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Original Article

Chinese Preschool Children Growth Reference Standard and Related Curve: Based on GAMLSS Approach

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Abstract

Background: The current national growth and development standard of preschool children in China was formulated in 2003, which has many deficiencies. It is necessary to construct more scientific percentile curve and growth reference standards in order to evaluate more effectively the growth, development and health status of Chinese children.

Methods: Based on the physical and health data of 31 provinces in China measured in 2010 and 2014, the GAMLSS model was used to construct the growth reference standard and correlation curve.

Results: We obtained growth reference standards for percentile curve and Z-score curve of height-for-age, sitting height-for-age, Weight-for-age, Chest circumference-for-age of Chinese preschool children. The C50 percentile of all indicators showed an obvious increasing trend with aged 3.0 to 6.5. Such as, the height of boys and girls increased by 21.1cm and 20.3cm respectively, the sitting height boys and girls increased by 10.3cm and 10.1cm respectively, the weight of boys and girls increased by 7.1 kg and 6.3 kg respectively, the Chest circumference of boys and girls increased by 6cm and 5.2 cm respectively.

Conclusion: The children's growth and development charts provided in this study provide effective monitoring and personalized evaluation tools for the growth and development assessment of preschool children, as well as for the reduction of malnutrition, prevention and control of childhood obesity. It is recommended to be used in some areas such as child health, medical treatment and public health.

Keywords: Preschool children; China; Growth standards; Percentile curve

Introduction

The current national growth and development standards of preschool children in China were formulated by the General Administration of Sport of China in 2003 (referred to as the "2003 Standard") (1,2). Due to the limitation of statistical methods, this criterion is a non-continuous criterion (i.e. non-growth criterion) in both horizontal and vertical dimensions, using the mean, standard deviation and percentile of the actual sample values as direct reference values. The standard has some shortcomings such as large fluctuation and discontinuity, which makes it im-

possible to carry out personalized evaluation. The evaluation of human growth and development needs a more scientific evaluation standard, so it is urgent to establish a new growth and development standard in China.

Many countries and major international organizations have established child growth standards. In the early 1990s, WHO began to develop children's growth standards (3) and reformulated the international growth standard for children aged 0-5 in 2006, and then developed the growth standard for children aged 5-19 (4, 5).The International Federation of Fetal and Neonatal Growth, led by the University of Oxford, has carried out the research project of Intergrowth-21st, which established the International Fetal and Neonatal Growth Standards (6). Many developed countries have developed their own growth standard charts, such as Japan (7), the United Kingdom (8), the United States (9), Italy (10), etc. as well as some developing countries, such as Turkey (11), Iran (12), Pakistan (13), etc.

With the development of mathematical statistics, the methods of standard formulation have made continuous progress. The GAMLSS (Generalized Additive Model for Location, Scale and Shape) Model is a Generalized Additive Model, which can construct percentile curves for non-normally distributed data with skewness and kurtosis, and the established model has high validity (14). Since GAMLSS birth, it has become an international trend to use GAMLSS model to develop the standard percentile curve. Such as, in 2006, based on the comparison of more than 30 methods for the development of growth curve, the WHO expert group finally selected GAMLSS model to develop growth percentile curve for children aged 0-5 years (15) and 5-19 years (5), and takes these percentile curve as the standard of children's growth and development. In addition, The International Pulmonary Function Organization used GAMLSS to establish a reference standard for percentile curve of lung function from 3 to 95 years (16). The China Physical Fitness Surveillance Center has done a series of nationwide surveys since 2000 to monitor physical health in the Chinese population. However, no one has used GAMLSS model to construct the percentile growth curve for preschool children in China.

So, in this study, based on the data of two national surveys in 2010 and 2014, we intended to establish the growth reference standard and growth curve chart of Chinese children aged 3-6 yr by using the most advanced percentile curve model of GAMLSS in the world. We aimed to improve the physical health evaluation system of preschool children in China, provide reference standards and assessment means for medical, health care and scientific research work.

Materials and Methods

Study population

We selected a nationally representative sample of the civilian, non-institutionalized Chinese population by use of a complex, stratified, multistage probability cluster sampling design. The first stage covered all 31 provinces in China. Then, three cities were randomly selected from each province according to their economic condition assessed by Gross Domestic Product (second stage). Three districts (for urban area) and three counties (for rural area) were randomly selected from each city (third stage). Three streets/towns were selected from each district/county (fourth stage) and one kindergartens were selected from each street/town (fifth stage). The final stage used systematic sampling to select equal number of eligible participants from each kindergarten. Assuming a response rate of 100/130 with expected enrollment of 1,600 for each province.

The study was approved by local Ethics Committee of the university.

Study indicators

Height, Sitting height, Weight and Chest circumference.

Data collection

The data were measured from April to June in 2010 and 2014 respectively. According to the requirements of "*National Physical Fitness Test Methods and Judgment Criteria*", Participants were

weighed to the nearest 0.1 kg on a calibrated digital scale in lightweight clothing without shoes. Height and sitting height was measured to the nearest 0.1 cm with a calibrated stadiometer. Waist circumference measurements were taken horizontally to the nearest 0.1 cm at the midway between the inferior margin of the last rib and the iliac crest, standing with feet 25–30 cm apart.

A stringent quality assurance and quality control program was implemented to ensure data validity and reliability. All investigators and research staffs underwent one-week training sessions on use of the standardized protocols and instruments for data collection. All the children tested were in good health.

Data analysis

In order to ensure the quality of data and reduce the errors of statistical analysis, we first make a comprehensive logical judgment on the data. The logical judgment is based on the "Re-Test Reference Table" formulated by General Administration of Sport of China (17).

Finally, the removal rates of data items in 2010 and 2014 were 0.2% and 0.4% respectively. A total of 101,861 valid samples were collected twice, including 51,159 (25,583 boys and 25,576 girls) in 2010 and 50,702 (25,381 boys and 25,321 girls) in 2014, the sample distribution by sex and age were shown in Table 1.

Table 1: Sample distribution by sex and age

Age (yr)	*Boys*		*Girls*	
	n	(%)	n	(%)
3.0	4635	48.2	4988	51.8
3.5	8315	51.2	7941	48.8
4.0	6549	49.1	6781	50.9
4.5	6305	50.8	6109	49.2
5.0	6842	48.9	7151	51.1
5.5	6050	51.5	5696	48.5
6.0	12268	50.1	12231	49.9
Total	50964	50.0	50897	50.0

Research methods: GAMLSS approach

We intended to establish the standard percentile curve values and related charts of the growth indicators of children aged 3-6 years by means of GAMLSS model (19), GAMLSS Model is a Generalized Additive Model based on location, scale and shape (15). The model is presented in a specific distribution form of D (μ, σ, ν, τ), and its formula is:

$$Y \sim D(\mu, \sigma, \nu, \tau)$$
$$g_1(\mu) = s_1(u) = X_1 \beta_1 + s_{11}(x_{11}) + \ldots + s_{1J1}(x_{1J1})$$
$$g_2(\sigma) = s_2(u) = X_2 \beta_2 + s_{21}(x_{21}) + \ldots + s_{2J2}(x_{2J2})$$
$$g_3(\nu) = s_3(u) = X_3 \beta_3 + s_{31}(x_{31}) + \ldots + s_{3J3}(x_{3J3})$$
$$g_4(\tau) = s_4(u) = X_4 \beta_4 + s_{41}(x_{41}) + \ldots + s_{4J4}(x_{4J4})$$
$$u = x^{\xi}$$

D distribution represents distribution models such as BCCG(Box-Cox Cole-Green), BCPE(Box-Cox Power exponential), BCPEo(Box-Cox Power expon. orig), BCT(Box-Cox *t*) or BCTo(Box-Cox *t* orig). The distribution model usually contains four parameters. The first parameter reflects the position, such as the mean and median, etc. The second parameter is to reflect the scale (that is, data dispersion), such as standard deviation, mean square deviation, coefficient of variation, etc. The third and fourth parameters reflect the shape of the distribution, such as skewness and kurtosis. In addition, ξ is the power transformation index of the explanatory variable x. The variable df plays a role in adjusting the smoothness and fitting effect of the fitting curve. If df value is large, the fitting curve smoothness is poor but the fitting effect is good; otherwise, if df value is small, the fitting curve smoothness is good but the fitting effect is poor.

Test of percentile curve. In order to verify the validity of the percentile standard curve, it is necessary to carry out the goodness of fit test on the

sample percentage and theoretical percentage under the percentile curve. If it is found that the fitting effect of percentile curve is not ideal, the degree of freedom of parameters will be readjusted and repeated tests will be conducted until an ideal result is obtained.

Appropriate software was used for different data in this study. Specifically, Excel was used for preliminary processing of the eigenvalues of sample data. The modeling process was realized by R-3.6.3 software, and the growth curve was drawn by Origin 2017 software.

Results

According to the above GAMLSS Model modeling principle and method, firstly, the optimal submodels of height, sitting height, weight and chest circumference indicator were obtained, respectively. Then, the power conversion coefficients of independent variables and the degree of freedom of parameters of each sub-model are obtained. Finally, the corresponding percentile curve reference standard and Z-score reference standard are obtained. The specific content is described as follows.

Height indicator

For boys and girls, ξ was 0.9838 and 1.4999 respectively, and the optimal distribution model was $BCPE_O$ and BCT_O. For boys and girls the total degree of freedom was 18.11 and 16.26, respectively. The percentile reference standard of height and standard deviation units are shown in Table 2. The standard curve of the percentile is shown in "height-for-age" in Fig. 1. Accordingly, C50 increased with age, for example, the height of boys and girls aged 3.0 to 6.5 increased by 21.1 cm and 20.3 cm, respectively. The height of boys was 1.7 cm taller than that of girls on average.

Table 2: Height percentile and Z-score for reference standard of Children Aged 3 ~ 6 (cm)

	Age		*C3*	*C5*	*C10*	*C35*	*C50*	*C65*	*C90*	*C95*	*C97*	*-2S*	*-1S*	*0S*	*+1S*	*+2S*
	Year	Month														
Boy	3.0	36-41	89.7	91.1	93.3	98.2	100.1	102.1	107.0	109.1	110.5	89.0	94.9	100.1	105.4	111.3
	3.5	42-47	93.6	94.9	96.8	101.2	102.9	104.7	109.2	111.2	112.5	93.0	98.2	102.9	107.7	113.2
	4.0	48-53	97.1	98.3	100.0	104.2	106.0	107.7	112.2	114.2	115.5	96.5	101.4	106.0	110.7	116.2
	4.5	54-59	100.3	101.4	103.2	107.5	109.3	111.1	115.7	117.7	119.0	99.7	104.6	109.3	114.2	119.7
	5.0	60-64	103.1	104.4	106.2	110.7	112.6	114.5	119.1	121.0	122.3	102.5	107.7	112.6	117.6	122.9
	5.5	65-71	105.7	107.0	109.0	113.7	115.6	117.6	122.1	123.9	125.1	105.1	110.5	115.6	120.7	125.7
	6.0	72-77	107.9	109.3	111.4	116.3	118.4	120.5	125.1	126.9	128.1	107.2	112.9	118.4	123.7	128.7
	6.5	78-83	109.9	111.4	113.6	118.9	121.2	123.4	128.1	130.0	131.1	109.2	115.3	121.2	126.7	131.7
Girl	3.0	36-41	89.5	90.6	92.4	96.5	98.3	100.1	105.0	107.3	109.0	88.9	93.7	98.3	103.4	109.9
	3.5	42-47	92.7	93.9	95.6	99.6	101.4	103.1	107.4	109.3	110.7	92.1	96.9	101.4	106.0	111.4
	4.0	48-53	96.0	97.1	98.8	102.8	104.5	106.3	110.6	112.5	113.8	95.4	100.0	104.5	109.2	114.5
	4.5	54-59	98.9	100.1	101.8	106.1	107.9	109.7	114.1	115.9	117.2	98.4	103.2	107.9	112.7	117.8
	5.0	60-64	101.7	103.0	104.8	109.3	111.2	113.0	117.5	119.3	120.5	101.1	106.2	111.2	116.1	121.1
	5.5	65-71	104.4	105.7	107.6	112.4	114.3	116.3	120.9	122.7	124.0	103.7	109.1	114.3	119.4	124.6
	6.0	72-77	106.3	107.6	109.7	111.0	116.7	118.7	123.4	125.2	126.4	105.6	111.3	116.7	121.9	127.1
	6.5	78-83	107.9	109.3	111.4	116.4	118.6	120.7	125.5	127.4	128.7	107.2	113.0	118.6	124.0	129.2

Note: Due to space limitation, this table only lists the values of percentile values and standard deviation units of boys aged 0.5 years. In specific use, height standards of any age range can be obtained.The following criteria are the same

Sitting height indicator

As for boys and girls, ξ was 1.037 and 1.177 respectively, and the optimal distribution model was BCTo. For boys and girls the total degree of freedom was 13.66 and 14.44, respectively. According to Table 3 and Fig. 1 (sitting height-for-age), C50 increased with age, for example, the height of boys and girls aged 3.0 to 6.5 increased by 10.3 cm and 10.1 cm, respectively. The sitting height of boys was 0.7 cm taller than that of girls on average.

Table 3: Sitting height percentile and Z-score for reference standard of children aged 3 ~ 6 (cm)

	Age		C3	C5	C10	C35	C50	C65	C90	C95	C97	-2S	-1S	0S	+1S	+2S
	Year	Month														
Boy	3.0	36-41	51.4	52.3	53.5	56.1	57.2	58.2	60.8	62.1	62.9	50.9	54.4	57.2	60.0	63.4
	3.5	42-47	53.1	53.9	55.1	57.6	58.6	59.6	62.1	63.2	64.0	52.7	55.9	58.6	61.3	64.4
	4.0	48-53	54.6	55.4	56.5	59.0	60.0	61.0	63.5	64.6	65.4	54.2	57.3	60.0	62.7	65.8
	4.5	54-59	55.9	56.7	57.8	60.4	61.5	62.5	65.1	66.2	66.9	55.5	58.7	61.5	64.2	67.3
	5.0	60-64	57.3	58.1	59.2	61.9	62.9	64.0	66.6	67.7	68.4	56.9	60.1	62.9	65.8	68.8
	5.5	65-71	58.7	59.4	60.6	63.3	64.4	65.5	68.2	69.2	70.0	58.2	61.5	64.4	67.3	70.4
	6.0	72-77	59.9	60.7	61.9	64.7	65.9	67.1	69.8	70.9	71.7	59.4	62.8	65.9	69.0	72.1
	6.5	78-83	61.0	61.9	63.2	66.2	67.5	68.7	71.6	72.7	73.5	60.6	64.2	67.5	70.7	73.9
Girl	3.0	36-41	50.9	51.7	52.9	55.5	56.5	57.5	60.2	61.5	62.4	50.4	53.8	56.5	59.3	62.9
	3.5	42-47	52.6	53.4	54.5	56.9	57.9	58.9	61.3	62.5	63.3	52.2	55.3	57.9	60.5	63.8
	4.0	48-53	54.0	54.8	55.9	58.4	59.4	60.3	62.8	63.9	64.7	53.6	56.7	59.4	62.0	65.1
	4.5	54-59	55.3	56.2	57.3	59.8	60.9	61.9	64.4	65.5	66.3	54.9	58.1	60.9	63.6	66.7
	5.0	60-64	56.7	57.5	58.7	61.3	62.3	63.4	65.9	67.0	67.7	56.3	59.6	62.3	65.1	68.1
	5.5	65-71	58.0	58.9	60.1	62.7	63.8	64.8	67.3	68.4	69.2	57.6	60.9	63.8	66.5	69.5
	6.0	72-77	59.2	60.1	61.3	64.1	65.2	66.3	68.8	69.9	70.6	58.8	62.2	65.2	68.0	71.0
	6.5	78-83	60.4	61.3	62.6	65.4	66.6	67.7	70.3	71.4	72.1	59.9	63.5	66.6	69.5	72.5

Weight indicator

As for boys and girls, ξ was 1.5, and the optimal distribution model was BCPEo. For both boys and girls, the total degree of freedom was 15.0. According to Table 4 and Fig. 1 (weight-for-age), C50 increased with age, for example, the weight of boys and girls aged 3.0 to 6.5 increased by 7.1 kg and 6.3 kg, respectively. The weight of boys was 0.9 kg heavier than that of girls on average.

Chest circumference indicator

As for boys and girls, ξ was 1.5, and the optimal distribution model was BCTo. For boys and girls the total degree of freedom was 15.8 and 11.8, respectively. According to Table 5 and Fig. 1(chest-for-age), C50 increased with age, for example, the chest circumference of boys and girls aged 3.0 to 6.5 yr increased by 6 cm and 5.2 cm, respectively. The chest circumference of boys was 1.1 cm larger than that of girls on average.

Goodness of fit test of percentile curves

In order to verify the validity of the reference standard, it is necessary to carry out the goodness of fit test on the established percentile curve, that is, to compare the percentage of samples under the percentile curve estimated by each indicator model with the percentage of theoretical expectation. The difference between the percentage of samples and the theoretical percentage of all indicators was small (Table 6). The specific index differences were as follows: height was within 1.0%, sitting height was within 0.4%, body weight was within 1.1%, and chest circumference was within 0.9%, so the percentile curve of each index model established had a good degree of fit.

Table 4: Weight percentile and Z-score for reference standard of children aged 3 ~ 6 yr (kg)

	Age		***C3***	***C5***	***C10***	***C35***	***C50***	***C65***	***C90***	***C95***	***C97***	***-2S***	***-1S***	***0S***	***+1S***	***+2S***
	Year	Month														
Boy	3.0	36-41	12.5	12.9	13.5	15.0	15.7	16.5	18.8	19.9	20.7	12.3	13.9	15.7	18.0	21.1
	3.5	42-47	13.2	13.5	14.1	15.8	16.5	17.3	19.7	21.0	21.9	13.0	14.6	16.5	18.9	22.3
	4.0	48-53	13.9	14.3	14.9	16.6	17.4	18.3	20.9	22.3	23.3	13.7	15.4	17.4	20.0	23.9
	4.5	54-59	14.7	15.1	15.7	17.6	18.5	19.4	22.4	23.9	25.1	14.4	16.3	18.5	21.3	25.8
	5.0	60-64	15.4	15.8	16.5	18.6	19.5	20.6	23.9	25.7	27.1	15.2	17.1	19.5	22.8	27.8
	5.5	65-71	16.1	16.5	17.3	19.5	20.6	21.8	25.6	27.6	29.1	15.8	17.9	20.6	24.3	29.9
	6.0	72-77	16.8	17.2	18.0	20.4	21.7	23.1	27.3	29.5	31.3	16.5	18.7	21.7	25.8	32.1
	6.5	78-83	17.5	17.9	18.8	21.4	22.8	24.5	29.3	31.7	33.7	17.1	19.5	22.8	27.6	34.5
Girl	3.0	36-41	12.1	12.4	13.0	14.4	15.1	15.9	17.9	18.9	19.6	11.9	13.4	15.1	17.2	20.0
	3.5	42-47	12.7	13.0	13.6	15.2	15.9	16.6	18.8	19.9	20.6	12.5	14.1	15.9	18.1	21.1
	4.0	48-53	13.3	13.7	14.3	16.0	16.7	17.5	19.9	21.1	22.0	13.1	14.8	16.7	19.1	22.5
	4.5	54-59	14.0	14.4	15.1	16.9	17.7	18.6	21.3	22.6	23.6	13.7	15.6	17.7	20.3	24.2
	5.0	60-64	14.6	15.1	15.8	17.8	18.7	19.7	22.7	24.3	25.4	14.4	16.4	18.7	21.6	26.1
	5.5	65-71	15.3	15.8	16.5	18.7	19.7	20.8	24.2	26.0	27.3	15.1	17.2	19.7	23.0	28.0
	6.0	72-77	16.0	16.3	17.2	19.7	20.6	21.6	25.4	27.3	28.8	15.7	17.9	20.6	24.2	29.6
	6.5	78-83	16.8	17.0	17.9	20.5	21.4	22.5	26.5	28.8	30.0	16.5	18.6	21.4	25.3	30.8

Table 5: Chest circumference percentile and Z-score for reference standard of children aged 3 ~ 6 yr (cm)

	Age		***C3***	***C5***	***C10***	***C35***	***C50***	***C65***	***C90***	***C95***	***C97***	***-2S***	***-1S***	***0S***	***+1S***	***+2S***
	Year	Month														
Boy	3.0	36-41	46.8	47.5	48.5	50.8	51.8	52.8	55.4	56.6	57.5	46.5	49.2	51.8	54.5	58.0
	3.5	42-47	47.5	48.2	49.1	51.4	52.5	53.5	56.3	57.6	58.5	47.2	49.9	52.5	55.3	59.0
	4.0	48-53	48.2	48.8	49.8	52.2	53.2	54.3	57.3	58.7	59.8	47.9	50.5	53.2	56.2	60.4
	4.5	54-59	48.8	49.5	50.5	52.9	54.0	55.2	58.4	60.1	61.3	48.5	51.2	54.0	57.3	62.0
	5.0	60-64	49.6	50.2	51.2	53.7	54.9	56.1	59.6	61.5	62.9	49.2	52.0	54.9	58.4	63.7
	5.5	65-71	50.3	50.9	52.0	54.6	55.8	57.1	61.0	63.0	64.6	49.9	52.7	55.8	59.6	65.5
	6.0	72-77	50.9	51.6	52.7	55.4	56.8	58.3	62.7	65.2	67.1	50.6	53.5	56.8	61.1	68.3
	6.5	78-83	51.5	52.2	53.4	56.4	57.8	59.5	64.7	67.8	70.4	51.2	54.3	57.8	62.7	72.0
Girl	3.0	36-41	45.9	46.7	47.7	50.1	51.0	52.0	54.7	56.0	56.9	45.5	48.5	51.0	53.8	57.5
	3.5	42-47	46.5	47.2	48.3	50.6	51.6	52.7	55.4	56.8	57.8	46.1	49.0	51.6	54.5	58.4
	4.0	48-53	47.2	47.9	48.9	51.2	52.3	53.3	56.3	57.8	58.9	46.8	49.6	52.3	55.3	59.5
	4.5	54-59	47.8	48.5	49.5	51.9	53.0	54.1	57.2	58.8	60.1	47.5	50.3	53.0	56.1	60.8
	5.0	60-64	48.4	49.1	50.1	52.6	53.7	54.9	58.2	60.0	61.4	48.1	50.9	53.7	57.1	62.2
	5.5	65-71	49.0	49.7	50.8	53.3	54.5	55.8	59.4	61.4	62.9	48.7	51.6	54.5	58.1	63.8
	6.0	72-77	49.6	50.3	51.4	54.1	55.3	56.7	60.6	62.8	64.5	49.3	52.2	55.3	59.2	65.5
	6.5	78-83	50.2	51.0	52.1	54.9	56.2	57.7	62.0	64.4	66.3	49.9	52.9	56.2	60.4	67.4

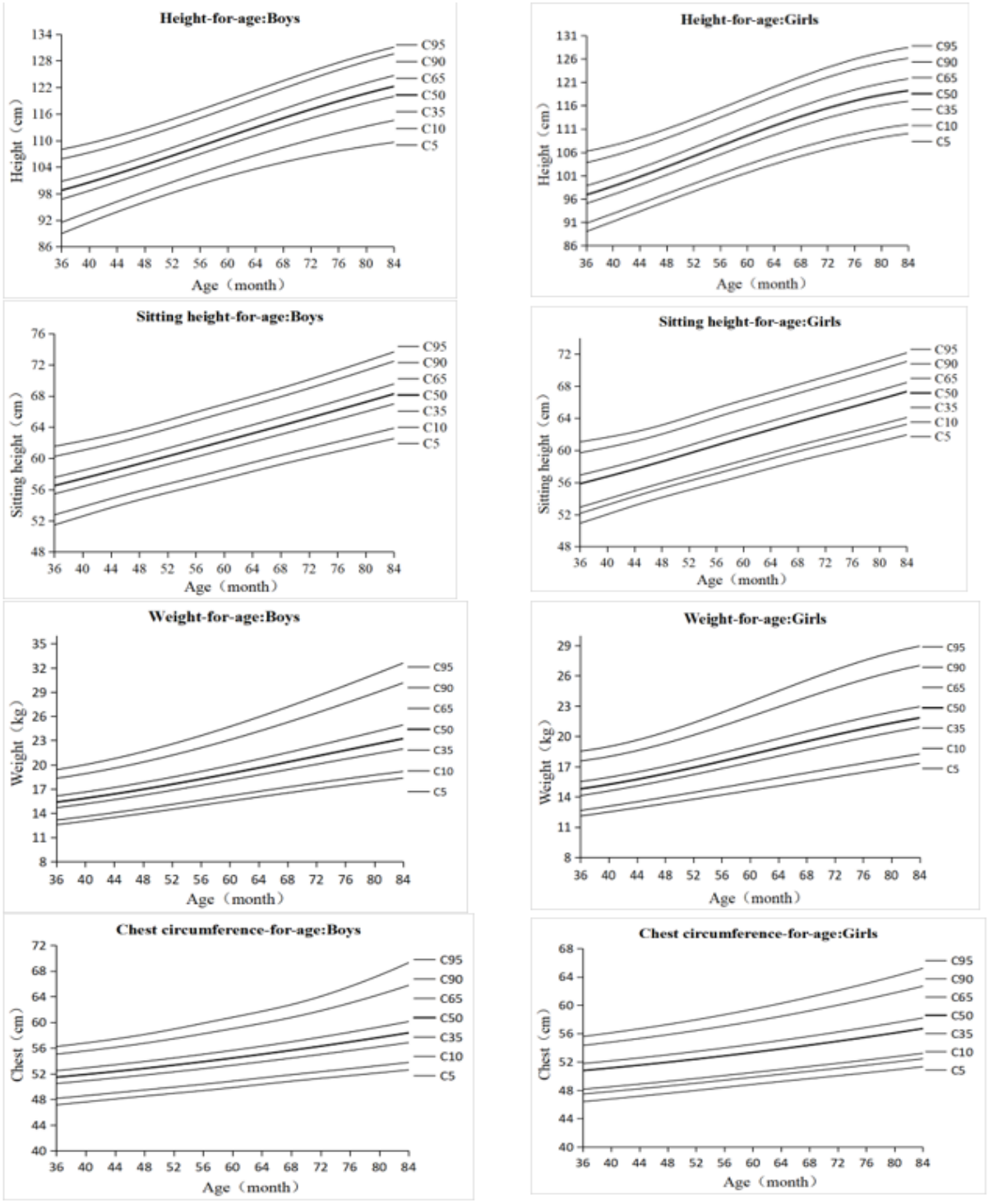

Fig. 1: The standard percentile curve of height-for-age, sitting height-for-age, weight-for-age, chest circumference, for age 3-6 years old children in china

Table 6: Percentages of cases below the fitted percentile curves for different auxology index

Theoretical percentile	*Boy*				*Girl*			
	Height	Sitting height	Weight	Chest	Height	Sitting height	Weight	Chest
0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.4	0.5
2	2.0	2.0	2.0	2.0	1.9	1.9	2.0	2.0
10	10.2	9.8	9.7	9.8	10.0	9.8	10.1	10.0
25	25.4	25.3	24.8	25.6	25.0	25.4	25.3	24.6
50	50.0	50.1	49.5	49.5	49.8	50.1	49.9	50.1
75	75.5	74.8	74.5	75.9	76.0	74.9	75.0	74.4
90	90.1	90.0	89.0	89.9	90.9	89.8	88.9	90.1
98	97.9	98.0	98.9	97.8	98.2	98.1	98.0	97.9
99.6	99.2	99.6	99.4	99.5	98.8	99.9	99.7	99.1

Discussion

The necessity of establishing reference standard for infant growth in China

Growth reference standard is an important tool for assessing a person's nutritional status. In 2003, China formulated the National Physical Fitness Measurement Standard for Children Aged 3-6 years. This standard is not perfect and cannot be personalized evaluation. Taking the height of boys as an example, the "2003standard" in Fig. 2 shows that in the longitudinal dimension of age, the age grouping is very simple, with only seven discrete age group standards, which is not smooth curve.

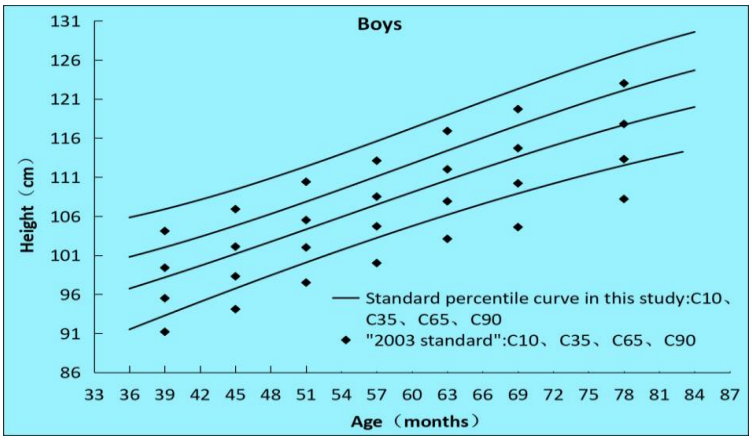

Fig. 2: Percentile standard curve of this study was compared with "2003 standard" of boy's height
Note: The four "smooth curves" in the figure are the 10th , 35th , 65th and 90th percentile curves of the standard curve in this study"◆" refers to the 10th , 35th , 65th and 90th percentiles of the "2003 Standard"

For cross-sectional sizes in the same age group, only five graded reference values are given. The new growth standard is the percentile curve standard (Fig. 2), which is smooth and continuous and contains arbitrary percentile curves. Therefore, the criteria in this study are the evaluation criteria of any age and percentile, which can achieve the purpose of personalized evaluation and overcome the discontinuity, large fluctuation between grades and mutation of the "2003 Standard ". Since 2000, the nutritional status of children has been continuously improved and

their physic has changed a lot. The continued use of the "2003 Standard" is bound to lead to deviation. Therefore, this research standard is superior to "2003 standard".

The sample is broadly representative

This study had a large sample size and wide representative. The samples were from the large-scale national Physical Fitness Surveillance jointly organized and implemented by 10 ministries and commissions, including the General Administration of Sport of China, the Ministry of Education of China and the National Health Commission of China. The physical fitness surveillance covered all 31 provinces in mainland China, and the sample selection method was strictly based on the cluster stratified sampling principle. Four surveys completed since 2000, the members of this research group have participated in these surveys. Based on the physical growth and development data of children aged 3-6 years from the third (2010) and fourth (2014) physical survey, this study established the reference standard for the growth and development percentile curve of preschool children.

GAMLSS model has significant advantages

GAMLSS and LMS (Lambda-Median-Sigma) are two main methods for the development of growth standards in the world. However, LMS method only has median (μ), standard deviation (σ), skewness (ν) but does not include kurtosis (τ) parameter, so its use is limited. The GAMLSS model can model not only skew distribution data, but also "kurtosis" distribution data or data with both "skew" and "kurtosis" distribution data, including "high skew" and "peak" distribution data. Therefore, the percentile curve developed by this model can better reflect the authenticity of original data.

GAMLSS model was extended by Rigby and Stasinopoulos based on LMS in 2004, and it contains four parameters: μ, σ, ν and τ. Although the model has only been in existence for 17 years, its theoretical system has been gradually improved and developed rapidly due to its powerful functions (18), and it has been widely used in the construction of percentile curve of time series data and the formulation of relevant standards (19).

In this study, there were different degrees of "skewness" and "kurtosis" in the original data of growth and development indicators of boys and girls aged 3-6 years, which is consistent with the modeling conditions of GAMLSS model. Goodness of fit test of percentile curve show that percentages of cases below the fitted percentile curves for all indicators are off by less than 1.5%, which shows that the model has good effectiveness overall. Therefore, the use of GAMLSS model in this study to establish growth criteria for children aged 3-6 has achieved good results. However, due to the fact that 2010 and 2014 year data has been used for this study, it is necessary to state caution in using the results of this study due to not up-to-date data.

Conclusion

Firstly, the data in this study were obtained from national physical fitness surveillance in 31 provinces in China, which was widely representative. GAMLSS model applied in this study included four parameters of "median, standard deviation, kurtosis and skewness", and the established percentile standard curve was smooth and stable. The test showed that the model had a good goodness of fit. In short, this research standard is superior to "2003 standard".

Secondly, the children's growth and development charts provided in this study provide effective monitoring and evaluation tools for the growth and development assessment of preschool children, as well as for the reduction of malnutrition, prevention and control of childhood obesity. We recommend it to be used in some areas such as child health, medical treatment and public health.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission,

redundancy, etc.) have been completely observed by the authors.

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Declaration of interests

The author(s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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