One-year Increment of Fat Mass and Lean Body Mass of Japanese School Children Using Bioelectrical Impedance

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Abstract

Bioelectrical impedance analysis (BIA) and skinfold thickness (SF) (triceps and subscapular) methods were applied to 436 Japanese school children (228 boys and 208 girls) aged from 9 to 11 years with a one-year follow-up to determine changes in body composition. By BIA one-year increment (Δ) of lean body mass (LBM) for boys increased significantly ($p < 0.01$) and Δ LBM was almost equivalent to that for Δ weight (Wt). Δ Wt and Δ fat mass (FM) between the age 10 (from ages 10 to 11) and age 11 (from ages 11 to 12) groups in girls achieved statistical significance ($p < 0.01$ and $p < 0.001$, respectively) and Δ Wt was almost completely comprised of the Δ FM in these age groups. Δ FM in the age 11 group for girls was statistically higher than that in the age 10 group, and this obvious increase of FM in the age 11 group was presumed to be the effect of menses in consideration of the maximum one-year increment of Ht (Δ Ht) in the age 10 group.

These results of the assessment of body composition by BIA supported those of previous reports, and therefore BIA can be considered as a useful method to estimate changes in body composition of school children because it is simple and non-invasive and can be performed rapidly.

Key words: fat mass, children, bioelectrical impedance analysis, follow-up studies

Introduction

Obesity in school children has increased in Japan¹⁾. Children who are obese are likely to become an obese adult and childhood obesity may cause life style related disease later in life^{2,3)}. However, very few reports provided data on the change of body fat in childhood, to assist us to solve the problem of obesity. In most instances, physical indices, such as the Rohrer index, body mass index, and degree of obesity, calculated from height and weight are used in the initial screening of obesity; however, percentage of fat mass (%Fat)⁴⁾ is rarely used. It is because there is no simple method to estimate %Fat in school children. In recent years, bioelectrical impedance analysis (BIA) as a simple means of estimating the %Fat has been investigated⁵⁻⁹⁾. In order to obtain essential fundamental information, changes in body composition of school children were estimated by using the BIA method. In this study BIA method was applied to Japanese school children with a one-year follow-up to investigate changes in body composition.

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Subjects and Methods

1. Subjects

Four hundred and thirty six children (228 boys and 208 girls), aged from 9 to 11 years old, from the 3rd grade to the 5th grade of three primary schools in Hirosaki city, took part in this study. A detailed explanation was given before the study began, and informed consent was obtained from the parents of all subjects, by their school administrators and school nurses.

2. Measurements

Body height (Ht) and weight (Wt) were measured to the nearest 0.1 cm and 0.1 kg, respectively, with the subjects wearing light clothing and no shoes. Skinfold thickness (SF) was measured at the triceps and subscapular with a skinfold caliper (Eiken type, Meiko Co., Tokyo, Japan) to the closer 0.5 mm interval. Bioelectrical impedance (Z) measurements were taken on the right side of the body with subjects lying on their back using an impedance analyzer (SIF-891, Impedance Fat Meter, Selco Co., Tokyo, Japan). This device, with a tetrapolar surface configuration, used an 0.8 mA 50 kHz alternating current. Electrodes were placed on the dorsal surface of the wrist and ankle at the distal metacarpals and metatarsals, respectively. Two

series physical measurements were carried out during the periodic school examination with the first one in October 1993 and the second in October 1994. %Fat was estimated from impedance according to Nakadomo's equations for children¹⁰:

$$\text{Boys: body density (g/cm}^3\text{)} = 1.1439 - 0.0890 (\text{Wt(kg)} \cdot \text{Z(ohm)}) / \text{Ht}^2(\text{cm})$$

$$\text{Girls: body density (g/cm}^3\text{)} = 1.1228 - 0.0758 (\text{Wt(kg)} \cdot \text{Z(ohm)}) / \text{Ht}^2(\text{cm})$$

Lohman's equation¹¹ was used to calculate %Fat from body density. Lean body mass (LBM) and fat mass (FM) were calculated from %Fat and Wt:

$$\text{FM (kg)} = \text{Wt(kg)} \times \% \text{Fat}(\%) / 100$$

$$\text{LBM (kg)} = \text{Wt(kg)} - \text{FM(kg)}$$

Degree of obesity (DOB) was calculated from measured Wt and the standard Wt:

$$\text{DOB (\%)} = (\text{measured Wt(kg)} / \text{standard Wt(kg)}) \times 100 - 100$$

The standard Wt was calculated from Murata's formulas by sex, age, and height¹². In this study, school children aged 9, 10, and 11 were followed to ages 10, 11, and 12, respectively; these groups are referred to the age 9, 10, and 11 groups.

3. Statistics

Numerical values showed the median (interquartile range: 25th to 75th centile). Statistical analysis was performed using Mann-Whitney's U-Test and Wilcoxon signed-ranks tests. Values were considered significant at $p < 0.05$.

Results

Measured values in the first year are shown in Table 1 as the median and 25th to 75th centiles. Median Ht and Wt measured in October were slightly greater than the national average data of 1993 published in 1994 of the same year¹¹. Both Ht and Wt increased with statistical significance with age, except for Wt between the ages of 9 and 10 for girls. However, the values of SF were not significant different among the three age groups for both boys and girls. DOB, impedance, and %Fat are shown in Table 2. The differences in DOB and %Fat achieved statistical significance between the ages of 9 and 10 for girls, and differences in impedance achieved statistical significance ($p < 0.05$) between the ages of 10 and 11 for both boys and girls ($p < 0.05$, $p < 0.001$, respectively). %Fat for boys remained almost constant at ages from 9 to 11 and for girls reached a maximum value at the age of 9.

Table 1 Hight(HT), weight(WT) and skinfold thickness(SF) of subjects in initial year(1993).

		Median (interquartile range: 25th to 75th centile)				
	Age (yr)	Number	Ht (cm)	Wt (kg)	SF ^a (mm)	
Boys	9	74	131.7(127.7~135.5) $\neg$ ***	28.5(25.3~33.5) $\neg$ ***	25.0(19.0~33.0)	
	10	72	137.3(134.1~141.4) $\neg$ ***	31.8(28.8~36.5) $\neg$ **	25.3(20.0~31.5)	
	11	82	141.6(137.3~145.4) $\neg$	35.0(31.2~41.2) $\neg$	30.0(22.5~39.5)	
Girls	9	61	132.5(129.5~135.8) $\neg$ ***	29.9(26.4~34.2)	29.0(23.8~39.5)	
	10	76	138.3(133.5~142.7) $\neg$ ***	32.4(27.9~36.7) $\neg$ ***	27.5(21.8~32.8)	
	11	71	144.2(139.5~151.8) $\neg$	38.0(33.4~41.9) $\neg$	29.5(24.5~42.8)	

^a: skinfold thickness (total of triceps and subscapular).

: $p < 0.01$, *: $p < 0.001$.

Table 2 Degree of obesity(DOB), impedance and percentage of fat mass(%Fat) in initial year(1993).

		Median (interquartile range: 25th to 75th centile)		
	Age (yr)	DOB ^a (%)	Impedance (Ω)	%Fat (%)
Boys	9	2.1(-5.3~13.7)	590(557~621)	17.6(15.0~21.1)
	10	2.7(-6.1~9.7)	587(557~628) $\neg$ *	17.8(15.3~20.5)
	11	2.8(-6.7~23.0)	568(520~608) $\neg$	17.6(15.4~22.9)
Girls	9	4.3(-3.7~16.3) $\neg$ *	622(593~664)	19.7(17.3~23.2) $\neg$ *
	10	-0.4(-6.7~7.9) $\neg$	610(575~666) $\neg$ ***	18.3(16.1~21.3) $\neg$
	11	-1.3(-7.2~12.6)	578(513~615) $\neg$	17.5(14.9~20.4)

^a: calculated from Murata's formulas.

*: $p < 0.05$, ***: $p < 0.001$.

Values obtained by subtracting measured values from year 1 from those in year 2 are shown in Table 3. One-year increment of Ht (Δ Ht) was positive and statistically significant ($p < 0.001$) in each age group for boys and girls, with maximum differences in yearly increments in the age 11 group for boys and in the age 10 group for girls. There were statistically significant differences ($p < 0.001$, respectively) in Δ Ht between the age 10 and age 11 groups for both boys and girls. The Δ Wt was also positive and statistically significant ($p < 0.001$) in each age group for boys and girls, with differences in yearly increments reaching a maximum in the age 11 group for boys and girls. Δ SF was statistically significant ($p < 0.001$) and achieved a negative value in the age 11 group for boys, which

was lower with statistical significance ($p<0.001$) than Δ SF in the age 10 group for boys. Δ SF in the age 9 and 10 groups for girls was statistically significant ($p<0.05$, $p<0.01$, respectively), for the distribution of Δ SF was skewed toward a negative value in spite of zero being the median value. There was no statistically significant difference in Δ SF among the age 9, 10, and 11 groups for girls.

Table 3 One-year increment of height, weight and skinfold thickness

		Median (interquartile range: 25th to 75th centile)		
	group	Δ Ht (cm)	Δ Wt (kg)	Δ SF ^a (mm)
Boys	age 9 group	5.5(5.0~6.0)***	3.0(2.0~4.0)***	1.0(-4.0~ 6.0)
	age 10 group	5.7(5.0~6.9)*** ***	3.7(2.8~5.0)***	-0.8(-5.0~ 3.0) ***
	age 11 group	6.7(5.5~8.8)*** J	4.3(3.0~5.6)***	-4.5(-8.0~-1.0)*** J
Girls	age 9 group	6.8(5.7~7.9)***	4.0(2.8~5.5)***	0.0(-6.1~ 2.0)*
	age 10 group	7.0(5.9~8.3)*** ***	4.3(3.0~5.7)***	-2.0(-6.0~ 2.0)**
	age 11 group	5.9(4.7~7.4)*** J	5.5(3.7~7.0)***	-1.0(-6.9~ 5.5)

Δ Ht, Δ Wt, Δ SF: one-year increment of height, weight, and skinfold thickness, respectively.

^a: skinfold thickness (total of triceps and subscapular).

***: $p<0.001$ between the age 10 and 11 groups.

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$ between the values from the results of the 1st and 2nd physical examinations (1 year apart).

One-year increments of DOB (Δ DOB) except in the age 11 group for girls showed negative values (Table 4). Statistically significant differences ($p<0.05$, $p<0.01$, respectively) in Δ DOB were shown between the age 9 and age 10 groups, and between the age 10 and 11 groups for girls. All Δ %Fat except in the age 11 group for girls were negative and all Δ %Fat were statistically significant ($p<0.01$ or $p<0.001$) in all groups, including both boys and girls. In boys, there was a trend for Δ %Fat to decrease with age, but in girls there was a tendency toward an increase with age. Δ %Fat in the age 11 group for girls changed from a negative to a positive value while Δ %Fat between the age 10 and 11 groups were significantly different ($p<0.001$). All of the Δ LBM per Δ Ht (Δ LBM/ Δ Ht) showed a statistically significant increase ($p<0.001$) in each age group for boys and girls. There were a significant differences ($p<0.05$) in Δ LBM/ Δ Ht between the age 9 and age 10 groups for boys and the age 10 and age 11 groups for girls. There was no significant difference in Δ LBM/ Δ Ht between boys and girls.

Table 4 One-year increment of degree of obesity, %Fat and lean body mass/height

		Median (interquartile range: 25th to 75th centile)		
	group	Δ DOB ^a (%)	Δ %Fat (%)	Δ LBM/ Δ Ht (kg/cm)
Boys	age 9 group	-1.4(-4.3~ 1.1)*	-1.1(-3.6~ 0.8)**	0.50(0.40~0.70)*** J
	age 10 group	-0.6(-3.5~ 2.8)	-1.4(-3.7~ 0.6)***	0.57(0.48~0.76)*** J
	age 11 group	-1.3(-4.6~ 0.7)***	-2.1(-4.2~-0.3)***	0.67(0.52~0.80)***
Girls	age 9 group	-0.4(-2.9~ 2.4) J	-2.7(-5.5~-0.6)***	0.61(0.48~0.80)***
	age 10 group	-2.0(-5.5~ 0.4)*** **	-2.1(-4.1~-0.7)*** ***	0.63(0.49~0.75)*** J
	age 11 group	0.4(-1.9~ 3.2) J	1.1(-0.6~ 2.5)** J	0.67(0.55~0.90)*** J

Δ DOB, Δ %Fat, Δ LBM/ Δ Ht: one-year increment of Degree of obesity, percentage of body fat, and lean body mass/height, respectively.

^a: calculated from Murata's formulas.

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$ between the age 9 and 10 groups or the age 10 and 11 groups.

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$ between the values from the results of the 1st and 2nd physical examinations (1 year apart).

Δ Wt, Δ FM, and Δ LBM for boys and girls by box plot are shown in Figure 1. Δ LBM for boys showed a significant increase ($p<0.01$ and $p<0.001$) with age and the differences in the Δ LBM were greater than those of Δ Wt with age. Δ FM was almost constant or decreased in spite of the increase of Δ Wt. Δ Wt and Δ FM between the age 10 and age 11 groups for girls achieved statistical significance ($p<0.01$ and $p<0.001$, respectively) and the differences in Δ Wt were almost equal to the differences in Δ FM in these 2 age groups.

Fig.1 One-year increment of weight (□), fat mass (■) and lean body mass (▨) for boys and girls by Box Plot. *: $p<0.05$, **: $p<0.01$, ***: $p<0.001$.

Discussion

There are many methods to estimate body composition. Many studies of body composition have been reported and are almost always cross-sectional^{13,14}. This study is a one-year prospective study in which the changes of body composition of Japanese school children aged 9 to 11 were followed. The correlation coefficients were significant for the %Fat between BIA and hydrodensitometry ($r=0.732$ for boys and $r=0.645$ for girls)¹⁰. BIA is simply and easily performed and is a useful method to assess body composition¹⁵.

It was reported that the growth spurt in Japanese boys and girls starts at the mean ages of 11.1 and 9.4, respectively and the maximum Δ Wt is at the mean ages of 13 and 12 for boys and girls, respectively¹⁶. For these periods two thirds of the Δ Wt was composed of Δ LBM for boys and of Δ FM for girls and Δ SF for boys reaches a minimum value at the age of 13 when reaching the maximum growth spurt in height¹⁷. But in our study of small number of subjects the Δ SF was minimal at the age of 11 and further lessened with age for boys among our subjects; Δ SF for girls showed almost the same trend, except that values were higher than those for boys. It was thought that within the range of age in the male subjects in this study a growth spurt would not be shown, but that a growth spurt for girls would be shown from the viewpoint of their Ht, Wt, Δ Ht, and Δ Wt. Both the median values of Ht and Wt according to age as of October 1 in our study were less than such mean values according to age obtained on April 1 in the Reports of School Health Statistics for 1994¹¹ for boys and girls. Δ SF for boys in the age 11 group was

statistically lower than that in the age 10 group (Table 3). Δ LBM in the age 9, 10, and 11 groups for boys were almost equivalent to or greater than the Δ Wt (Fig. 1) and this suggested that the rate of Δ LBM comprising the Δ Wt was larger than two thirds of Δ Wt published previously¹⁹. Δ SF for girls did not show an obvious difference (Table 3) but Δ FM in the age 11 group was statistically higher than that in the age 10 group. This obvious increase of FM in the age 11 group was presumed to be the effect of menses in consideration of the highest Δ Ht in the age 10 group¹⁶. Δ LBM/ Δ Ht in each age group showed a significant increase for boys and girls. However, there was no significant difference in Δ LBM/ Δ Ht between the age of 10 and 11 for boys, although the Δ Ht was significantly greater at age 11 than at age 10. Δ LBM/ Δ Ht between the age of 10 and 11 for girls was significantly different because of the effect of the increase of Δ LBM over Δ Ht. Δ LBM/ Δ Ht between boys and girls in each age group did not show a significant difference.

These results of the assessment of body composition by BIA were supported by those of previous reports^{14,15}. BIA, one of the methods to estimate body composition, can be considered a useful method to estimate changes in body composition of school children because it is simple and non-invasive and can be performed rapidly.

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