



# Evaluation of Hip/Height<sup>P</sup> Ratio as an Index for Adiposity and Metabolic Complications in Obese Children: Comparison with Waist-related Indices

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**Aim:** To investigate whether body adiposity index (BAI; hip/height<sup>1.5</sup>–18), pediatric BAI (BAIp; hip/height<sup>0.8</sup>–38), and other hip/height<sup>P</sup> ratios are useful in obese children.

**Method:** Ninety obese Japanese children, 55 boys and 35 girls, who visited our University Clinic, were enrolled. The age was 9.92 ± 2.6 (mean ± SD) years, and the percentage overweight (POW) was 51.6 ± 18.8%. We set the power value of the hip/height<sup>P</sup> 0, 0.5, 0.8, 1, 1.5, and 2 and studied the association with overweight indices, biochemical data, and fat area measured by computed tomography. Waist, waist/height ratio, and waist/hip ratio were also evaluated.

**Results:** Hip/height and hip/height<sup>0.8</sup> (BAIp) were more closely correlated with POW, body mass index percentile, and percentage body fat than hip/height<sup>1.5</sup> (BAI). The correlation coefficient of hip/height with POW ( $r=0.855$ ) was the highest among the studied hip/height<sup>P</sup> indices. The approximate line to predict POW was  $411 \times \text{hip/height} - 207$ . The waist/height was also highly correlated with POW ( $r=0.879$ ). Hip and hip/height<sup>0.5</sup> were more closely correlated with visceral fat area than hip/height, BAIp, and hip/height<sup>1.5</sup>. Hip and hip/height<sup>0.5</sup> were significantly correlated with insulin. Only hip was also significantly associated with dyslipidemia. All hip/height<sup>P</sup> indices were not significantly correlated with alanine aminotransferase (ALT). Waist was significantly correlated with serum lipids, ALT, and insulin.

**Conclusion:** Hip/height and BAIp are better markers for overweight (adiposity) in obese children than BAI. However, hip/height, BAIp, and BAI are not useful to predict metabolic complications. Waist appears to be the best index for obese children overall at this time.

**Key words:** Body adiposity index, Overweight, Body fat, Visceral adipose tissue, Waist circumference

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## Introduction

The prevalence of obesity has rapidly increased since the last several decades in many countries. WHO stated that the worldwide prevalence of obesity increased to more than double between 1980 and 2014<sup>1</sup>. Globally, the prevalence of childhood obesity is also still high, however, recent obesity trends in children and adolescents suggest a plateau in some countries<sup>2</sup>. Even so, childhood obesity is a major health problem because obese children are likely to remain

obese as adults, and the obesity-related complications such as dyslipidemia, fatty liver, and insulin resistance are also likely to persist during adulthood. These complications lead to early atherosclerosis and diabetes mellitus. In addition, the treatment of severely obese children is not easy. To prevent obesity in middle age, early precautions and interventions are required during childhood. Therefore, it is important to find an indicator that can accurately predict the degree of both adiposity and metabolic complications in children.

In 2011, a new anthropometric indicator, body adiposity index (BAI), was proposed as a good marker for adiposity in Mexican–American and African–American adults<sup>3</sup>. BAI is calculated using the following equation:  $\text{BAI} = \text{hip circumference (cm)} / \text{height (m)}^{1.5} - 18$ . BAI was reported to be strongly correlated

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**Table 1.** Characteristics of the obese boys and girls

	All children ( <i>n</i> =90)	Boys ( <i>n</i> =55)	Girls ( <i>n</i> =35)	Statistics* (B vs. G)
Age (year)	9.92 ± 2.6	10.5 ± 2.6	9.10 ± 2.5	<i>p</i> < 0.05
Height (cm)	139.6 ± 14.5	143.1 ± 13.6	134.1 ± 14.5	<i>p</i> < 0.01
Weight (kg)	53.3 ± 16.5	57.1 ± 16.4	47.3 ± 15.0	<i>p</i> < 0.01
POW (%)	51.6 ± 18.8	52.5 ± 20.0	50.2 ± 16.9	ns
BMI percentile	97.8 ± 2.5	97.6 ± 2.6	98.2 ± 2.2	ns
BMI-SD	2.24 ± 0.54	2.19 ± 0.54	2.35 ± 0.54	ns
PBF (%)	35.6 ± 6.0	35.1 ± 5.8	36.5 ± 6.2	ns
Waist (cm)	82.4 ± 11.1	85.4 ± 11.5	77.7 ± 8.8	<i>p</i> < 0.01
Waist/height	0.591 ± 0.054	0.597 ± 0.054	0.581 ± 0.051	ns
Waist/hip	0.940 ± 0.061	0.955 ± 0.058	0.916 ± 0.058	ns
Hip (cm)	87.7 ± 10.5	89.4 ± 10.0	85.1 ± 10.8	ns
Hip/height <sup>0.5</sup>	7.42 ± 0.59	7.46 ± 0.59	7.34 ± 0.59	ns
Hip/height	0.629 ± 0.040	0.625 ± 0.041	0.634 ± 0.036	ns
Hip/height <sup>1.5</sup> (×10 <sup>-2</sup> )	5.34 ± 0.45	5.24 ± 0.44	5.50 ± 0.42	<i>p</i> < 0.01
Hip/height <sup>2</sup> (×10 <sup>-3</sup> )	4.56 ± 0.59	4.41 ± 0.54	4.79 ± 0.59	<i>p</i> < 0.01
BAI	35.4 ± 4.5	34.4 ± 4.4	37.0 ± 4.3	<i>p</i> < 0.01
BAIp	29.1 ± 4.3	29.1 ± 4.5	29.2 ± 4.1	ns
	( <i>n</i> =65)	( <i>n</i> =42)	( <i>n</i> =23)	
Total AT area (cm <sup>2</sup> )	331.8 ± 104.9	346.0 ± 109.3	305.8 ± 93.1	ns
VAT area (cm <sup>2</sup> )	71.4 ± 27.2	75.5 ± 26.8	64.0 ± 26.8	ns
SAT area (cm <sup>2</sup> )	260.4 ± 87.2	270.6 ± 93.0	241.8 ± 73.8	ns

Data are expressed as means ± SD. BMI; body mass index, POW; percentage overweight, PBF; percentage body fat, Waist; waist circumference at the level of umbilicus, Hip; hip circumference at the maximum level, BAI; body adiposity index (hip/height<sup>1.5</sup>–18), BAIp; BAI for pediatrics (hip/height<sup>0.8</sup>–38), AT; adipose tissue, VAT; visceral adipose tissue, SAT; subcutaneous adipose tissue, \*; using an unpaired *t*-test.

with body fat as measured by dual-energy X-ray absorptiometry (DEXA). However, some investigators had some questions about the usefulness of BAI in adults. For example, Schulze and Stefan described the effect of sexual dimorphism in body fatness on BAI<sup>4</sup>. In addition, it was reported that the association of cardiovascular risk factors, such as blood pressure, serum lipids, glucose, and adipocytokines, with BAI was weaker than that with waist-related indices, such as waist circumference, waist/hip ratio, waist/height ratio, and visceral adipose tissue level<sup>5-7</sup>. In obese adolescents, Thivel *et al.*<sup>8</sup> reported that body mass index (BMI) was better than BAI for estimating adiposity. However, in children, it is not well known whether BAI is a useful marker. In 2013, BAI for pediatrics (BAIp): hip circumference (cm)/height (m)<sup>0.8</sup>–38 was also proposed to predict body fatness in 5–12-year-old children, and BAI was shown to overestimate the percentage of body fat measured using a bioimpedance method<sup>9</sup>. To the best of our knowledge, there are no reports in which the relationship between BAI or BAIp and obesity-related complications or abdominal adi-

pose tissue area measured by computed tomography (CT) has been studied. Therefore, we studied hip-to-height<sup>p</sup> ratio (hip/height<sup>p</sup>) in obese children.

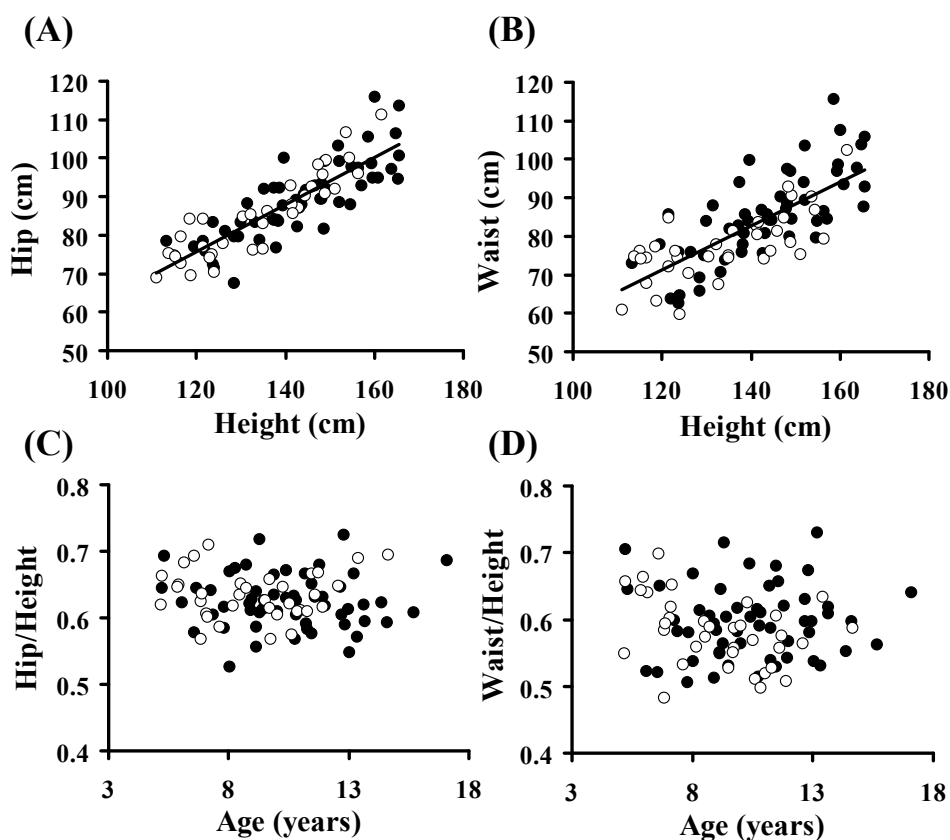
## Aim

The aim of this study was to investigate which hip/height<sup>p</sup>, including BAI and BAIp, is useful in children to predict not only adiposity but also obesity-related complications and whether the hip/height<sup>p</sup> is better than waist-related indices.

## Methods

### Subjects

Ninety obese Japanese children, 55 boys and 35 girls, who visited the Clinic for Obese Children at either Showa University or Showa University Koto Toyosu Hospital, were enrolled in the study (Table 1). According to the criteria for childhood obesity adopted by the Ministry of Education, Culture, Sports, Science and Technology in Japan, a child was considered to be



**Fig. 1.** Distribution between height and hip circumference (A) or waist circumference (B) and between age and hip/height ratio (C) or waist/height ratio (D). Closed circles, Boys; Open circles, Girls. Pearson's correlation coefficients were  $r=0.853$  (Boys, 0.812; Girls, 0.899) in Fig (A) and  $r=0.745$  (Boys, 0.740; Girls, 0.700) in Fig (B), and all statistical differences were  $p<0.001$ . Age and hip/height, Fig (C);  $r=0.101$  (Boys, 0.174; Girls, 0.067), and all correlations were not significant (ns). Age and waist/height, Fig (D);  $r=-0.073$ , ns (Boys, 0.034, ns; Girls,  $-0.375$ ,  $p<0.05$ ).

obese when the percentage overweight (POW) exceeded 20%. POW=20% means that one's body weight is 120% of standard body weight, which is defined as the mean body weight corresponding to the height for that age obtained from the national statistics for Japanese school children in 2000<sup>10</sup>. The age of the subjects ranged from 5 to 17 ( $9.92 \pm 2.6$ ; mean  $\pm$  SD) years. The mean POW, BMI-for-age percentile value (BMI percentile), and BMI-for-age Z-score (BMI-SD) were  $51.6 \pm 18.8$  (%),  $97.8 \pm 2.5$  (percentile), and  $2.24 \pm 0.54$  (SD), respectively. They had no endocrine, metabolic, or kidney diseases.

They were subjected to anthropometric measurements, and blood was drawn after an overnight fast. Serum total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), alanine aminotransferase (ALT), glucose, and insulin were measured at the clinical laboratories of both Showa University Hospital and Showa University Koto Toyosu

Hospital. Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation ( $LDL-C = TC - HDL-C - TG/5$ ). Non-HDL-C was calculated using the following equation: non-HDL-C =  $TC - HDL-C$ . Atherogenic index (AI) was calculated using the following equation:  $AI = (TC - HDL-C)/HDL-C$ .

This study protocol was approved by the Showa University Research Ethics Committee. Informed consent was obtained from the subjects' parents.

#### Anthropometric Measurements

Anthropometric measurements were performed, as previously described<sup>11, 12</sup>, by the medical staff at both the clinics. In brief, height was measured to the nearest 0.1 cm and body weight to the nearest 0.1 kg using a stadiometer. The waist circumference was measured at the level of the umbilicus (waist) and hip circumference was measured at the level of maximum

**Table 2.** Correlation between hip/height<sup>P</sup> indices and overweight indices in obese children

	POW (%)	BMI percentile	BMI-SD	PBF (%)	Waist (cm)	Waist/Height	Waist/Hip
Hip (cm)	0.410 <sup>§</sup>	0.235 <sup>*</sup>	0.021	0.481 <sup>§</sup>	0.875 <sup>§</sup>	0.303 <sup>***</sup>	-0.025
Hip/height <sup>0.5</sup>	0.641 <sup>§</sup>	0.447 <sup>§</sup>	0.282 <sup>§</sup>	0.598 <sup>§</sup>	0.825 <sup>§</sup>	0.498 <sup>§</sup>	-0.017
Hip/height <sup>0.8</sup> (BAIp)	0.809 <sup>§</sup>	0.624 <sup>§</sup>	0.544 <sup>§</sup>	0.639 <sup>§</sup>	0.650 <sup>§</sup>	0.648 <sup>§</sup>	-0.003
Hip/height	0.855 <sup>§</sup>	0.700 <sup>§</sup>	0.704 <sup>§</sup>	0.592 <sup>§</sup>	0.420 <sup>§</sup>	0.699 <sup>§</sup>	0.011
Hip/height <sup>1.5</sup> (BAI)	0.655 <sup>§</sup>	0.613 <sup>§</sup>	0.781 <sup>§</sup>	0.305 <sup>***</sup>	-0.157	0.563 <sup>§</sup>	0.035
Hip/height <sup>2</sup>	0.455 <sup>§</sup>	0.475 <sup>§</sup>	0.700 <sup>§</sup>	0.122	-0.408 <sup>§</sup>	0.411 <sup>§</sup>	0.043
Waist (cm)	0.558 <sup>§</sup>	0.260 <sup>*</sup>	0.142	0.511 <sup>§</sup>		0.615 <sup>§</sup>	0.459 <sup>§</sup>
Waist/height	0.879 <sup>§</sup>	0.564 <sup>§</sup>	0.686 <sup>§</sup>	0.547 <sup>§</sup>			0.699 <sup>§</sup>
Waist/hip	0.397 <sup>§</sup>	0.110	0.274 <sup>**</sup>	0.204			

Abbreviations are the same as in Table 1. <sup>§</sup>;  $p < 0.001$ , <sup>\*\*\*</sup>;  $p < 0.005$ , <sup>\*\*</sup>;  $p < 0.01$ , <sup>\*</sup>;  $p < 0.05$ .

extension of the buttocks (hip) to the nearest 0.1 cm. Skinfold thickness was measured to the nearest 0.1 cm using the skinfold caliper at triceps (halfway between the acromion and olecranon) and subscapular (1 cm below the inferior angle of the scapula).

POW, BMI percentile, and BMI-SD values were calculated from the Annual Report of School Health Statistics Research 2000 (Ministry of Education, Culture, Sports, Science and technology in Japan) using MS-EXCEL 2010 (Microsoft Co. Redmond, WA, USA.)<sup>10</sup>. The percentage body fat (PBF) based on the sum of triceps and subscapular skinfold thickness was obtained using Brozek's equation<sup>13</sup>, after body density was calculated using Nagamine's formula<sup>14</sup>.

### Measurement of Abdominal Adipose Tissue Distribution

Total adipose tissue, visceral adipose tissue (VAT), and subcutaneous adipose tissue (SAT) area were measured by CT<sup>11</sup>. A single-slice CT scan of the abdomen was performed at the level of the umbilicus and analyzed for cross-sectional area of the adipose tissue. Adipose tissue area was measured in cm<sup>2</sup> assuming a density of -40 to -140 Hounsfield Units for adipose tissue, as described by Tokunaga *et al.*<sup>15</sup>.

### Hip/height<sup>P</sup> Ratio

BAI is based on hip/height<sup>1.5</sup> and BAIp is based on hip/height<sup>0.8</sup>. To investigate which hip/height<sup>P</sup> formula was best fit for obese children, we studied the relation of hip/height<sup>P</sup> with overweight indices, PBF, adipose tissue area, and obesity-related complications. We set the power value to 0, 0.5, 0.8, 1, 1.5, or 2 and calculated the correlation coefficients between the hip/height<sup>P</sup> ratio and these obesity markers. Similarly, the waist-related indices (waist, waist/height, and waist/hip) were also studied.

### Statistics

Data are presented as the means and SD. The statistical significance between means was estimated using an unpaired *t*-test for boys and girls. Differences were considered statistically significant at  $p < 0.05$ . Pearson's correlation coefficients were calculated by least-squares linear regression analysis. The statistical analyses were performed using SPSS version 11.0 (SPSS Inc., Chicago, IL, USA).

## Results

### Anthropometric Data and Fat Area Measured by CT in Obese Children

The anthropometric data and adipose tissue areas measured by CT for obese boys and girls in the study are summarized in **Table 1**. The mean age, height, body weight, and waist were higher in the obese boys than in the obese girls, whereas overweight indices (POW, BMI percentile, and BMI-SD), PBF, waist/height ratio, and waist/hip ratio were similar in both sexes.

Hip, hip/height<sup>0.5</sup>, and hip/height were similar in both sexes, whereas hip/height<sup>1.5</sup> and hip/height<sup>2</sup> were lower in the obese boys than in the obese girls. BAI was also lower in the boys than in the girls. BAIp was not significantly different between the boys and girls.

Abdominal adipose tissue areas were measured in 42 obese boys and 23 obese girls enrolled in the study. Total adipose tissue area, VAT area, and SAT area were not significantly different between sexes. The mean VAT area of obese children in this study was  $71.4 \pm 27.2$  cm<sup>2</sup>, whereas the criterion<sup>16</sup> of excess VAT accumulation in Japanese school-age children is 60 cm<sup>2</sup>.

The distribution between height and hip or waist and between age and hip/height or waist/height in the study subjects is shown in **Fig. 1**. The hip and waist were positively correlated with height, similarly in

**Table 3.** Correlation between hip/height<sup>P</sup> and adipose tissue (AT) area measured by CT

	Total AT area (cm <sup>2</sup> )	VAT area (cm <sup>2</sup> )	SAT area (cm <sup>2</sup> )
Hip (cm)	0.846 <sup>§</sup>	0.569 <sup>§</sup>	0.840 <sup>§</sup>
Hip/height <sup>0.5</sup>	0.828 <sup>§</sup>	0.503 <sup>§</sup>	0.839 <sup>§</sup>
Hip/height <sup>0.8</sup> (BAIp)	0.725 <sup>§</sup>	0.380 <sup>*</sup>	0.754 <sup>§</sup>
Hip/height	0.568 <sup>§</sup>	0.236	0.609 <sup>§</sup>
Hip/height <sup>1.5</sup> (BAI)	0.031	-0.161	0.088
Hip/height <sup>2</sup>	-0.269 <sup>*</sup>	-0.347 <sup>***</sup>	-0.216
Waist (cm)	0.937 <sup>§</sup>	0.675 <sup>§</sup>	0.916 <sup>§</sup>
Waist/height	0.661 <sup>§</sup>	0.416 <sup>§</sup>	0.666 <sup>§</sup>
Waist/hip	0.328 <sup>**</sup>	0.337 <sup>**</sup>	0.290 <sup>*</sup>

Abbreviations are the same as in Table 1. <sup>§</sup>;  $p < 0.001$ , <sup>\*\*\*</sup>;  $p < 0.005$ , <sup>\*\*</sup>;  $p < 0.01$ , <sup>\*</sup>;  $p < 0.05$ .

**Table 4.** Correlation between hip/height<sup>P</sup> indices and obesity-related complications in obese children

	TC (mg/dl)	TG (mg/dl)	HDL-C (mg/dl)	LDL-C (mg/dl)	non HDL-C (mg/dl)	AI	ALT (U/L)	Insulin ( $\mu$ U/L)
Hip (cm)	-0.038	0.214 <sup>*</sup>	-0.214 <sup>*</sup>	-0.033	0.048	0.115	0.139	0.526 <sup>§</sup>
Hip/height <sup>0.5</sup>	-0.019	0.170	-0.201	0.002	0.063	0.144	0.120	0.452 <sup>§</sup>
Hip/height <sup>0.8</sup> (BAIp)	0.003	0.095	-0.155	0.037	0.067	0.153	0.080	0.302
Hip/height	0.020	0.017	-0.097	0.060	0.060	0.141	0.035	0.137
Hip/height <sup>1.5</sup> (BAI)	0.043	-0.138	0.049	0.082	0.024	0.067	-0.063	-0.222 <sup>*</sup>
Hip/height <sup>2</sup>	0.044	-0.192	0.113	0.076	-0.001	0.018	-0.102	-0.359 <sup>§</sup>
Waist (cm)	-0.064	0.221 <sup>*</sup>	-0.317 <sup>***</sup>	-0.018	0.063	0.214 <sup>*</sup>	0.210 <sup>*</sup>	0.513 <sup>§</sup>
Waist/height	-0.036	0.070	-0.273 <sup>**</sup>	0.054	0.074	0.283 <sup>**</sup>	0.163	0.161
Waist/hip	-0.065	0.084	-0.289 <sup>**</sup>	0.023	0.050	0.261 <sup>*</sup>	0.189	0.093

Abbreviations are the same as in Table 1. <sup>§</sup>;  $p < 0.001$ , <sup>\*\*\*</sup>;  $p < 0.005$ , <sup>\*\*</sup>;  $p < 0.01$ , <sup>\*</sup>;  $p < 0.05$ .

boys and girls ( $p < 0.001$ ). The hip/height and waist/height were not significantly correlated with age except the girl's waist/height, which was negatively correlated with age ( $p < 0.05$ ). Overall, the distribution of hip and waist in the enrolled obese boys and girls was similar; therefore, we combined both data and calculated correlation factors.

### Correlation between Hip/height<sup>P</sup> Indices and Overweight Indices

**Table 2** summarizes the relationships between hip/height<sup>P</sup> indices and anthropometric indices in obese children. The correlation coefficients of BAIp or BAI were same as those of hip/height<sup>0.8</sup> or hip/height<sup>1.5</sup>, respectively (**Tables 2–4**).

All hip/height<sup>P</sup> indices were significantly correlated with overweight indices. Particularly hip/height<sup>0.8</sup> (BAIp), hip/height, and hip/height<sup>1.5</sup> (BAI) were highly correlated among hip/height<sup>P</sup>. Hip/height and hip/height<sup>0.8</sup> were more closely correlated with POW and BMI percentile value than hip/height<sup>1.5</sup>. However, hip/

height<sup>1.5</sup> was more closely correlated with BMI-SD value ( $r = 0.781$ ) than hip/height and hip/height<sup>0.8</sup>. Hip/height<sup>0.8</sup> was more closely correlated with PBF ( $r = 0.639$ ) than hip/height and hip/height<sup>1.5</sup>. The correlation coefficients of these three hip/height<sup>P</sup> ( $P = 0.8, 1, \text{ and } 1.5$ ) with overweight indices were higher than those of waist and waist/hip. In addition, waist/height was most closely correlated with overweight indices among the waist-related indices studied. Hip was of course highly correlated with waist. Hip/height was highly correlated with waist/height.

The correlation between hip/height and POW was very high ( $r = 0.855, p < 0.001$ ). **Fig. 2** shows the scatter graph. The approximate line for prediction of POW was as follows:  $\text{POW} = 411 \times \text{hip/height} - 207$ . If one's hip/height is 0.626, POW is expected to be 50.3%, which is equal to 150.3% of the standard weight. The waist/height was also highly correlated with POW ( $r = 0.879, p < 0.001$ ). The approximate line to predict POW was  $\text{POW} = 308 \times \text{waist/height} - 131$ . If one's waist/height is 0.588, POW is estimated

to be 50.1%.

### Correlation between Hip/height<sup>P</sup> Indices and Adipose Tissue Area by CT

Hip and hip/height<sup>0.5</sup> were more closely correlated with total adipose tissue, VAT, and SAT area than hip/height<sup>0.8</sup> (BAIp) and hip/height (Table 3). Hip/height<sup>1.5</sup> (BAI) was not significantly correlated with adipose tissue area. Hip was the best index to predict VAT accumulation ( $r=0.569$ ,  $p<0.001$ ).

On the other hand, all three waist-related indices were significantly correlated with abdominal adipose tissue areas. In the study, waist was most strongly correlated with VAT ( $r=0.675$ ,  $p<0.001$ ) (Table 3).

### Correlation between Hip/height<sup>P</sup> Indices and Biochemical Data

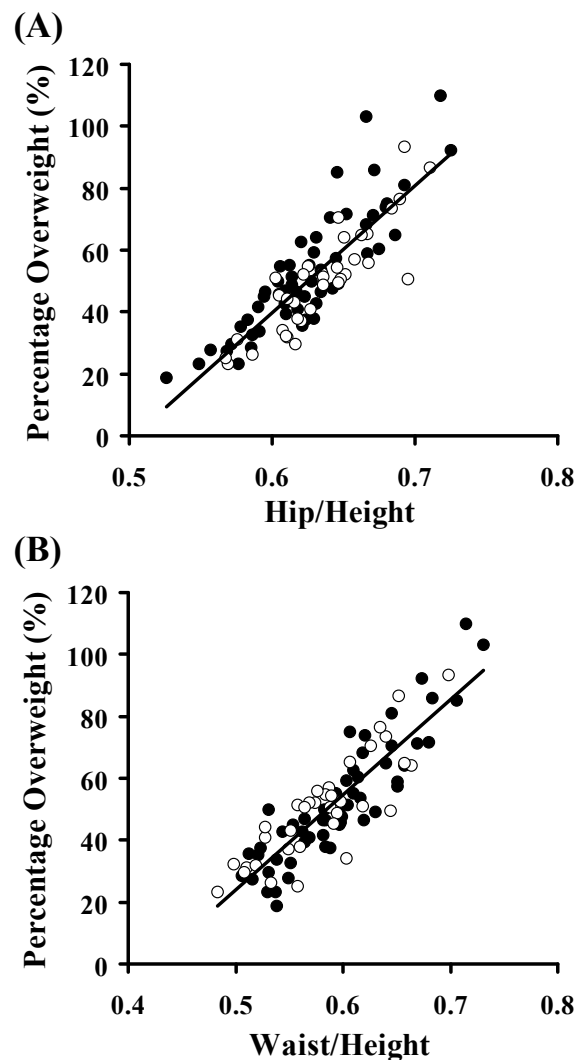
The median values of TC, TG, and LDL-C in the obese children (177, 75, and 104 mg/dL, respectively) were higher than those in Japanese standard values<sup>17)</sup> (170, 60, and 95 mg/dL, respectively), and the median value of HDL-C (52 mg/dL) was lower than the standard value (60 mg/dL)<sup>17)</sup>. The mean value of ALT was  $56.0 \pm 62.2$  U/L (mean  $\pm$  SD), and the mean value of insulin was  $17.2 \pm 10.9$   $\mu$ U/L. In Japan, we considered that the value  $>25$  U/L and 15  $\mu$ U/L is high, respectively<sup>16)</sup>. Therefore, many children in the study already had dyslipidemia, fatty liver, and insulin resistance. However, fasting plasma glucose levels were within normal limits (data not shown).

Only hip was significantly correlated with TG and HDL-C (Table 4). Other hip/height<sup>P</sup> indices were not significantly correlated with serum lipids, including non-HDL-C and AI. Hip/height<sup>P</sup> indices were not correlated with ALT either. Hip and hip/height<sup>0.5</sup> were significantly correlated with insulin; however, hip/height<sup>1.5</sup> and hip/height<sup>2</sup> were inversely correlated strangely.

Waist was significantly correlated with TG, HDL-C, AI, ALT, and insulin. Waist/height and waist/hip were significantly correlated with only HDL-C and AI (Table 4).

## Discussion

Almost all hip/height<sup>P</sup> indices studied in this study were significantly correlated with overweight indices (POW, BMI-percentile, and BMI-SD) and PBF. On judging these correlation factors, hip/height appears to be the best index among them. The correlation coefficients of hip/height with overweight indices were also higher than those of waist-related indices (waist, waist/height, and waist/hip), except the correlation of waist/height with POW.



**Fig. 2.** Correlation between percentage overweight and hip/height (A) or waist/height (B). Closed circles, Boys; Open circles, Girls. Pearson's correlation coefficients were  $r=0.855$  (Boys, 0.870; Girls, 0.870) and  $r=0.879$  (Boys, 0.898; Girls, 0.850), respectively, and all were significant,  $p<0.001$ .

The associations between hip/height and POW and between waist/height and POW were very strong. If one's hip/height is  $>0.63$  or waist/height is  $>0.59$ , he or she is considered to be severely obesity, POW  $>50\%$ <sup>10)</sup>. It is well known that BMI itself cannot be used for defining childhood obesity<sup>10)</sup>. In Japan, we use the POW method, but not the BMI-for-age method, for the evaluation of childhood obesity. We believe that POW is more accurate for the evaluation of overweight than BMI-percentile value and BMI-SD score<sup>10)</sup>.

The correlation between hip/height or hip/height<sup>0.8</sup> (BAIp) and overweight indices was higher

than that of hip/height<sup>1.5</sup> (BAI). In addition, BAIP was more correlated with PBF than hip/height or BAI. Some groups<sup>8, 18-20</sup> have also reported that BMI (SD) is rather a better tool than BAI for estimating body fat in pediatric field. El Aarbaoui *et al.*<sup>9</sup> have proposed that BAIP is better than BAI. However, Thivel *et al.*<sup>8</sup> reported in 2015 that BAIP did not provide better estimate of adiposity than BMI in obese 12–16-year-old adolescents. We could not investigate the body fat levels by DEXA in this study. DEXA is now considered to be the gold standard method for the estimation of body adiposity. However, the body fat percentage measured by DEXA has been reported to be influenced by the bone mineral density and also by height in children<sup>21</sup>. In general, the overweight indices, such as POW, must be significantly associated with body fat volume because muscle volumes do not increase so fast in normal children. As mentioned above, hip/height appears to be a more useful marker of overweight than BAIP, based on the correlation factors. Furthermore, the formula of hip/height is simpler than BAIP. In this study, we also found that waist/height is a very good indicator for predicting overweight. Hip/height and waist/height are interesting because they do not require body–weight data.

Hip and hip/height<sup>0.5</sup> were more closely correlated with total adipose tissue, VAT, and SAT area than any other hip/height<sup>P</sup> indices, including BAIP. Hip was the best index to predict VAT accumulation among hip/height<sup>P</sup>, whereas waist was more closely correlated than hip. To the best of our knowledge, this is the first report studying the association between hip/height<sup>P</sup> indices with abdominal adipose tissue area measured by CT.

The correlations between hip/height<sup>P</sup> indices and complications were weak. Only hip was significantly correlated with TG, HDL-C, and insulin. On the other hand, waist was significantly correlated with TG, HDL-C, AI, ALT, and insulin. Only hip was significantly correlated with VAT; therefore, hip was correlated with complications as well as waist. These results suggest that hip/height, BAIP, and BAI are not useful markers for metabolic complications because they are not associated with VAT area.

VAT accumulation in obesity relates not only to the development of complication risks but also directly relates to the development of obesity-related complications<sup>22</sup>. In Japan, metabolic syndrome has been designated to be a multiple risk factor clustering syndrome, which is caused by VAT accumulation<sup>22</sup>. Therefore, abdominal obesity is necessary as an essential factor required in the diagnosis with waist circumference at the level of umbilicus as a first screening tool. In children, excessive accumulation of VAT is a

major health problem as well as in adults. Our previous studies showed that VAT area by CT at the umbilical level is the best predictor for liver dysfunction, dyslipidemia, and insulin resistance<sup>11, 16</sup>. The correlation of VAT area and waist is very high<sup>10, 11, 16</sup>. Therefore, waist, at the umbilical level, is a more useful surrogate marker for complications than POW or BMI percentile<sup>11, 16</sup>. The critical value for VAT area and waist are approximately 60 cm<sup>2</sup> and 80 cm, respectively, in Japanese school-age children<sup>11, 16</sup>. Although it is important to accurately evaluate overweight (adiposity), it is more important to predict whether metabolic complications exist.

Thivel *et al.* have devised a new index using waist circumference named BAI-waist circumference (BAIW), which is similar to BAI<sup>8</sup>. The formula is as follows: BAIW = waist circumference/height<sup>1.5</sup> – 18. Unfortunately, they<sup>8</sup> reported that BAIW underestimated total body adiposity, and the correlation with adiposity measured by DEXA was weaker than BAI and BAIP.

## Conclusion

We investigated whether hip/height<sup>P</sup> is useful for the evaluation of obesity in children. Hip/height and BAIP (hip/height<sup>0.8</sup>) are better markers for overweight (adiposity) in obese children than BAI (hip/height<sup>1.5</sup>). Hip/height appears to be better than BAIP. However, hip/height, BAIP, and BAI are not useful to predict metabolic complications. Waist is considered to be the best index for obese children overall at this time because waist significantly reflects the metabolic complications.

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## Conflicts of Interest

We have no conflicts of interest to declare.

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