozgören E, Sabir N. 2007. Comparison of ultrasonographic and anthropometric methods to assess body fat in childhood obesity. *Int J Obes* 31: 53-58.
- 5) Midorikawa T, Ohta M, Hikiyama Y, Torii S, Bembien MG, Sakamoto S. 2011. Prediction and validation of total and re-

- gional fat mass by B-mode ultrasound in Japanese prepubertal children. *Br J Nutr* 106: 944-950.
- 6) Midorikawa T, Sanada K, Yoshitomi A, Abe T. 2009. Is the use of ultrasound-derived prediction equations for adults useful for estimating total and regional skeletal muscle mass in Japanese children? *Br J Nutr* 101: 72-78.
- 7) Abe T, Kearns CF, Fukunaga T. 2003. Sex differences in whole body skeletal muscle mass measured by magnetic resonance imaging and its distribution in young Japanese adults. *Br J Sports Med* 37: 436-440.
- 8) Sanada K, Kearns CF, Midorikawa T, Abe T. 2006. Prediction and validation of total and regional skeletal muscle mass by ultrasound in Japanese adults. *Eur J Appl Physiol* 96: 24-31.
- 9) Ogiu N, Nakamura Y, Ijiri I, Hiraiwa K, Ogiu T. 1997. A statistical analysis of the internal organ weights of normal Japanese people. *Health. Phys* 72: 368-383.