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Body Mass Index Reference for Screening Overweight and Obesity in Chinese School-age Children[1]

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Purpose To establish and propose a national body mass index (BMI) reference for screening overweight and obesity in Chinese school-age children and adolescents. **Methods** 2000 CNSSCH (Chinese National Survey on Students Constitution and Health) data, including 216 620 primary and secondary school students aged 7 to 18 years old, were used as a reference population. Compared with those of the NCHS internatioanl reference, three temporary sets of cut-off BMI were proposed by testing different combinations of P_{85}, P_{90}, and P_{95}. When physiological and biochemical measures between and among "obesity", "overweight", and "normal weight" groups were taken into consideration, set II was selected to be the most appropriate one. The sex-age-specific curves were then plotted and smoothed by using B-spline method. **Results** Based on the samples from costal developed metropolis, the BMI curves successfully overcame the shortcomings of lower and level-off tendency of the Chinese total population. Temporary set II, composed by cut-offs of P_{85} for overweight and P_{95} for obesity, was finally selected by its sensitivity and peculiarity. BMI 24 and 28 were used as cut-offs for overweight and obesity for both males and females aged 18 years old. These cut-offs, consistent with Chinese Adult's Reference, was proposed as the Body mass index reference for screening overweight and obesity in Chinese school-age children and adolescents. **Conclusion** The new reference clearly showed its superiorty in both prospectivity and actuality. The proposed reference minimized the gaps of the BMI curve between Chinese adolescents and the international reference. Most importantly was that it was consistent with the Eastern Asia ethnic characteristics of body fatness growth. It was therefore proposed by the Working Group on Obesity in China (WGOC) to use it as an nationwide reference for screening overweight and obesity of school-age children and adolescents in China.

Key words: Body mass index, Chinese school-age children; Overweight; Reference

INTRODUCTION

Accompanied with the rapid socioeconomic progress in China in recent 20 years, the prevalence of overweight and obesity in both adults and children becomes more and more serious, mainly in the urban areas[1-2]. In Beijing, for example, even applying the "2000 NCHS/CDC Sex-Age BMI Reference", 15% of the boys and 10% of the girls aged 7-12 years old are overweight, and 10% of the boys and 7% of the girls in the same ages are obese, respectively. In other words, one of the four boys and one of the six girls in the primary schools in Beijing are overweight and obese[3].

Previous surveys and investigations in China have shown that the related factors on childhood obesity are similar to those in the developed countries[4-5]. These factors include mainly over-consumption of energy, serious inactivity, and the lifestyle change from being active to sedentary, as well as the unhealthy living and dietary habits. In other words, the Chinese children's overweight and obesity are mainly caused by having unhealthy life styles.

Although the problem of childhood obesity in China is far from reaching the prevalence levels in the developed countries, such as in the United States, we must learn from their lessons. One of the main factors for causing the serious spread of obesity in those countries is the hesitation in taking strong preventive measures at the early stages of obesity in 1970-1990[6]. For this reason, we have to take clear

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and stronger strategies and measures now, because it's much easier to control the spread of obesity since the beginning than to have the therapy measures after the occurrence of obesity[7].

As the first step of taking preventive measures, an accurate reference for screening overweight and obesity is deemed necessary. This reference should be established by using sex-age-percentiles of BMI, as most developed countries are using now. However, the figures of the weight-for-height standards widely used in China now are much lower than the international ones[3]. Many children screened out as "overweight" and "obesity" are actually weighed normally. Application of such standard will mislead adolescents to inappropriate weight reduction and making harmful impact on their physical fitness and health. On contrary, if we use the international criteria that are unsuitable for Chinese, many overweight and obesity youth will not be detected, while they continuously suffer from the health consequence of obesity, and develop the related disease risks in their adult life[6].

In 2004, the Working Group on Obesity in China (WGOC), supported by the International Life Sciences Institute (ILSI) Focal Point in China, began to establish a set of nationwide reference for screening overweight and obesity in school-age children. This reference used sex-age-BMI percentiles according to the following principles: a) To keep consistency and agreement among different studies over the classification of obesity, and make it easy for international comparison. The two recognized international norms, the NCHS and IOTF references, were taken in consideration[8-9]. b) Evidence and documents were widely collected, to make sure if one of these references was suitable for the Chinese children and adolescents and was convincing scientifically. c) The new reference should be successively linked up with the BMI reference for the adults that had already set up in China in 2001[10]. d) To have adequate clinical evidence to verify the definitions of overweight and obesity.

METHODS

Reference Population

The sample of 2000 CNSSCH (Chinese National Survey on Students Constitution and Health) was selected as the reference population for this study[11]. This survey is a series of cross-sectional, nationally representative examination led by the Chinese National SSCH (Survey on Students Constitution and Health) Association, and has conducted every five years in China since 1985 under the auspices of Ministry of Education, Ministry ot Health and State Bureau of Sports. All 30 provinces, except for Tibet (non-Han nationality data), Macao, Hong Kong and Taiwan, participated in this survey, and followed the same procedures and methodology for sampling and conducting the interviews and examinations. All the subjects were elementary and secondary school students aged 7-18 years old. The subjects used in this study were all Han ancestry (the major nationality in China accounts for more than 92% of the total population). According to the residence, the subjects in each province were divided into four groups: urban male, rural male, urban girl and rural girl. Each of these groups consisted equal numbers from three socioeconomic classes, characterized as 1st ('upper'), 2nd ('middle') and 3rd ('lower'). The socioeconomic strata were defined by five indices: the regional gross domestic product, total annual income per capita, average food consumption per capita, natural population growth, and the regional social welfare index. Same age definition was used and decimal years were calculated as the difference between date of data collection and birth date of the subjects. The subjects, both of the urban and rural residence, were born and reside (at least one year) in the locality.

Methods of Statistical Analysis

All subjects had a thorough medical examination before the measurements were taken, and overt disease or physical or mental deformities were excluded. In each province, 180-200 subjects for every sex-age subgroups of 7 to18 years old were sampled. The total number of subjects selected were intitally 242 575. In order to avoid the interference of malnutrition, stunted and wasted subjects were excluded by applying the "Height-for-Age Norm" and "Weight-for-Height Norm", respectively[11]. Finally, 216 620 subjects aged 7-18 years old were sampled as reference population.

Sex-age-specific-BMI curves were made for the urban boys, rural boys, urban girls and rural girls, respectively. P_{75}, P_{80}, P_{85}, P_{90}, P_{95}, and P_{97} of the body mass indices in these groups were taken for international comparisons. A special group, the "metropolis group" was further selected from the urban boy and urban girl groups, for the purpose of setting up the cut-offs of defining overweight and obesity. The subjects came from six metropolis and big cities including Beijing, Shanghai, Tianjin, Shenyang, Dalian, and Qingdao all located in the most developed coastal areas where the youth's physical growth status are the highest level in China. For verifying between and among the "normal weight", "overweight" and "obesity" subjects, Student's *t*-test and covariance test were used, and

sensitivity and specificity were calculated. In determining the final cut-offs of defining overweight and obesity, B-spline method was used for smoothing the sex-age-BMI reference curves.

All the data collection and calculation were performed by using SPSS/PC 10.0 package in the Institute of Child and Adolescent Health, Peking University Health Science Center.

RESULTS

Comparison Between Chinese Groups' BMI-for-age Percentiles and the Cut-offs of NCHS and IOTF References

The present study compared the 75th, 80th ,85th, 90th, 95th, and 97th of the four Chinese population-based BMI curves with the cut-offs of the NCHS, IOTF references (85th for overweight and 95th for obesity). The purpose was to identify if these international references can be used for defining overweight and obesity sensitively and validly for the Chinese children and adolescents. The two comparisons showed the similar results. To take NCHS as an example, it clearly showed that the 85th and 95th percentiles of the Chinese rural groups were too low to compare with those of the NCHS cut-offs. Actually these populations were not contributable for establishing the cut-offs for the Chinese definitions. The 85th and 95th percentiles of the Chinese urban girls were also lower than those of the NCHS cut-offs since the early school ages, whereas the curves showed a significant lower and level-off tendency since the early adolescence, leading the Sino-US gaps of the percentile curve become broader and broader until 18-year-old. As for the Chinese urban boys, the gaps on the 85th and 95th (especially that of the former) were not as significant as that of the girls, but the curves also showed a lower and level-off tendency since the mid-adolescence. For the 18-year-old boys, the Sino-US gaps are 2.2 and 3.3 (kg/m^2) for the 85th and 95th, respectively.

Comparisons were also conducted between Chinese high BMI percentiles with cut-offs of the reference in other developed countries, such as Sweden. In general, the similar results were obtained.

Figs. 1 and 2 showed comparisons of BMI percentiles of the Chinese metropolis groups and the NCHS cut-offs. For boys, the 85th and 95th of the BMI-for-age curves were quite similar to that of the US boys at early ages. However, the curves showed a lower and level-off tendency since 15-year-old, leading the Sino-US gaps at 18-year-old to increase by 1.4 and 2.4 kg/m^2 for 85th and 95th, respectively. For girls, both the 85th and 95th of the BMI-for-age curves became gradually lower with age increase, and the Sino-US gaps at 18-year-old were as high as 2.2 and 4.4, respectively. These gaps are thought to be caused both by the general lower body mass and level-off tendency since early adolescence. It clearly suggests that the NCHS and other international reference are actually inappropriate for screening out overweight and obesity in Chinese adolescents, even if in the metropolis populations. In other words, in order to overcome the shortcoming of less sensitivity, we should have to establish our own BMI reference.

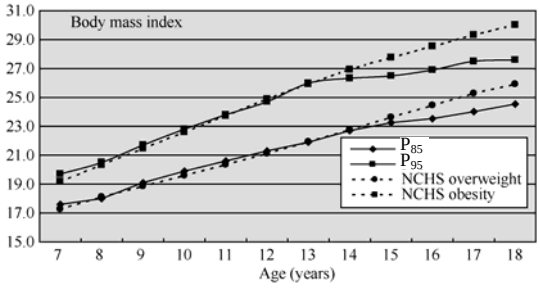

FIG. 1. Comparison of P_{85} and P_{95} of BMI curves for Chinese boys in 6 metropolis cities with the NCHS cut-offs of overweight and obesity.

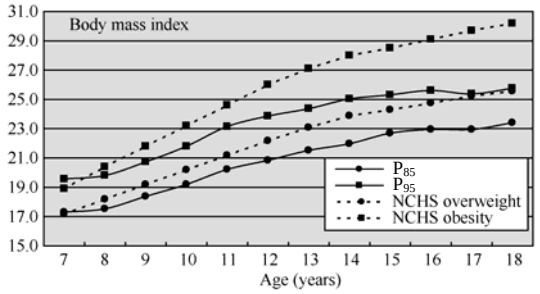

FIG. 2. Comparison of P_{85} and P_{95} of BMI curves for Chinese girls in 6 metropolis cities with the NCHS cut-offs of overweight and obesity.

Identification of Cut-offs

Metropolis groups were then used as the final reference population. BMI-for-age curves were conducted for boys and girls aged 7 through 18 years old, respectively. According to the common international rules, three temporary sets of defining overweight and obesity was established by separately using the P_{85}, P_{90}, and P_{95}: a) set I: P_{85} for overweight and P_{90} for obesity; b) set II: P_{85} for overweight and P_{95} for obesity; c) set III: P_{90} for overweight and P_{95} for obesity (Tables 1 and 2). These cut-offs have in some extent overcome the lower and level-off tendency of the Chinese whole populations, and

effectively narrowing the gaps with the NCHS reference. However, all the three sets of cut-offs has only reached 24 (for overweight) and 30 (for obesity) levels of BMI for the 18-year-old.

TABLE 1

Comparisons Between Three Temporary Definitions for Chinese Boys and NCHS Cut-offs

Age (years)	Set I (P_{85}, P_{90})		Set II (P_{85}, P_{95})		Set III (P_{90}, P_{95})		NCHS Cut-offs	
	Cut-off	Obesity	Overweight	Obesity	Overweight	Obesity	Overweight	Obesity
7-	17.0	17.8	17.0	19.6	17.8	19.6	17.37	19.18
8-	17.7	18.5	17.7	20.4	18.5	20.4	18.11	20.33
9-	18.4	19.4	18.4	21.3	19.4	21.3	18.85	21.47
10-	19.4	20.5	19.4	22.2	20.5	22.2	19.6	22.6
11-	20.1	21.2	20.1	23.0	21.2	23.0	20.35	23.73
12-	21.0	22.1	21.0	23.9	22.1	23.9	21.12	24.89
13-	21.9	23.0	21.9	25.0	23.0	25.0	21.93	25.93
14-	22.8	23.9	22.8	25.9	23.9	25.9	22.77	26.93
15-	23.5	25.0	23.5	26.8	25.0	26.8	23.63	27.76
16-	24.2	26.1	24.2	27.7	26.1	27.7	24.45	28.53
17-	25.0	27.0	25.0	28.5	27.0	28.5	25.28	29.32
18	24.8	28.0	24.8	28.2	28.0	28.2	25.92	30.02

TABLE 2

Comparisons Between Three Temporary Definitions for Chinese Girls and NCHS Cut-offs

Age (years)	Set I (P_{85}, P_{90})		Set II (P_{85}, P_{95})		Set III (P_{90}, P_{95})		NCHS Cut-offs	
	Overweight	Obesity	Overweight	Obesity	(yrs)	Overweight	Obesity	Overweight
7-	16.4	17.1	16.4	18.3	17.1	18.3	17.17	18.93
8-	17.0	17.7	17.0	19.0	17.7	19.0	18.18	20.36
9-	17.7	18.4	17.7	19.8	18.4	19.8	19.19	21.78
10-	18.4	19.2	18.4	20.7	19.2	20.7	20.19	23.2
11-	19.1	20.1	19.1	21.8	20.1	21.8	21.18	24.59
12-	20.0	21.0	20.0	22.7	21.0	22.7	22.17	25.95
13-	20.9	21.9	20.9	23.5	21.9	23.5	23.08	27.07
14-	21.9	23.0	21.9	24.4	23.0	24.4	23.88	27.97
15-	22.9	23.9	22.9	25.3	23.9	25.3	24.29	28.51
16-	23.9	25.0	23.9	26.2	25.0	26.2	24.74	29.1
17-	24.4	26.0	24.4	27.0	26.0	27.0	25.23	29.72
18	24.2	26.2	24.2	28.0	26.2	28.0	25.56	30.22

Several physiological and biochemical measures were used to verify between and among the “normal weight”, “overweight” and “obesity” groups. T-test and covariance analysis were used to differentiate among the three groups for the three temporary sets of cut-offs. In brief, only the comparison results by using set II are presented in tables.

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) may be the best measure for verifying between and among “obesity”, “overweight” and “normal weight” groups. They came from all the 216 620 subjects aged 7-18 years old who participated in the 2000 CNSSCH. As shown in Tables 3 and 4, the differences of SBP were more significant between the “overweight” and “normal weight”, especially in early ages, and among boys.

TABLE 3

Comparisons of Systolic Blood Pressure Between and Among Obesity, Overweight and Normal Weight Boys (mmHg)

Age (years)	Obesity			Overweight			Normal Weight			T-tests			Covariance Analysis
	n	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	A & B	A & C	B & C	
7-	421	102.4	12.0	427	97.8	10.4	7598	95.0	9.3	***	***	***	***
8-	423	104.5	12.2	422	101.2	10.0	7595	96.7	9.4	***	***	***	***
9-	417	106.8	12.2	413	102.7	10.3	7409	98.4	9.5	***	***	***	***
10-	409	109.1	13.9	413	106.5	11.1	7376	100.0	9.8	**	***	***	***
11-	412	110.7	12.4	406	107.6	11.6	7339	101.7	10.2	**	***	***	***
12-	402	111.7	10.8	400	108.0	10.9	7157	102.8	10.4	***	***	***	***
13-	323	116.2	13.1	328	112.2	11.1	5800	105.8	10.8	***	***	***	***
14-	349	117.3	11.9	349	114.7	10.9	6268	108.2	11.1	**	***	***	***
15-	381	119.7	12.0	385	117.0	11.0	6846	110.9	11.0	**	***	***	***
16-	392	121.1	11.6	400	116.4	11.0	7071	112.5	10.8	***	***	***	***
17-	403	122.7	11.3	404	119.0	11.1	7240	113.8	10.9	***	***	***	***
18	389	122.6	13.1	390	119.4	12.3	6977	114.7	11.3	***	***	***	***

Note. Data comes from the 2000 Chinese National Survey on Student's Constitution and Health, 110 334 boys aged 7-18 years old. A= "obesity" group, B= "overweight" group, C= "normal weight" group. Student's T -test and covariance analysis, * P<0.05, ** P<0.01, *** P<0.001.

TABLE 4

Comparisons of Systolic Blood Pressure Between and Among Obesity, Overweight and Normal Weight Girls (mmHg)

Age (years)	Obesity			Overweight			Normal Weight			T-tests			Covariance Analysis
	n	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	A & B	A & C	B & C	
7-	420	98.5	11.6	419	96.8	9.7	7516	94.2	9.3	**	***	**	***
8-	407	100.6	10.6	416	98.9	9.5	7367	95.9	9.3	**	***	**	***
9-	393	103.4	11.6	392	101.9	10.5	7168	97.7	9.5	**	***	***	***
10-	422	107.3	12.3	417	104.2	11.5	7493	99.9	10.0	***	***	***	***
11-	403	110.3	13.5	409	106.5	11.4	7274	102.2	10.2	***	***	***	***
12-	376	111.0	11.5	381	108.4	11.5	6760	103.7	10.5	**	***	***	***
13-	401	110.8	10.5	401	107.6	10.0	7194	103.5	10.0	***	***	***	***
14-	420	110.6	10.4	421	107.1	10.3	7568	104.3	10.1	***	***	***	***
15-	398	112.0	11.0	400	109.2	10.6	7118	105.4	10.3	***	***	***	***
16-	420	112.3	10.4	421	108.9	10.6	7522	105.7	9.8	***	***	***	***
17-	400	113.1	11.4	401	110.2	9.5	7163	106.5	9.9	***	***	***	***
18	417	112.0	11.1	416	110.0	10.7	7499	106.0	10.2	*	***	**	***

Note. Data comes from the 2000 Chinese National Survey on Student's Constitution and Health, 110 334 boys aged 7-18 years old. A= "obesity" group, B= "overweight" group, C= "normal weight" group. Student's T -test and covariance analysis, * P<0.05, ** P<0.01, *** P<0.001.

Tables 5 and 6 showed the same phenomenon of DBP among three groups. Although the differences between the "obesity" and "overweight" were relatively low, especially in some ages of the girls (P<0.05).

Total serum cholesterol (TC), triglyceride (TG) and high-density lipoprotein cholesterol (HDL-C) were used as lipidemia biochmical measures. The data were derived from an investigation of F. Y. ZHAI and his collegues in Beijing. As shown in Tables 7-9, 692 school-age children aged 10-12 years old were recurited by using the set II of definition. In general, no significance of covariance analysis was found, for both boys and girls, though the differences between "obesity" and "overweight" by *t*-test were significant (P<0.05) in most of the sex-age subgroups (Table 7). The analysis of TG showed a highly significant difference between "obesity" and "overweight",

TABLE 5

Comparisons of Diastolic Blood Pressure Between and Among Obesity, Overweight and Normal Weight Boys (mmHg)

Age (years)	Obesity			Overweight			Normal Weight			T-tests			Covariance Analysis
	n	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	A & B	A & C	B & C	
7-	421	63.5	11.0	427	61.6	9.5	7598	58.7	9.9	**	***	***	***
8-	423	65.8	10.7	422	63.9	9.1	7595	60.3	9.8	**	***	***	***
9-	417	67.5	10.7	413	64.6	9.4	7409	61.6	9.7	***	***	***	***
10-	409	69.1	11.0	413	66.8	10.4	7376	62.7	9.8	**	***	***	***
11-	412	69.6	10.3	406	67.5	9.9	7339	63.9	9.6	***	***	***	***
12-	402	68.8	10.1	400	66.4	10.2	7157	64.2	9.6	**	***	***	***
13-	323	70.9	9.5	328	68.2	10.1	5800	65.1	9.5	***	***	***	***
14-	349	70.7	9.1	349	70.0	9.1	6268	66.7	9.4	*	***	***	***
15-	381	72.3	8.9	385	71.4	8.1	6846	68.3	9.0	*	***	***	***
16-	392	73.5	9.3	400	71.2	9.1	7071	69.5	8.9	**	***	***	***
17-	403	75.2	8.9	404	73.5	7.7	7240	70.5	8.6	*	***	***	***
18	389	75.0	9.4	390	73.3	8.5	6977	71.0	9.0	**	***	***	***

Note. Data comes from the 2000 Chinese National Survey on Student's Constitution and Health, 110 334 boys aged 7-18 years old. A= "obesity" group, B= "overweight" group, C= "normal weight" group. Student's T-test and covariance analysis, *P<0.05, ** P<0.01, ***P<0.001.

TABLE 6

Comparisons of Diastolic Blood Pressure Between and Among Obesity, Overweight and Normal Weight Girls (mmHg)

Age (years)	Obesity			Overweight			Normal Weight			T-tests			Covariance Analysis
	n	Mean	*s*	*n*	Mean	*s*	*n*	Mean	*s*	A & B	A & C	B & C	
7-	420	62.4	9.5	419	61.3	9.2	7516	58.7	9.6	*	***	***	***
8-	407	64.0	9.4	416	62.9	8.8	7367	60.0	9.8	*	**	***	***
9-	393	65.7	9.9	392	64.4	9.2	7168	61.3	9.8	**	***	***	***
10-	422	67.8	10.2	417	65.7	10.1	7493	62.9	9.7	**	***	***	***
11-	403	69.2	10.6	409	67.7	9.2	7274	64.5	9.5	**	***	***	***
12-	376	69.5	9.8	381	68.2	8.7	6760	65.4	9.4	*	***	***	***
13-	401	69.8	8.6	401	67.1	9.6	7194	65.2	8.8	***	***	***	***
14-	420	69.9	8.9	421	68.5	8.5	7568	66.1	8.6	*	***	***	***
15-	398	70.8	9.4	400	69.0	8.1	7118	66.7	8.4	**	***	***	***
16-	420	71.6	8.1	421	69.9	8.5	7522	67.1	8.1	**	***	***	***
17-	400	71.0	7.9	401	69.9	8.0	7163	67.5	8.2	*	***	***	***
18	417	71.6	8.7	416	70.2	8.8	7499	67.5	8.3	*	***	***	***

Note. Data comes from the 2000 Chinese National Survey on Student's Constitution and Health, 110 334 boys aged 7-18 years old. A= "obesity" group, B= "overweight" group, C= "normal weight" group. Student's T-test and covariance analysis, * P<0.05, **P<0.01, *** P<0.001.

TABLE 7

Comparisons of Lipid Cholesterol (TC) Between and Among the Obesity, Overweight, and Normal Weight Youths Aged 10-12 Years Old (mmol/L)

Age (years)	Obesity		Overweight		Normal Weight		T-tests			Covariance Analysis
	Mean	*s*	Mean	*s*	Mean	*s*	A & B	A & C	B & C	
	Boys									
10-	4.88	0.61	4.68	0.6	4.38	0.63	*		*	*
11-	4.71	0.73	4.43	0.81	4.36	0.69	*			
12-	4.07	0.62	4.29	0.85	3.80	0.76	*		*	
	Girls									
10-	4.71	0.73	4.48	0.93	4.36	0.66	*			**
11-	4.8	0.73	4.48	0.93	4.36	0.66	*			
12-	4.07	0.62	4.13	0.71	3.89	0.82				

Note. Data cmes from Zhai FY *et al*., 2003. A= “obesity” group, B= “overweight” group, C= “normal weight” group. Student’s T-test and covariance analysis, * $P<0.05$, ** $P<0.01$.

TABLE 8

Comparisons of Lipid Triglyceride (TG) Between and Among the Obesity, Overweight, and Normal Weight Youths Aged 10-12 Years Old (mmol/L)

Age (years)	Obesity		Overweight		Normal Weight		T-tests			Covariance Analysis
	Mean	*s*	Mean	*s*	Mean	*s*	A & B	A & C	B & C	
	Boys									
10-	1.21	0.49	1.11	0.55	0.76	0.24	*	**	***	***
11-	1.27	0.68	0.93	0.36	0.76	0.28	**	**	*	***
12-	1.44	0.63	0.89	0.31	0.78	0.36	***	***	*	***
	Girls									
10-	1.33	0.24	1.21	0.66	0.69	0.24	**	***	***	***
11-	1.37	0.9	1.11	0.48	0.75	0.28	**	***	***	***
12-	1.57	1.01	1.11	0.45	0.78	0.38	***	***	***	***

Note. * $P<0.05$, ** $P<0.01$, *** $P<0.001$. The meaning of A, B, C see TABLE 7.

TABLE 9

Comparisons of Lipid High Densitylipoprotein-C (HDL-C) Between and Among the Obesity, Overweight, and Normal Weight Youth Aged 10-12 Years Old (mmol/L)

Age (years)	Obesity		Overweight		Normal Weight		T-tests			Covariance Analysis
	Mean	*s*	Mean	*s*	Mean	*s*	A & B	A & C	B & C	
	Boys									
10-	1.47	0.22	1.48	0.22	1.58	0.29				
11-	1.4	0.24	1.47	0.2	1.61	0.33		*	*	**
12-	1.18	0.19	1.35	0.25	1.42	0.34	**	**		**
	Girls									
10-	1.4	0.24	1.42	0.28	1.51	0.28		*	*	*
11-	1.47	0.58	1.4	0.21	1.58	0.29	**		*	*
12-	0.98	0.17	1.29	0.31	1.41	0.32	***	***	**	**

Note. * $P<0.05$, ** $P<0.01$, *** $P<0.001$. The meaning of A, B, C see TABLE 7.

and between "overweight" and "normal weight", especially among girls. As for boys, high significances (P<0.001) could be found in each of the age subgroups. Table 9 demonstrated a general rising tendency from "obesity" to "overweight", and from "overweight" to "normal weight". The difference between the "overweight" and "normal weight" was significant for girls (P<0.05), whereas significant difference was only found between the "obesity" and "normal weight" for boys.

The present study demonstrated that a high sensitivity could be found when P_{85} of BMI was used as a cut-off of overweight. Based on the blood pressure verification, more than 83.3% for SBP and 78.1% for DBP of the sensitivity were reached. In other words, all the three temporary sets of cut-offs could achieve the major purpose of this study, that is, to differentiate sensitively the overweight from normal weight and obesity. On the other hand, it's better to use P_{95} and P_{97}, especially when the young adolescents were assessed. To take TG and HDL-C as examples, using the P_{90} of BMI as a cut-off of obesity, only about 41% for boys and 47% for girls were found, whereas this specificity was 55% for both boys and girls by using P_{95}, and 64% and 69% by using P_{97}, respectively.

However, perfect combination of sensitivity and specificity is needed for estabolishing a nationwide screen reference. That is to not only reflect the sensitivity, but also demonstrate clearly specificity in differntiating obesity, overweight and normal weight individuals. If temporary set I (P_{85} and P_{90}) was used, most of the overweight children would be screened out (high senstivity) , but many of those screened out as "obesity" were mistakenly identified (low specificity). On the other hand, relative high specificity would be achieved if temporary set III (P_{90} and P_{95}) was used, with the compensation of low sensitivity, because many youth who were actually overweight would be ruled out. In other words, definition of set III would fail to detect and prevent some early childhood obesity in China. For this reason, set II should be proposed as cut-offs for defining overweight and obesity for the Chinese school-age children and adolescents.

Revised BMI Reference for Oeverweight and Obesity

Based on the temporary set II (85th for overweight and 95th for obesity), minor revision was proposed. The retionale are as follows: a) the cut-offs of the 7-12 years old are slightly adjusted, in order to be consistent with that of the international criteria, such as the NCHS reference; b) the cut-offs of the overweight and obesity for 18-year-old group was suggested to be 24 and 28, respectively, in order to link with the Chinese adult's BMI definition of overweight and obesity; c) according to the characteristics of the Chinese females who have the relative small increments of adolescent physical growth and relative large separating tendency within population, minor corrections were performed on females BMI-for-age percentile curves in the 13- to 18-year period; d) the verification was again performed after the revision; e) the curves were modified and amended by using B-Spline method; and finally, the new "BMI Classification Reference for Screening Overweight and Obesity in Chinese School-age Children and Adolescent" was established and proposed (Table 10, Figs. 3 and 4).

TABLE 10
Body Mass Index Reference Norm for Screening Overweight and Obesity in Chinese Children and Adolescents

Age	Boys		Girls	
(years)	Overweight	Obesity	Overweight	Obesity
7-	17.4	19.2	17.2	18.9
8-	18.1	20.3	18.1	19.9
9-	18.9	21.4	19.0	21.0
10-	19.6	22.5	20.0	22.1
11-	20.3	23.6	21.1	23.3
12-	21.0	24.7	21.9	24.5
13-	21.9	25.7	22.6	25.6
14-	22.6	26.4	23.0	26.3
15-	23.1	26.9	23.4	26.9
16-	23.5	27.4	23.7	27.4
17-	23.8	27.8	23.8	27.7
18	24.0	28.0	24.0	28.0

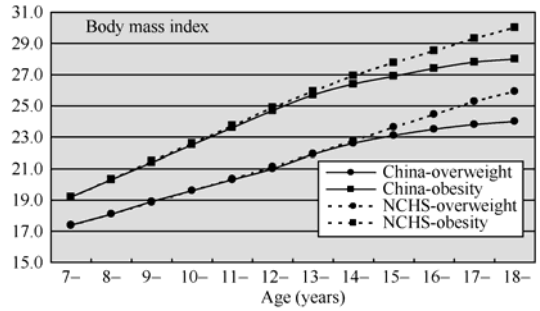

FIG. 3. BMI Classification Reference for Screening Overweight and Obesity in Chinese School-age Children and Adolescents (for boys).

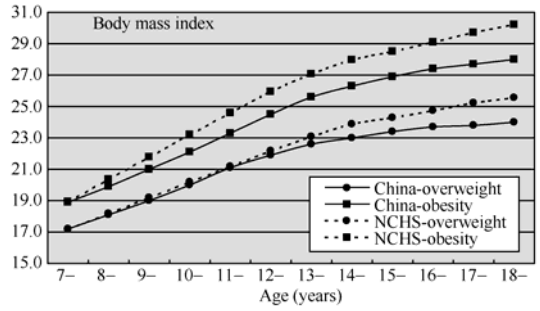

FIG. 4. BMI Classification Reference for Screening Overweight and Obesity in Chinese School-age Children and Adolescents (for girls).

The newly proposed BMI cut-offs were applied to the data of 2000 CNSSCH, finding that the proposed reference were suitable and applicabe for the prevention of childhood obesity and overweight in China, and that the results fitted well with China's present status. The practical use of this new reference will be described elsewhere as a separate paper in this journal.

DISCUSSION

Assessment on the Reference Population

One of the most important factors for the proposed reference was to select the reference population in the 2000 CNSSCH data. The data have the following merits: a) It was a set of most recently standardized cross-sectional data, and the samples were reprentative of the nationwide growth status of the Chinese school-age children and adolescents; b) It covered almost all of the Chinese administration areas, and there were at least 160 subjects in each sex-age group in every province, being sufficient enough for estabolishing a national BMI reference[12]; c) CNSSCH is a consecutive survey conducted every five year interval. Although large socio-demographic changes have been occurred since 1985, more than 87% of the subjects were selected from the same examining school settings identified since 1985. In such case, the data were actually a cohort surveillance one. The present study suggests that the previous data of CNSSCH in 1985, 1991 and 1995 can be used to analyze the epidemic trend of overweight and obesity among Chinese children and adolescents in recent 20 years[11].

Enlightenment From the International Comparisons

The first critical consideration for establishing the cut-offs of the Chinese sex-age-specific BMI reference is the sensitivity[12]. Our preliminary analyses have documented that if the proposed reference is based on the population with high growth level, such as the "metropolis groups" mentioned above, more than 90% of the Chinese overweitht and obesity children and adolescents would be successfully screened out, while the BMI curves of cut-offs for children aged 7- to 12- years old are quite similar with that of the international definitions. On the other hand, large gaps of BMI percentiles exist between the Chinese youth and their counterparts from the developed countries. These gaps become larger and larger with the age of adolescents, even if the Chinese rural youth with low BMI level are not considered to be included during the estabolishment of the reference. Because of this fact, a simple adoption from the international cut-offs would no doubt improve the specifity of screening out the overweight and obesity ones, but it would sacrifice the sensitivity, especially among the adolescents[13]. We would like to emphasize this review because many adolescents concerned would be ruled out from the too high cut-offs of overweight and obesity, thus the early prevention of childhood obesity would not be achievable[14].

The second potential problem of our proposed reference was its screening specifity for adolescents, because the cut-off curves was getting smaller with age since mid-adolescence (Figs. 3 and 4). For those 18-year-old, the cut-offs were only 24 for overweight and 28 for obesity, that are less than the 25 and 30, respectively, set by the NCHS or IOTF intenational references. Two factors aroused us to make these changes. Firstly, there were are significant gaps on the age-specific BMI curves since the mid-adolescence between the Chinese "metropolis boys" with highest physical growth level in China and the international cut-offs. Secondly, more significant low and level-off tendency was seen in

girls since the early adolescence compared with the curves described by NCHS reference, thus it was not appropriate to adopt the current international references. In addition, the girls had relative low body mass since the early ages, and their lower and level-off tendency of BMI occurs earlier than that of the boys. In view of of this fact, the rising gradients of BMI-for-age curves of the girls were smoother than that of the Chinese boys, leading to a broader gap between the Chinese girls and the international cut-offs.

The lower and level-off tendency of the Chinese adolescents could only be partially explained by a smaller number of severe obesese subjects found during the adolescnt period, because China is acturally on her early stage to spread epidemic of obesity[15]. However, it was most likely that such tendency, especially that for Chinese girls, was attributable to the ethnic difference in body composition during adolescent period compared with those in developed countries. Many reports have shown that in the Asian populations, such as the Chinese and Japanese, the growth and development of the skeleton and muscle are relatively lower than the other ethnic groups[16-17]. In other words, with same BMI, the Asian population will have rlative higher body fat percentage than that of the other ethnic groups[17].

The same phenomenon could also be found in the Chinese adults, especially in the females, suggesting strongly the necessity of establishing a Chinese BMI-for-age reference for defining overweight and obesity. The Working Group for Obesity in China (WGOC, 2002) under the support of International Life Science Institute Focal Point in China, conducted a meta-analysis of 13 Chinese population studies on the relations between BMI, waist cicumference and risk factors of related chronic diseases. The ressults had clearly documented that: a) In Chinese adults, BMI at 24 and 28 could be recommended as the cut-offs to reflect the increments of prevalence of hypertendsion, 2-type deabetes, dyslipidemia and clustering of risk factors (two and more than two risk factors); b) the BMI at 24 with best sensitivity and specificity for identification of these risk factors, and the BMI at 28 which might identify the risk factors with specificity around 90% were suitable for defining overweight and obesity of the Chinese adults; c) The analyses of population attributable risk percentage illustrated that reducing BMI to lower than 24 could prevent 45% to 50% clustering of risk factors, and treatment of obese persons (BMI $\geqslant$ 28) with drugs could prevent 15%-17% clustering of risk factors[10,18]. Asayama and other Japanese scholars also had documented that it was better to use the BMI at 24 and 28 as cut-offs of defining overweight and obesity for Japanese, because they came from the BMI curve which were more suitable for reflecting the body composition, physical growth level, and the somatotypic characteristics of the Japanese and other Asian populations. Furthermore, many evidances have shown significant increments of prevalence of hypertendsion, deabetes, dyslipidemia and clustering of risk factors when BMI is over these cut-offs[16].

The present study examined also the blood pressures and serum lipoprotein profile. Together with other excellent evidence on the posstive relationship between disease risks and bigger BMI percentiles, the present results clearly support our establisment of cut-off BMI for overweight and obesity. Similar with the current reference for adults, it is better to set up the cut-off BMI at the age of 18, that are connecting at the adult BMI 24 and 28 rather than 25 and 30, for defining overweight and obesity. However, in view of the fact that it is more difficult to find clinical evidence of health risks associated with childhood obesity, more researches on this issue have to be carried out further in the future.

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