Body mass index percentile curves and cut off points for assessment of overweight and obesity in Shanghai children

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Background: Body mass index as a measure for overweight and obesity is widely accepted. There are no references of BMI for Shanghai adolescents and children. This study was undertaken to construct percentile curves of body mass index (BMI) and cut off points for overweight and obesity of children in Shanghai.

Methods: The data on birthday, height and weight of the 96 104 children from Shanghai (48 790 boys and 47 314 girls) were measured during 1999 to 2002. The BMI percentile curves for Shanghai children aged 0-18 years were constructed by the LMS method. Based on the recommendations of the International Obesity Task Force (IOTF) and the Working Group on Obesity in China (WGOC), the percentile curves passing through 25 and 30 kg/m^2 or 24 and 28 kg/m^2 at age of 18 were established as overweight and obesity cut off points for Shanghai children.

Results: The age and sex specific BMI percentile curves of Shanghai children were constructed. The BMI in childhood changes substantially with age. The medians at birth are 13.7 and 13.4 kg/m^2 for boys and girls, respectively, and increase to 18.3 and 17.8 kg/m^2 at age of 6 months. They decrease to 15.7 kg/m^2 at age of 5.5 years for boys, and 15.4 kg/m^2 at age of 6 years for girls, and then increase to 21.4 and 20.1 kg/m^2 at age of 18 years for boys and girls respectively. The percentile curves passing through 24 and 28 kg/m^2 at age of 18 years are P75.5 and P93.3 for boys, and P89.1 and P98.2 for girls, whereas those passing through 25 and 30 kg/m^2 at age of 18 are P82.0 and P96.5 for boys and P93.0 and P99.2 for girls.

Conclusions: Based on the recommendations of the IOTF and WGOC, the BMI cut off points for overweight and obesity for Shanghai children aged 2-18 years have been constructed for the first time in China.

Introduction

The increasing prevalence of obesity in adults and children has become a global public heath problem.[1-3] The definition of obesity is recognized important in understanding the prevalence of obesity as well as its monitoring and intervention. Many indices are available for obesity. BMI-by-age references are recommended by WHO to define overweight and obesity in adults,[4] and now is used for children and adolescents.[5-8] In 2000, the International Obesity Task Force (IOTF) constructed the international BMI references by the LMS method.[9] To the present, however, no research paper has been conducted on the establishment of BMI references for children by the LMS method in China.[10-13] In this paper, we introduce the construction of BMI percentiles and the cutoff points for overweight and obesity for Shanghai children by the LMS method.

Methods

The data on birthday, height and weight of 96 104 children and adolescents aged 0-19 years (48 790 boys and 47 314 girls) were measured during 1999 to 2002 in Shanghai.

Their BMI percentile curves were constructed by the LMS method.[14,15]

The percentile curves pass through 25 and 30 kg/m^2, or 24 and 28 kg/m^2 at age of 18 years are defined as cut off points of overweight and obesity for Shanghai children and adolescents according to the recommendations of the IOTF and the Working Group on Obesity in China (WGOC).[9,16,17]

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Table 1. Sample size by age

Age	Boys	Girls
birth	2666	2387
0-0.25	1484	1325
0.25-0.5	1132	1038
0.5-0.75	1203	1058
0.75-1	589	572
1-2	2053	1998
2-3	2155	1908
3-4	1959	1817
4-5	2774	2597
5-6	2673	2551
6-7	2035	1935
7-8	1852	1881
8-9	2243	2147
9-10	3021	2906
10-11	3014	2948
11-12	3048	2958
12-13	2048	1938
13-14	2066	1886
14-15	2219	2026
15-16	2152	2514
16-17	1996	2231
17-18	1714	1920
18-19	2694	2773
0-19	48790	47314
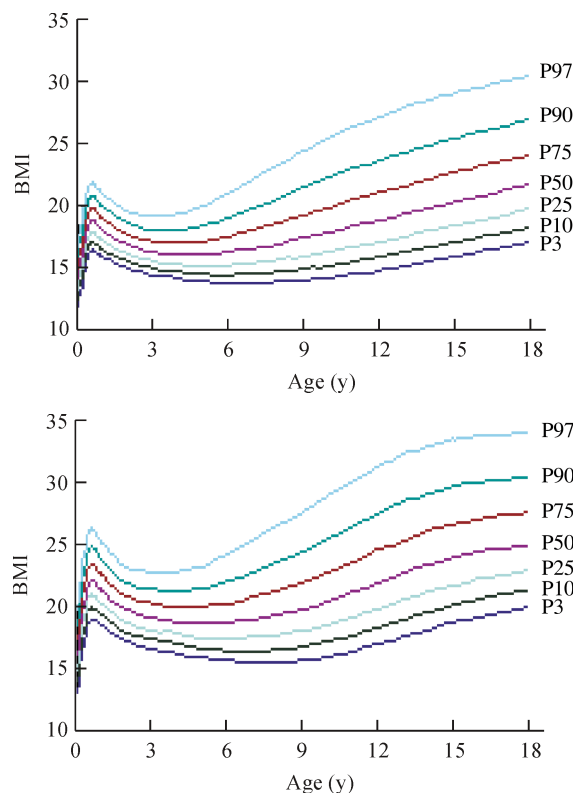
Fig. 1. BMI percentile curves for children aged 0-18 years.

Table 2. L, M and S values by age

Age	L		M		S	
	Boy	Girl	Boy	Girl	Boy	Girl
0	0.74	0.04	13.7	13.4	0.10	0.10
1	-1.09	-1.21	17.7	17.3	0.08	0.08
2	-1.71	-1.48	16.4	16.1	0.07	0.07
3	-2.06	-1.74	15.9	15.7	0.08	0.07
4	-2.21	-1.89	15.7	15.4	0.08	0.08
5	-2.18	-1.94	15.6	15.3	0.10	0.09
6	-2.04	-1.91	15.8	15.4	0.11	0.10
7	-1.85	-1.78	16.2	15.6	0.12	0.11
8	-1.67	-1.62	16.6	15.8	0.14	0.12
9	-1.51	-1.47	17.1	16.2	0.15	0.13
10	-1.39	-1.35	17.5	16.7	0.15	0.14
11	-1.31	-1.27	18.0	17.2	0.16	0.14
12	-1.27	-1.23	18.5	17.8	0.16	0.14
13	-1.24	-1.21	19.0	18.4	0.16	0.14
14	-1.21	-1.21	19.5	18.9	0.16	0.14
15	-1.19	-1.23	20.0	19.3	0.16	0.14
16	-1.17	-1.25	20.5	19.7	0.16	0.14
17	-1.15	-1.28	21.0	19.9	0.16	0.13
18	-1.12	-1.31	21.4	20.1	0.15	0.13

Data cleaning

Before the establishment of the model, the data from the samples were cleaned by omitting the data out of median±5SD. The data of 43 boys (0.09%) and 42 girls (0.09%) were omitted. Finally, the data of 48 747 boys and 47 272 girls were used for modeling.

Model fitting and L, M and S values by age

While constructing the percentiles by the LMS method, the appropriate e.d.f (equivalent degrees of freedom) values must be selected so that the percentile curves fit the data well and were acceptably smooth. After model fitting for several times, the e.d.f values for L, M and S were 6-12-8 and 7-12-8 for boys and girls, respectively. Transform Age was selected for Age Scale. Power and offset values were 0.2 and 0. Table 2 shows L, M and S values by age.

BMI percentile curves for children aged 0-18 years

The percentiles were calculated out by the following equation when the L, M and S values were obtained by age: percentile=$M*(1+L*S*Z)^{1/L}$. Z represents normal equivalent deviate for required percentile. For example, Z score for 3rd percentile is -1.9, 50th percentile is

Results

Samples

The age distribution of 96 104 children is shown in Table 1.

Table 3. BMI percentiles for boys and girls aged 0-18 years

Age	Boys									Girls								
	P3	P5	P10	P25	P50	P75	P90	P95	P97	P3	P5	P10	P25	P50	P75	P90	P95	P97
0	11.2	11.5	12.0	12.8	13.7	14.6	15.4	15.9	16.3	11.1	11.3	11.8	12.5	13.4	14.3	15.2	15.8	16.2
1	15.5	15.7	16.1	16.8	17.7	18.7	19.6	20.3	20.7	15.2	15.4	15.8	16.5	17.3	18.2	19.2	19.8	20.3
2	14.5	14.7	15.0	15.7	16.4	17.3	18.2	18.8	19.3	14.2	14.4	14.7	15.3	16.1	16.9	17.8	18.4	18.7
3	14.0	14.2	14.5	15.1	15.9	16.8	17.7	18.3	18.8	13.9	14.1	14.4	15.0	15.7	16.5	17.4	18.0	18.4
4	13.7	13.9	14.2	14.8	15.7	16.6	17.7	18.5	19.0	13.5	13.7	14.0	14.7	15.4	16.3	17.3	18.0	18.4
5	13.4	13.6	14.0	14.7	15.6	16.8	18.1	19.0	19.7	13.2	13.4	13.8	14.5	15.3	16.3	17.5	18.3	18.8
6	13.3	13.6	14.0	14.8	15.8	17.2	18.7	19.9	20.8	13.1	13.3	13.7	14.4	15.4	16.6	17.9	18.8	19.5
7	13.3	13.6	14.1	15.0	16.2	17.7	19.5	20.9	22.0	13.0	13.3	13.7	14.5	15.6	16.9	18.4	19.5	20.4
8	13.4	13.7	14.2	15.2	16.6	18.3	20.4	22.0	23.2	13.0	13.3	13.7	14.6	15.8	17.3	19.0	20.3	21.2
9	13.6	13.9	14.5	15.6	17.1	19.0	21.2	23.0	24.3	13.1	13.4	13.9	14.9	16.2	17.8	19.7	21.1	22.1
10	13.8	14.1	14.7	15.9	17.5	19.6	22.1	23.9	25.3	13.3	13.7	14.2	15.3	16.7	18.4	20.5	21.9	23.0
11	14.0	14.4	15.1	16.3	18.0	20.2	22.8	24.8	26.3	13.7	14.0	14.6	15.7	17.2	19.1	21.3	22.8	24.0
12	14.4	14.8	15.4	16.7	18.5	20.8	23.5	25.6	27.1	14.1	14.5	15.1	16.3	17.8	19.8	22.0	23.6	24.8
13	14.7	15.1	15.8	17.2	19.0	21.4	24.2	26.3	27.8	14.6	14.9	15.6	16.8	18.4	20.4	22.7	24.3	25.6
14	15.1	15.5	16.3	17.6	19.5	21.9	24.8	26.9	28.5	15.0	15.4	16.0	17.3	18.9	20.9	23.2	24.9	26.1
15	15.5	15.9	16.7	18.1	20.0	22.5	25.3	27.5	29.1	15.4	15.8	16.4	17.7	19.3	21.3	23.6	25.3	26.5
16	15.9	16.4	17.1	18.6	20.5	23.0	25.9	28.0	29.6	15.8	16.2	16.8	18.0	19.7	21.7	23.9	25.5	26.7
17	16.3	16.7	17.5	19.0	21.0	23.5	26.4	28.5	30.0	16.1	16.4	17.1	18.3	19.9	21.9	24.1	25.7	26.8
18	16.7	17.1	17.9	19.4	21.4	23.9	26.8	28.9	30.5	16.3	16.7	17.3	18.5	20.1	22.0	24.2	25.7	26.9

Table 4. BMI references for Shanghai boys aged 2-18 years (kg/m^2)

Age	IOTF		WGOC	
	25	30	24	28
2	17.7	19.1	17.3	18.6
3	17.1	18.7	16.8	18.1
4	17.0	18.9	16.7	18.1
5	17.3	19.5	16.8	18.6
6	17.8	20.5	17.2	19.4
7	18.4	21.7	17.8	20.3
8	19.1	22.8	18.4	21.3
9	19.8	23.9	19.0	22.2
10	20.5	24.9	19.7	23.1
11	21.2	25.8	20.3	23.9
12	21.8	26.6	20.9	24.7
13	22.4	27.4	21.5	25.4
14	23.0	28.0	22.0	26.0
15	23.5	28.6	22.5	26.5
16	24.1	29.1	23.1	27.1
17	24.5	29.6	23.5	27.6
18	25.0	30.0	24.0	28.0

Table 5. BMI references for Shanghai girls aged 2-18 years (kg/m^2)

Age	IOTF		WGOC	
	25	30	24	28
2	18.1	19.7	17.7	19.1
3	17.7	19.5	17.3	18.8
4	17.7	19.7	17.2	18.9
5	17.9	20.4	17.4	19.4
6	18.4	21.5	17.8	20.3
7	19.0	22.8	18.3	21.2
8	19.7	24.0	18.9	22.2
9	20.4	25.1	19.5	23.2
10	21.2	26.2	20.3	24.2
11	22.1	27.3	21.1	25.2
12	22.9	28.3	21.8	26.1
13	23.6	29.1	22.5	26.8
14	24.1	29.6	23.0	27.4
15	24.5	29.9	23.4	27.7
16	24.8	30.1	23.7	27.9
17	24.9	30.1	23.9	28.0
18	25.0	30.0	24.0	28.0

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0, 97th percentile is 1.9. Fig. 1 shows seven BMI percentile curves for boys and girls aged 0-18 years.

BMI references for Shanghai children aged 2-18 years

Based on the recommendations of the IOTF, the percentile curves passing through 25 and 30 kg/m^2 at age of 18 years are the 82.0th and 96.5th percentiles for boys, and the 93.0th and 99.2th percentiles for girls, as the overweight and obesity cutoff points. Base on the recommended cut off points for Chinese adults by the WGOC, the percentile curves passing through 24 and

28 kg/m^2 at age of 18 years are the 75.5th and 93.3th percentiles for boys, and 89.1th and 98.2th percentiles for girls. Tables 4 and 5 show 2 sets of BMI references for Shanghai children aged 2-18 years.

Discussion

Body mass index (BMI) has been used to access overweight and obesity for adults since the l980s, but not in children until the 1990s.[5] A workshop organized by the IOTF in 1997 proposed that adult BMI cut off

points must be linked to BMI percentiles for children to provide child cut off points.[18] Following this suggestion, Cole et al constructed the international obesity references for children aged 2-18 years based on the dataset from 6 national representative surveys in 2000.[9] Up to the present only a few research papers have been published about BMI in China, two reported BMI distribution and references for Shanghai children aged 0-6 years,[10,11] and the other two reported BMI percentiles for Shanxi children aged 0-18 years. The results were compared with those of the USA, the Netherlands and other countries.[12,13] In these studies, the LMS method was not used and the references were not used in the assessment of obesity prevalence. Based on the recommendations of the IOTF and WGOC, we constructed BMI cut off points for overweight and obesity of Shanghai children by the LMS method for the first time in China, which are preliminary references for the assessment of obesity prevalence in Shanghai children.

The BMI percentiles from our research change substantially with age. The medians at birth are 13.7 and 13.4 kg/m^2 for boys and girls, respectively, and then increase to 18.3 and 17.8 kg/m^2 at age of 6 months. After that they decrease to 15.7 kg/m^2 at age of 5.5 years for boys, and 15.4 kg/m^2 at age of 6 years for girls, and then increase to 21.4 and 20.1 kg/m^2 at age of 18 years for boys and girls respectively. The early adiposity rebound time for boys indicates the severe situation of obesity for Shanghai boys.

The percentiles for overweight and obesity cutoff points in different countries are not the same. For example, the percentile curves for boys passing through 25 kg/m^2 at age of 18 are the 90.4th, 94.5th, 89.5th, 81.9th, 95.3th and 82.0th for the UK, the Netherlands, Singapore, the USA, Xi'an and Shanghai respectively, where for girls are 88.3th, 93.5th, 93.0th, 83.5th, 94.5th and 93.0th, respectively,[9] suggesting that the overweight prevalence in Shanghai boys is close to that of the USA (the highest prevalence), but in Shanghai girls it is lower, or similar to that of the Netherlands and Singapore. This result indicates the marked difference in overweight prevalence between boys and girls in Shanghai. The different percentiles on BMI cut off points in these countries are also associated with sampling time of the database.

WHO recommended the cut off points at 23 and 25 kg/m^2 for Asians based on the characteristics of body-fat percentage of Asian population.[19] The WGOC suggested the cutoff points at 24 and 28 kg/m^2 after elucidation of the relationship of BMI in Chinese adults with relative diseases. Different cut off points result in different outcomes of obesity prevalence. The

WGOC BMI references must be tested because we have found that overweight and obesity prevalence assessed by the WGOC references is lower than that by other references, especially for girls.[20] There are two opinions for the use of BMI in assessing overweight and obesity. One suggests using the same cut off points of BMI for boys and girls, such as the IOTF.[9] Another suggests using the same percentile of BMI for boys and girls, for instance the US CDC.[6,7] Zimmermann et al[21] and Flegal et al[22] compared the US CDC references and the IOTF references with body fat percent, and found that the sensitivity and specificity of the US CDC references are better than those of the IOTF. Reilly et al[23] also found that the sensitivity of the IOTF references is lower than that of 1990 UK references. Our research has set up two sets of references, but further research is needed on whether the same percentiles or the same cut off points are optimal in assessing overweight prevalence in Chinese children. And BMI cut off points to define overweight and obesity in Asians are still controversial.[16,24,25] To determine this, we must know which one may accurately reflect the obesity prevalence in Shanghai and China, and which one is more reasonable in obesity prevention and treatment.

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