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Increased Ratio of Trunk to Appendicular Fat and Increased Blood Pressure

– Study of a General Population of Hamamatsu Children –

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Background: Body fat distribution is defined as the pattern of fat deposits in different regions of the body and usually expressed as a ratio. There are few studies on the relationship between blood pressure and the ratio of central fat measured on dual-energy X-ray absorptiometry (DXA) in childhood.

Methods and Results: The source population consisted of 521 fifth-grade children who attended elementary school in Hamamatsu, Japan, with 401 (77.0%) included in the study. Regional fat was determined using a DXA scanner in a mobile test room. The ratio of trunk to appendicular fat was calculated as trunk fat mass divided by appendicular (arms and legs) fat mass. In boys, the trunk-to-appendicular fat ratio was significantly related to systolic blood pressure and diastolic blood pressure after adjusting for confounding factors such as height and pubic hair appearance. In addition, an increase in trunk-to-appendicular fat ratio was related to an increase in blood pressure after adjusting for confounding factors including whole body fat volume and trunk fat volume. The relationship between fat distribution and blood pressure was not observed in girls.

Conclusions: An excessive proportion of trunk fat was related to increased blood pressure in the boys in a general population of Japanese children. The relationship between fat distribution and blood pressure was independent of the relationship between fat volume and blood pressure. (*Circ J* 2012; **76:** 2848–2854)

Key Words: Blood pressure; Body fat distribution; Child; Densitometry

Abdominal obesity is well-recognized for its important role in adult cardiometabolic risk, surpassing general obesity.[1–3] In childhood, trunk fat deposits measured using dual-energy X-ray absorptiometry (DXA) are also related to blood pressure and high-density lipoprotein cholesterol (HDLC).[4,5] There is a high correlation, however, between volume of abdominal fat and volume of total body fat deposits.[6] Substantial confusion remains about how abdominal and total body fat deposits might predict cardiovascular risk. The relationship of abdominal fat to blood pressure and serum lipids in children should thus be explored independently of total body fat. A few studies have investigated whether the amount of abdominal fat in children is associated with blood pressure and serum lipids irrespective of the total amount of body fat.[7,8] A study of Portuguese children found a correlation between abdominal fat deposits, measured using trunk skinfolds, and serum lipids, which was independent of whole body fat.[7] A study of French children also suggested an association between abdominal fat deposits, estimated on waist circumference, with blood pressure, independent of overall adiposity.[8] Furthermore, among Chinese children, trunk fat deposits measured using DXA and adjusted for total body fat were a predictor of metabolic risk.[9]

Body fat distribution is defined as the pattern of fat deposits in different regions of the body and usually expressed as a ratio. Most epidemiological studies measure fat distribution with the waist-to-hip ratio and distinguish it from the amount of fat.[10] As a risk factor, distribution of abdominal fat is as predictive of cardiovascular disease as the amount of abdominal fat deposited.[10]

DXA is a safe technique that precisely determines bone and soft-tissue composition for either the whole body or regions such as the arms, legs, and trunk.[11] The information can then be used to assess fat distribution with a ratio of trunk to peripheral fat and a ratio of android to gynoid fat. DXA has been used in a few studies to investigate fat distribution and cardiometabolic risk in adults.[12,13] Walton et al reported that body fat distribution determined using android-to-gynoid fat ratio, ir-

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Table 1. Subject Characteristics

Characteristics	Boys (n=198)	Girls (n=203)	P-value
Age (years)	11.2±0.3	11.2±0.3	0.425
Height (cm)	141.5±6.2	143.3±7.0	0.007
Weight (kg)	34.9±7.3	35.2±7.0	0.675
Body mass index (kg/m²)	17.3±2.6	17.0±2.3	0.230
Waist circumference (cm)	63.2±7.7	62.5±6.4	0.304
Waist-to-height ratio	0.45±0.05	0.44±0.04	0.013
% Whole body fat	19.2±6.0	20.8±4.6	0.002
Fat mass index (kg/m²)	3.53±1.67	3.71±1.33	0.244
Arm fat mass (kg)	1.06±0.61	1.08±0.47	0.749
Leg fat mass (kg)	3.05±1.52	3.40±1.43	0.018
Trunk fat mass (kg)	2.26±1.55	2.47±1.31	0.135
Trunk-to-appendicular fat ratio	0.53±0.10	0.54±0.09	0.106
SBP (mmHg)	105.6±10.6	106.6±10.2	0.333
DBP (mmHg)	58.1±7.4	59.6±8.2	0.054
LDLC (mmol/L)	2.41±0.56	2.51±0.52	0.074
HDLC (mmol/L)	1.97±0.42	1.85±0.37	0.003
Pubic hair appearance			
None	188 (94.9)	135 (66.5)	<0.001
At grade 5	10 (5.1)	55 (27.1)	
At grade 4	0 (0.0)	12 (5.9)	
At grade 3	0 (0.0)	1 (0.5)	

Data given as mean ± SD or n (%).
Fat mass index was calculated as fat mass divided by height squared. Trunk-to-appendicular fat ratio was calculated as trunk fat mass divided by appendicular fat mass. Unpaired t-test was used to compare characteristics between boys and girls except for pubic hair appearance, for which the Mann-Whitney U-test was used.
DBP, diastolic blood pressure; HDLC, high-density lipoprotein cholesterol; LDLC, low-density lipoprotein cholesterol; SBP, systolic blood pressure.

respective of total fat deposits, influenced serum lipid levels.[12] In childhood, researchers in the field of fat distribution have not embraced the use of DXA, with the exception of Daniels et al.[14] They found that the android-to-gynoid fat ratio in black and white US children was associated with less favorable plasma lipids and blood pressure, and that fat distribution was correlated with cardiovascular risk factors independent of total fat deposits.[14] This is of particular importance in a young population with relatively normal body fat mass,[14] but there is a substantial shortage of information concerning the relationship between fat distribution measured by DXA and cardiovascular risk factors in childhood. It is therefore necessary to examine an Asian population with relatively normal body fat mass. To this end, we investigated the relationship between DXA-measured trunk-to-appendicular fat ratio and blood pressure and serum lipids in a general population of Hamamatsu children.

Methods

Subjects

The source population consisted of 521 children (268 boys and 253 girls) who attended fifth grade at either of the 2 elementary schools in Hamamatsu, Japan: Aritama Elementary School (November 2010 and December 2011) or Sekishi Elementary School (December 2010 and November 2011). Because there are no another schools, all children who lived in the present study area went to 1 of these 2 schools. The source population was the general population of Hamamatsu children. Parents received printed information of study procedures, including DXA radiation exposure dose for the children, and provided written informed consent before enrollment of participants in the study. The study was approved by the Ethics Committee of the Kinki University Faculty of Medicine and performed in accordance with ethical standards set forth in the 1964 Declaration of Helsinki.

Whole Body and Regional Fat Mass

Whole body and regional fat mass were measured with a single DXA scanner (QDR-4500A, Hologic, Bedford, MA, USA) brought to the schools in a mobile test room. Participants wore light clothing without metal objects. Trunk, arm, and leg fat were measured as previously described.[15] Arm, leg, and head measurements were isolated from trunk measurements using specific anatomical landmarks in the anterior view planogram (chin, center of the glenohumeral joint, and femoral neck axis).

Whole body fat was evaluated using a percentage of total body fat (% whole body fat) and a height-normalized index (fat mass index, FMI; kg/m²). FMI was used to avoid the ambiguities of body fat as a percentage of body weight and can be calculated as total body fat mass (kg) divided by height squared (m²).[16] The trunk-to-appendicular fat ratio was calculated as trunk fat mass divided by appendicular fat mass. Appendicular fat mass was calculated as the sum of fat mass from both arms and legs.

Blood Pressure and Serum Lipids

Blood pressure was measured at the same session as body fat mass. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were read by physicians with an automated device (BP-103i II; Colin, Komaki, Japan). Cuff size was based on

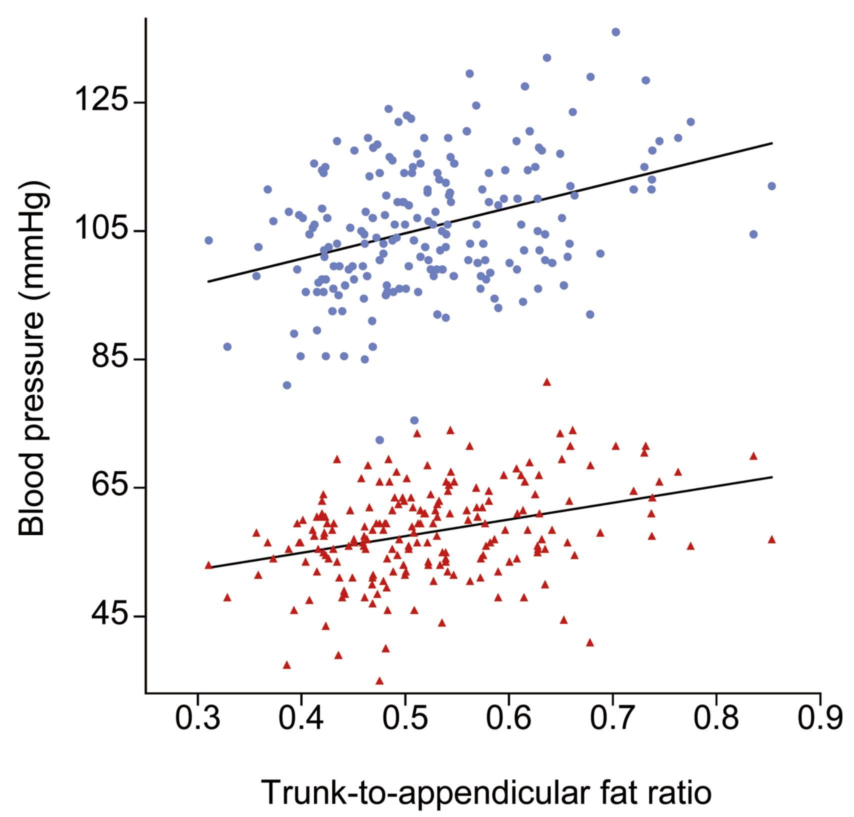

Figure. Blood pressure vs. trunk-to-appendicular fat ratio in boys. (●) Systolic blood pressure (SBP); (▲) diastolic blood pressure (DBP). Pearson's correlation coefficient for trunk-to-appendicular fat ratio to SBP was 0.367 (P<0.001), and that to DBP was 0.342 (P<0.001).

circumference of the arm. Measurements were performed in a seated position with legs uncrossed after resting for 5 min and in a quiet, appropriate environment at room temperature and were performed with the left arm supported at the level of the heart. The mean of 2 readings was used for analysis.

Blood samples were obtained at the same session. Low-density lipoprotein cholesterol (LDLC) was measured using Determiner L LDL-C (Kyowa Medex, Tokyo, Japan). HDLC was measured using MetaboRead HDL-C (Kyowa Medex). Inter- and intra-assay coefficients of variation were calculated from reference materials QAP troll 1X and QAP troll 2X (Sysmex, Kobe, Japan) as <4% for all blood tests.

Other Variables

Body weight, height, and waist circumference were assessed at the same session as the other measurements. Measurement of waist circumference was previously reported in detail.[15] Body mass index (kg/m^2) was calculated as weight (kg) divided by height squared (m^2). The first appearance of pubic hair was determined from self-reported responses to a questionnaire.

Statistical Analysis

Unpaired t-test was used to compare characteristics between boys and girls. Pearson's correlation test was used to examine associations between trunk-to-appendicular fat ratio and blood pressure. Linear regression analysis was used to compare the relationship of body fat variables to blood pressure and serum lipids, after adjusting for height and pubic hair appearance, both of which are known to influence blood pressure and serum lipid levels.[17,18] Pearson's correlation test was also used to characterize the relationships among body fat variables. Adjusted means of blood pressure and serum lipids stratified by trunk-to-appendicular fat ratio were calculated after adjusting for potential confounding factors including FMI using the general linear model. Analysis of variance (ANOVA) or analysis of covariance (ANCOVA) were used to identify differences among the crude and adjusted means. Simple or multiple linear regression analysis was used for trend tests of the crude and adjusted means. Multiple regression analysis was also used to compare the trunk-to-appendicular fat ratio and trunk fat mass. P<0.05 was considered statistically significant. SPSS Statistics Desktop for Japan, version 20.0 (IBM Japan, Tokyo, Japan) was used for statistical analysis.

Results

A total of 413 children (205 boys and 208 girls) underwent DXA measurements of regional body fat. Blood pressure, serum lipids, and information on pubic hair appearance were further obtained successfully from 401 children (198 boys and 203 girls; 77.0% of the target group), who comprised the study population.

Participant characteristics are listed in **Table 1**. Height, % whole body fat, and leg fat mass were significantly higher in girls than boys, while waist-to-height ratio and HDLC were significantly higher in boys than girls. There was a significant difference in pubic hair appearance between boys and girls.

Figure shows the relationship between trunk-to-appendicular fat ratio and blood pressure in boys. We found that trunk-to-appendicular fat ratio was significantly correlated with SBP and DBP. The association of body fat variables to blood pres-

Table 2. Body Fat vs. Blood Pressure and Serum Lipids

	SBP		DBP		LDLC		HDLC	
	β	P-value	β	P-value	β	P-value	β	P-value
Boys (n=198)								
% Whole body fat	0.156	0.025	0.143	0.048	0.276	<0.001	–0.318	<0.001
Fat mass index	0.195	0.005	0.166	0.023	0.298	<0.001	–0.318	<0.001
Arm fat mass	0.194	0.008	0.165	0.030	0.306	<0.001	–0.333	<0.001
Leg fat mass	0.176	0.019	0.127	0.105	0.285	<0.001	–0.308	<0.001
Trunk fat mass	0.239	0.001	0.192	0.012	0.305	<0.001	–0.340	<0.001
Trunk-to-appendicular fat ratio	0.314	<0.001	0.321	<0.001	0.160	0.025	–0.224	0.002
Girls (n=203)								
% Whole body fat	0.228	0.001	0.048	0.496	0.085	0.230	–0.323	<0.001
Fat mass index	0.266	<0.001	0.072	0.317	0.047	0.513	–0.379	<0.001
Arm fat mass	0.265	<0.001	0.051	0.498	0.062	0.417	–0.415	<0.001
Leg fat mass	0.282	<0.001	0.076	0.337	0.036	0.649	–0.373	<0.001
Trunk fat mass	0.248	0.001	0.067	0.385	0.043	0.579	–0.420	<0.001
Trunk-to-appendicular fat ratio	0.093	0.186	0.072	0.312	–0.039	0.590	–0.215	0.003

β, standard coefficient in linear regression analysis, after adjusting for height and pubic hair appearance. Fat mass index was calculated as fat mass divided by height squared. Trunk-to-appendicular fat ratio was calculated as trunk fat mass divided by appendicular fat mass. Abbreviations as in Table 1.

Table 3. Body Fat Variables

	Fat mass index		Arm fat mass		Leg fat mass		Trunk fat mass		Trunk-to-appendicular fat ratio	
	r	P-value†	r	P-value†	r	P-value†	r	P-value†	r	P-value†
% Whole body fat	0.958	<0.001	0.901	<0.001	0.913	<0.001	0.896	<0.001	0.443	<0.001
Fat mass index			0.968	<0.001	0.956	<0.001	0.964	<0.001	0.494	<0.001
Arm fat mass					0.938	<0.001	0.957	<0.001	0.467	<0.001
Leg fat mass							0.931	<0.001	0.363	<0.001
Trunk fat mass									0.632	<0.001

†Pearson's correlation test. Fat mass index was calculated as fat mass divided by height squared. Trunk-to-appendicular fat ratio was calculated as trunk fat mass divided by appendicular fat mass.

sure and serum lipids is given in Table 2. In boys, the trunk-to-appendicular fat ratio was significantly associated with SBP, DBP, LDLC, and HDLC, and the highest standard coefficient existed between trunk-to-appendicular fat ratio and blood pressure. In girls, the trunk-to-appendicular fat ratio was significantly associated with HDLC.

Associations between body fat variables are shown in Table 3. The trunk-to-appendicular fat ratio was significantly associated with other body fat variables including FMI. FMI was strongly associated with % whole body fat, arm fat mass, leg fat mass, and trunk fat mass.

Mean blood pressure and serum lipids stratified according to trunk-to-appendicular fat ratio are listed in Table 4. Crude mean blood pressure increased significantly with an increase in trunk-to-appendicular fat ratio in both sexes. After adjustment for confounding factors including FMI, increased blood pressure was still significantly associated with a high ratio of trunk to appendicular fat in boys, but this association was not observed in girls.

Comparison of standard coefficients of body fat variables with those for blood pressure and serum lipids is given in Table 5. In boys, both the SBP and DBP were significantly related to trunk-to-appendicular fat ratio but not to trunk fat mass. In girls, SBP was significantly related to trunk fat mass, but not to trunk-to-appendicular fat ratio. In contrast, HDLC showed a significant correlation with trunk fat mass in both sexes.

Discussion

The present study found a positive relationship between DXA-measured trunk-to-appendicular fat ratio and blood pressure in a general population of Hamamatsu children. In boys, increased ratio of trunk to appendicular fat was associated with increases in blood pressure. The association between fat distribution and blood pressure was independent of the association between whole body fat and blood pressure (Table 4). When trunk-to-appendicular fat ratio and trunk fat mass were used as independent variables, multiple regression analysis found that blood pressure was related to trunk-to-appendicular fat ratio but not trunk fat volume (Table 5). In girls, no association was found between blood pressure and fat distribution, and blood pressure was related to whole body fat. This information is particularly relevant for boys who have a normal amount of body fat that follows a more centralized distribution.

The association of cardiovascular disease with android or central fat distribution rather than gynoid or peripheral fat distribution is well-known.[10] Most studies have used simple anthropometric measurements such as waist-to-hip ratio to evaluate android fat distribution,[19] while only a limited number have determined android-to-gynoid fat ratios using ad-

Table 4. Mean Blood Pressure and Serum Lipids vs. Quartile Groups of Trunk-to-Appendicular Fat Ratio

	SBP (mmHg)	DBP (mmHg)	LDLC (mmol/L)	HDLC (mmol/L)
Boys (n=198)				
Crude mean				
Q1	100.8±1.3	55.2±0.9	2.38±0.06	1.98±0.05
Q2	104.4±1.6	56.5±1.0	2.40±0.07	2.15±0.06
Q3	106.7±1.2	59.6±0.9	2.38±0.08	1.95±0.06
Q4	110.6±1.5	61.2±1.2	2.50±0.10	1.80±0.06
P-value for difference†	<0.001	<0.001	0.647	<0.001
P-value for trend‡	<0.001	<0.001	0.326	0.006
Adjusted mean§				
Q1	101.8±1.4	55.6±1.0	2.43±0.08	1.90±0.06
Q2	104.9±1.4	56.6±1.0	2.44±0.08	2.12±0.06
Q3	106.5±1.4	59.5±1.0	2.38±0.08	1.95±0.05
Q4	109.2±1.5	60.8±1.1	2.41±0.08	1.91±0.06
P-value for difference†	0.011	0.004	0.950	0.023
P-value for trend‡	0.001	<0.001	0.738	0.754
Girls (n=203)				
Crude mean				
Q1	105.0±1.4	58.6±1.2	2.69±0.08	1.88±0.05
Q2	104.5±1.6	57.3±1.2	2.44±0.07	1.89±0.04
Q3	108.4±1.3	62.1±1.0	2.44±0.06	1.92±0.05
Q4	108.5±1.4	60.5±1.1	2.48±0.08	1.72±0.05
P-value for difference†	0.079	0.015	0.052	0.035
P-value for trend‡,§	0.025	0.041	0.059	0.057
Adjusted mean§				
Q1	106.3±1.4	59.0±1.1	2.67±0.07	1.84±0.05
Q2	105.3±1.4	57.3±1.1	2.44±0.07	1.85±0.05
Q3	108.4±1.4	62.0±1.1	2.45±0.07	1.91±0.05
Q4	106.4±1.4	60.1±1.2	2.49±0.08	1.81±0.05
P-value for difference†	0.425	0.029	0.085	0.476
P-value for trend‡,§	0.553	0.147	0.107	0.952

Data given as mean ± SE. Q1–Q4, lowest to highest quartile groups.
†ANOVA or ANCOVA was used to assess differences among quartile groups; ‡simple or multiple linear regression analysis was used for trend tests; §adjusted for fat mass index, height, and pubic hair appearance. Fat mass index was calculated as fat mass divided by height squared. Trunk-to-appendicular fat ratio was calculated as trunk fat mass divided by appendicular fat mass.
Abbreviations as in Table 1.

Table 5. Standard Coefficient of Body Fat variables vs. Blood Pressure and Serum Lipids

	SBP		DBP		LDLC		HDLC	
	β	P-value	β	P-value	β	P-value	β	P-value
Boys (n=198)								
Trunk-to-appendicular fat ratio	0.278	0.002	0.343	<0.001	–0.032	0.737	–0.022	0.806
Trunk fat mass	0.134	0.132	–0.002	0.981	0.212	0.025	–0.369	<0.001
Girls (n=203)								
Trunk-to-appendicular fat ratio	–0.076	0.361	0.017	0.840	–0.092	0.290	–0.007	0.935
Trunk fat mass	0.351	<0.001	0.135	0.118	0.028	0.743	–0.371	0.000

β, standard coefficient in multiple linear regression analysis. The dependent variable was blood pressure or serum lipid. The independent variables were trunk-to-appendicular fat ratio and trunk fat mass. Trunk-to-appendicular fat ratio was calculated as trunk fat mass divided by appendicular fat mass.
Abbreviations as in Table 1.

vanced technology such as DXA. DXA can determine the precise amount of fat for the whole body or specific regions.[11] Walton et al. reported that the android-to-gynoid fat ratio in healthy adults, determined by DXA and independent of total body fat, was related to adverse changes in serum lipids and lipoproteins, a sign of increased coronary artery disease risk.[12] Niedrauer et al similarly reported that the proportion of trunk body fat (trunk fat mass/total body-fat mass) was associated with less favorable plasma lipids in healthy adults.[13] In contrast, the use of DXA has not been embraced in the field of fat distribution research in children, with the exception of a study by Daniels et al, which found that the android-to-gynoid fat

ratio in black and white US children was independent of total body fat and significantly associated with blood pressure.[14] Very few studies, however, have followed up on this finding. In the present study, the trunk-to-appendicular fat ratio was associated with blood pressure independent of whole body fat and trunk fat in Japanese boys. The present results are consistent with the blood pressure results of the Daniels et al study and suggest that not only the amount of fat but also the pattern of its distribution influence blood pressure level. Regarding serum lipids, Daniels et al reported that fat distribution was associated with HDLC independent of whole body fat.[14] In contrast, we found that HDLC was associated with fat volume, but not with fat distribution. Thus, there appears to be a discrepancy between the present findings and those of Daniels et al. Further studies are needed to determine more conclusively whether fat distribution is associated with serum lipids in childhood.

Although we found that an increased ratio of trunk to appendicular fat was related to increased blood pressure in boys, the relationship between fat distribution and blood pressure was not observed in girls. It is well known that sex affects fat deposit patterns, and that women have more subcutaneous fat than men, who have more visceral fat.[20] Visceral fat secretes adipocytokines and causes metabolic syndrome.[1–3] Therefore, obesity-related metabolic disorders are much lower in premenopausal women than men.[20] In fact, the present study found that leg fat mass, which is a subcutaneous fat, was significantly higher in girls than boys. These findings suggest that the portion of visceral fat mass in trunk fat mass is smaller in girls than in boys. The sex difference in the visceral fat may explain the lack of association between trunk-to-appendicular fat ratio and blood pressure in girls.

Traditionally, the waist-to-hip ratio was used to determine android or gynoid fat distribution.[21] Gynoid refers to a relative excess of fat in the hips and thighs, while the android type refers to excess upper-body fat.[12] Thus the waist-to-hip ratio has been used to differentiate between these fat distribution types.[21] Recently, DXA has become available as a tool to measure regional fat,[22–24] with precise distinctions between trunk, arm, and leg fat.[15] In the present study we analyzed regional fat in the trunk, arms, and legs but not the waist (android) or hips (gynoid) in order to focus on the trunk-to-appendicular fat ratio. It has been reported that leg/total and leg/trunk ratios of regional fat have a favorable influence on serum lipids in adult patients with coronary atherosclerosis,[25] as well as in obese women.[26] In the present study, the trunk-to-appendicular fat ratio had an unfavorable influence on blood pressure in a general population of children, while the appendicular-to-trunk fat ratio had a favorable influence.

There are several limitations worth noting. First, previous studies reported the association of visceral fat measured on computed tomography (CT) and magnetic resonance imaging with cardiometabolic risk factors in children and adolescents.[27–29] The present study cannot clarify whether visceral fat deposits influenced blood pressure because the methods used to estimate trunk fat deposits did not specifically measure visceral fat, but DXA-measured abdominal fat is an excellent predictor of intra-abdominal fat measured on CT,[30] and therefore the trunk-to-appendicular fat ratio may be associated with visceral fat in boys. Second, the study design was cross-sectional, and we did not confirm whether the central fat distribution influenced blood pressure. Third, although the mean body height and weight of participants were similar to children in a national survey,[31] data were obtained from only 2 elementary schools in Japan.

In conclusion, fat distribution measured as a ratio of trunk to appendicular fat mass in a general population of Hamamatsu children was associated with blood pressure and independent of whole body fat and trunk fat volume. Knowing the ratio of trunk to appendicular fat is valuable for the evaluation of body fat. This information is particularly relevant for boys who have a normal amount of body fat that follows a more centralized distribution.

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Disclosures

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