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Forty years trends in weight and height/length and their distribution of children under 7 years in nine cities of China, 1975-2015: results from five repeated cross-sectional surveys

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ABSTRACT

Objective Secular trends of mean height and weight have been well documented, while what changes in their distribution in populations are rarely reported. We used five cross-sectional surveys data to analyze the updated changes of mean weight/height and their distribution in Chinese developed regions from 1975-2015.

Design The large-scale cross-sectional survey on growth was carried out respectively in 1975, 1985, 1995, 2005 and 2015 by using the same methods in the same sites.

Setting Nine cities were located in northern, central and southern region of China.

Population Healthy children under 7 years and their sample size were respectively 94496 in 1975, 79177 in 1985, 79152 in 1995, 69760 in 2005 and 83583 in 2015.

Main outcome measures Weight and height were measured by the same methods in the five surveys.

Results The increasing trends of mean weight and height were observed and weight relative increments were more than that of height. The height distribution had shifted upward and the relative increments of 3rd centile were the highest. The weight distribution also shifted upward and the increments of different centiles were similar in under 2years children, while a larger increase of the 97th centile was observed in older than 2 years children. The annual increments of height at 0-2y and weight at 3-6y increased more obviously. The increments of the previous 3 decades become higher, while the 4th decade increments slowed down.

Conclusions Weight relative increments were more than that of height. Their distribution had shifted upward and height low centiles relative increments were more significant, while weight high centiles increased more obviously in older than 2years children, which supplied data for health promotion at population levels.

KEYWORDS: Children, Weight, Height/length, Distribution, Secular changes, China.

Strengths and limitations of this study

- The series of surveys with the same method in the same regions, spanning 40 years, had undergone the rapid development and transformation of China's social economy.
- The distribution of height and weight were shown by their centiles and their changes are rarely reported, which would supply more data for health promotion and early obesity prevention at population levels.
- The changes of annual increments of physical growth, calculated by using the five cross-sectional surveys data, only roughly illustrated the trends of growth velocity in different times.
- We only described the changes of body proportion by comparing the relative increments of weight and height because the weight for height or BMI in 1975 was not obtained due to lack of raw data.

INTRODUCTION

Secular trend in growth is an important biologic-phenomenon during human development [1]. It could not only provide data for understanding the evolution of human physique and indirectly evaluating changes of social environmental, but also reveal the potential problems of nutritional health in children earlier at population levels, and provide more updated data for clinical diagnosis and treatment.

Under the background of the industrial revolution and rapid social-economic development, the data of western developed countries in the past 100 years had revealed that population height had increased, especially in the early stage of social rapid development. It reflects the positive effect of environmental improvement on human growth, which were also considered to be the main cause of the trends [2]. However, the increasing trend has slowed down or even stagnated despite the further social development after the 1990s in some developed countries [3-7], and it is believed that population height had gradually reached the maximum genetic potential. On the other hand, many reports from developing countries still show a rapid increasing trend [8-11]. Therefore, it was necessary to obtain more data in different countries and times in order to fully understanding population-level trends and racial differences in growth.

With the high prevalence of obesity and the track phenomenon of obesity, overweight and obesity in early childhood has been the focus of global attention [12]. Early prevention of obesity at the population level has become the most important public health strategy [13]. Analyzing the secular changes of physical growth distribution could help to understanding trends of different growth levels, especially supply more specific data for changes of the upper and lower ends of the distribution of growth in population, which provide more important clues for timely formulating effective population prevention and healthy promotion strategies. However, the changes of growth were more concentrated on the average level at present, the secular changes of their distribution are rarely reported.

In China, the first large-scale national survey on growth, named "The National Survey on the Physical Growth and Development of Children in the Nine Cities of China" (NSPGDC), was carried out in 1975 [14]. Then it was carried out in 1985 [15], 1995 [16], 2005 [17] and 2015 [18] by using the same methods in the same sites. The previous four surveys data had illustrated a significant increasing trend [19]. In order to understand whether the rapid increasing will be continued or how do the variations and distributions of height and weight change? Therefore, we analyzed the latest forty years' changes of physical growth under 7years children in Chinese developed regions by using the NSPGDC I-V data to supply more data for related research fields.

METHODS

Study Design and Setting

The NSPGDC I-V were large-scale cross-sectional surveys and conducted across nine cities during June-October in 1975, 1985, 1995, 2005 and 2015. The nine cities included Beijing (Municipality), Harbin (Heilongjiang's provincial capital), Xi'an

(Shanxi's provincial capital), Shanghai (Municipality), Nanjing (Jiangsu's provincial capital), Wuhan (Hubei's provincial capital), Guangzhou (Guangdong's provincial capital), Fuzhou (Fujian's provincial capital), and Kunming (Yunnan's provincial capital). All of these surveyed sites were nearly the same in the NSPGDC I-V.

Participants

Healthy children under 7 years, who are local residences or those lived in the region for longer than 2/3 of their time of life, were included in the five surveys and their exclusion criteria were the same: gestational age at birth <37 weeks or birth weight <2.5 kg, twins or multiple births, participants suffering from chronic systemic disease, congenital diseases, endocrine diseases, diseases of the nervous system, and those presenting with fever for more than 7 days in the past 2 weeks or continuous diarrhea more than five times every day for 5 days or longer [14-18].

Multistage stratified cluster sampling method was used according to urban/suburban areas and administrative districts in each city. The hospitals, communities and kindergartens in each selected administrative district were considered as the cluster sample unit to respectively collect newborns, children aged 1 month to 3 years and children over 3 years (including 3 years). The urban areas represent the better socio-economic environment of each city, thus were selected to understand the growth trends in Chinese developed regions in this paper.

All children were divided into 22 age groups: birth (0-3days), 1m-, 2m-, 3m-, 4m-, 5m-, 6m-, 8m-, 10m-, 12m-, 15m-, 18m-, 21m-, 2y-, 2.5y-, 3y-, 3.5y-, 4y-, 4.5y-, 5y-, 5.5y-, and 6-7y.

Data collection and Quality Control

Weight and height/length were measured by trained investigators using standardized method in the five surveys [14-18]. Weight was obtained by Newborn scales (accurate to 10 g) for newborns in 1975-2015, and Lever scales (accurate to 50 g, in 1975-2005) or Electronic scales (accurate to 50 g, in 2015) for children aged 1 month or older. Length under 3 years of age was measured by using Infantometer (accurate to 0.1cm) and height of children aged older than 3 years was measured by using Height-Sitheight Stadiometer (accurate to 0.1cm) in the five surveys.

Measuring equipments in all sites were uniform and were calibrated daily using standard weights for weight scale (the error less than 50 g) and steel rule with length of 2 m for Infantometer, Height-Sitheight Stadiometer. All investigators had participated in rigorous specialized training and passed an examination before the survey. Measurement errors were no more than 50 g in weight or 0.5 cm in length within intra-observer and inter-observer measurements. The 5% of total subjects in each site were repeat measured randomly per day, and the proportion of subjects beyond allowable errors was less than 10%.

Ethical considerations

The NSPGDC was approved by the Ethics Committee of the Capital Institute of Pediatrics, and informed consent was verbal. Members of the survey's staff explained to the parents of children the purpose of the survey and all participations were voluntary.

Statistical Methods

SPSS 20.0 for Windows was used to clean and analyze the data. The mean weight and height/length were described by $\bar{x}\pm$

SD and their distributions were shown by centiles. Total increments, per-decade increments and the relative increments (calculated by the formula: $\frac{measurments\ in\ 2015 - measurements\ in 1975}{measurements\ in\ 1975} \times 100\%$) of weight and height/length were calculated from 1975 to 2015. The independent samples t test was used to comparison the difference between neighboring two surveys. The annual increment of weight and height/length means during birth to 6years in the five surveys were also calculated which were used to roughly reflect the growth velocity, we compared their changes from 1975 to 2015 to understand the changes of growth velocity in Chinese developed regions. A value of $p < 0.05$ was considered statistically significant.

RESULTS

Summary of participants

The total sample size was respectively 94496 in 1975, 79177 in 1985, 79152 in 1995, 69760 in 2005 and 83583 in 2015. Table 1 had shown sex–age subgroup sample size.

Table 1 Sample size of the NSPGDC I-V (1975-2015)

Age group	1975		1985		1995		2005		2015	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Birth	2052	2001	1800	1800	1800	1800	1554	1512	2264	2147
1m~	1992	1940	1800	1800	1800	1800	1599	1573	1903	1896
2m~	1976	1901	1800	1800	1800	1794	1571	1559	1871	1856
3m~	2037	1985	1800	1800	1800	1795	1566	1588	1895	1893
4m~	2070	1938	1800	1800	1799	1800	1589	1581	1897	1852
5m~	2026	1994	1800	1800	1790	1788	1576	1580	1811	1841
6m~	2210	2202	1800	1800	1800	1800	1604	1585	1901	1884
8m~	2117	2090	1800	1800	1800	1793	1608	1622	1890	1881
10m~	2045	2072	1800	1800	1800	1794	1584	1581	1859	1862
12m~	2169	2053	1800	1800	1800	1800	1591	1594	1875	1870
15m~	2062	2029	1800	1800	1800	1800	1583	1579	1846	1886
18m~	2097	2029	1800	1800	1800	1800	1582	1572	1881	1869
21m~	2149	2083	1800	1800	1800	1800	1582	1573	1857	1815
2y~	2387	2247	1800	1800	1800	1800	1581	1582	1909	1869
2.5y~	2421	2286	1800	1800	1800	1800	1551	1561	1858	1878
3y~	2209	2190	1800	1800	1800	1800	1585	1601	1903	1908
3.5y~	2301	2238	1800	1800	1800	1800	1588	1600	1933	1924
4y~	2241	2202	1800	1799	1800	1800	1588	1602	1943	1866
4.5y~	2298	2244	1800	1800	1800	1800	1593	1599	1944	1895
5y~	2182	2237	1799	1780	1800	1800	1592	1595	1912	1892
5.5y~	2223	2151	1800	1800	1799	1800	1605	1597	1893	1908
6~7y	2580	2540	1800	1799	1800	1800	1629	1623	1922	1924
Total	47844	46652	39599	39578	39588	39564	34901	34859	41967	41616

Changes in average weight and height/length from 1975-2015

A significant increasing trend in weight and height/length was observed during the lasted forty years in the nine cities. The average increments of boys were 1.41kg in weight and 3.5cm in height/length, and those of girls were 1.24kg in weight and 3.3cm in height/length. The increments were different in different age groups, which become higher and higher with age (table2).

Table2 Means weight and height/length and the increments from 1975-2015

Age group	Boys						Girls					
	Weight (kg)			Height/length (cm)			Weight (kg)			Height/length (cm)		
	$\bar{x}\pm SD$ (kg)		I^a (kg)	$x\pm SD$ (cm)		I^a (cm)	$x\pm SD$ (kg)		I^a (kg)	$x\pm SD$ (cm)		I^a (cm)
	1975	2015		1975	2015		1975	2015		1975	2015	
Birth	3.27±0.36	3.38±0.40	0.11*	50.6±1.9	50.4±1.6	-0.2*	3.17±0.36	3.26±0.40	0.09*	50.0±1.8	49.8±1.6	-0.2*
1m~	4.97±0.67	4.95±0.60	-0.02	56.5±2.4	56.3±2.1	-0.2*	4.64±0.54	4.62±0.56	-0.02	55.5±2.4	55.2±2.0	-0.3*
2m~	5.95±0.76	6.18±0.70	0.23*	59.6±2.6	60.2±2.2	0.6*	5.49±0.69	5.68±0.64	0.19*	58.4±2.5	58.9±2.1	0.5*
3m~	6.73±0.79	7.11±0.79	0.38*	62.3±2.5	63.4±2.1	1.1*	6.23±0.75	6.51±0.74	0.28*	60.9±2.4	61.9±2.2	1.0*
4m~	7.32±0.85	7.78±0.89	0.46*	64.4±2.5	65.8±2.2	1.4*	6.69±0.79	7.11±0.77	0.42*	62.9±2.4	64.1±2.1	1.2*
5m~	7.70±0.88	8.26±0.94	0.56*	65.9±2.6	67.7±2.3	1.8*	7.19±0.84	7.60±0.85	0.41*	64.5±2.5	66.1±2.3	1.7*
6m~	8.22±0.96	8.68±0.94	0.46*	68.1±2.7	69.5±2.3	1.4*	7.62±0.89	8.03±0.90	0.41*	66.7±2.8	67.9±2.3	1.2*
8m~	8.71±0.99	9.35±1.03	0.64*	70.6±2.7	72.5±2.4	1.9*	8.14±0.95	8.70±1.02	0.56*	69.0±2.8	70.9±2.6	1.9*
10m~	9.14±1.03	9.88±1.11	0.74*	72.9±2.8	75.1±2.6	2.2*	8.57±0.97	9.24±1.05	0.67*	71.4±2.7	73.7±2.7	2.3*
12m~	9.66±1.08	10.26±1.10	0.60*	75.6±3.1	77.6±2.7	2.0*	9.04±1.02	9.65±1.06	0.61*	74.1±3.0	76.2±2.7	2.1*
15m~	10.15±1.11	11.07±1.19	0.92*	78.3±3.2	81.4±3.0	3.1*	9.54±1.10	10.46±1.16	0.92*	76.9±3.2	80.1±3.0	3.2*
18m~	10.67±1.19	11.50±1.26	0.83*	80.7±3.3	84.0±3.0	3.3*	10.08±1.13	10.89±1.19	0.81*	79.4±3.4	82.8±3.0	3.4*
21m~	11.18±1.23	12.38±1.35	1.20*	83.0±3.6	87.3±3.1	4.3*	10.56±1.15	11.73±1.25	1.17*	81.7±3.5	86.1±3.1	4.4*
2.0y~	11.95±1.27	12.98±1.48	1.03*	86.5±3.8	90.6±3.6	4.1*	11.37±1.21	12.36±1.41	0.99*	85.3±3.5	89.3±3.6	4.0*
2.5y~	12.84±1.35	14.28±1.71	1.44*	90.4±3.8	95.6±3.8	5.2*	12.28±1.33	13.57±1.68	1.29*	89.3±3.9	94.2±3.8	4.9*
3.0y~	13.63±1.42	15.46±2.02	1.83*	93.8±4.0	99.4±4.0	5.6*	13.16±1.37	14.85±1.81	1.69*	92.8±3.9	98.3±3.8	5.5*
3.5y~	14.45±1.52	16.62±2.18	2.17*	97.2±4.3	103.2±4.1	6.0*	14.00±1.51	15.95±1.96	1.95*	96.3±4.1	102.0±4.0	5.7*
4.0y~	15.26±1.56	17.76±2.46	2.50*	100.8±4.5	106.7±4.2	5.9*	14.89±1.54	16.90±2.21	2.01*	100.1±4.3	105.4±4.1	5.3*
4.5y~	16.07±1.69	19.02±2.77	2.95*	103.9±4.5	110.1±4.5	6.2*	15.63±1.60	18.14±2.53	2.51*	103.1±4.4	108.9±4.4	5.8*
5.0y~	16.88±1.84	20.35±3.10	3.47*	107.2±4.6	114.1±4.6	6.9*	16.46±1.69	19.47±2.85	3.01*	106.5±4.4	112.8±4.5	6.3*
5.5y~	17.65±1.86	21.71±3.52	4.06*	110.1±4.6	117.1±4.7	7.0*	17.18±1.77	20.74±3.17	3.56*	109.2±4.5	116.0±4.6	6.8*
6~7y	19.25±2.10	23.69±4.03	4.44*	114.7±4.9	121.8±4.9	7.1*	18.67±2.03	22.34±3.60	3.67*	113.9±4.9	120.2±5.0	6.3*

Note: a I is equal to weight or height/length of the NSPGDC V (2015) minus those of the NSPGDC I (1975). *: $p<0.05$.

Figure 1 displayed the relative increments of weight and height/length from 1975 to 2015: the weight relatively increased by 4-10% in under 2years children and 12-23% in older than 2years children, which were significantly higher than height/length relative increments (increased by 1-3% in under 1year children, and 3-6% in older than 1years children). Comparing the relative increments between boys and girls, we found that their relative increments of weight were similar for under 4years, while that of boys were higher for older than 4years. The height/length relative increments were similar between boys and girls.

Changes in weight and height/length distribution during 40years

The 3rd, 50th, 97th centiles were used to describe the distributions of weight and height/length. Figure 2 illustrated that the three centiles of weight or height/length had significantly increased, and their increments were different.

For weight, the actual increments of the three centiles in under 2years children were similar, while in older than 2years children, the increments of 97th centile were significantly higher than that of the 3rd and 50th centile, for example, the increments of the 3rd, 50th, 97th in 5.5y- boys were 2.26kg, 3.56kg and 8.44kg (figure 2). Furthermore, we found the relative increments of 3rd centile in under 2years children were slightly higher than those of 50th and 97th centile, for example, the 3rd, 50th and 97th in 6m- boys relatively increased by 6.4%, 5.5% and 3.7%. But a larger relative increase of the 97th centile was observed in older than 2years children, for example, the relatively increments of the 3rd, 50th and 97th centile in 5.5y- boys were respectively 15.8%, 20.3% and 39.0%.

For height/length, the actual increments of 3rd centile were slightly higher than those of 50th and 97th centile in under 5 years children, and then were similar in older than 5 years children. For example, the 3rd, 50th and 97th centile increased respectively 2.3cm, 1.3cm, 0.7cm in 6m- boys, 5.5, 5.1, 4.6cm in 2.5y- boys, and 7.1, 7.1, 7.1cm in 5.5y- boys (figure 2). From the relative increment perspective, that of 3rd centile was the highest, for example, the 3rd, 50th and 97th centile respectively increased by 3.5%, 2.5%, 1.5% in 12m- boys, and 7.0%, 6.4%, 6.0% in 5.5y- boys.

Forty years changes in annual increments of weight and height/length from birth to 6 years

Table 3 displayed the changes of annual increments of weight and height/length during birth to 6 years from 1975-2015. The annual increments of weight after 3 years old increased more obviously, while the height/length annual increments of 0-2y had increased larger than other ages.

Table 3 Annual increments of weight and height/length during birth to 6years, 1975-2015

	Per-year weight increments (kg)												**Per-year height/length increments (cm)**											
	Boys						Girls						**Boys**						Girls					
	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]
0~1y	6.08	6.40	6.56	6.82	6.65	0.57	5.59	5.86	6.06	6.25	6.14	0.55	23.4	24.7	25.2	26.2	25.7	2.3	22.5	23.8	24.5	25.3	24.9	2.4
1~2y	2.09	2.08	2.22	2.51	2.55	0.46	2.07	2.16	2.25	2.56	2.54	0.47	10.2	10.7	11.1	12.0	12.3	2.1	10.4	10.8	11.4	12.3	12.5	2.1
2~3y	1.80	1.85	1.91	2.14	2.29	0.49	1.89	1.86	1.98	2.22	2.27	0.38	7.9	7.8	8.3	8.6	9.1	1.2	8.1	8.0	8.2	8.6	9.1	1.0
3~4y	1.62	1.64	1.81	2.06	2.32	0.70	1.73	1.74	1.88	2.07	2.22	0.49	6.9	6.9	6.9	7.1	7.5	0.6	7.1	7.0	7.1	7.2	7.5	0.4
4~5y	1.62	1.76	1.99	2.38	2.50	0.88	1.60	1.72	1.94	2.14	2.38	0.78	6.6	6.6	6.9	7.1	7.1	0.5	6.6	6.8	7.0	7.1	7.1	0.5
5~6y	1.71	1.86	2.12	2.39	2.69	0.98	1.63	1.72	2.01	2.23	2.47	0.84	6.1	6.2	6.3	6.3	6.6	0.5	6.0	6.2	6.3	6.4	6.6	0.6

Note: a D is equal to annual increments of weight or height/length in the NSPGDC V (2015) minus those of the NSPGDC I (1975).

Per-decade changes of mean weight and height/length

Figure 3 had shown that the increments of the second decade (1995-1985) were higher than that of the first decade (1975-1985), and lower than that of the third decade (1995-2005). In the fourth decade, the increments had become smaller than the third decade. Table4 displayed the age- and gender specific increments of the four decades.

Table 4 Comparison of pre-decade increments in mean weight and height/length (1975-1985, 1985-1995, 1995-2005 and 2005-2015)

Age group	Weight (kg)								Height/Length (cm)							
	Boys				Girls				Boys				Girls			
	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]
Birth	-0.06	0.09	0.03	0.05	-0.05	0.08	0.04	0.02	-0.4	0.2	0.0	0.0	-0.4	0.2	-0.1	0.1
1m~	-0.07	0.20	0.01	-0.16	-0.04	0.21	-0.08	-0.11	0.0	0.4	-0.1	-0.5	0.1	0.5	-0.5	-0.4
2m~	0.07	0.14	0.11	-0.09	0.05	0.20	0.01	-0.07	0.5	0.3	0.1	-0.3	0.4	0.4	-0.1	-0.2

3m~	0.01	0.24	0.19	-0.06	-0.01	0.20	0.14	-0.05	0.1	0.6	0.3	0.1	0.2	0.5	0.4	-0.1
4m~	0.04	0.20	0.20	0.02	0.09	0.23	0.15	-0.05	0.1	0.6	0.6	0.1	0.2	0.7	0.4	-0.1
5m~	0.09	0.23	0.30	-0.06	0.05	0.29	0.12	-0.05	0.4	0.7	0.8	-0.1	0.3	0.7	0.7	0.0
6m~	0.17	0.23	0.13	-0.07	0.16	0.22	0.13	-0.10	0.5	0.6	0.6	-0.3	0.3	0.6	0.5	-0.2
8m~	0.29	0.19	0.16	0.00	0.22	0.29	0.09	-0.04	0.7	0.7	0.6	-0.1	0.7	0.9	0.5	-0.2
10m~	0.30	0.21	0.27	-0.04	0.23	0.29	0.19	-0.04	0.9	0.8	0.9	-0.4	0.9	1.0	0.5	-0.1
12m~	0.21	0.29	0.33	-0.23	0.20	0.28	0.28	-0.15	0.9	0.8	1.0	-0.7	1.0	0.8	0.9	-0.6
15m~	0.23	0.32	0.34	0.03	0.24	0.31	0.34	0.03	0.9	1.1	1.1	0.0	1.0	1.0	1.3	-0.1
18m~	0.21	0.37	0.40	-0.15	0.25	0.32	0.36	-0.12	0.9	1.1	1.3	0.0	1.0	1.2	1.3	-0.1
21m~	0.24	0.41	0.56	-0.01	0.31	0.38	0.52	-0.04	1.4	1.2	1.7	0.0	1.4	1.4	1.5	0.1
2.0y~	0.29	0.33	0.62	-0.21	0.29	0.38	0.56	-0.24	1.4	1.2	2.1	-0.6	1.3	1.5	1.8	-0.6
2.5y~	0.29	0.43	0.72	0.00	0.27	0.42	0.76	-0.16	1.3	1.6	2.1	0.2	1.0	1.7	2.3	-0.1
3.0y~	0.32	0.47	0.89	0.15	0.28	0.57	0.79	0.05	1.3	1.7	2.1	0.5	1.4	1.7	1.7	0.7
3.5y~	0.30	0.62	0.96	0.29	0.26	0.68	0.90	0.11	1.3	1.7	2.2	0.8	1.0	1.9	2.1	0.7
4.0y~	0.35	0.62	1.14	0.39	0.32	0.60	1.03	0.06	1.3	1.6	2.3	0.7	1.1	1.6	2.1	0.5
4.5y~	0.42	0.75	1.31	0.47	0.49	0.68	1.21	0.13	1.4	1.8	2.4	0.6	1.4	1.7	2.5	0.2
5.0y~	0.51	0.95	1.56	0.45	0.33	1.05	1.09	0.54	1.4	1.9	2.6	1.0	1.1	2.2	1.9	1.1
5.5y~	0.65	1.08	1.78	0.55	0.54	1.08	1.47	0.47	1.5	2.1	2.7	0.7	1.6	2.1	2.5	0.6
6~7y	0.56	1.16	1.54	1.18	0.41	1.28	1.19	0.79	1.5	1.7	2.1	1.8	1.2	2.0	1.8	1.3

Note: a I1 is equal to means of weight or height/length in 1985 minus those in 1975, b I2 is equal to means of weight or height/length in 1995 minus those in 1985, c I3 is equal to means of weight or height/length in 2005 minus those in 1995, d I4 is equal to means of weight or height/length in 2015 minus those in 2005.

DISCUSSION

Our study displayed a rapidly increasing trend in weight and height/length of under 7 years in nine cities during 1975-2015. These trends were consistent with rapid socio-economic development in China: (1) The Gross Domestic Product (GDP) of nine provinces, whose capital were the nine cities, has increased from ¥562 in 1975 to ¥62971 in 2014 and their household disposable income increased from ¥351 in 1975 to ¥32301 in 2014. (2) National statistical data illustrated that the number of doctors per 10,000 people had increased from 12 persons in 1975 to 23 persons in 2014, the infant mortality rate changed from 62.6‰ in 1975 to 8.1‰ in 2014 and the mortality rate of under 5 years children decreased from 85.2‰ in 1975 to 10.7‰ in 2014. (3) The national nutrition survey, which started in 1982 and the latest survey was in 2012, indicated that the nutritional intake of Chinese population had significantly improved, for example, the daily intake of milk, egg, fish and shrimps, and meat were respectively 9.9g, 15.5g, 21.6g and 62.0g in 1982, which increased to 37.8g, 29.5g, 32.4g and 98.5g in 2012. It was suggested that the comprehensive improvement of social economy, medical and health care, as well as food and nutritional supply had provided a favorable environment for children growth [2,6,20,21].

Secular increments of children growth are influenced by both genetic and environmental factors. In this paper, we found that height/length and weight of under 7 years children average increased 3.3-3.5cm and 1.2-1.4kg during the last 40 years, and the increments became higher with age, which reached to 6-7cm at 6y- group (1.5-1.8cm/decade). The increments of height/length were slightly higher than that of some western countries: the increments of height were 1-2cm in Dutch children aged 1-4 years during 50 years (1955-2009) [7], 1-3cm in South Asian children in the Netherlands aged 2-6 years during about

40 years (1976-2010) [22], 2.7-3.3cm in Czech children aged 2.5years during 50 years (1951-2001) [23], 0.9-1.1cm in Turkish children aged 5years during 30 years (1975-2008) [24], and1.1-1.5cm in Canadian children aged 6years per decade during 1891-1974 [25]. In Japan, data from 1950-2000 had illustrated that the height increments of 6years children were 1.6cm/decade [6], which were similar with our results. Furthermore, the height increments of 6years old boys and girls in South Korea during 1965-2005 (10.3cm, 11.7cm) were higher than our results (7.1cm, 6.3cm). Therefore, we found the height increments in Chinese, Japanese and South Korean children were higher than those of western countries, which might be related to the social and economic backwardness or even retrogression during World War II and then the rapid social development after World War II. The rapid height increments may be the integrated results of catching up and a positive secular trend in physical growth [26].

Inequality proportion increments of weight and height would predict the changes of body type. Our results had shown that the weight relative increments were significantly higher than that of height, which illustrated that the body type of Chinese children were from slender to thickset during the last 40 years. The changes of weight distribution had shown that the increments of low centiles were higher than that of medium and high centiles for under 2years children, which suggested the nutrition improvement of low-growth-level infants and young children were more obvious in the past 40 years. However, after 2years old, the relative increases in the 97th centile were larger than that of 3rd and 50th centile, it indicated a rapid increases at the upper end of weight, which predicting that obesity after 2years old might become a potential health problem when children's nutrition improving. This is consistent with the fact that obesity in Chinese children and adolescents has become more prominent since 1980s: the prevalence of obesity in preschool children was from 0.91% in 1986 to 3.44% in 2006 [27] and that in school-age boys of large cities was from 1.0% in 1985 to 17.8% in 2010 [28]. Global data has illustrated that childhood obesity have increased dramatically and become a very important health problem for children and adults [12 29]. Therefore, timely monitoring levels and trends of weight distribution at the population level would be more helpful for projection of epidemic of obesity as early as possible and supply more data for design effective public health strategies. Moreover, these results also suggest that when updating weight reference, the upper ends of the reference will significantly raise if we do not consider the up-shift of weight distribution, which will be more unfavorable to the prevention of obesity and other related health problems.

The height/length distribution had shifted upward whether the high or low centiles in our results. The increasing of low centile would be an important manifestation of the improvement of children's nutrition. The height changes of high centiles indicated that the linear growth has not reached the maximum genetic potential and will gradually be brought into full play with the environment improving. Comparison of the relative increments among different centiles, we found the increments of low centiles were higher, especially in under 3years old children, which indicated that the improvement of linear growth was more significantly in vulnerable children when the environment had improved.

Physical growth velocity of under 7years children was roughly approximated by calculating annual increments of corresponding age from cross sectional surveys. It had illustrated that the annual increments of height and weight during the first year of life were similar with the WHO longitudinal growth velocity in 2009 (25.8cm, 6.27kg in boys and 24.7cm, 6.14kg in girls)[30], which suggested that the annual increments from large-scale cross-sectional survey could roughly reflect the growth velocity. Therefore, we calculated the annual increments of height and weight in NSPGDC I-V in order to analyze the changes of growth velocity during 1975-2015. These results indicated that the growth velocity of height during the first two years after birth had increased more significantly than that other ages. It is suggested that the linear growth of infants would be more sensitive to environmental improvement, and environmental intervention in infancy might be more effective to improve their linear growth, which is consistent with the research reports of TM Cole [31]. From the changes of weight growth velocity, we found that the increments of weight growth velocity in older than 3years children became higher and higher, which suggested that 3years old and later might be the high-incidence age group of obesity, and should be taken as the key window period for early obesity intervention.

The fourth decade (2005-2015) increments of weight and height had slowed down when comparing that the previous 3 decades, which suggested that the physical growth secular increasing trend of under 7years children in Chinese developed regions had moved from rapidly increasing to slowly increasing and the physical growth of children will be reaching their full genetic potential for growth with the social-economic development. The trends were consistent with that of other developed countries [4 6 7 32].

There was a limitation in our study. The annual increments of physical growth were calculated by using the five cross-sectional surveys data to describe the changes of growth velocity, and they were not growth velocity in the strict sense. Even so, we compared these data with the growth velocity of WHO and found they were similar, therefore, we thought these results might roughly illustrate the trends of growth velocity in different times and they would supply some data to comprehensively know about the secular trends of physical growth in developed regions in Chinese children.

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Competing Interests None declared.

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Contributions Yaqin Zhang contributed to data analysis, preparation and writing the initial draft of the manuscript. Hui Li designed the study, directed the data analysis and modified the manuscript. Huahong Wu inputted and cleared up the data. Xinnan Zong contributed to data analysis. All authors read, critically reviewed and approved the final manuscript as submitted.

Data sharing statement No additional data are available.

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Figure legends

Figure 1 The relative increments of mean weight and height/length from 1975 to 2015

Figure2 Changes in the distribution of weight and height/length from 1975-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1975 and 2015)

Figure3 Per-decade changes in mean weight and height/length from 1975-2015

What is already known on this subject?

- The increasing trend of mean height and weight of children has been illustrated in many countries, and their significant differences among different populations and times were also observed.
- Understanding the changes in weight and height distribution at the population level is important since mean values may hide differences in patterns at both the upper and lower ends of the distribution, which will supply more data for our projections of future pattern as well as timely designing effective public health strategies. However, the secular changes in weight and height distributions are rarely reported.

What this study adds?

- The study has shown a continued increase of weight and height during 1975-2015, but the increments slowed down in the lasted 10years in Chinese developed regions.
- The height and weight distribution had shifted upward and height low centiles relative increments were more significant, while weight high centiles increased more obviously in older than 2years children, which supplied some data for health promotion and overweight prevention at population levels.
- The changing of height annual increments suggested that environmental intervention in infancy might be more effective to improve the linear growth of children. Meanwhile, the more obvious changes of weight annual increments in older than 3years children became higher and higher, had illustrated that 3years old and later may be

the key window period for early obesity intervention.

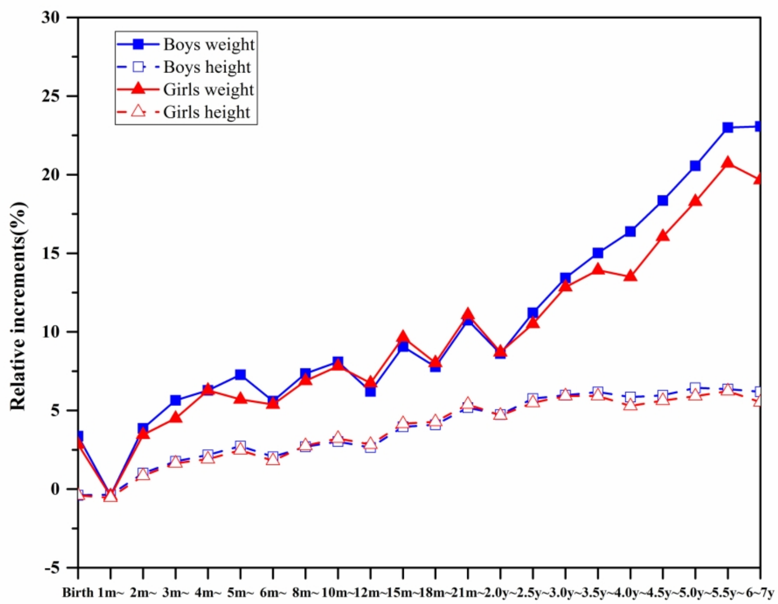

Figure 1 The relative increments of mean weight and height/length from 1975 to 2015

272x208mm (300 x 300 DPI)

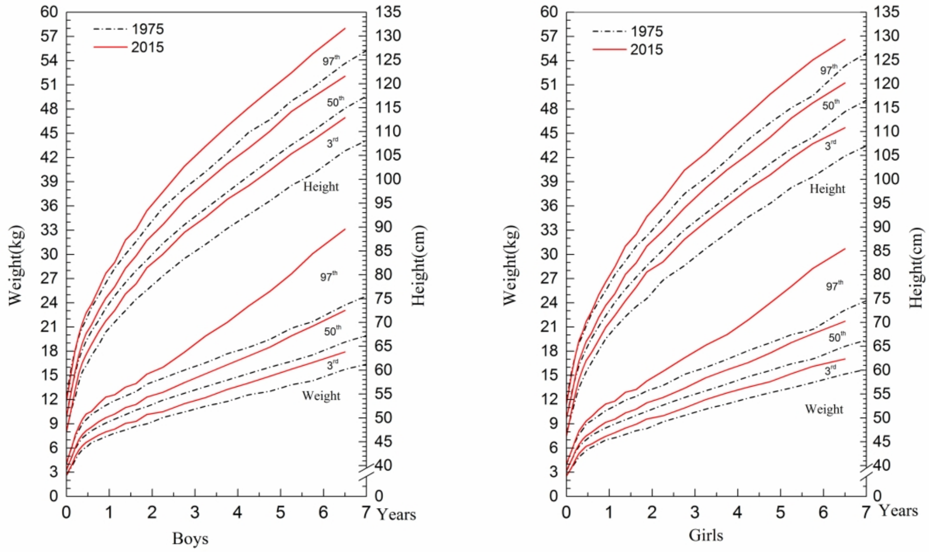

Figure2 Changes in the distributions of weight and height/length from 1975-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1975 and 2005)

288x200mm (300 x 300 DPI)

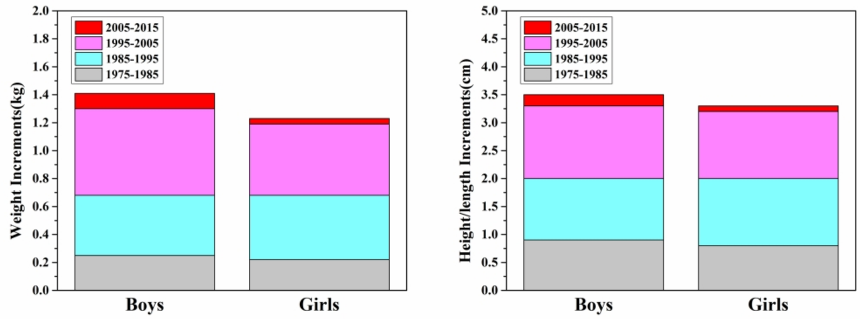

Figure3 Per-decade changes in mean weight and height/length

289x202mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	*4*
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5-8
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	8-10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	8-10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Secular trends in weight, height and weight for height among children under 7 years in nine cities of China, 1975-2015: results from five repeated cross-sectional surveys

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Secular trends in weight, height and weight for height among children under 7 years in nine cities of China, 1975-2015: results from five repeated cross-sectional surveys

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Word count: 2848

ABSTRACT

Objective To analyze the trends in mean value and the distribution of weight, height, and weight for height in Chinese developed regions from 1975-2015.

Design Five repeated cross-sectional surveys were carried out using the same methods in the same sites in 1975, 1985, 1995, 2005 and 2015.

Setting Nine cities in northern, central and southern region of China.

Population Healthy children under 7 years, the sample sizes were 94496 in 1975, 79177 in 1985, 79152 in 1995, 69760 in 2005 and 83583 in 2015.

Main outcome measures Weight and height were measured by the same methods in the five surveys.

Results The increasing trends in the mean weight, height and weight for height were observed. The distribution of height, weight and weight for height had shifted upward and the increments in the 3rd, 50th and 97th centiles were different. The relative increments in the 3rd centile were larger than that in the 50th and 97th centiles for height among children under 7 years and for weight among children under 2 years, but the increments in the 97th centile were the largest for weight among children older than 2 years. The trends in each centiles of weight for height were similar with that of weight. The annual increments of height and weight had increased over time and were more significant at 0-2years for height and at 4-6 years for weight. The per-decade increments in1975-1985, 1985-1995 and 1995-2005 became larger and larger, while the increments of 2005-2015 had slowed down.

Conclusions The rapid increasing trends of weight, height and weight for height had slowed down since 2005 in developed regions of China. The relative increments in the low centile of height were more significant, while the high centile of weight and weight for height increased more significant in older children.

KEYWORDS: Children, Weight, Height/length, Weight for height, Distribution, Secular changes, China.

Strengths and limitations of this study

- The series of surveys with the same method in the same sites, spanning 40 years, had undergone the rapid development and transformation of China's social economy.
- Changes of the 3rd, 50th and 97th centile would illustrate the trends of the distribution of height, weight and weight for height at population level, which would provide more data for public health promotion.
- The changes of annual increments of physical growth, calculated using the five cross-sectional surveys data, could roughly illustrate the trends of growth velocity in different times.

- We only described the 30 years changes of body proportion using weight for height from 1985 to 2015 due to the lack of related data in 1975.

INTRODUCTION

Secular trend in growth is an important phenomenon during human development [1], which could not only provide data for the evolution of human physique and be used to indirectly reflect changes of social environment, but also could reveal the potential problems of children's nutrition and health at population levels and provide more reference for clinical diagnosis and treatment.

Under the background of the industrial revolution and rapid social-economic development, the data of western developed countries in the past 100 years had revealed that population height had increased, especially in the early stage of social rapid development. It reflects the positive effect of environmental improvement on human growth, which were also considered to be the main cause of the trends [2]. However, the increasing trend had slowed down or even stagnated despite the further social development after the 1990s in some developed countries [3-7], and it was believed that population height had gradually reached the maximum genetic potential. On the other hand, many reports from developing countries still showed a rapid increasing trend [8-11]. Therefore, it was necessary to obtain more data in different countries and times in order to fully understanding population-level trends and racial differences in growth.

With the high prevalence of obesity and the track phenomenon of obesity, overweight and obesity in early childhood has been the focus of global attention [12]. Early prevention of obesity at the population level has become the most important public health strategy [13]. Analyzing the secular changes in the whole distribution of weight and weight for height, especially changes in the upper and lower ends of the distribution of growth in population, will help to fully understand the status of weight in population and provide more important clues for timely finding the potential nutritional problems, which will help policymakers decide where to focus strategies and interventions. However, the changes in growth were almost concentrated on the average level at present, there is little research on the changes in the distribution of physical growth indicators.

In China, the first large-scale national survey on growth, named "The National Survey on the Physical Growth and Development of Children in the Nine Cities of China" (NSPGDC), was carried out in 1975 [14]. Then it was carried out in 1985 [15], 1995 [16], 2005 [17] and 2015 [18] using the same methods in the same sites. The NSPGDC I-IV data had illustrated a significant increasing trend [19]. To understand whether the increasing trend is continuing and how the distributions of height or weight change, we used the NSPGDC I-V data to analyze the latest forty years trends in growth of children under 7years in Chinese developed regions.

METHODS

Study Design and Setting

Five large-scale cross-sectional surveys were conducted across nine cities during June-October in 1975, 1985, 1995, 2005 and 2015, which were respectively named the NSPGDC I-V. The nine cities included Beijing (Municipality), Harbin (Heilongjiang's provincial capital), Xi'an (Shanxi's provincial capital), Shanghai (Municipality), Nanjing (Jiangsu's provincial capital), Wuhan (Hubei's provincial capital), Guangzhou (Guangdong's provincial capital), Fuzhou (Fujian's provincial capital), and Kunming (Yunnan's provincial capital). All of these surveyed sites were nearly the same in the NSPGDC I-V.

Participants

Healthy children under 7 years were included in the five surveys and their exclusion criteria were the same: non-local residences who lived in the region for shorter than 2/3 of their time of life, gestational age at birth <37 weeks or birth weight <2.5 kg, twins or multiple births, participants suffering from chronic systemic disease, congenital diseases, endocrine diseases, diseases of the nervous system, and those presenting with fever for more than 7 days in the past 2 weeks or continuous diarrhea more than five times every day for 5 days or longer [14-18].

Multistage stratified cluster sampling method was used according to urban/suburban areas and administrative districts in each city. The hospitals, communities and kindergartens in each selected administrative district were considered as the cluster sample unit to respectively collect newborns, children aged 1 month to 3 years and children over 3 years (including 3 years). All of the children who were included in the five surveys had participated the investigation. The urban areas represent the better socio-economic environment of each city, thus were selected to illustrate the growth trends in Chinese developed regions in this paper.

All children were divided into 22 age groups: birth (0-3days), 1m-, 2m-, 3m-, 4m-, 5m-, 6m-, 8m-, 10m-, 12m-, 15m-, 18m-, 21m-, 2y-, 2.5y-, 3y-, 3.5y-, 4y-, 4.5y-, 5y-, 5.5y-, and 6-7y.

Data collection and Quality Control

Weight and height/length were measured by trained investigators using standardized method in the five surveys [14-18]. Weight was obtained by Newborn scales (accurate to 10 g) for newborns, and Lever scales (accurate to 50 g, in 1975-2005) or Electronic scales (accurate to 50 g, in 2015) for children aged 1 month or older. Length was measured using Infantometer (accurate to 0.1cm) for children under 3 years and height was measured using Height-Sitheight Stadiometer (accurate to 0.1cm) for children aged 3 years or older in the five surveys.

Measuring equipments in all sites were uniform and were calibrated daily using standard weights for weight scale (the error less than 50 g) and steel rule with length of 2 m for Infantometer, Height-Sitheight Stadiometer. All investigators had participated in rigorous specialized training and passed an examination before the investigation. Measurement errors were no more than 50 g in weight or 0.5 cm in height within intra-observer and inter-observer measurements. The 5% of total subjects in each site were repeat measured randomly per day, and the proportion of subjects beyond allowable errors was less than 10%.

Ethical considerations

The NSPGDC was approved by the Ethics Committee of the Capital Institute of Pediatrics. The investigators explained the purpose of the survey to the parents of children before the investigation and no sensitive data were collected. The participants orally agreed to participate in the survey after receiving additional verbal information. All results are published on a group level and no individuals can be identified.

Statistical Methods

SPSS 20.0 for Windows was used to analyze the data. The mean weight and height were described by $\bar{x} \pm SD$ and the 3rd, 50th, 97th centiles were used to describe the distributions of weight and height. Total crude increments, per-decade crude increments and their relative increments (calculated by the formula $\frac{measurments\ in\ 2015 - measurements\ in 1975}{measurements\ in\ 1975} \times 100\%$) of weight and height were calculated from 1975 to 2015. Weight for age Z-scores (WAZ) and height for age Z-scores (HAZ) in the five surveys were calculated based upon the WHO Child Growth Standards (2006) for under 60months children and the WHO child growth reference (2007) for children aged 60-83months by the LMS method. Because we measured the length for children aged 24-35months, they had been transformed into height by reducing 0.7cm in length then HAZ was calculated. Weight for height was used to evaluate the body proportion of children and only 30 years changes of weight for height from 1985 to 2015 were analyzed due to the scarcity of data in 1975 and their weight for height Z-scores (WFHZ) were also calculated based on the WHO child Growth Standards (2006) by the LMS method. The independent samples t test was used to compare the difference between neighboring two surveys. The annual increment of weight and height during birth to 6years in the five surveys were also calculated which were used to roughly reflect the growth velocity, we compared their changes from 1975 to 2015 to understand the changes of growth velocity. A value of $p < 0.05$ was considered statistically significant.

Patient and public involvement

This study is a secondary data analysis of the NSPGDC and patients or public are not involved in development of the research question, design and conduct of the study or dissemination of the results.

RESULTS

Summary of participants

The sample sizes were respectively 94 496 in 1975, 79 177 in 1985, 79 152 in 1995, 69 760 in 2005 and 83 583 in 2015. Table 1 had shown sex–age subgroup sample size.

Table 1 Sample size of the NSPGDC I-V (1975-2015)

Age	1975		1985		1995		2005		2015	
group	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Birth	2052	2001	1800	1800	1800	1800	1554	1512	2264	2147
1m~	1992	1940	1800	1800	1800	1800	1599	1573	1903	1896
2m~	1976	1901	1800	1800	1800	1794	1571	1559	1871	1856
3m~	2037	1985	1800	1800	1800	1795	1566	1588	1895	1893
4m~	2070	1938	1800	1800	1799	1800	1589	1581	1897	1852
5m~	2026	1994	1800	1800	1790	1788	1576	1580	1811	1841
6m~	2210	2202	1800	1800	1800	1800	1604	1585	1901	1884
8m~	2117	2090	1800	1800	1800	1793	1608	1622	1890	1881

10m~	2045	2072	1800	1800	1800	1794	1584	1581	1859	1862
12m~	2169	2053	1800	1800	1800	1800	1591	1594	1875	1870
15m~	2062	2029	1800	1800	1800	1800	1583	1579	1846	1886
18m~	2097	2029	1800	1800	1800	1800	1582	1572	1881	1869
21m~	2149	2083	1800	1800	1800	1800	1582	1573	1857	1815
2y~	2387	2247	1800	1800	1800	1800	1581	1582	1909	1869
2.5y~	2421	2286	1800	1800	1800	1800	1551	1561	1858	1878
3y~	2209	2190	1800	1800	1800	1800	1585	1601	1903	1908
3.5y~	2301	2238	1800	1800	1800	1800	1588	1600	1933	1924
4y~	2241	2202	1800	1799	1800	1800	1588	1602	1943	1866
4.5y~	2298	2244	1800	1800	1800	1800	1593	1599	1944	1895
5y~	2182	2237	1799	1780	1800	1800	1592	1595	1912	1892
5.5y~	2223	2151	1800	1800	1799	1800	1605	1597	1893	1908
6~7y	2580	2540	1800	1799	1800	1800	1629	1623	1922	1924
Total	47844	46652	39599	39578	39588	39564	34901	34859	41967	41616

Changes in means of weight, height and weight for height

A significant increasing trend in weight and height was observed during the lasted forty years in the nine cities. The average crude increments of boys were 1.41kg in weight and 3.5cm in height/length, and those of girls were 1.24kg in weight and 3.3cm in height/length. Table 2 illustrated that the crude increments became larger and larger with age.

Table2 Means of weight and height and the crude increments from 1975-2015

Age group	Boys						Girls					
	Weight (kg)			Height (cm)			Weight (kg)			Height (cm)		
	$\bar{x}\pm SD$		I^a	$x\pm SD$		I^a	$x\pm SD$		I^a	$x\pm SD$		I^a
	1975	2015		1975	2015		1975	2015		1975	2015	
Birth	3.27±0.36	3.38±0.40	0.11*	50.6±1.9	50.4±1.6	-0.2*	3.17±0.36	3.26±0.40	0.09*	50.0±1.8	49.8±1.6	-0.2*
1m~	4.97±0.67	4.95±0.60	-0.02	56.5±2.4	56.3±2.1	-0.2*	4.64±0.54	4.62±0.56	-0.02	55.5±2.4	55.2±2.0	-0.3*
2m~	5.95±0.76	6.18±0.70	0.23*	59.6±2.6	60.2±2.2	0.6*	5.49±0.69	5.68±0.64	0.19*	58.4±2.5	58.9±2.1	0.5*
3m~	6.73±0.79	7.11±0.79	0.38*	62.3±2.5	63.4±2.1	1.1*	6.23±0.75	6.51±0.74	0.28*	60.9±2.4	61.9±2.2	1.0*
4m~	7.32±0.85	7.78±0.89	0.46*	64.4±2.5	65.8±2.2	1.4*	6.69±0.79	7.11±0.77	0.42*	62.9±2.4	64.1±2.1	1.2*
5m~	7.70±0.88	8.26±0.94	0.56*	65.9±2.6	67.7±2.3	1.8*	7.19±0.84	7.60±0.85	0.41*	64.5±2.5	66.1±2.3	1.7*
6m~	8.22±0.96	8.68±0.94	0.46*	68.1±2.7	69.5±2.3	1.4*	7.62±0.89	8.03±0.90	0.41*	66.7±2.8	67.9±2.3	1.2*
8m~	8.71±0.99	9.35±1.03	0.64*	70.6±2.7	72.5±2.4	1.9*	8.14±0.95	8.70±1.02	0.56*	69.0±2.8	70.9±2.6	1.9*
10m~	9.14±1.03	9.88±1.11	0.74*	72.9±2.8	75.1±2.6	2.2*	8.57±0.97	9.24±1.05	0.67*	71.4±2.7	73.7±2.7	2.3*
12m~	9.66±1.08	10.26±1.10	0.60*	75.6±3.1	77.6±2.7	2.0*	9.04±1.02	9.65±1.06	0.61*	74.1±3.0	76.2±2.7	2.1*
15m~	10.15±1.11	11.07±1.19	0.92*	78.3±3.2	81.4±3.0	3.1*	9.54±1.10	10.46±1.16	0.92*	76.9±3.2	80.1±3.0	3.2*
18m~	10.67±1.19	11.50±1.26	0.83*	80.7±3.3	84.0±3.0	3.3*	10.08±1.13	10.89±1.19	0.81*	79.4±3.4	82.8±3.0	3.4*
21m~	11.18±1.23	12.38±1.35	1.20*	83.0±3.6	87.3±3.1	4.3*	10.56±1.15	11.73±1.25	1.17*	81.7±3.5	86.1±3.1	4.4*
2.0y~	11.95±1.27	12.98±1.48	1.03*	86.5±3.8	90.6±3.6	4.1*	11.37±1.21	12.36±1.41	0.99*	85.3±3.5	89.3±3.6	4.0*
2.5y~	12.84±1.35	14.28±1.71	1.44*	90.4±3.8	95.6±3.8	5.2*	12.28±1.33	13.57±1.68	1.29*	89.3±3.9	94.2±3.8	4.9*
3.0y~	13.63±1.42	15.46±2.02	1.83*	93.8±4.0	99.4±4.0	5.6*	13.16±1.37	14.85±1.81	1.69*	92.8±3.9	98.3±3.8	5.5*
3.5y~	14.45±1.52	16.62±2.18	2.17*	97.2±4.3	103.2±4.1	6.0*	14.00±1.51	15.95±1.96	1.95*	96.3±4.1	102.0±4.0	5.7*
4.0y~	15.26±1.56	17.76±2.46	2.50*	100.8±4.5	106.7±4.2	5.9*	14.89±1.54	16.90±2.21	2.01*	100.1±4.3	105.4±4.1	5.3*
4.5y~	16.07±1.69	19.02±2.77	2.95*	103.9±4.5	110.1±4.5	6.2*	15.63±1.60	18.14±2.53	2.51*	103.1±4.4	108.9±4.4	5.8*
5.0y~	16.88±1.84	20.35±3.10	3.47*	107.2±4.6	114.1±4.6	6.9*	16.46±1.69	19.47±2.85	3.01*	106.5±4.4	112.8±4.5	6.3*
5.5y~	17.65±1.86	21.71±3.52	4.06*	110.1±4.6	117.1±4.7	7.0*	17.18±1.77	20.74±3.17	3.56*	109.2±4.5	116.0±4.6	6.8*
6~7y	19.25±2.10	23.69±4.03	4.44*	114.7±4.9	121.8±4.9	7.1*	18.67±2.03	22.34±3.60	3.67*	113.9±4.9	120.2±5.0	6.3*

Note: a I is equal to weight or height/length of the NSPGDC V (2015) minus those of the NSPGDC I (1975). *: p<0.05.

Figure 1 displayed the relative increments of weight and height from 1975 to 2015: weight relatively increased by 3-8% in children under 1years and 8-23% in children older than 1years, which were significantly larger than the relative increments of height (1-3% in children under 1year, and 3-6% in children older than 1years). Comparing gender difference of the relative increments, we found that the relative increments of weight in boys and girls were similar for children under 4years, but the relative increments of weight in boys older than 4years were larger than that in same-age girls. The relative increments of height in boys and girls were similar.

Table 3 had showed that weight for height had increased from 1985 to 2015 and the increments became larger and larger after 100cm, especially in boys.

Table3 Means weight for height and its increments from 1985-2015

Height (cm)	Weight							
	Boys				Girls			
	1985	2015	Crude Increments (kg)	Relative Increments %	1985	2015	Crude Increments (kg)	Relative Increments %
	$\bar{x}\pm$SD (kg)	$\bar{x}\pm$SD (kg)	1985-2015	1985-2015	$\bar{x}\pm$SD (kg)	$\bar{x}\pm$SD (kg)	1985-2015	1985-2015
50	3.17±0.26	3.34±0.30	0.17*	5.4	3.16±0.27	3.32±0.28	0.16*	5.2
55	4.63±0.52	4.79±0.53	0.16*	3.4	4.53±0.47	4.69±0.47	0.16*	3.6
60	6.02±0.59	6.25±0.60	0.23*	3.8	5.89±0.55	6.12±0.58	0.23*	3.9
65	7.40±0.62	7.61±0.65	0.21*	2.8	7.21±0.61	7.38±0.63	0.17*	2.3
70	8.66±0.75	8.78±0.77	0.12*	1.4	8.34±0.72	8.52±0.78	0.18*	2.1
75	9.58±0.78	9.86±0.83	0.28*	2.9	9.21±0.70	9.53±0.76	0.32*	3.5
80	10.50±0.78	10.82±0.93	0.32*	3.0	10.19±0.81	10.46±0.85	0.27*	2.6
85	11.63±0.95	11.87±0.95	0.24*	2.1	11.27±0.84	11.52±0.91	0.25*	2.2
90	12.70±0.94	12.99±1.09	0.29*	2.3	12.44±0.93	12.65±1.04	0.21*	1.7
95	13.84±1.08	14.02±1.11	0.18*	1.3	13.56±0.91	13.89±1.13	0.33*	2.5
100	15.05±1.13	15.57±1.25	0.52*	3.5	14.81±1.14	15.44±1.30	0.63*	4.2
105	16.28±1.13	17.17±1.56	0.89*	5.5	16.17±1.23	16.79±1.44	0.62*	3.8
110	17.79±1.43	18.97±1.95	1.18*	6.6	17.36±1.30	18.39±1.67	1.03*	5.9
115	19.35±1.46	20.60±2.28	1.25*	6.4	18.94±1.53	20.36±2.13	1.42*	7.5
120	20.50±1.47	23.03±2.81	2.53*	12.4	20.60±1.48	22.53±2.67	1.93*	9.4

Changes in the distribution of weight, height and weight for height

Figure 2 illustrated that the 3rd, 50th and 97th centiles of weight or height had significantly increased during 40years, and the increments of the three centiles were different. For weight, the crude increments of the three centiles in children under 2years were similar, while in children older than 2years, the crude increments of 97th centile were significantly larger than that of the 3rd and 50th centile, for example, the crude increments of the 3rd, 50th, 97th in 5.5y- boys were 2.26kg, 3.56kg and 8.44kg. Furthermore, we found the relative increments of the 3rd centile in children under 2years were slightly larger than those of the 50th and 97th centile, for example, the 3rd, 50th and 97th centile in 6m- boys relatively increased by 6.4%, 5.5% and 3.7%. But a larger relative increment of the 97th centile was observed in children older than 2years, for example, the relatively increments of the 3rd, 50th and 97th centile in 5.5y- boys were respectively 15.8%, 20.3% and 39.0%. For height, the crude and relative increments of the 3rd centile were slightly larger than those of the 50th and 97th centile. For example, the 3rd, 50th and 97th centile increased respectively 2.3cm, 1.3cm, 0.7cm in 6m- boys (relatively increase by 3.6%, 1.9%, 1.0%), 5.5, 5.1, 4.6cm in 2.5y- boys (relatively increase by 6.6%,5.6%,4.7%).

Figure 3 had shown that the 3rd, 50th and 97th centile of weight for height increased from 1985 to 2015, and the increments of the three centiles were similar in children whose height were shorter than 100cm, while the increments of the 97th centile were significantly larger in children whose height were taller than 100cm than that of the 3rd and 50th centile. For example, the crude increments of the 3rd, 50th and 97th were respectively 0.37kg, 0.37kg and 0.43kg at 60cm (corresponding relative increments were 7.7%, 6.3%, 6.1%), and 1.13kg, 1.38kg, 3.29kg at 110cm (corresponding relative increments were 7.5%, 8.0%, 16.2%) in boys.

Forty years changes in annual increments of weight and height from birth to 6 years

Table 4 displayed the annual increments of weight and height from birth to 6 years during 1975-2015. The changes in the annual increments of weight were more significant at 4-6 years, while the changes in annual increments of height were larger at 0-2years.

Table 4 Annual increments of weight and height/length during birth to 6years, 1975-2015

	1-year increments of weight (kg)												1-year increments of height/length (cm)											
	Boys						Girls						**Boys**						Girls					
	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]
0~1y	6.08	6.40	6.56	6.82	6.65	0.57	5.59	5.86	6.06	6.25	6.14	0.55	23.4	24.7	25.2	26.2	25.7	2.3	22.5	23.8	24.5	25.3	24.9	2.4
1~2y	2.09	2.08	2.22	2.51	2.55	0.46	2.07	2.16	2.25	2.56	2.54	0.47	10.2	10.7	11.1	12.0	12.3	2.1	10.4	10.8	11.4	12.3	12.5	2.1
2~3y	1.80	1.85	1.91	2.14	2.29	0.49	1.89	1.86	1.98	2.22	2.27	0.38	7.9	7.8	8.3	8.6	9.1	1.2	8.1	8.0	8.2	8.6	9.1	1.0
3~4y	1.62	1.64	1.81	2.06	2.32	0.70	1.73	1.74	1.88	2.07	2.22	0.49	6.9	6.9	6.9	7.1	7.5	0.6	7.1	7.0	7.1	7.2	7.5	0.4
4~5y	1.62	1.76	1.99	2.38	2.50	0.88	1.60	1.72	1.94	2.14	2.38	0.78	6.6	6.6	6.9	7.1	7.1	0.5	6.6	6.8	7.0	7.1	7.1	0.5
5~6y	1.71	1.86	2.12	2.39	2.69	0.98	1.63	1.72	2.01	2.23	2.47	0.84	6.1	6.2	6.3	6.3	6.6	0.5	6.0	6.2	6.3	6.4	6.6	0.6

Note: a D is equal to annual increments of weight or height/length in the NSPGDC V (2015) minus those of the NSPGDC I (1975).

Per-decade changes in the means of weight, height and weight for height

The weight, height and weight for height were standardized using the WHO growth standard to summarize the trends of each decade during the forty years. Figure 4 illustrated that WAZ and HAZ rapidly increased during the first 3 decades, while their increasing trends were not significant during the fourth decade and their increments in 1975-1985, 1985-1995, 1995-2005 and 2005-2015 were respectively 0.17, 0.29, 0.31, 0.00 in WAZ and 0.27, 0.35, 0.35, 0.00 in HAZ. We found that WFHZ had increased during 1985-2005, but slightly deceased during 2005-2015. The increments of WFHZ were 0.28 in 1985-1995, 0.15 in 1995-2005 and -0.03 in 2005-2015. The per-decade crude increments of mean weight and mean height from 1975 to 2015 were shown in table 5 and that of mean weight for height from 1985 to 2015 were shown in table 6.

Table 5 Comparison of pre-decade increments in mean weight and height/length (1975-1985, 1985-1995, 1995-2005 and 2005-2015)

Age group	Weight (kg)		Height (cm)	
	Boys	Girls	Boys	Girls

	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]
Birth	-0.06*	0.09*	0.03*	0.05*	-0.05*	0.08*	0.04*	0.02	-0.4*	0.2*	0.0	0.0	-0.4*	0.2*	-0.1	0.1
1m~	-0.07*	0.20*	0.01	-0.16*	-0.04*	0.21*	-0.08*	-0.11*	0.0	0.4*	-0.1	-0.5*	0.1	0.5*	-0.5*	-0.4*
2m~	0.07*	0.14*	0.11*	-0.09*	0.05*	0.20*	0.01	-0.07*	0.5*	0.3*	0.1	-0.3*	0.4*	0.4*	-0.1	-0.2*
3m~	0.01	0.24*	0.19*	-0.06*	-0.01	0.20*	0.14*	-0.05	0.1	0.6*	0.3*	0.1	0.2*	0.5*	0.4*	-0.1
4m~	0.04	0.20*	0.20*	0.02	0.09*	0.23*	0.15*	-0.05	0.1	0.6*	0.6*	0.1	0.2*	0.7*	0.4*	-0.1
5m~	0.09*	0.23*	0.30*	-0.06	0.05	0.29*	0.12*	-0.05	0.4*	0.7*	0.8*	-0.1	0.3*	0.7*	0.7*	0.0
6m~	0.17*	0.23*	0.13*	-0.07*	0.16*	0.22*	0.13*	-0.10*	0.5*	0.6*	0.6*	-0.3*	0.3*	0.6*	0.5*	-0.2*
8m~	0.29*	0.19*	0.16*	0.00	0.22*	0.29*	0.09*	-0.04	0.7*	0.7*	0.6*	-0.1	0.7*	0.9*	0.5*	-0.2*
10m~	0.30*	0.21*	0.27*	-0.04	0.23*	0.29*	0.19*	-0.04	0.9*	0.8*	0.9*	-0.4*	0.9*	1.0*	0.5*	-0.1
12m~	0.21*	0.29*	0.33*	-0.23*	0.20*	0.28*	0.28*	-0.15*	0.9*	0.8*	1.0*	-0.7*	1.0*	0.8*	0.9*	-0.6*
15m~	0.23*	0.32*	0.34*	0.03	0.24*	0.31*	0.34*	0.03	0.9*	1.1*	1.1*	0.0	1.0*	1.0*	1.3*	-0.1
18m~	0.21*	0.37*	0.40*	-0.15*	0.25*	0.32*	0.36*	-0.12*	0.9*	1.1*	1.3*	0.0	1.0*	1.2*	1.3*	-0.1
21m~	0.24*	0.41*	0.56*	-0.01	0.31*	0.38*	0.52*	-0.04	1.4*	1.2*	1.7*	0.0	1.4*	1.4*	1.5*	0.1
2.0y~	0.29*	0.33*	0.62*	-0.21*	0.29*	0.38*	0.56*	-0.24*	1.4*	1.2*	2.1*	-0.6*	1.3*	1.5*	1.8*	-0.6*
2.5y~	0.29*	0.43*	0.72*	0.00	0.27*	0.42*	0.76*	-0.16*	1.3*	1.6*	2.1*	0.2	1.0*	1.7*	2.3*	-0.1
3.0y~	0.32*	0.47*	0.89*	0.15*	0.28*	0.57*	0.79*	0.05	1.3*	1.7*	2.1*	0.5*	1.4*	1.7*	1.7*	0.7*
3.5y~	0.30*	0.62*	0.96*	0.29*	0.26*	0.68*	0.90*	0.11	1.3*	1.7*	2.2*	0.8*	1.0*	1.9*	2.1*	0.7*
4.0y~	0.35*	0.62*	1.14*	0.39*	0.32*	0.60*	1.03*	0.06	1.3*	1.6*	2.3*	0.7*	1.1*	1.6*	2.1*	0.5*
4.5y~	0.42*	0.75*	1.31*	0.47*	0.49*	0.68*	1.21*	0.13	1.4*	1.8*	2.4*	0.6*	1.4*	1.7*	2.5*	0.2
5.0y~	0.51*	0.95*	1.56*	0.45*	0.33*	1.05*	1.09*	0.54*	1.4*	1.9*	2.6*	1.0*	1.1*	2.2*	1.9*	1.1*
5.5y~	0.65*	1.08*	1.78*	0.55*	0.54*	1.08*	1.47*	0.47*	1.5*	2.1*	2.7*	0.7*	1.6*	2.1*	2.5*	0.6*
6~7y	0.56*	1.16*	1.54*	1.18*	0.41*	1.28*	1.19*	0.79*	1.5*	1.7*	2.1*	1.8*	1.2*	2.0*	1.8*	1.3*

Note: a I1 is equal to means of weight or height in 1985 minus those in 1975, b I2 is equal to means of weight or height in 1995 minus those in 1985, c I3 is equal to means of weight or height in 2005 minus those in 1995, d I4 is equal to means of weight or height in 2015 minus those in 2005. *: p<0.05.

Table 6 Comparison of pre-decade increments in mean weight for height (1985-1995, 1995-2005 and 2005-2015)

Height(cm)	Weight (kg)					
	Boys			Girls		
	I1[a]	I2[b]	I3[c]	I1[a]	I2[b]	I3[c]
50	0.12*	0.07*	-0.02	0.12*	0.06*	-0.02
55	0.15*	0.00	0.01	0.15*	0.06	-0.05
60	0.18*	0.02	0.03	0.19*	0.03	0.01
65	0.16*	0.09*	-0.04	0.17*	0.06	-0.06
70	0.13*	0.05	-0.05	0.17*	0.05	-0.05
75	0.22*	0.08	-0.02	0.22*	0.13*	-0.02
80	0.22*	0.14*	-0.05	0.19*	0.13*	-0.05
85	0.17*	0.10	-0.03	0.17*	0.09	-0.01
90	0.16*	0.14*	0.00	0.15*	0.15*	-0.09
95	0.18*	0.11	-0.12	0.27*	0.24*	-0.17*
100	0.37*	0.24*	-0.08	0.37*	0.29*	-0.04
105	0.41*	0.58*	-0.11	0.34*	0.35*	-0.07
110	0.44*	0.62*	0.12	0.65*	0.56*	-0.18
115	0.63*	0.65*	-0.04	0.69*	0.66*	0.06
120	1.55*	0.60*	0.38	1.16*	0.51*	0.26

Note: a I1 is equal to means of weight for height in 1995 minus those in 1985, b I2 is equal to means of weight for height in 2005 minus those in

1995, c I3 is equal to means of weight for height in 2015 minus those in 2005. *: $p<0.05$.

DISCUSSION

Our study displayed a rapidly increasing trend in physical growth of children under 7 years in nine cities during 1975-2015. The trend may be associate with the rapid socio-economic development in China: Firstly, the Gross Domestic Product (GDP) of nine provinces, whose capital were the nine cities, has increased from ¥562 in 1975 to ¥62971 in 2014 and their household disposable income increased from ¥351 in 1975 to ¥32301 in 2014. Secondly, the national statistical data illustrated that the medical and health care services had been improved, for example, the number of doctors per 10,000 people had increased from 10 persons in 1975 to 22 persons in 2015, the infant mortality rate changed from 62.6‰ in 1975 to 8.1‰ in 2015 and the mortality rate of children under 5 years decreased from 85.2‰ in 1975 to 10.7‰ in 2015, the newborn mortality rate decreased from 33.1‰ in 1991 to 5.4‰ in 2015. Thirdly, the national nutrition survey, which started in 1982 and the latest survey was in 2012, indicated that the nutritional intake of Chinese population had significantly improved, for example, the daily intake of milk, egg, fish and shrimps, and meat were respectively 9.9g, 15.5g, 21.6g and 62.0g in 1982, which increased to 37.8g, 29.5g, 32.4g and 98.5g in 2012. It was suggested that the comprehensive improvement of social economy, medical and health care, as well as food supply had provided a favorable environment for children growth [2 6 20 21].

The extent of secular growth changes are influenced by many factors. In this paper, we found that height and weight of children under 7 years average increased 3.3-3.5cm and 1.2-1.4kg during the last 40 years and the crude increments became larger with age, which reached to 6-7cm at 6y- group (1.5-1.8cm/decade). The increments of height were slightly larger than that of some western countries: the increments of height were 1-2cm in Dutch children aged 1-4 years during 50 years (1955-2009) [7], 1-3cm in South Asian children in the Netherlands children aged 2-6 years during about 40 years (1976-2010) [22], 2.7-3.3cm in Czech children aged 2.5years during 50 years (1951-2001) [23], 0.9-1.1cm in Turkish children aged 5years during 30 years (1975-2008) [24], and1.1-1.5cm in Canadian children aged 6years per decade during 1891-1974 [25]. In Japan, data from 1950-2000 had illustrated that the height increments of 6years children were 1.6cm/decade [6], which were similar to our results. Furthermore, the height increments of 6years boys and girls in South Korea during 1965-2005 (10.3cm, 11.7cm) were higher than our results (7.1cm, 6.3cm). Therefore, we found the height increments in Chinese, Japanese and South Korean children were higher than those of western countries, which might be related to the social and economic backwardness or even retrogression during World War II and then the rapid social development after World War II. The rapid increasing of height may be the integrated results of catching up and a positive secular trend in physical growth [26].

Inequality proportion increments of weight and height would predict the changes of body proportion. Our results had shown that the relative increments of weight were significantly larger than that of height, which illustrated that the body proportion of Chinese children were from slender to thickset over the last 40 years. The positive changes of weight for height from 1985 to 2015 also established the facts, that is, weight of children in 2015 were greater 0.16-2.53kg than those of children in 1985 for a given height. The changes in the distribution of weight and weight for height had shown an upward shift. In younger children (under 2 years), the increments of the 3rd, 50th, 97th centiles were similar, even slightly higher in the 3rd centile, , which suggested the nutritional status of all of the infant and young children had improved, especially the improvement of low-growth-level infants and young children in population were more significant . However, in older children (older than 2yearsor taller than 100cm), the relative increments in the 97th centile were significantly larger than those in the 3rd and 50th centile, which indicated that the upward shift of weight and weight for height were pronounced in the upper ends of the distribution. The results predict that overweight or obesity might become a potential health problem as children's nutrition improving among older children. This is consistent with the fact that obesity in Chinese children and adolescents has become more prominent since 1980s: the prevalence of obesity in preschool children was from 0.91% in 1986 to 3.44% in 2006 [27] and that in school-age boys of large cities was from 1.0% in 1985 to 17.8% in 2010 [28]. Global data has illustrated that childhood obesity have increased dramatically and become a very important health problem for children and adults [12 29]. Therefore, timely monitoring trends in the distribution of weight and weight for height at the population level would be more helpful for projection of obesity epidemic as early as possible and provide more data for design effective public health strategies. Moreover, these results also suggest that if we do not consider the pronounced upward-shift in the upper centiles when updating weight or weight for height reference, the upper ends of the reference will significantly raise, which will be more unfavorable to the prevention of obesity and other related health problems.

The height had shifted upward in all centiles in our results. The increasing in low centile would be an important manifestation of the improvement of children's nutrition. The changes in high centiles of height indicated that the linear growth has not reached the maximum genetic potential and will gradually be fully exploited with the environment improving. Comparison of the relative increments among all centiles, we found the increments in low centiles were larger compare to other centiles, especially in children under 3years, which indicated that the improvement of linear growth was more significantly in vulnerable children when the environment had improved.

Physical growth velocity of children under 7years was roughly approximated by calculating annual increments of corresponding age using this series cross sectional surveys' data. It illustrated that the annual increments of height and weight during the first year of life were similar to the WHO longitudinal growth velocity in 2009 (25.8cm, 6.27kg in boys and 24.7cm, 6.14kg in girls)[30], which suggested that the annual increments from large-scale cross-sectional survey could roughly reflect the growth velocity. Therefore, we calculated the annual increments of height and weight in NSPGDC I-V in order to analyze the changes of growth velocity during 1975-2015. These results indicated that the growth velocity of height during the first two years after birth had increased more significantly compare to other ages, which may be the results of the improvement in feeding pattern of children under 2 years [31]. It is also suggested that the linear growth of infants would be more sensitive to environmental improvement, and environmental intervention in infancy might be more effective to improve their linear growth, which is consistent with the research reports of Cole TJ [32]. From the changes of weight growth velocity, we found that the increments of weight growth velocity in children over 4years became larger, which suggested that 4years old and later should be taken as the key window period for early obesity intervention.

From the per-decade increment, we found that the rapid increasing trend had not be continued and the increments of the fourth decade (2005-2015) in weight, height and weight for height had slowed down or even stagnated when comparing with that of the previous 3 decades. The secular growth trend of children under 7years in Chinese developed regions was consistent with other developed countries [4 6 7 33]. The trends of height may be associate with the population genetic potential of height, population height will gradually reach the maximum genetic potential after rapid increasing under the background of social and economic sustainable development in developed regions of China. Meanwhile, the slight deceleration of increasing trend in weight or weight for height might be relate to the focus on overweight and obesity of children and spreading of healthy promotion strategies among population in past years, especially the latest 10 years.

There were some limitations in our study. Firstly, the annual increments of physical growth calculated by the five cross-sectional surveys data were used to describe the changes of growth velocity. We compared these data with the growth velocity of WHO and found they were similar, therefore, we thought these results might roughly illustrate the trends of growth velocity in different periods and they would provide some data for comprehensively understanding the secular trends of physical growth in developed regions of China. Secondly, we could not obtain data of body proportion in 1975, thus we can only analyze the changes of body proportion by weight for height from 1985 to 2015.

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Competing Interests None declared.

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Contributions Yaqin Zhang contributed to data analysis, preparation and writing the initial draft of the manuscript. Hui Li designed the study, directed the data analysis and modified the manuscript. Huahong Wu inputted and cleared up the data. Xinnan Zong contributed to data analysis. All authors read, critically reviewed and approved the final manuscript as submitted.

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Figure legends

Figure 1 The relative increments of mean weight and height/length from 1975 to 2015

Figure2 Changes in the 3rd, 50th and 97th centiles of weight and heightlength from 1975-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1975 and 2015)

Figure3 Changes in the 3rd, 50th and 97th centiles of weight for height from 1985-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1985 and 2015)

Figure4 The Z-score of weight, height and weight for height base on WHO growth standard from 1975-2015

What is already known on this subject?

- The increasing trend of mean height and weight of children has been illustrated in many countries, and their significant differences among different populations and times were also observed.
- Understanding the changes in the distribution of weight, height and weight for height at the population level is important since mean values may hide differences in patterns at both the upper and lower ends of the distribution, which will supply more data for our projections of future pattern as well as timely designing effective public health strategies. However, the secular changes in the distribution of weight, height and weight for height are rarely reported.

What this study adds?

- The study has shown a continued increase of weight and height during 1975-2015, but the increments slowed down in the latest 10years in Chinese developed regions.
- The distribution of weight, height and weight for height had shifted upward and the relative increments in the low centiles of height were more significant, while the relative increments in the high centiles of weight and weight for height increased more significant in older children, which provided some data for health promotion and overweight prevention at population levels.
- The changing in annual increments of height suggested that environmental intervention in infancy might be more effective to improve the linear growth of children. Meanwhile, the more obvious changes in annual increments of weight among older than 4years children had illustrated that 4years old and later may be the key window period for early obesity intervention.

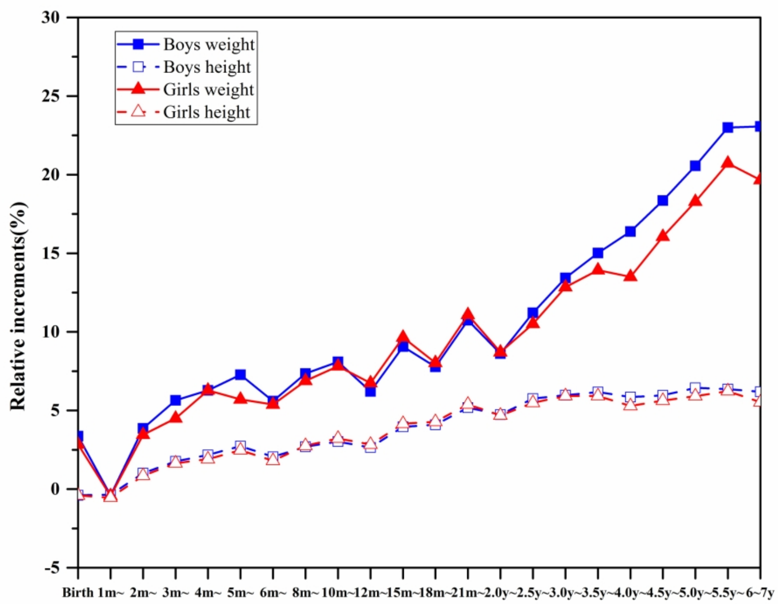

Figure 1 The relative increments of mean weight and height/length from 1975 to 2015

272x208mm (300 x 300 DPI)

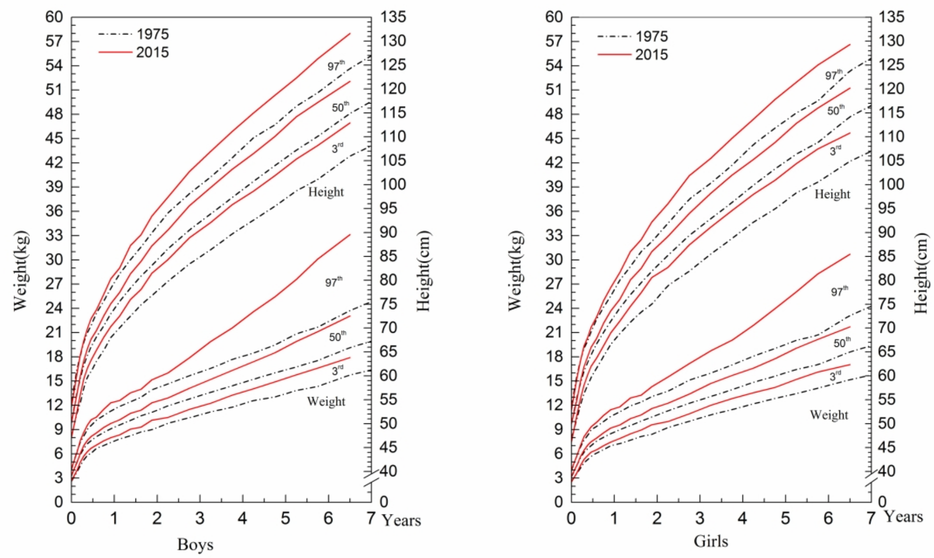

Figure2 Changes in the distributions of weight and height/length from 1975-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1975 and 2005)

288x200mm (300 x 300 DPI)

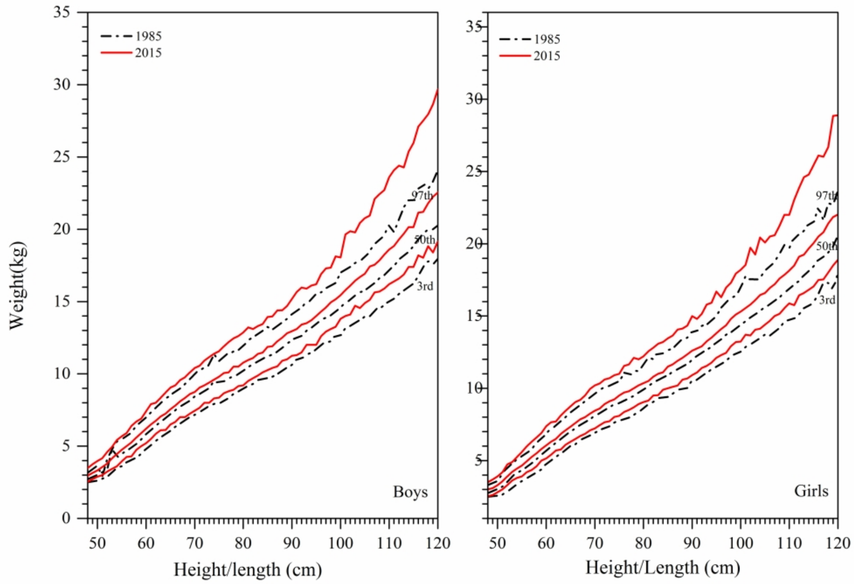

Figure3 Changes in the 3rd, 50th and 97th centiles of weight for height from 1985-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1985 and 2015)

288x200mm (300 x 300 DPI)

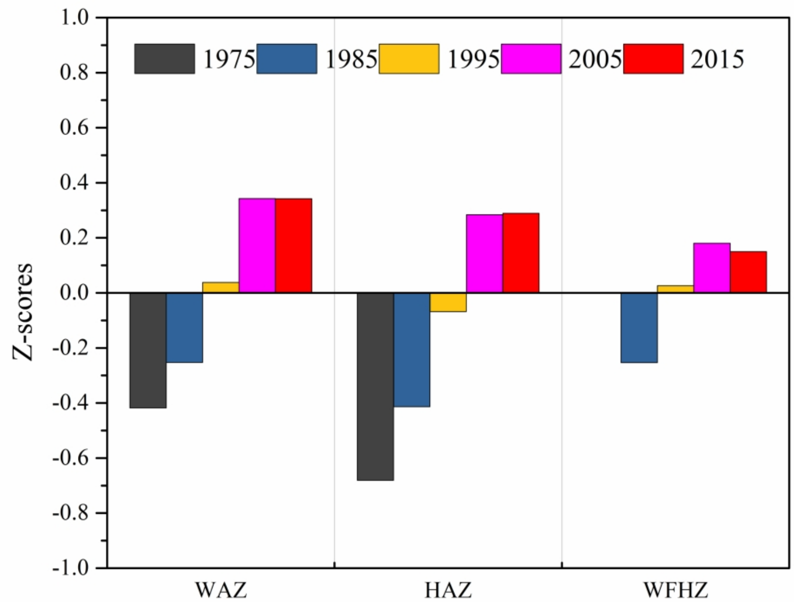

Figure4 The Z-score of weight, height and weight for height base on WHO growth standard from 1975-2015

272x208mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3-4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	*4*
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5-9
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Secular trends in weight, height and weight for height among children under 7 years in nine cities of China, 1975-2015: results from five repeated cross-sectional surveys

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ABSTRACT

Objective To analyze the secular trends in mean value and the distribution of weight, height and weight for height of children under 7 years in Chinese developed regions.

Design Five repeated cross-sectional surveys were conducted using the same methods in the same sites during 1975-2015.

Setting Nine cities in northern, central and southern regions of China.

Population Healthy children under 7 years, the sample sizes were 94496 in 1975, 79177 in 1985, 79152 in 1995, 69760 in 2005 and 83583 in 2015.

Main outcome measures Weight and height were measured by the same methods in the five surveys.

Results The increasing trends in the mean value of weight, height and weight for height were observed and their distribution had shifted upward. The unbalanced increments in various centiles occurred and the relative increments in the 3rd centile of height for children under 7 years were larger than those in the 50th and 97th centiles. Although the relative increments in the 3rd centile of weight for children under 2 years were larger than those in the 50th and 97th centiles, the increments in the 97th centile for children older than 2 years became the largest comparing with other centiles. The changes in each centile of weight for height were similar with those of weight. The annual increments of height and weight increased over time and were more significant between age birth and 2years for height and between age 4 and 6 years for weight. The per-decade increments in1975-1985, 1985-1995 and 1995-2005 became larger, while those in 2005-2015 slowed down.

Conclusions The rapid increasing trends of weight, height and weight for height had slowed down since 2005 in Chinese developed regions. The relative increments in the low centile of height were more significant, while the high centile of weight and weight for height increased more significant in older children.

KEYWORDS: Children, Weight, Height, Weight for height, Distribution, Secular changes, China.

Strengths and limitations of this study

- The series of surveys with the same method in the same sites, spanning 40 years, had undergone the rapid development and transformation of China's social economy.
- Changes of the 3rd, 50th and 97th centile would illustrate the trends of the distribution of height, weight and weight for height at population level, which would provide more data for public health promotion.
- The changes of annual increments of physical growth, calculated using the five cross-sectional surveys data, could roughly illustrate the trends of growth velocity in different times.

- We only discuss the 30 years changes of body proportion using weight for height from 1985 to 2015 due to the lack of related data in 1975.

INTRODUCTION

Secular trend in growth is an important phenomenon during human development [1], which could not only provide data for the evolution of human physique and indirectly reflect changes of social environment, but could also reveal the potential problems of children's nutrition and health at population levels and provide more reference for clinical diagnosis and treatment.

Data from the past 100 years that span industrial revolution and rapid social-economic development indicate that populations in western developed countries had increased in height, especially in the early stage of social rapid development. This reflects the positive effect of environmental improvement on human growth, which was also considered to be the main cause of the trends [2]. However, the increasing trend had slowed down or even stagnated despite the further social development after the 1990s in some developed countries [3-7], and it was evident that population height had gradually reached the maximum genetic potential. On the other hand, many reports from developing countries still showed a rapid increasing trend [8-11]. Therefore, it was necessary to obtain more data in different countries and at various times to fully understand population-level trends and racial differences in growth.

With the high prevalence of obesity and the track phenomenon of obesity, overweight and obesity in early childhood attract global attention [12]. Early prevention of obesity at the population level has become the most important public health strategy [13]. Analyzing the secular changes in the whole distribution of weight and weight for height, especially changes in the upper and lower ends of the distribution of growth in population, will help fully understand the status of weight in population and provide more important clues to find potential nutritional problems. This will ultimately help policymakers consider and decide strategies and interventions. However, many studies on the growth changes concentrate on the average level in population until now, there is little research on the changes in the distribution of physical growth indicators.

In China, the first large-scale national survey on growth, named "The National Survey on the Physical Growth and Development of Children in the Nine Cities of China" (NSPGDC), was carried out in 1975 [14]. Then it was conducted again in 1985 [15], 1995 [16], 2005 [17] and 2015 [18] using the same methods in the same sites. The NSPGDC I-IV data had illustrated a significant increasing trend [19]. To understand whether the increasing trend continues and how the distributions of height and weight change, we used the NSPGDC I-V data to analyze the latest forty years trends in growth of children under 7 years in developed regions of China.

METHODS

Study Design and Setting

Five large-scale cross-sectional surveys were conducted across nine cities during June-October in 1975, 1985, 1995, 2005 and 2015, which were respectively named the NSPGDC I-V. The nine cities were Beijing (Municipality), Harbin

(Heilongjiang's provincial capital), Xi'an (Shanxi's provincial capital), Shanghai (Municipality), Nanjing (Jiangsu's provincial capital), Wuhan (Hubei's provincial capital), Guangzhou (Guangdong's provincial capital), Fuzhou (Fujian's provincial capital), and Kunming (Yunnan's provincial capital). All surveyed sites were nearly the same in the NSPGDC I-V.

Participants

Healthy children under 7 years were included in the five surveys and their exclusion criteria were the same: non-local residences who lived in the region for shorter than 2/3 of their time of life, gestational age at birth <37 weeks or birth weight <2.5 kg, twins or multiple births, participants suffering from chronic systemic disease, congenital diseases, endocrine diseases, diseases of the nervous system, and those with fever for more than 7 days in the past 2 weeks or continuous diarrhea more than five times every day for 5 days or longer [14-18].

Multistage stratified cluster sampling method was used. Some administrative districts located in the urban or suburban areas of each city were selected. The hospitals, communities and kindergartens in each selected administrative district were considered as the cluster sample unit to respectively collect newborns, children age 1 month to 3 years and children over 3 years (including 3 years). All children included in the five surveys were involved. Because urban areas represent the better socio-economic environment of each city, they were selected to illustrate the growth trends in Chinese developed regions in this paper.

All children were divided into 22 age groups: birth (0-3days), 1m-, 2m-, 3m-, 4m-, 5m-, 6m-, 8m-, 10m-, 12m-, 15m-, 18m-, 21m-, 2y-, 2.5y-, 3y-, 3.5y-, 4y-, 4.5y-, 5y-, 5.5y-, and 6-7y.

Data collection and Quality Control

Weight and height/length were measured by trained investigators using standardized method in the five surveys [14-18]. Weight was obtained by Newborn scales (accurate to 10 g) for newborns, and Lever scales (accurate to 50 g, in 1975-2005) or Electronic scales (accurate to 50 g, in 2015) for children age 1 month or older. Length was measured using Infantometer (accurate to 0.1cm) for children under 3 years and height was measured using Height-Sitheight Stadiometer (accurate to 0.1cm) for children age 3 years or older in the five surveys.

Measuring equipment in all sites were uniform and calibrated daily using standard weights for weight scale (the error less than 50 g) and steel rule with length of 2 m for Infantometer, Height-Sitheight Stadiometer. All investigators had participated in rigorous specialized training and passed an examination prior to the investigation. Measurement errors were no more than 50 g in weight or 0.5 cm in height within intra-observer and inter-observer measurements. The 5% of total subjects in each site were repeat measured randomly per day, and the proportion of subjects beyond allowable errors was less than 10%.

Ethical considerations

Since the study is a secondary data analysis of the NSPGDC I-V and all results are published on a group level and no individuals can be identified, ethical approvals are not required.

Statistical Methods

SPSS 20.0 for Windows was used to analyze the data. The mean weight and height were described by $\bar{x} \pm SD$ and the 3rd, 50th, 97th centiles were calculated to describe their distributions. Total crude increments, per-decade crude increments and the relative increments (calculated by the formula $\frac{measurments\ in\ 2015 - measurements\ in 1975}{measurements\ in\ 1975} \times 100\%$) of weight and height were calculated from 1975 to 2015. Weight for age Z-scores (WAZ) and height for age Z-scores (HAZ) were calculated based upon the WHO Child Growth Standards (2006) for children under 60months and the WHO child growth reference (2007) for children age 60-83months by the LMS method. Because we measured the length for children age 24-35months, they had been transformed into height by reducing 0.7cm in length then HAZ was calculated. Weight for height was used to evaluate the body proportion of children and only 30 years changes from 1985 to 2015 were analyzed due to the scarcity of data in 1975 and their weight for height Z-scores (WFHZ) were also calculated based on the WHO child Growth Standards (2006) by the LMS method. The independent samples t-test were used to compare the difference between two neighboring surveys. The annual increment of weight and height from birth to 6years were also calculated to roughly reflect the growth velocity, then we compared their changes from 1975 to 2015 to understand the changes of growth velocity. A value of $p < 0.05$ was considered statistically significant.

Patient and public involvement

This study is a secondary data analysis of the NSPGDC and patients or public are not involved in development of the research question, design and conduct of the study or dissemination of the results.

RESULTS

Summary of participants

The sample sizes were 94496 in 1975, 79177 in 1985, 79152 in 1995, 69760 in 2005 and 83583 in 2015. Table 1 shows sex–age subgroup sample size.

Table 1 Sample size of the NSPGDC I-V (1975-2015)

Age	1975		1985		1995		2005		2015	
group	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Birth	2052	2001	1800	1800	1800	1800	1554	1512	2264	2147
1m~	1992	1940	1800	1800	1800	1800	1599	1573	1903	1896
2m~	1976	1901	1800	1800	1800	1794	1571	1559	1871	1856
3m~	2037	1985	1800	1800	1800	1795	1566	1588	1895	1893
4m~	2070	1938	1800	1800	1799	1800	1589	1581	1897	1852
5m~	2026	1994	1800	1800	1790	1788	1576	1580	1811	1841
6m~	2210	2202	1800	1800	1800	1800	1604	1585	1901	1884
8m~	2117	2090	1800	1800	1800	1793	1608	1622	1890	1881
10m~	2045	2072	1800	1800	1800	1794	1584	1581	1859	1862
12m~	2169	2053	1800	1800	1800	1800	1591	1594	1875	1870
15m~	2062	2029	1800	1800	1800	1800	1583	1579	1846	1886
18m~	2097	2029	1800	1800	1800	1800	1582	1572	1881	1869
21m~	2149	2083	1800	1800	1800	1800	1582	1573	1857	1815
2y~	2387	2247	1800	1800	1800	1800	1581	1582	1909	1869

2.5y~	2421	2286	1800	1800	1800	1800	1551	1561	1858	1878
3y~	2209	2190	1800	1800	1800	1800	1585	1601	1903	1908
3.5y~	2301	2238	1800	1800	1800	1800	1588	1600	1933	1924
4y~	2241	2202	1800	1799	1800	1800	1588	1602	1943	1866
4.5y~	2298	2244	1800	1800	1800	1800	1593	1599	1944	1895
5y~	2182	2237	1799	1780	1800	1800	1592	1595	1912	1892
5.5y~	2223	2151	1800	1800	1799	1800	1605	1597	1893	1908
6~7y	2580	2540	1800	1799	1800	1800	1629	1623	1922	1924
Total	47844	46652	39599	39578	39588	39564	34901	34859	41967	41616

Changes in mean weight, height and weight for height

A significant increasing trend in weight and height was observed during the lasted forty years in the nine cities. The average crude increments of boys were 1.41kg in weight and 3.5cm in height/length, and those of girls were 1.24kg in weight and 3.3cm in height/length. Table 2 illustrates that the crude increments became larger with age.

Table 2 Means of weight and height and the crude increments from 1975-2015

Age group	Boys						Girls					
	Weight (kg)			Height (cm)			Weight (kg)			Height (cm)		
	$\bar{x}\pm SD$		I^a	$x\pm SD$		I^a	$x\pm SD$		I^a	$x\pm SD$		I^a
	1975	2015		1975	2015		1975	2015		1975	2015	
Birth	3.27±0.36	3.38±0.40	0.11*	50.6±1.9	50.4±1.6	-0.2*	3.17±0.36	3.26±0.40	0.09*	50.0±1.8	49.8±1.6	-0.2*
1m~	4.97±0.67	4.95±0.60	-0.02	56.5±2.4	56.3±2.1	-0.2*	4.64±0.54	4.62±0.56	-0.02	55.5±2.4	55.2±2.0	-0.3*
2m~	5.95±0.76	6.18±0.70	0.23*	59.6±2.6	60.2±2.2	0.6*	5.49±0.69	5.68±0.64	0.19*	58.4±2.5	58.9±2.1	0.5*
3m~	6.73±0.79	7.11±0.79	0.38*	62.3±2.5	63.4±2.1	1.1*	6.23±0.75	6.51±0.74	0.28*	60.9±2.4	61.9±2.2	1.0*
4m~	7.32±0.85	7.78±0.89	0.46*	64.4±2.5	65.8±2.2	1.4*	6.69±0.79	7.11±0.77	0.42*	62.9±2.4	64.1±2.1	1.2*
5m~	7.70±0.88	8.26±0.94	0.56*	65.9±2.6	67.7±2.3	1.8*	7.19±0.84	7.60±0.85	0.41*	64.5±2.5	66.1±2.3	1.7*
6m~	8.22±0.96	8.68±0.94	0.46*	68.1±2.7	69.5±2.3	1.4*	7.62±0.89	8.03±0.90	0.41*	66.7±2.8	67.9±2.3	1.2*
8m~	8.71±0.99	9.35±1.03	0.64*	70.6±2.7	72.5±2.4	1.9*	8.14±0.95	8.70±1.02	0.56*	69.0±2.8	70.9±2.6	1.9*
10m~	9.14±1.03	9.88±1.11	0.74*	72.9±2.8	75.1±2.6	2.2*	8.57±0.97	9.24±1.05	0.67*	71.4±2.7	73.7±2.7	2.3*
12m~	9.66±1.08	10.26±1.10	0.60*	75.6±3.1	77.6±2.7	2.0*	9.04±1.02	9.65±1.06	0.61*	74.1±3.0	76.2±2.7	2.1*
15m~	10.15±1.11	11.07±1.19	0.92*	78.3±3.2	81.4±3.0	3.1*	9.54±1.10	10.46±1.16	0.92*	76.9±3.2	80.1±3.0	3.2*
18m~	10.67±1.19	11.50±1.26	0.83*	80.7±3.3	84.0±3.0	3.3*	10.08±1.13	10.89±1.19	0.81*	79.4±3.4	82.8±3.0	3.4*
21m~	11.18±1.23	12.38±1.35	1.20*	83.0±3.6	87.3±3.1	4.3*	10.56±1.15	11.73±1.25	1.17*	81.7±3.5	86.1±3.1	4.4*
2.0y~	11.95±1.27	12.98±1.48	1.03*	86.5±3.8	90.6±3.6	4.1*	11.37±1.21	12.36±1.41	0.99*	85.3±3.5	89.3±3.6	4.0*
2.5y~	12.84±1.35	14.28±1.71	1.44*	90.4±3.8	95.6±3.8	5.2*	12.28±1.33	13.57±1.68	1.29*	89.3±3.9	94.2±3.8	4.9*
3.0y~	13.63±1.42	15.46±2.02	1.83*	93.8±4.0	99.4±4.0	5.6*	13.16±1.37	14.85±1.81	1.69*	92.8±3.9	98.3±3.8	5.5*
3.5y~	14.45±1.52	16.62±2.18	2.17*	97.2±4.3	103.2±4.1	6.0*	14.00±1.51	15.95±1.96	1.95*	96.3±4.1	102.0±4.0	5.7*
4.0y~	15.26±1.56	17.76±2.46	2.50*	100.8±4.5	106.7±4.2	5.9*	14.89±1.54	16.90±2.21	2.01*	100.1±4.3	105.4±4.1	5.3*
4.5y~	16.07±1.69	19.02±2.77	2.95*	103.9±4.5	110.1±4.5	6.2*	15.63±1.60	18.14±2.53	2.51*	103.1±4.4	108.9±4.4	5.8*
5.0y~	16.88±1.84	20.35±3.10	3.47*	107.2±4.6	114.1±4.6	6.9*	16.46±1.69	19.47±2.85	3.01*	106.5±4.4	112.8±4.5	6.3*
5.5y~	17.65±1.86	21.71±3.52	4.06*	110.1±4.6	117.1±4.7	7.0*	17.18±1.77	20.74±3.17	3.56*	109.2±4.5	116.0±4.6	6.8*
6~7y	19.25±2.10	23.69±4.03	4.44*	114.7±4.9	121.8±4.9	7.1*	18.67±2.03	22.34±3.60	3.67*	113.9±4.9	120.2±5.0	6.3*

Note: a I is equal to weight or height of the NSPGDC V (2015) minus those of the NSPGDC I (1975). *: $p<0.05$.

Figure 1 displays the relative increments of weight and height from 1975 to 2015: weight relatively increased by 3-8% in children under 1 year and 8-23% in children older than 1 year, which were significantly larger than those of height (1-3% in children under 1 year, and 3-6% in children older than 1years). When stratified by gender, we found that the relative increments of height at age 0-7years and of weight at age 0-4years were similar in boys and girls, but the relative increments of weight at 4-7years were larger in boys.

Table 3 shows that weight for height had increased from 1985 to 2015 and the increments became larger after 100cm, especially in boys.

Table3 Means weight for height and its increments from 1985-2015

Height (cm)	Weight							
	Boys				Girls			
	1985	2015	Crude Increments (kg)	Relative Increments %	1985	2015	Crude Increments (kg)	Relative Increments %
	$\bar{x}\pm$SD (kg)	$\bar{x}\pm$SD (kg)	1985-2015	1985-2015	$\bar{x}\pm$SD (kg)	$\bar{x}\pm$SD (kg)	1985-2015	1985-2015
50	3.17±0.26	3.34±0.30	0.17*	5.4	3.16±0.27	3.32±0.28	0.16*	5.2
55	4.63±0.52	4.79±0.53	0.16*	3.4	4.53±0.47	4.69±0.47	0.16*	3.6
60	6.02±0.59	6.25±0.60	0.23*	3.8	5.89±0.55	6.12±0.58	0.23*	3.9
65	7.40±0.62	7.61±0.65	0.21*	2.8	7.21±0.61	7.38±0.63	0.17*	2.3
70	8.66±0.75	8.78±0.77	0.12*	1.4	8.34±0.72	8.52±0.78	0.18*	2.1
75	9.58±0.78	9.86±0.83	0.28*	2.9	9.21±0.70	9.53±0.76	0.32*	3.5
80	10.50±0.78	10.82±0.93	0.32*	3.0	10.19±0.81	10.46±0.85	0.27*	2.6
85	11.63±0.95	11.87±0.95	0.24*	2.1	11.27±0.84	11.52±0.91	0.25*	2.2
90	12.70±0.94	12.99±1.09	0.29*	2.3	12.44±0.93	12.65±1.04	0.21*	1.7
95	13.84±1.08	14.02±1.11	0.18*	1.3	13.56±0.91	13.89±1.13	0.33*	2.5
100	15.05±1.13	15.57±1.25	0.52*	3.5	14.81±1.14	15.44±1.30	0.63*	4.2
105	16.28±1.13	17.17±1.56	0.89*	5.5	16.17±1.23	16.79±1.44	0.62*	3.8
110	17.79±1.43	18.97±1.95	1.18*	6.6	17.36±1.30	18.39±1.67	1.03*	5.9
115	19.35±1.46	20.60±2.28	1.25*	6.4	18.94±1.53	20.36±2.13	1.42*	7.5
120	20.50±1.47	23.03±2.81	2.53*	12.4	20.60±1.48	22.53±2.67	1.93*	9.4

Changes in the distribution of weight, height and weight for height

Figure 2 illustrates that the 3rd, 50th and 97th centiles of weight or height had significantly increased during 40 years, and the unbalanced increments of the three centiles occurred. For weight, the crude increments of the three centiles in children under 2 years were similar, while in children older than 2years, the crude increments of 97th centile were significantly larger than those of the 3rd and 50th centile. For example, the crude increments of the 3rd, 50th, 97th in 5.5y- boys are 2.26kg, 3.56kg and 8.44kg. Furthermore, we found that the relative increments of the 3rd centile in children under 2 years were slightly larger than those of the 50th and 97th centile. For example, the 3rd, 50th and 97th centile in 6m- boys relatively increased by 6.4%, 5.5% and 3.7%. But a larger relative increment of the 97th centile was observed in children older than 2 years. For example, the 3rd, 50th and 97th centile in 5.5y- boys relatively increased by 15.8%, 20.3% and 39.0%. For height, the crude and relative increments of the 3rd centile were slightly larger than those of the 50th and 97th centile. For example, the 3rd, 50th and 97th centile increased 2.3cm, 1.3cm, 0.7cm in 6m- boys (relatively increase by 3.6%, 1.9%, 1.0%) and 5.5, 5.1, 4.6cm in 2.5y- boys (relatively increase by 6.6%,5.6%,4.7%).

Figure 3 shows that the 3rd, 50th and 97th centile of weight for height increased from 1985 to 2015, and the increments of the three centiles were similar for height shorter than 100cm, while the increments of the 97th centile were significantly larger than those of the 3rd and 50th centile for height taller than 100cm. For example, the crude increments of the 3rd, 50th and

97th were 0.37kg, 0.37kg, 0.43kg at 60cm (relatively increased by 7.7%, 6.3%, 6.1%) and 1.13kg, 1.38kg, 3.29kg at 110cm (relatively increased by 7.5%, 8.0%, 16.2%) in boys.

Forty years changes in annual increments of weight and height from birth to 6 years

Table 4 displays that the annual increments of weight and height from birth to 6 years increased during 1975-2015. The annual increments increased more significantly between birth and 2years for height and between age 4 and 6 years for weight.

Table 4 Annual increments of weight and height/length during birth to 6years, 1975-2015

	1-year increments of weight (kg)												1-year increments of height/length (cm)											
	Boys						Girls						**Boys**						Girls					
	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]	1975	1985	1995	2005	2015	D[a]
0~1y	6.08	6.40	6.56	6.82	6.65	0.57	5.59	5.86	6.06	6.25	6.14	0.55	23.4	24.7	25.2	26.2	25.7	2.3	22.5	23.8	24.5	25.3	24.9	2.4
1~2y	2.09	2.08	2.22	2.51	2.55	0.46	2.07	2.16	2.25	2.56	2.54	0.47	10.2	10.7	11.1	12.0	12.3	2.1	10.4	10.8	11.4	12.3	12.5	2.1
2~3y	1.80	1.85	1.91	2.14	2.29	0.49	1.89	1.86	1.98	2.22	2.27	0.38	7.9	7.8	8.3	8.6	9.1	1.2	8.1	8.0	8.2	8.6	9.1	1.0
3~4y	1.62	1.64	1.81	2.06	2.32	0.70	1.73	1.74	1.88	2.07	2.22	0.49	6.9	6.9	6.9	7.1	7.5	0.6	7.1	7.0	7.1	7.2	7.5	0.4
4~5y	1.62	1.76	1.99	2.38	2.50	0.88	1.60	1.72	1.94	2.14	2.38	0.78	6.6	6.6	6.9	7.1	7.1	0.5	6.6	6.8	7.0	7.1	7.1	0.5
5~6y	1.71	1.86	2.12	2.39	2.69	0.98	1.63	1.72	2.01	2.23	2.47	0.84	6.1	6.2	6.3	6.3	6.6	0.5	6.0	6.2	6.3	6.4	6.6	0.6

Note: a D is equal to annual increments of weight or height/length in the NSPGDC V (2015) minus those of the NSPGDC I (1975).

Per-decade changes in the mean weight, height and weight for height

The weight, height and weight for height were standardized using the WHO growth standard to summarize the trends of each decade during the forty years. Figure 4 illustrates that WAZ and HAZ rapidly increased during the first 3 decades, while their increasing trends were not significant during the fourth decade and their increments in 1975-1985, 1985-1995, 1995-2005 and 2005-2015 were respectively 0.17, 0.29, 0.31, 0.00 in WAZ and 0.27, 0.35, 0.35, 0.00 in HAZ. We found that WFHZ had increased during 1985-2005, but slightly decreased during 2005-2015. The increments of WFHZ were 0.28 in 1985-1995, 0.15 in 1995-2005 and -0.03 in 2005-2015. The per-decade crude increments of mean weight and height from 1975 to 2015 are shown in table 5 and that of mean weight for height from 1985 to 2015 are shown in table 6.

Table 5 Comparison of pre-decade increments in mean weight and height (1975-1985, 1985-1995, 1995-2005 and 2005-2015)

Age group	Weight (kg)								Height (cm)							
	Boys				Girls				Boys				Girls			
	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]	I1[a]	I2[b]	I3[c]	I4[d]
Birth	-0.06*	0.09*	0.03*	0.05*	-0.05*	0.08*	0.04*	0.02	-0.4*	0.2*	0.0	0.0	-0.4*	0.2*	-0.1	0.1
1m~	-0.07*	0.20*	0.01	-0.16*	-0.04*	0.21*	-0.08*	-0.11*	0.0	0.4*	-0.1	-0.5*	0.1	0.5*	-0.5*	-0.4*
2m~	0.07*	0.14*	0.11*	-0.09*	0.05*	0.20*	0.01	-0.07*	0.5*	0.3*	0.1	-0.3*	0.4*	0.4*	-0.1	-0.2*
3m~	0.01	0.24*	0.19*	-0.06*	-0.01	0.20*	0.14*	-0.05	0.1	0.6*	0.3*	0.1	0.2*	0.5*	0.4*	-0.1
4m~	0.04	0.20*	0.20*	0.02	0.09*	0.23*	0.15*	-0.05	0.1	0.6*	0.6*	0.1	0.2*	0.7*	0.4*	-0.1
5m~	0.09*	0.23*	0.30*	-0.06	0.05	0.29*	0.12*	-0.05	0.4*	0.7*	0.8*	-0.1	0.3*	0.7*	0.7*	0.0
6m~	0.17*	0.23*	0.13*	-0.07*	0.16*	0.22*	0.13*	-0.10*	0.5*	0.6*	0.6*	-0.3*	0.3*	0.6*	0.5*	-0.2*
8m~	0.29*	0.19*	0.16*	0.00	0.22*	0.29*	0.09*	-0.04	0.7*	0.7*	0.6*	-0.1	0.7*	0.9*	0.5*	-0.2*
10m~	0.30*	0.21*	0.27*	-0.04	0.23*	0.29*	0.19*	-0.04	0.9*	0.8*	0.9*	-0.4*	0.9*	1.0*	0.5*	-0.1

12m~	0.21*	0.29*	0.33*	-0.23*	0.20*	0.28*	0.28*	-0.15*	0.9*	0.8*	1.0*	-0.7*	1.0*	0.8*	0.9*	-0.6*
15m~	0.23*	0.32*	0.34*	0.03	0.24*	0.31*	0.34*	0.03	0.9*	1.1*	1.1*	0.0	1.0*	1.0*	1.3*	-0.1
18m~	0.21*	0.37*	0.40*	-0.15*	0.25*	0.32*	0.36*	-0.12*	0.9*	1.1*	1.3*	0.0	1.0*	1.2*	1.3*	-0.1
21m~	0.24*	0.41*	0.56*	-0.01	0.31*	0.38*	0.52*	-0.04	1.4*	1.2*	1.7*	0.0	1.4*	1.4*	1.5*	0.1
2.0y~	0.29*	0.33*	0.62*	-0.21*	0.29*	0.38*	0.56*	-0.24*	1.4*	1.2*	2.1*	-0.6*	1.3*	1.5*	1.8*	-0.6*
2.5y~	0.29*	0.43*	0.72*	0.00	0.27*	0.42*	0.76*	-0.16*	1.3*	1.6*	2.1*	0.2	1.0*	1.7*	2.3*	-0.1
3.0y~	0.32*	0.47*	0.89*	0.15*	0.28*	0.57*	0.79*	0.05	1.3*	1.7*	2.1*	0.5*	1.4*	1.7*	1.7*	0.7*
3.5y~	0.30*	0.62*	0.96*	0.29*	0.26*	0.68*	0.90*	0.11	1.3*	1.7*	2.2*	0.8*	1.0*	1.9*	2.1*	0.7*
4.0y~	0.35*	0.62*	1.14*	0.39*	0.32*	0.60*	1.03*	0.06	1.3*	1.6*	2.3*	0.7*	1.1*	1.6*	2.1*	0.5*
4.5y~	0.42*	0.75*	1.31*	0.47*	0.49*	0.68*	1.21*	0.13	1.4*	1.8*	2.4*	0.6*	1.4*	1.7*	2.5*	0.2
5.0y~	0.51*	0.95*	1.56*	0.45*	0.33*	1.05*	1.09*	0.54*	1.4*	1.9*	2.6*	1.0*	1.1*	2.2*	1.9*	1.1*
5.5y~	0.65*	1.08*	1.78*	0.55*	0.54*	1.08*	1.47*	0.47*	1.5*	2.1*	2.7*	0.7*	1.6*	2.1*	2.5*	0.6*
6~7y	0.56*	1.16*	1.54*	1.18*	0.41*	1.28*	1.19*	0.79*	1.5*	1.7*	2.1*	1.8*	1.2*	2.0*	1.8*	1.3*

Note: a I1 is equal to means of weight or height in 1985 minus those in 1975, b I2 is equal to means of weight or height in 1995 minus those in 1985, c I3 is equal to means of weight or height in 2005 minus those in 1995, d I4 is equal to means of weight or height in 2015 minus those in 2005. *: $p<0.05$.

Table 6 Comparison of pre-decade increments in mean weight for height (1985-1995, 1995-2005 and 2005-2015)

Height(cm)	Weight (kg)					
	Boys			Girls		
	I1[a]	I2[b]	I3[c]	I1[a]	I2[b]	I3[c]
50	0.12*	0.07*	-0.02	0.12*	0.06*	-0.02
55	0.15*	0.00	0.01	0.15*	0.06	-0.05
60	0.18*	0.02	0.03	0.19*	0.03	0.01
65	0.16*	0.09*	-0.04	0.17*	0.06	-0.06
70	0.13*	0.05	-0.05	0.17*	0.05	-0.05
75	0.22*	0.08	-0.02	0.22*	0.13*	-0.02
80	0.22*	0.14*	-0.05	0.19*	0.13*	-0.05
85	0.17*	0.10	-0.03	0.17*	0.09	-0.01
90	0.16*	0.14*	0.00	0.15*	0.15*	-0.09
95	0.18*	0.11	-0.12	0.27*	0.24*	-0.17*
100	0.37*	0.24*	-0.08	0.37*	0.29*	-0.04
105	0.41*	0.58*	-0.11	0.34*	0.35*	-0.07
110	0.44*	0.62*	0.12	0.65*	0.56*	-0.18
115	0.63*	0.65*	-0.04	0.69*	0.66*	0.06
120	1.55*	0.60*	0.38	1.16*	0.51*	0.26

Note: a I1 is equal to means of weight for height in 1995 minus those in 1985, b I2 is equal to means of weight for height in 2005 minus those in 1995, c I3 is equal to means of weight for height in 2015 minus those in 2005. *: $p<0.05$.

DISCUSSION

Our study display a rapidly increasing trend in physical growth of children under 7 years in nine cities during 1975-2015. The trend may be associated with the rapid socio-economic development in China: First, the Gross Domestic Product (GDP) of nine provinces, whose capital were the nine cities we selected, has increased from ¥562 in 1975 to ¥62971 in 2014, and their household disposable income increased from ¥351 in 1975 to ¥32301 in 2014. Second, the national statistical data illustrates that the medical and health care services improved, such that the number of doctors per 10,000 people increased from 10 persons in 1975 to 22 persons in 2015, the infant mortality rate changed from 62.6‰ in 1975 to 8.1‰ in 2015 and the mortality rate of children under 5 years decreased from 85.2‰ in 1975 to 10.7‰ in 2015, the newborn mortality rate decreased from 33.1‰ in 1991 to 5.4‰ in 2015. Third, the national nutrition survey, which started in 1982 and the latest survey was in 2012, indicates that the nutritional intake of Chinese population had significantly improved, for example, the daily intake of milk, egg, fish and shrimps, and meat were respectively 9.9g, 15.5g, 21.6g and 62.0g in 1982, which increased to 37.8g, 29.5g, 32.4g and 98.5g in 2012. It is suggested that the comprehensive improvement of social economy, medical and health care, as well as food supply provided a favorable environment for children growth [2 6 20 21].

The extent of secular growth changes is influenced by many factors. In this paper, we found that height and weight of children under 7 years average increased 3.3-3.5cm and 1.2-1.4kg during the last 40 years, and the crude increments also increased with age, which reached to 6-7cm at 6y- group (1.5-1.8cm/decade). The increments of height were slightly larger than those of some western countries: the increments of height were 1-2cm in Dutch children aged 1-4 years during 50 years (1955-2009) [7], 1-3cm in South Asian children in the Netherlands children aged 2-6 years during about 40 years (1976-2010) [22], 2.7-3.3cm in Czech children aged 2.5years during 50 years (1951-2001) [23], 0.9-1.1cm in Turkish children aged 5years during 30 years (1975-2008) [24], and1.1-1.5cm in Canadian children aged 6years per decade during 1891-1974 [25]. In Japan, data from 1950-2000 illustrate that the height increments of 6years children were 1.6cm/decade [6], which were similar to our results. Furthermore, the height increments of 6 years boys and girls in South Korea during 1965-2005 (10.3cm, 11.7cm) were higher than our results (7.1cm, 6.3cm). Therefore, we found the height increments in Chinese, Japanese and South Korean children were higher than those of western countries, which could be related with the social and economic backwardness or even retrogression during World War II and then the rapid social development after World War II. The rapid increase in height may indicate the integrated results of catching up and a positive secular trend in physical growth [26].

Inequality proportion increments of weight and height could predict the changes of body proportion. Our results show that the relative increments of weight were significantly larger than those of height, which illustrates that the body proportion of Chinese children were from slender to thickset over the last 40 years. The positive changes of weight for height from 1985 to 2015 also established the facts, that is, weight of children in 2015 were 0.16-2.53kg greater than those in 1985 for a given height. The changes in the distribution of weight and weight for height had shown an upward shift. In younger children (under 2 years), the increments of the 3rd, 50th, 97th centiles were similar, even slightly higher in the 3rd centile, which suggests the nutritional status of all infants and young children had improved, especially in the improvement of low-growth-level infants and young children in population. However, in older children (older than 2years or taller than 100cm), the relative increments in the 97th centile of weight and weight for height were significantly larger than those in the 3rd and 50th centile, which indicated the upward shift of weight and weight for height was more prominent in the upper ends of the distribution. The results predict that overweight or obesity might become a potential health problem as children's nutrition improving among older children. This is consistent with the fact that obesity in Chinese children has become more common since 1980s: the prevalence of obesity was from 0.91% in 1986 to 3.44% in 2006 for preschool children [27] and from 1.0% in 1985 to 17.8% in 2010 for school-age boys of large cities [28]. Global data illustrate that childhood obesity has increased dramatically and has become a very important health problem for children and adults [12 29]. Therefore, timely monitoring trends in the distribution of weight and weight for height at the population level would be more helpful for projection of obesity epidemic as early as possible and provide more data for design effective public health strategies. Moreover, these results also suggest that if we do not consider the pronounced upward-shift in the upper centiles when updating weight or weight for height reference, the upper ends of the reference will significantly rise, which will be more unfavorable to the prevention of obesity and other related health problems.

The height has shifted upward in all centiles in our results. The increasing in low centile would be an important manifestation of the improvement of children's nutrition. The changes in high centiles of height indicate that the linear growth has not reached the maximum genetic potential and will gradually be fully exploited with the environment improving. Compared the relative increments among all centiles, we found the increments in low centiles were larger than other centiles, especially in children under 3 years. This indicates the improvement of linear growth was more significantly in vulnerable children when the environment improved.

Physical growth velocity of children under 7 years was roughly approximated by calculating annual increments of corresponding age using this series of cross sectional surveys' data. It demonstrates that the annual increments of height and weight during the first year of life were similar to the WHO longitudinal growth velocity in 2009 (25.8cm, 6.27kg in boys and 24.7cm, 6.14kg in girls)[30], which suggests that the annual increments from large-scale cross-sectional survey could roughly reflect the growth velocity. Therefore, we calculated the annual increments of height and weight in NSPGDC I-V in order to analyze the secular changes of growth velocity. These results indicate that the growth velocity of height during the first two years after birth had increased more significantly than other ages, which may be related to the improvement of feeding pattern of children under 2 years [31]. It is also suggested that the linear growth of infants would be more sensitive to environmental improvement, and environmental intervention in infancy may be more effective to improve their linear growth, which is consistent with the research reports of Cole TJ [32]. From the changes of weight growth velocity, we found that the increments of weight growth velocity in children over 4 years were more obvious, which indicates that 4 years old and later should be considered as the key window period for early obesity intervention.

From the per-decade increment, we found the rapid increasing trend had not being continued and the increments of the fourth decade (2005-2015) in weight, height and weight for height had slowed down or even stagnated when comparing with the previous 3 decades. The secular growth trend of children under 7 years in developed regions of China was consistent with that of other developed countries [4 6 7 33]. The trends of height may be associated to the population genetic potential of height, population height will gradually reach the maximum genetic potential after rapid increasing under the background of social and economic sustainable development in developed regions of China. Meanwhile, the slight deceleration of increasing trend in weight or weight for height may be related to the focus on overweight and obesity of children and spreading of healthy promotion strategies among population in past years, especially the latest 10 years.

There were some limitations in our study. First, the annual increments of physical growth calculated by the five cross-sectional surveys data were used to describe the changes of growth velocity. We compared this data with the growth velocity of WHO and found that they were similar. Therefore, we thought these results might roughly illustrate the trends of growth velocity in different periods and provide some data for comprehensively understanding the secular trends of physical growth in developed regions of China. Second, we could not obtain data of body proportion in 1975, thus we can only analyze the changes of body proportion by weight for height from 1985 to 2015.

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Competing Interests None declared.

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Contributions Yaqin Zhang contributed to data analysis, preparation and writing the initial draft of the manuscript. Hui Li designed the study, directed the data analysis and modified the manuscript. Huahong Wu inputted and cleared up the data. Xinnan Zong contributed to data analysis. All authors read, critically reviewed and approved the final manuscript as submitted.

Data sharing statement No additional data are available.

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Figure legends

Figure 1 The relative increments of mean weight and height/length from 1975 to 2015

Figure2 Changes in the 3rd, 50th and 97th centiles of weight and heightlength from 1975-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1975 and 2015)

Figure3 Changes in the 3rd, 50th and 97th centiles of weight for height from 1985-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1985 and 2015)

Figure4 The Z-score of weight, height and weight for height base on WHO growth standard from 1975-2015

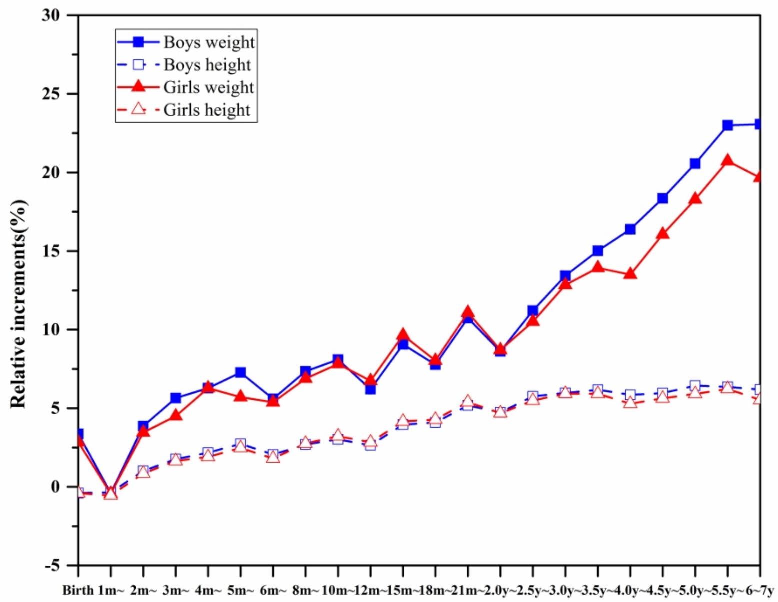

Figure 1 The relative increments of mean weight and height/length from 1975 to 2015

272x208mm (300 x 300 DPI)

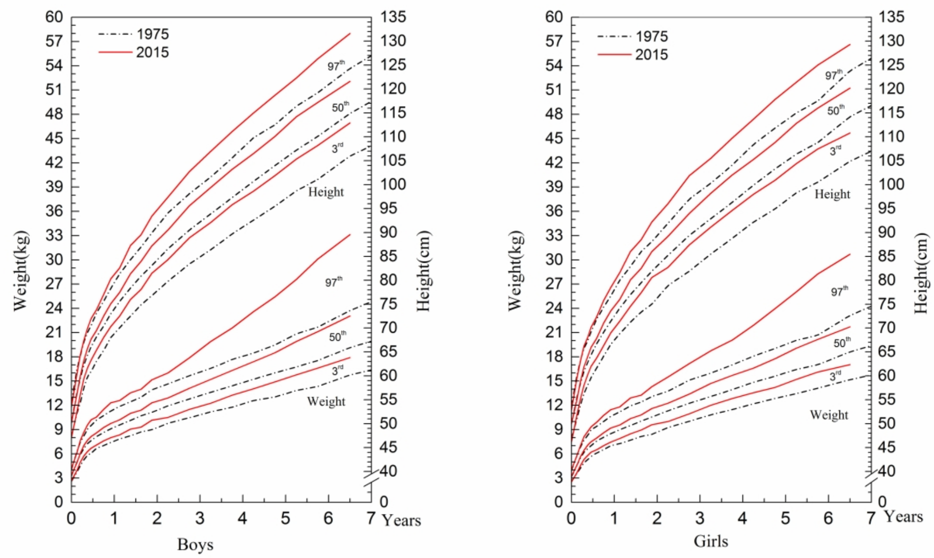

Figure2 Changes in the distributions of weight and height/length from 1975-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1975 and 2005)

288x200mm (300 x 300 DPI)

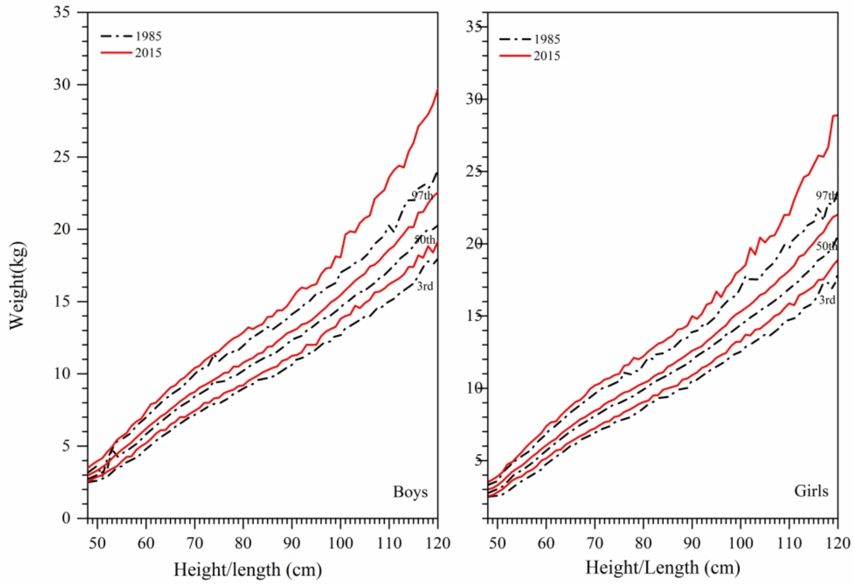

Figure3 Changes in the 3rd, 50th and 97th centiles of weight for height from 1985-2015 (the lines were respectively the percentile of 3rd, 50th and 97th from bottom to up in 1985 and 2015)

288x200mm (300 x 300 DPI)

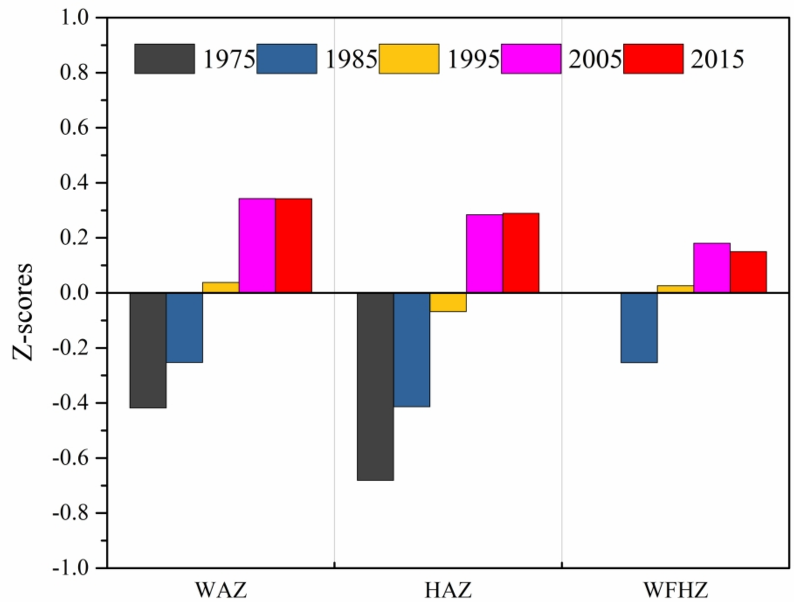

Figure4 The Z-score of weight, height and weight for height base on WHO growth standard from 1975-2015

272x208mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	**Item #**	**Recommendation**	**Reported on page #**
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1-2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			**3**
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			**3-5**
Study design	4	Present key elements of study design early in the paper	3-4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	*4*
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	N/A
Results			5-9

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	N/A
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	5-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-9
Discussion			9-12
Key results	18	Summarise key results with reference to study objectives	9-10
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9-11
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-12
Other information			12
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	12

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.