Prevalence of central fatness in 1992–1994: 40% of Japanese boys 6–17 years

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Abstract. Obesity in children is a serious public health problem in Japan. However, the prevalence of central fatness has not been well determined in Japanese youth. We studied the relationship between body mass index (BMI) and waist circumference (WC) using line of equality analysis in 5,787 boys and 4,639 girls aged 6 to 17 years who participated in the 1992–1994 national survey on body sizes. WC was measured at the level of maximum waist narrowing in girls (WC1) and at the level of the top of iliac crest in boys (WC2). Using the 1978–1981 national survey data as baseline reference, excess fatness was defined as measurements exceeding the 90th centile in WC or in BMI. Among boys, 2,466 (42.6%) had WC2 >90th centile and 1,029 (17.8%) BMI >90th centile; whereas among girls, 895 (19.3%) had WC1 >90th centile and 673 (14.5%) BMI >90th centile. WC2-standard deviation scores (SDS) exceeded BMI-SDS in 5,060 (87.4%) boys and WC1-SDS exceeded BMI-SDS in 3,168 (68.3%) girls, respectively. Our results suggested a much higher prevalence of central fatness than generally recognized for Japanese children and adolescents, in particular, in Japanese boys.

Key words: Body mass index, Central obesity, Line of equality, Standard deviation score, Waist circumference

THE PREVALENCE of overweight and obesity among children has steadily increased over the past 3 decades in Japan. In 1977, 2.5–6.5% of children aged 6 through 14 years were overweight (more than 120% of ideal weight) whereas in 2010, 4.5–11.0% were overweight. These statistics were based on the nationally representative samples annually collected by the Japanese Ministry of Education, Culture, Sports, and Science and Technology [1]. Using the same Japanese governmental data [1], Hermanussen *et al.* interpreted that there was no evidence of any major rise in the prevalence of obesity as expressed by mean body mass index (BMI) for age and time of birth in Japan and suggested that Japanese children and adolescents may be more resistant against environmental factors that have contributed to obesity in affluent Western societies [2]. Wang *et al.* showed that

during the 1990s in Brazil and the U.S.A., an additional 0.5% of the entire child population became overweight each year, and that in Canada, Australia and parts of Europe, an additional 1% of all children become overweight each year; in contrast, in Japan, annualized change in the prevalence of obesity among school children was less than 0.1% and third lowest among 24 countries studied. The annualized change in the combined prevalence of overweight and obesity among school children in Japan was reported as 0.4–0.5% [3]. Our clinical experience, however, does not support these global comparison data which suggests that Japanese youth have remained relatively thin compared to those in other industrialized countries.

In this study, we compared data on waist circumference (WC), together with BMI in the same subject, collected in national survey in 1992–1994. This is the only national dataset of BMI and WC available for the study. The prevalence of central fatness in relation to that of generalized obesity and overweight will clarify unique feature of fatness in Japanese youth.

Submitted Aug. 9, 2017; Accepted Oct. 28, 2017 as EJ17-0357

Released online in J-STAGE as advance publication Dec. 8, 2017

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Materials and Methods

Study population

This study analyzed cross-sectional national survey data collected between 1992 and 1994 from children from 28 regions throughout the country [4]. There were 10,426 Japanese children and adolescents (5,787 boys and 4,639 girls), aged 6–17 years, with both BMI and WC determined. The Research Institute of Human Engineering for Quality Life, as sponsored by the Japanese Ministry of International Trade and Industry, conducted the survey on body sizes of Japanese people of various ages for the sizing of ready for use garments. This study is based on the secondary analysis of data without individually identifiable information.

All measurements, including height, weight and WC, were conducted by trained measurers, and BMI were calculated. BMI and WC were converted to standard deviation scores (SDS) and percentile values by the LMS methods [5, 6], using the 1978–1981 Japanese growth references for height, weight, BMI and WC [7–9]. LMS method summarizes the centiles by three smooth curves representing skewness (L curve), the median (M curve) and coefficient of variation (S curve). The assumption of LMS method is that the data at each age are normally distributed after the Box-Cox transformation. The L, M, and S values were smoothed for each age and gender using cubic spline curves.

Waist circumference 1 (WC1) vs. Waist circumference 2 (WC2)

For WC, two measurement sites were set: WC1 as measured at the level of maximal narrowing and WC2 as measured at the top of the iliac crest. Since the 1978–1981 national references contained only WC1 for girls and WC2 for boys, SDS were obtained for WC1 for girls and WC2 for boys, respectively.

BMI cut-off values

BMI cut-off values for Japanese children were undetermined. Thus, we arbitrarily adopted the 95th centile for obesity and the 85th centile for overweight according to the CDC classification for U.S. children [10]. We also studied the 90th centile for comparison.

Accuracy of diagnostic test: performance measures

In the absence of a “gold standard,” diagnostic test accuracy studies were performed in comparison with a reference standard of the “true” disease status and diag-

nostic test results are expressed as true positive, false positive, false negative and true negative [11]. We utilized WC >90th centile as “true” disease status following the International Diabetes Federation (IDF) recommendations [12].

Results

Table 1 shows descriptive statistics for height, weight, BMI, and WC (WC1 and WC2) by age and sex. Mean height, weight, BMI and WC1 were larger for boys than for girls at all ages examined, each reaching maximum values at 17 years of age. Mean BMI was larger in boys at all ages examined than in girls except at 13 years. Mean WC2 was larger in girls than in boys at 6–8 years and 11–13 years, and was larger in boys than in girls at 9–10 years and 14–17 years. Mean WC2 was larger than mean WC1 at all ages examined in both sexes. The differences between WC2 and WC1 were much larger in girls than in boys at all ages examined and these differences were statistically significant ($p < 0.01$). Sex differences for WC2 were smaller than those for WC1 at all ages examined ($p < 0.01$).

The numbers of children classified as excessively fat are shown in relation to BMI centile values and disease status (Table 2). Subjects were classified into two groups; those with abnormal test results and those with normal test results using BMI 95th (90th, 85th) centile as cut-offs. Disease status (overweight + obesity) was positive if WC >90th centile and negative if WC <90th centile. There were 2,466 (42.6%) boys having WC2 >90th centile and 3,321 (57.4%) having WC2 <90th centile, whereas there were 1,029 (17.8%) boys having BMI >90th centile and 4,758 (82.2%) having BMI <90th centile. The differences between WC1-SDS and BMI-SDS were much smaller in girls at all ages examined. There were 895 (19.3%) girls having WC1 >90th centile and 3,744 (80.7%) having WC1 <90th centile whereas there were 673 (14.5%) girls having BMI >90th centile and 3,966 (85.5%) having BMI <90th centile.

Assuming WC >90th centile as “true” disease status for excess central fatness for both boys and girls, sensitivity, specificity, positive predictive value (PPV), false positive/true positive (FP/TP) ratio and false positive (FP) rate were calculated (Table 3). Test positive, as defined by BMI >95th centile, yielded sensitivity 0.25, specificity 1.00, PPV 0.99, FP/TP ratio 0.01 and FP rate 0.002 for boys and sensitivity 0.42, specificity 0.99, PPV 0.94, FP/TP ratio 0.06 and FP rate 0.006 for girls,

Table 1 Mean and standard deviations (SD) for height, weight, BMI, WC1 and WC2 for Japanese children age 6–17 years, the 1992–1994 national survey data

Age year	boys						girls					
	<i>N</i>	Height cm	Weight kg	BMI kg/m ²	WC1 cm	WC2 cm	<i>N</i>	Height cm	Weight kg	BMI kg/m ²	WC1 cm	WC2 cm
6	98	117.7 (4.9)	22.1 (3.3)	15.9 (1.5)	52.5 (3.9)	54.9 (4.5)	118	117.8 (5.3)	21.9 (3.6)	15.7 (1.8)	51.5 (4.1)	55.9 (5.1)
7	309	122.1 (4.9)	24.3 (4.3)	16.2 (2.0)	54.1 (5.1)	57.4 (5.6)	275	121.1 (5.2)	23.5 (3.8)	15.9 (1.7)	52.3 (3.9)	57.5 (5.2)
8	378	127.3 (5.3)	27.0 (4.7)	16.6 (2.1)	56.0 (5.3)	59.7 (5.7)	317	127.2 (5.6)	26.5 (4.6)	16.3 (2.0)	54.0 (4.7)	60.5 (5.9)
9	467	132.6 (5.5)	30.3 (5.6)	17.2 (2.3)	58.3 (6.2)	62.5 (6.5)	397	132.3 (5.7)	29.3 (4.9)	16.7 (2.0)	55.2 (4.8)	61.9 (5.9)
10	471	138.2 (5.7)	34.5 (7.2)	18.0 (2.8)	60.8 (7.3)	65.9 (7.3)	377	139.7 (6.4)	34.0 (6.6)	17.3 (2.3)	57.7 (5.6)	65.2 (7.0)
11	438	143.7 (6.6)	38.1 (7.9)	18.3 (2.8)	62.3 (7.5)	67.6 (7.4)	338	145.5 (6.6)	38.5 (6.7)	18.1 (2.2)	59.4 (4.8)	67.9 (6.6)
12	454	151.6 (7.8)	43.6 (9.2)	18.8 (2.8)	63.9 (7.4)	69.9 (7.9)	304	151.2 (6.2)	43.1 (7.9)	18.7 (2.6)	60.9 (5.1)	70.8 (7.1)
13	564	158.5 (7.4)	49.0 (9.5)	19.4 (2.8)	65.8 (7.0)	73.1 (7.4)	316	154.5 (5.4)	46.7 (7.3)	19.5 (2.6)	62.6 (5.2)	73.7 (7.2)
14	355	163.4 (6.9)	54.4 (11.0)	20.3 (3.4)	68.2 (7.8)	75.9 (8.4)	257	156.3 (5.1)	49.3 (6.9)	20.2 (2.5)	63.6 (4.9)	75.6 (6.5)
15	596	168.0 (5.6)	59.4 (9.4)	21.0 (3.0)	70.0 (7.0)	77.9 (7.1)	475	157.1 (5.3)	51.3 (7.0)	20.8 (2.5)	64.5 (5.1)	76.2 (6.6)
16	950	168.5 (5.7)	60.5 (9.9)	21.3 (3.1)	70.8 (7.1)	78.6 (7.8)	846	157.7 (5.4)	52.2 (6.5)	21.0 (2.3)	64.8 (4.8)	76.6 (6.5)
17	707	169.6 (5.4)	62.8 (10.1)	21.8 (3.2)	72.4 (7.7)	79.9 (7.4)	619	158.1 (5.3)	53.2 (7.3)	21.3 (2.5)	65.5 (5.1)	77.9 (6.9)

N, numbers; BMI, body mass index; WC1, waist circumference 1; WC2, waist circumference 2

respectively. Test positives as defined by BMI >90th centile and by BMI >85th centile are also shown.

Table 4 shows mean and standard deviations of BMI-SDS and WC2-SDS for boys, and BMI-SDS and WC1-SDS for girls, respectively. Standard deviation scores for WC were much higher than for BMI. The differences between WC-SDS and BMI-SDS were statistically significant and were larger in boys than in girls.

Comparisons of BMI-SDS and WC-SDS are presented as scatter diagrams against the line of equality for boys and girls at 7, 10, 13, 16 years of age, respectively (Fig. 1). At all ages examined, WC2-SDS exceeded BMI-SDS in boys and WC1-SDS exceeded BMI-SDS in girls, with the differences between WC-SDS and BMI-SDS being much larger in boys.

Table 5 shows the prevalence of fatness based on BMI

and WC in Japanese children and adolescents aged 6–17 years, the 1992–1994 national survey data. WC exceeded BMI in prevalence in boys 6–17 years and in girls 13–17 years ($p < 0.05$). In adolescent boys, the prevalence of fatness surpassed 40%.

Discussion

The prevalence and trends in obesity have not explicitly been determined in Japanese children and adolescents, primarily due to lack of population-specific cut-off values for overweight and obesity. We have previously reported that the 2001 prevalence of overweight was 12.9% in Japanese boys and 12.5% in Japanese girls as assessed by using BMI >95th centile, although the Japanese government reported much smaller values (9.2% for

Table 2 Contingency table: numbers of children classified as excessively fat (WC >90th centile, and by BMI 95th, 90th and 85th centile)
a) BMI cut-off: 95th centile

BMI	boys			girls		
	WC2		total	WC1		total
	>90th centile	<90th centile		>90th centile	<90th centile	
>95th centile	628	6	634	373	22	395
<95th centile	1,838	3,315	5,153	522	3,722	4,244
total	2,466	3,321	5,787	895	3,744	4,639

b) BMI cut-off: 90th centile

BMI	boys			girls		
	WC2		total	WC1		total
	>90th centile	<90th centile		>90th centile	<90th centile	
>90th centile	969	60	1,029	555	118	673
<90th centile	1,497	3,261	4,758	340	3,626	3,966
total	2,466	3,321	5,787	895	3,744	4,639

c) BMI cut-off: 85th centile

BMI	boys			girls		
	WC2		total	WC1		total
	>90th centile	<90th centile		>90th centile	<90th centile	
>85th centile	1,207	164	1,371	660	297	957
<85th centile	1,259	3,157	4,416	235	3,447	3,682
total	2,466	3,321	5,787	895	3,744	4,639

BMI, body mass index; WC1, waist circumference 1; WC2, waist circumference 2

Table 3 Sensitivity, specificity, positive predictive value, false positive/true positive ratio and false positive rate calculated by WC >90th centile as 'true positive' for excess fatness, and BMI cut-off being at 95th, 90th and 85th centile

BMI cut-off centile	boys					girls				
	Sensitivity	Specificity	PPV	FP/TP ratio	FP rate	Sensitivity	Specificity	PPV	FP/TP ratio	FP rate
95th	0.25	1.00	0.99	0.01	0.002	0.42	0.99	0.94	0.06	0.006
90th	0.39	0.98	0.94	0.06	0.018	0.62	0.97	0.82	0.21	0.032
85th	0.49	0.95	0.88	0.14	0.049	0.74	0.92	0.69	0.45	0.079

BMI, body mass index; PPV, positive predictive value; FP/TP ratio, false positive/true positive ratio; FP rate, false positive rate

boys and 8.0% for girls, both aged 5–17 years) as based on a cut-off value of >+20% excess body weight [13]. No assessment of WC was made in either of these studies, and we suspect the prevalence of fatness may be much higher if WC was considered.

The present study showed large increases in BMI-SDS and WC-SDS in a period between 1978–1981 and 1992–1994 in Japanese youth aged 6–17 years, and the in-

creases were substantially more for WC than for BMI, reflecting a steeper increase in central fatness in Japanese youth. Since central fatness in children is known to be linked to adverse metabolic and cardiovascular complications in adulthood [14], the current trends should be a cause for a concern in terms of present and future morbidity and mortality. Adverse health consequences associated with central fatness are likely to be underestimated

Table 4 Mean and standard deviations for BMI-SDS and WC2-SDS for boys and for BMI-SDS and WC1-SDS for girls age 6–17 years, the 1992–1994 national survey data

Age years	boys			girls		
	BMI-SDS	WC2-SDS	<i>p</i>	BMI-SDS	WC1-SDS	<i>p</i>
6	0.30 (0.99)	0.91 (0.90)	<0.0001	0.26 (1.12)	0.56 (1.09)	<0.0001
7	0.31 (1.05)	0.99 (0.86)	<0.0001	0.31 (1.03)	0.48 (0.92)	<0.0001
8	0.26 (1.05)	1.00 (0.78)	<0.0001	0.29 (1.04)	0.47 (0.92)	<0.0001
9	0.27 (1.08)	0.97 (0.80)	<0.0001	0.27 (0.96)	0.32 (0.92)	0.0196
10	0.32 (1.11)	1.01 (0.81)	<0.0001	0.21 (1.00)	0.33 (0.94)	<0.0001
11	0.26 (1.07)	0.92 (0.76)	<0.0001	0.28 (0.95)	0.39 (0.91)	0.0001
12	0.21 (1.05)	0.91 (0.79)	<0.0001	0.15 (1.07)	0.38 (0.97)	<0.0001
13	0.22 (1.04)	1.09 (0.72)	<0.0001	0.18 (1.02)	0.52 (0.93)	<0.0001
14	0.29 (1.13)	1.20 (0.79)	<0.0001	0.16 (0.99)	0.53 (0.93)	<0.0001
15	0.37 (1.09)	1.28 (0.77)	<0.0001	0.16 (1.03)	0.54 (0.98)	<0.0001
16	0.27 (1.12)	1.23 (0.85)	<0.0001	0.17 (0.99)	0.58 (0.96)	<0.0001
17	0.32 (1.09)	1.31 (0.82)	<0.0001	0.21 (1.14)	0.67 (0.98)	<0.0001
all	0.28 (1.08)	1.11 (0.81)	<0.0001	0.21 (1.03)	0.50 (0.96)	<0.0001

BMI-SDS, body mass index- standard deviation scores; WC1-SDS, waist circumference 1-standard deviation scores; WC2-SDS, waist circumference 2-standard deviation scores

by monitoring BMI alone. Age- and sex-specific WC percentile references are now available for Japanese children and adolescents [9] and can be used as an additional measure of fatness. Thus, we suggest that WC be routinely measured at the time of annual physical examination in school in Japan. Indeed, WC identified much larger numbers of children with excess fatness than did BMI: WC in 1992–1994 exceeded 90th centile in 42.6% of Japanese boys and 19.3% of Japanese girls (WC2 for boys, WC1 for girls). The corresponding rates for BMI exceeding 90th centile were 17.8% of Japanese boys and 14.5% of girls in 1992–1994. Based on WC, more than 40% of Japanese boys and nearly 20% of girls were abdominally fat in 1992–1994. This unique feature may be missed by BMI measurement alone, and does not support the notion of “thin Japanese children.”

We adopted WC >90th centile as a substitute for a gold standard in the present study, since children who have a WC greater than the 90th centile are more likely to have multiple risk factors for cardiovascular disease and type 2 diabetes mellitus than those with smaller WC [15], and the IDF [12] has chosen to use globally the 90th centile as a cut-off for WC. Further, central fatness has been reported to have increased greatly in various industrialized countries, with central fatness overwhelm-

ing whole body fatness [16, 17].

The choice of a cut-off for test results is based upon clinical usefulness in this study. The optimum cut-off point is usually considered to be the point where the ROC curve sharply turns, as associated with both moderately high sensitivity and moderately high specificity. Sensitivity and specificity, however, are not equally important in a screening test of fatness. Missing fatness (false negative diagnosis) would be considered less important than erroneously categorizing a nonfat child as fat (false positive diagnosis). Setting the BMI cut-off at 95th centile, both the FP rate and the FP/TP ratio are negligibly small, although the number of false negative subjects is substantial. This finding indicates that apparently high performance of WC is not due to the diagnosis of a nonfat child as having central adiposity (false positive diagnosis).

Sex differences in the prevalence trends of central fatness merit a brief comment. We found that central adiposity was more prevalent among Japanese boys than among girls and there was a statistically significant increasing trend in the mean SD score for BMI and WC. These findings are in contrast with those of a previous UK study [16], showing that central adiposity was more prevalent among British girls than among British boys.

Fig. 1 Comparison of BMI and WC presented as a scatter diagram with the line of equality

The male predominance in central adiposity over female is not unique to the Japanese and is shared by various East Asian populations such as Korean [18], Taiwanese [19] and Hong Kong Chinese [20], although the reasons are unknown.

To our knowledge, this is the first report on the prevalence of central fatness in Japanese youth. Our results suggested a much higher prevalence of central fatness than generally recognized for Japanese children and adolescents.

Acknowledgements

We thank Research Institute of Human Engineering for Quality Life and Japanese Standards Association for providing the data in computer-readable form.

Disclosure

The authors declare no conflict of interest.

Table 5 Prevalence (%) of fatness based on BMI and WC in Japanese children age 6–17 years, the 1992–1994 national survey data. Values are percentage fatness exceeding 90th centile

Age years	boys			girls		
	BMI	WC2	<i>p</i>	BMI	WC1	<i>p</i>
6	14.3	33.7	0.0007	19.5	24.6	0.1730
7	17.8	37.9	<0.0001	15.6	16.7	0.3642
8	15.6	37.8	<0.0001	17.4	18.0	0.4175
9	18.8	34.5	<0.0001	14.6	14.1	0.4198
10	22.7	41.2	<0.0001	14.6	14.1	0.4176
11	18.3	29.2	0.0001	15.1	16.6	0.2991
12	17.4	32.2	<0.0001	16.4	16.4	—
13	15.1	40.2	<0.0001	13.0	18.0	0.0393
14	19.7	47.6	<0.0001	12.1	17.5	0.0410
15	19.0	51.3	<0.0001	12.6	21.3	0.0002
16	17.6	48.1	<0.0001	11.9	22.2	<0.0001
17	15.8	54.5	<0.0001	17.0	25.4	0.0001
all	17.8	42.6	<0.0001	14.5	19.3	<0.0001

BMI, body mass index; WC1, waist circumference 1; WC2, waist circumference 2

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