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National trends in stunting, thinness and overweight among Chinese school-aged children, 1985–2014

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Abstract

Objective We sought to examine changes in regional and sex disparities in stunting, thinness, and overweight among Chinese school-aged children from 1985 to 2014.

Methods We analyzed data on 1,489,953 children aged 7–18 years in the Chinese National Survey on Students' Constitution and Health. Stunting, thinness, and overweight were defined according to WHO anthropomorphic definitions. After adjustment for age, socioeconomic status, and school, logistic regression was used to estimate the prevalence of stunting, thinness, and overweight by region and sex over 30 years' time.

Results From 1985 to 2014, the prevalence of stunting progressively decreased from 16.4% in 1985 to 2.3% in 2014, thinness prevalence also declined overtime, from 8.4 to 4.0% and overweight prevalence continually increased from 1.1% in 1985 to 20.4% in 2014 in Chinese school-aged children. Stunting and thinness were more common in rural areas, although urban/rural differences declined over time. Overweight was a greater problem in urban than rural areas, and this difference increased over time. Some provinces showed high levels of stunting, thinness, and overweight. The stunting prevalence of boys was higher than girls from 1985 and 1995, but lower than girls for the past 15 years. Thinness was consistently more common in boys than girls across regions and time. Overweight continuously increased for boys and girls; however, the increase was more rapid in boys.

Conclusions Over the past 30 years, Chinese children have shifted in anthropomorphic measures indicating a shift from problems of under-nutrition to measures consistent with over-nutrition, particularly in urban areas and among boys. Some regions are burdened by problems of both under- and over-nutrition. Regional and sex-specific guidelines and public health policies for childhood nutrition are needed in China.

Introduction

While childhood overweight and obesity have become a great concern across the globe [1], childhood underweight remains a primary driver of early death and disability in low-income countries, especially in much of sub-Saharan Africa [2]. With the rapid growth of the national economies during the past several decades, many low- to middle-income countries (LMICs) are facing the double burden of under-nutrition combined with over nutrition [3–6]. Studies from South Asia and Latin America and the Caribbean show that the transition from underweight to overweight and obesity can be rapid, and might overwhelm the national capacity needed to engender a healthy transition [7–9]. China, coincident with its earlier economic development, has shown a similar transition, even in the poor rural locations [10].

Both under- and over-nutritional status during childhood are associated with adverse health consequences later in the

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life course [11]. A primary anthropometric measure to assess chronic undernutrition is stunting, defined as height-for-age *Z*-score (HAZ) < −2SD by using the World Health Organization (WHO) reference population [12, 13]. Stunting is a known risk factor for impaired child development and an increased chance of being overweight in adulthood [11, 14]. Despite a general decrease in the global prevalence, stunting still affects one third of children under 5 years in the developing world [11]. In China, this old problem still remains, especially in rural areas [15]. Thinness can also be a marker of malnutrition although thin children are not necessarily undernourished. Stunting and thinness in school-aged children is under studied, contrasting with the vast amount of literature on infant malnutrition and a current focus on childhood overweight [16–18]. Moreover, most previous studies in China of coexistence of under- and over-nutrition and nutrition transition are outdated, of relatively short study periods, and not nationally representative [10, 15, 19].

As the largest country in the world, changes observed in China may echo or forecast population changes in other Asian countries and LMICs [20]. Given its sheer size and regional variations across China, from urban to rural locations and from rich to poor locations, study of changes in anthropomorphic measures could provide worthwhile insights for other LMICs. This study analyzed data from a serial Chinese National Survey on Students' Constitution and Health (CNSSCH) [21–26]. The CNSSCH is, thus far, the largest nationally representative sample of school-age children in China, providing an opportunity to study trends in youth nutritional transitions. Study objectives were to: (1) describe the secular trends in the prevalence of stunting, thinness, and overweight during the past three decades; (2) identify the subpopulations by region most susceptible to stunting, thinness, and overweight across the country; and (3) identify whether the sex disparity in the prevalence of stunting, thinness, and overweight became larger or smaller, i.e., whether the pace of increase was different between boys and girls.

Methods

Participants

Data were obtained from the 1985, 1995, 2000, 2005, 2010, and 2014 cycles of the CNSSCH, a large national successive cross-sectional survey designed to investigate the health status of Chinese school-age children, which is a joint project of the Ministries of Education, Health, Science and Technology, the State Ethnic Affairs Commission, and the State Sports General Administration of the People's Republic of China [21–26]. The sampling procedure, as previously described in detail [5, 17, 18], was the same in all CNSSCH administrations at each time point. In brief, these surveys used the same multistage sampling method to select students from each of the mainland provinces. Each province was classified into two area groups (urban and rural location) according to residential regions and then further classified into sex- and age-specific subgroups. In each subgroup, an equal number of participants was selected from primary and secondary schools.

This study only included participants of the Han ethnicity, who account for 92% of the total Chinese population, from 26 mainland provinces and four municipalities of mainland China, excluding Tibet (where the Han ethnicity is a minority).

The sample sizes in CNSSCH of different years ranged from 12,191 to 25,678 in each sex- and age-specific subgroup and the ratio of boy/girl or urban/rural approximately equaled 1:1 in each survey. A total of 1,489,953 participants were included in analyses; all had complete data on age, sex, location, weight, and height (Table 1). The sample size in each subgroup was larger in 1985 than in the subsequent years, because the Chinese government consulted relevant experts after the 1985 survey and consequently revised the sample size, which is sufficient for statistical analyses. To ensure national representation, the surveys after 1985 proposed to select the same schools as in 1985, but fewer students in each school; thus, more than 85% of the schools sampled were identical in each survey.

All participants were selected by stratified cluster sampling, in that sampling took place in classes randomly selected from each grade in the selected school, so that the sample size in sex- and age-specific subgroups varied slightly in each survey after 1985. All eligible participants had lived in the same area for at least 1 year and completed a screening medical examination by physician before survey measurement. Exclusion criteria were: (1) serious organ disease (e.g., heart, lung, liver, kidney); (2) abnormal physical development (e.g., pygmyism, gigantism); (3) physical impairment or deformity (e.g., severe scoliosis, pectus carinatum, limp, genu valgum, and genu varum); and (4) acute disease, high fever or diarrhea during the past month, and not yet recovered. Each province had an equal size of sample from three socioeconomic classes ("upper," "moderate," and "low") at the regional level. Five aspects were taken into consideration in defining the socioeconomic status (SES) of the regional level: regional gross domestic product, total yearly income per capita, average food consumption per capita, natural growth rate of population, and the regional social welfare index [18, 27].

The project was approved by the Medical Research Ethics Committee of Peking University Health Science Center (IRB00001052-18002). With data collected from schools across China, the school principals determined the

Table 1 Sample sizes by region (urban/rural) and age for boys and girls participating in the CNSSCH from 1985 to 2014

	Boys						Girls					
	1985	1995	2000	2005	2010	2014	1985	1995	2000	2005	2010	2014
Urban location												
7–9	25664	12344	13507	14734	13435	13415	25678	12364	13513	14604	13438	13451
10–12	25665	13170	13591	14868	13463	13446	25655	13201	13631	14558	13463	13439
13–15	25669	13196	13612	14743	13463	13454	25673	13170	13516	14712	13462	13469
16–18	25412	13065	13160	14336	13409	13163	25253	13163	13062	14106	13371	13172
7–18	102410	51775	53870	58681	53770	53478	102259	51898	53722	57980	53734	53531
Rural location												
7–9	25656	12191	13551	14399	13449	13403	25653	12198	13445	14249	13479	13392
10–12	25666	13021	13479	14568	13451	13460	25663	12784	13461	14398	13479	13414
13–15	25670	13022	13239	14460	13474	13466	25671	12543	13392	14469	13458	13468
16–18	25638	12985	13065	14482	13431	13160	25550	12337	13057	14322	13459	13118
7–18	102630	51219	53334	57909	53805	53489	102537	49862	53355	57438	53875	53392
Total												
7–9	51320	24535	27058	29133	26884	26818	51331	24562	26958	28853	26917	26843
10–12	51331	26191	27070	29436	26914	26906	51318	25985	27092	28956	26942	26853
13–15	51339	26218	26851	29203	26937	26920	51344	25713	26908	29181	26920	26937
16–18	51050	26050	26225	28818	26840	26323	50803	25500	26119	28428	26830	26290
7–18	205040	102994	107204	116590	107575	106967	204796	101760	107077	115418	107609	106923

process for gaining informed parental consent (i.e., written vs. verbal, active vs. passive); informed consent was obtained from both children and their parents. Participants' information was anonymized and de-identified prior to analysis to protect their privacy.

Measures

Height (cm) and weight (kg) were measured using the same types of instruments according to the standard procedures in all survey sites [21–26]. Participants were required to wear only light clothing and stand straight, barefooted and at ease when being measured. Weight was measured to the nearest 0.1 kg with a standardized scale and height to the nearest 0.1 cm with a portable stadiometer. Both the scales and stadiometers were calibrated before use. The measurements were generally carried out at the same time of the day during the survey. BMI was calculated as body weight (kg) divided by height (m) squared (kg/m^2). BMI-for-age *Z*-score was calculated with the WHO 2007 references [28]. The reference population used here is the fixed population recommended by WHO [28]. Stunting was defined using the growth references of Height-for-age *Z*-score (HAZ): stunting: <−2SD; thinness and overweight were defined by using the growth references of BMI-for-age *Z*-score (BAZ): thinness: <−2SD; overweight (including obesity): >+1 SD [12]. Measurements at the survey site were conducted by a team of field professionals who had passed a training course in anthropometric measurements. The classification of urban and rural in the different survey years did not change since the initial classification as urban or rural in 1985, which means if an area initially classified as rural experienced urbanization, it remained classified as rural. To assess the possible impact of the urbanization, we divided 26 mainland provinces and four municipalities into four groups according to the urbanization rate quartiles (ordered by data from the 2010 Sixth National Census): first quartile including Xinjiang, Sichuan, Guangxi, Henan, Gansu, Yunnan, and Guizhou; second quartile including Ningxia, Shanxi, Shaanxi, Qinghai, Jiangxi, Hebei, Hunan, and Anhui; third quartile including Fujian, Neimenggu, Heilongjiang, Jilin, Chongqing, Hubei, Shandong, and Hainan; and fourth quartile including Shanghai, Beijing, Tianjin, Guangdong, Liaoning, Zhejiang, and Jiangsu [29]. Sex was self-reported.

Statistical analyses

We present prevalence estimates for stunting, thinness and overweight in different survey years according to sex, urban–rural location, age groups, and provinces. To test for trends across years, we regressed survey years as an ordinal variable on the binary outcomes of stunting, thinness, and overweight. The annual average percentage was calculated at three different stages: 10 years of data from 1985 to 1995, 10 years of data from 1995 to 2005, and 9 years of data

from 2005 to 2014. These figures were compared with assess whether the more recent 2005–2014 trends differed from those for the earlier 1985–1995 and 1995–2005 periods. We used Chi-square tests to compare the differences between sexes and survey years between 1985 and 2014, stratified by province. To assess regional and sex differences at each time point, we used logistic regression to estimate the prevalence odds ratio (POR) and 95%CI for stunting, thinness, and overweight in urban vs. rural location and for boys vs. girls, and estimated the PORs by age group with adjustment for age and socioeconomic status in the models. The design effect of cluster sampling by school was also taken into account in the models. All analyses were conducted using Stata12.1. Two-sided P values < 0.05 were considered significant.

Results

Trends in the prevalence of stunting, thinness, and overweight among Chinese children

As shown in Table 2 and Fig. 1, for the population overall, the prevalence of stunting progressively decreased from 16.4% in 1985 to 2.3% in 2014 (P trend test < 0.01). The greatest absolute decline was observed from the 1985 to 1995 period (from 16.4 to 8.1%). Thinness prevalence also declined overtime, from 8.4 to 4.0% (P trend test < 0.01) with the greatest absolute decline from 2005 to 2014 (6.2–4.0%). Overweight prevalence continually increased from 1.1% in 1985 to 20.4% in 2014 (P trend test < 0.01). Temporal trends in the prevalence of stunting, thinness, and overweight among different age groups were similar to the total sample (Table S1).

Trends in the prevalence of childhood stunting, thinness, and overweight by region in China

As shown in Table 3, overtime, regional differences in stunting and thinness declined, while regional differences in overweight became greater. In 2014, the stunting prevalence ranged from 0.30 to 9.0%, thinness prevalence ranged from 2.0 to 8.1%, and overweight prevalence ranged from 10.0 to 33.8% across the different provinces and municipalities. The prevalence of stunting and thinness reduced in all regions from 1985 to 2014, and children in western regions, such as Guizhou and Guangxi showed higher stunting and thinness prevalence compared with children in other regions in 2014. Meanwhile, the overweight prevalence was higher in the coastal provinces and municipalities like Tianjin and Beijing than other regions. Analyzed by province, from 1985 to 2014, significant declines in the prevalence of stunting and thinness and significant increases in overweight were observed ($P < 0.01$ for all 30 provinces). Further, in most of the provinces, sex differences in stunting and thinness were found in 1985 (greater among boys than girls), while sex differences in overweight were found in 2014 (greater among boys than girls).

PORs of urban children vs. rural children for stunting, thinness, and overweight

We estimated the PORs for stunting, thinness, and overweight of urban children compared with rural children at different years (Fig. 2). The PORs for stunting gradually attenuated over time, approaching one, while the PORs for thinness stayed relatively stable at around one. The exception was in 1985, when the prevalence of thinness was higher in urban children than their rural counterparts. In 2000, this pattern reversed, and the prevalence of thinness going forward has been lower in urban than rural children. The PORs for overweight showed a decreasing trend and each value was greater than one.These trends were also observed in different urbanization levels (data not shown).

PORs of boys vs. girls for stunting, thinness and overweight

Figure 3 shows that the PORs for stunting by sex attenuated over time. The stunting prevalence of boys was significantly higher than girls in 1985 and 1995, showed no difference with girls in 2000, and then was lower than girls from 2005 to 2014. The PORs for thinness were stable from 1985 to 2014, with boys having a higher prevalence of thinness than girls at each survey year. The PORs for overweight increased from 1985 to 2010 and then were stable to 2014. The prevalence of overweight in boys was consistently higher than for girls since 1985 and boys contributed more to the population increase in the overweight prevalence than did girls. Notably, the percentage change per decade in the prevalence of overweight during the different time epochs (1985–1995, 1995–2010, and 2010–2014) were greater in boys than in girls (Table 2).

Discussion

The prevalence of stunting and thinness among Chinese children and adolescents has progressively decreased over the past 30 years, while the overweight prevalence increased dramatically. The findings are consistent with prior studies [30, 31] and here extend to 2014 in a nationally representative sample.

The temporal change in childhood under- and over-nutrition over the past 30-years in China can be divided into three stages. First, from 1985 to 1995, under-nutrition

Table 2 Prevalence of stunting, thinness and overweight for boys and girls by survey year in urban and rural locations in China (%)

Category	Stunting			Thinness			Overweight		
	Total	Boys	Girls	Total	Boys	Girls	Total	Boys	Girls
Urban location									
1985	8.6	9.2	8.0	10.2	11.1	9.3	1.5	1.6	1.3
1995	4.2	4.2	4.1	7.2	7.6	6.9	7.6	9.7	5.5
2000	3.6	3.6	3.7	6.3	6.8	5.8	13.1	17.3	8.9
2005	2.8	2.7	3.0	5.4	5.8	4.9	16.6	22.1	11.1
2010	2.2	2.0	2.4	4.7	5.0	4.4	19.0	25.2	12.9
2014	1.4	1.3	1.6	3.8	4.0	3.5	23.4	30.3	16.6
P trend test[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Annual percentage change from 1985 to 1995	−0.44	−0.50	−0.39	−0.30	−0.35	−0.24	0.61	0.81	0.42
Annual percentage change from 1995 to 2005	−0.14	−0.15	−0.11	−0.18	−0.18	−0.20	0.90	1.24	0.56
Annual percentage change from 2005 to 2014	−0.16	−0.16	−0.16	−0.18	−0.20	−0.16	0.76	0.91	0.61
Rural location									
1985	24.2	25.6	22.9	6.7	7.5	5.8	0.8	0.5	1.0
1995	12.1	12.5	11.7	7.4	8.3	6.5	2.7	3.0	2.5
2000	10.0	10.1	9.8	7.9	8.7	7.1	5.3	6.4	4.2
2005	7.6	7.5	7.8	7.0	8.0	6.1	8.2	10.2	6.1
2010	5.3	5.0	5.5	5.6	6.2	5.1	11.8	15.2	8.5
2014	3.2	2.9	3.5	4.2	4.7	3.6	17.4	22.1	12.8
P trend test[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Annual percentage change from 1985 to 1995	−1.21	−1.31	−1.12	0.07	0.08	0.07	0.19	0.25	0.15
Annual percentage change from 1995 to 2005	−0.45	−0.50	−0.39	−0.04	−0.03	−0.04	0.55	0.72	0.36
Annual percentage change from 2005 to 2014	−0.49	−0.51	−0.48	−0.31	−0.37	−0.28	1.02	1.32	0.74
Total									
1985	16.4	17.4	15.4	8.4	9.3	7.6	1.1	1.1	1.1
1995	8.1	8.3	7.8	7.3	8.0	6.7	5.2	6.3	4.0
2000	6.8	6.8	6.7	7.1	7.8	6.5	9.2	11.9	6.5
2005	5.2	5.1	5.3	6.2	6.9	5.5	12.4	16.2	8.6
2010	3.7	3.5	4.0	5.2	5.6	4.7	15.4	20.2	10.7
2014	2.3	2.1	2.5	4.0	4.4	3.6	20.4	26.2	14.7
P trend test[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Annual percentage change from 1985 to 1995	−0.83	−0.91	−0.76	−0.11	−0.13	−0.09	0.41	0.52	0.29
Annual percentage change from 1995 to 2005	−0.29	−0.32	−0.25	−0.11	−0.11	−0.12	0.72	0.99	0.46
Annual percentage change from 2005 to 2014	−0.32	−0.33	−0.31	−0.24	−0.28	-0.21	0.89	1.11	0.68

[a]*P* value represent test of linear trends across year

(characterized by stunting and thinness) was a predominant public health concern, though stunting prevalence was declining rapidly; overweight prevalence was still very low and increased at a relatively slow pace. Second, from 1995 to 2005, declines in under-nutrition slowed, and increases in overweight accelerated. The pattern was changing from domination of under-nutrition to coexistence of under- and over-nutrition [5]. Third, from 2005 to 2014, declines in

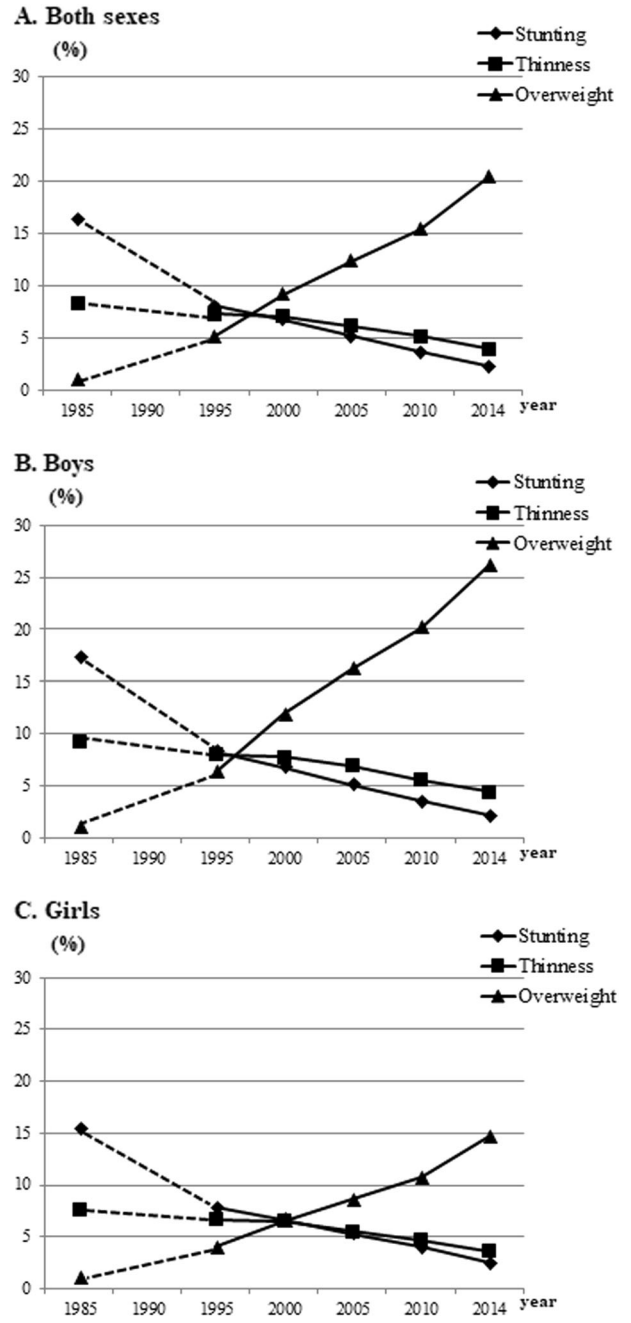

Fig. 1 The prevalence of stunting, thinness, and overweight by sex and survey year

stunting flattened, while the overweight prevalence dramatically increased. During this period, children were less likely to suffer from under-nutrition compared with over-nutrition at the national level.

We found that the change in childhood nutritional status in China's geographic regions was not evenly distributed over time. Recently, many provinces showed an overweight epidemic, particularly in coastal provinces or municipalities such as Beijing, Tianjin, and Shandong. These are also the regions with higher socioeconomic status compared with western regions of China [32]. This finding is consistent with our previous report that the shifts across the spectrum of BMI-for-age *Z*-scores experienced faster increases at the upper percentiles among Chinese children [27] and with Ji's study that north coastal residents, especially those of the upper socioeconomic status, had the earliest and largest increase in the prevalence of childhood overweight and obesity [33]. However, despite overweight prevalence increasing rapidly during the past three decades, under-nutrition remains a major public health issue, especially in rural locations and some provinces, such as Guizhou, Qinghai, and Hainan, where the prevalence of stunting plus thinness is more prevalent than overweight. Of concern, the Chinese provinces of Guangdong, Guangxi, Chongqing, and Sichuan are facing the double burden of under-nutrition and overweight. The coexistence of under- and over-nutrition has been reported in the literature in some sub-populations in LMICs [34]. The coexistence of both under-nutrition and overweight in Chinese children has important public health implications. These areas are facing the challenges of a double burden of malnutrition among children by adding obesity and related chronic disease to the public health agenda, while old nutritional problems of under-nutrition, especially, stunting still remain [15, 35]. Local Chinese governments should have the overall consciousness that the problems the other regions are experiencing may be their near future.

Across China, and at every survey point, the effects of under-nutrition were more prevalent in rural locations, while the effects of over-nutrition were seen more in urban locations. According to China's National Bureau of Statistics, Engel's coefficient (an indicator of the living standard of a country, with higher values indicating a poorer living standard) has been lower in urban than rural locations, though with improvements in both areas over time (53.3% in urban vs. 57.8% in rural in 1985; 36.2% in urban vs. 39.3% in rural in 2012) [36]. The poorer living standard in rural areas may be a partial explanation of urban-rural disparity in childhood under- and over-nutrition.

Examining the PORs over time, thinness was more prevalent in urban than rural children in 1985, and this pattern reversed from 2000 forward. Thinness is an indicator that mainly reflects acute growth faltering and can result from severe food shortage, disease, diarrhea, and acute febrile illnesses [9]. That the shift occurred in such a short time suggests food shortage or food distribution differences between urban and rural areas. In 1985, the Chinese urban areas implemented "Liangpiao," a restricted food ticket that was distributed to families every month according to the household population, to purchase food. Urban children at that time might be more easily influenced by the food shortage. In 1993, the government abolished urban grain rationing systems, the food supply improved quickly, and

Table 3 Prevalence of stunting, thinness and overweight by province for Chinese boys and girls in 1985 and 2014

Urbanization rate quartiles	Province	Stunting				Thinness				Overweight			
		1985		2014		1985		2014		1985		2014	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
First quartile	Xinjiang	11.7	9.0*	1.7	2.9*	11.6	10.8	1.9	2.7*	0.4	0.8*	33.2	16.8*
	Sichuan	29.9	27.3*	5.3	6.2	7.1	5.5*	5.5	3.9*	0.5	1.1*	17.3	9.9*
	Guangxi	31.8	29.0*	4.4	5.0	13.4	10.0*	7.2	5.0*	0.4	0.5	22.6	12.0*
	Henan	11.9	10.9#	0.8	1.3#	6.6	6.6	2.7	1.6*	0.9	0.8	26.5	17.3*
	Gansu	14.7	14.3	1.4	2.4	10.3	7.9*	3.6	3.4	0.6	0.8	22.1	13.0*
	Yunnan	22.9	20.5	3.0	2.8*	10.5	8.4*	7.6	5.8*	1.0	1.2	20.3	11.2*
	Guizhou	38.9	33.2*	8.9	9.0	8.1	6.4*	5.6	3.9*	0.7	1.3*	16.1	9.9*
Second quartile	Ningxia	16.0	13.9*	1.8	1.9	10.4	8.3*	5.5	4.1*	0.5	0.8#	20.9	11.1*
	Shanxi	15.3	14.4	1.4	2.0	8.1	6.6*	3.9	3.4	1.1	1.3	23.8	14.1*
	Shaanxi	16.1	15.0	3.4	4.8*	9.3	8.0*	3.6	2.3*	0.5	0.7	30.4	17.1*
	Qinghai	26.5	23.2*	3.1	3.4	19.6	15.2*	7.5	8.5	0.2	0.5#	14.1	6.0*
	Jiangxi	26.0	23.9*	2.1	3.3*	10.2	7.3*	4.0	2.6*	0.7	0.8	22.8	12.1*
	Hebei	11.4	10.6	0.8	1.0	5.8	5.1	2.7	2.8	1.8	1.7	34.6	18.4*
	Hunan	24.4	22.1#	3.1	3.9	10.6	7.6*	4.2	3.4	0.7	0.9	25.4	12.4*
	Anhui	18.1	14.9*	1.1	1.5	9.9	8.5*	5.4	3.6*	0.7	0.7	25.9	12.6*
Third quartile	Fujiang	21.2	18.4*	0.8	0.7	13.7	11.0*	4.3	3.4	0.6	0.6	21.8	10.6*
	Neimenggu	15.2	12.3*	1.0	1.2	7.3	5.5*	2.8	2.8	0.7	1.5*	29.0	19.0*
	Heilongjiang	14.4	13.1#	1.6	1.8	7.9	6.6*	4.2	3.7	0.8	1.3*	32.2	19.8*
	Jiilin	13.7	12.2*	1.1	1.1	8.3	6.3*	4.9	3.7*	1.0	1.0	26.0	19.2*
	Chongqing[b]	NA	NA	4.1	5.7*	NA	NA	4.9	2.8*	NA	NA	20.7	10.6*
	Hubei	22.0	18.1*	1.4	1.3	7.5	6.6#	3.7	2.8#	0.8	1.0	27.5	13.1*
	Shandong	8.7	7.9	0.4	0.3	5.8	5.2	2.1	2.0	2.6	1.9*	38.4	24.8*
	Hainan[a]	NA	NA	4.2	5.1	NA	NA	9.2	7.0*	NA	NA	14.4	7.8*
Fourth quartile	Shanghai	8.6	7.9	0.4	0.6	10.9	8.8*	3.1	2.4	2.5	1.6*	32.2	17.9*
	Beijing	6.3	6.5	0.2	0.5#	6.5	5.3*	2.6	3.7*	4.3	3.2*	39.8	21.5*
	Tianjin	7.4	7.0	0.2	0.6*	6.3	5.2*	2.3	2.4	2.2	2.1	41.6	26.0*
	Guangdong	19.4	17.9*	2.9	3.5	10.8	9.0*	6.5	5.9	0.4	0.3	18.1	9.8*
	Liaoning	9.2	7.3*	0.6	0.7	5.9	5.5	4.5	3.7	1.5	1.5	33.2	19.8*
	Zhejiang	14.3	10.9*	0.8	1.0	11.4	8.5*	2.7	2.1	0.5	0.7	26.5	12.6*
	Jiangsu	11.4	10.3#	0.4	0.5	7.7	5.8*	2.0	2.0	1.5	1.4	28.6	15.0*

[a]Hainan became a province in 1988; [b]Chongqing became a municipality in 1997.

*,#Sex difference significant at $P < 0.01$ and $P < 0.05$.

diverse foods became available first in urban areas [29]. With the developing food market, thinness prevalence decreased both in urban and rural areas and the gap was minimal between urban and rural children.

Unlike thinness, stunting reflects a more cumulative retardation of growth mainly due to chronic causes, such as poor diet, chronic hunger, and recurrent or chronic infections [9]. Although the stunting prevalence decreased dramatically both in urban and rural areas, the PORs trend for stunting indicated that the lower relative risk of stunting in urban children has been gradually attenuating. Further, we found that the disparities in under- and over-nutrition between urban–rural locations have decreased over the past 30 years. Prior research reporting on nutritional changes in rural and urban areas of China over time provides some insight for these observed changes in weight status. For example, in rural residents, daily pork intake more than doubled from 25.0 g/d in 1992 to 59.9 g/d in 2012, whereas in urban residents the values increased from 61.3 g/d in 1992 to 68.6 g/d in 2012. While this dietary indicator remains higher in urban than rural residents, the size of the difference is decreasing [37].

The overweight PORs of urban vs. rural children in the present study have showed a decreasing trend since 1995, which means that although the absolute burden of overweight remains considerably higher in urban areas, which

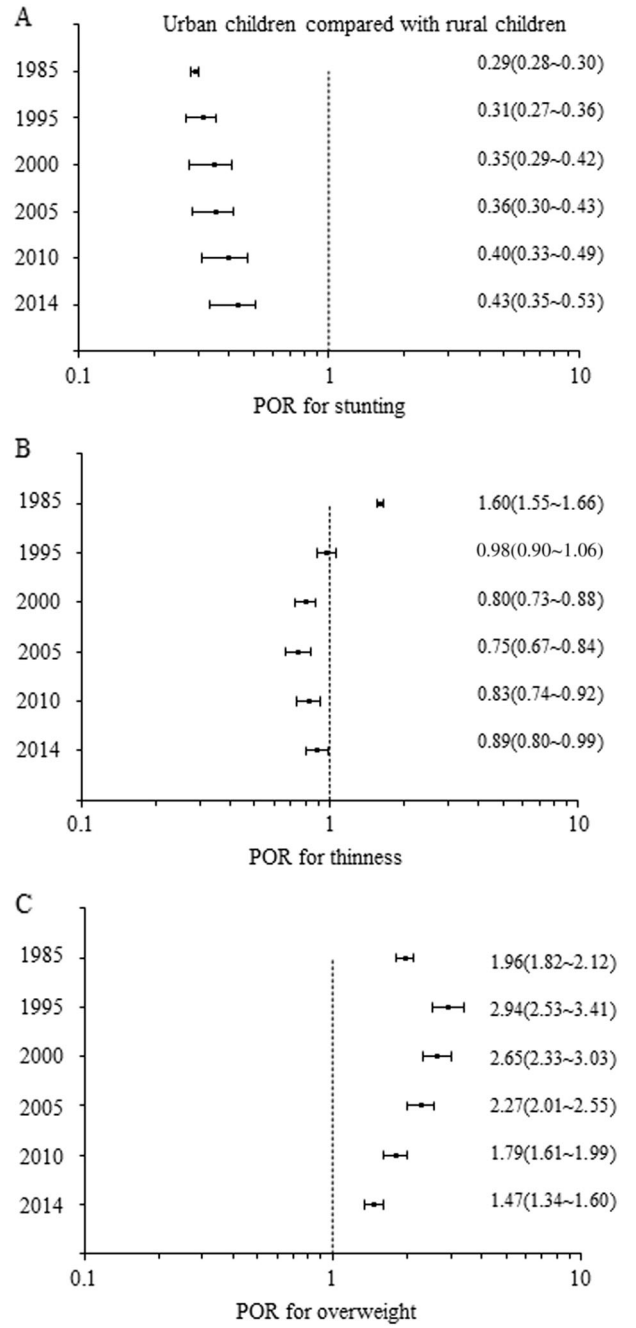

Fig. 2 Prevalence odds ratios (POR) with 95% confidence intervals (CI) for stunting, thinness and overweight of urban children compared with rural children in different years of CNSSCH adjusted for age, sex, socioeconomic status, and school. Note: To the right of the 1 on the *X* axis means greater among urban vs. rural locations

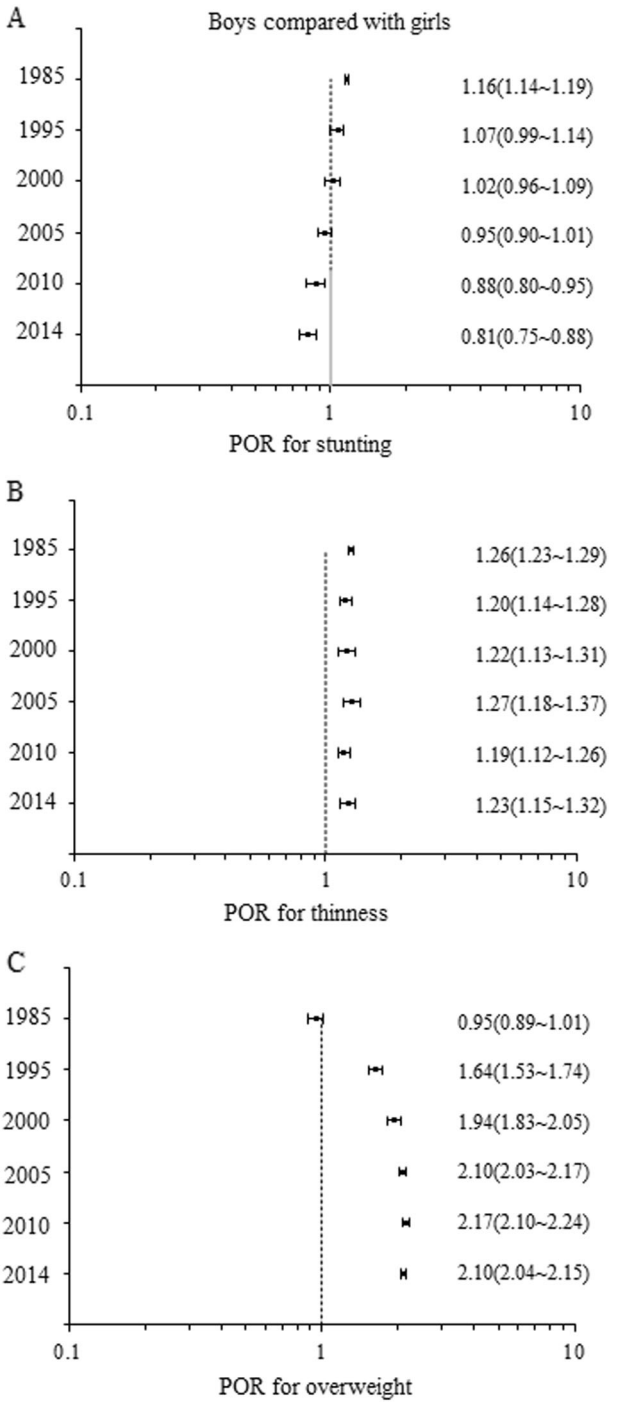

Fig. 3 Prevalence odds ratios (POR) with 95% confidence intervals (CI) for stunting, thinness and overweight of boys compared with girls in different years of CNSSCH adjusted for age, urban-rural location, socioeconomic status, and school. Note: To the right of the 1 on the *X* axis means greater among boys than girls

also have greater population numbers, the pace of the increase in the prevalence of overweight has become more rapid in rural locations over time. These results are consistent with our prior research [18, 29]. In the national level, overweight prevention and control should be the emphasis in urban locations of China [29], however the policymakers should pay attention to this subtle pattern change and not focus only on under-nutrition prevention to the neglect of the overweight epidemic in rural populations. While problems of overweight are still lower in rural than in urban populations, a future increase in chronic non-communicable diseases in China's rural populations would be a concern

given limited access to medical resources. Some nutritional strategies and interventions, such as China's program for improving student nutrition among rural compulsory school students (issued by the State Council in 2011) [38], may also benefit the whole nutritional status of rural children.

While prior studies reported on secular trends in the sex disparity in the prevalence of obesity and overweight among Chinese school-aged children [17, 18, 27], the novel contribution in the present study was the reporting on the sex difference in PORs for stunting and thinness changes, and with an analysis over the past 30 years. In China, girls are more vulnerable than boys to disadvantaged nutrient intakes due to "son preference" norm, especially in rural locations [15], which may be one explanation for the sex disparity observed in overweight status. In addition, parental perceptions of childhood weight and behaviors of diet and physical activities influence sex differences in childhood nutrition [17, 18]. The observed trends in PORs between 1985 and 2014 for stunting and overweight showed notable differences by sex. Over time, more boys, and especially urban boys, were overweight, while more girls, and especially rural girls were at risk for stunting. Sex specific preventive guidelines and public health policies for childhood nutrition should be formulated in the near future. Although some guidelines to control childhood obesity have been issued [39, 40], none of them consider sex differences.

The current study analyzed data from the largest nationally representative survey of Chinese school-aged children to date. The CNSSCH is a cross-sectional survey conducted in different subjects over time, though repeated in the same regions and schools. The observed trends for stunting, thinness, and overweight may not reflect the exact increments along with increasing age. CNSSCH data collection was carried out in schools, and therefore, some 15–18-year-old adolescents who could not attend senior high school, mainly in rural areas, were excluded from our sample [33]. The effects of this attrition, however, may be subtle given that similar patterns were observed across all six survey years.

In conclusion, overweight is more prevalent than stunting and thinness in current China. Although stunting and thinness has continually reduced, the progress has been unevenly distributed. Stunting and thinness are more common in rural areas, while overweight is more common in urban areas, though some regions are experiencing the challenges of both under- and over-nutrition in their populations. Today, girls in China are more likely to suffer from stunting. Boys tend to have a higher risk for thinness and overweight than girls and are contributing to a large and growing proportion of overweight children over time. Regional and sex-specific guidelines and public health policies for childhood nutrition are needed in China.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, et al. Child and adolescent obesity: part of a bigger picture. Lancet. 2015;385:2510–20.
2. GBD 2015 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet. 2016;388:1659–724.
3. Conde WL, Monteiro CA. Nutrition transition and double burden of undernutrition and excess of weight in Brazil. Am J Clin Nutr. 2014;100:1617S–22S.
4. Kroker-Lobos MF, Pedroza-Tobías A, Pedraza LS, Rivera JA. The double burden of undernutrition and excess body weight in Mexico. Am J Clin Nutr. 2014;100:1652S–8S.
5. Ma J, Wang Z, Song Y, Hu P, Zhang B. BMI percentile curves for Chinese children aged 7–18 years, in comparison with the WHO and the US Centers for Disease Control and Prevention references. Public Health Nutr. 2010;13:1990–6.
6. Jafar TH, Qadri Z, Islam M, Hatcher J, Bhutta ZA, Chaturvedi N. Rise in childhood obesity with persistently high rates of undernutrition among urban school-aged Indo-Asian children. Arch Dis Child. 2008;93:373–8.
7. Popkin BM, Adair LS, Ng SW. Now and then: the global nutrition transition: the pandemic of obesity in developing countries. Nutr Rev. 2012;70:3–21.
8. Bishwajit G. Nutrition transition in South Asia: the emergence of non-communicable chronic diseases. F1000Res. 2015;4:8.
9. Sunguya BF, Ong KI, Dhakal S, et al. Strong nutrition governance is a key to addressing nutrition transition in low and middle-income countries: review of countries' nutrition policies. Nutrition. 2014;13:65.
10. Piernas C, Wang D, Du S, Zhang B, Wang Z, Su C, Popkin BM. The double burden of under- and overnutrition and nutrient adequacy among Chinese preschool and school-aged children in 2009–2011. Eur J Clin Nutr. 2015;69:1323–9.
11. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382:427–51.

12. World Health Organization. Growth reference 5–19 years [WWW document]. 2007. http://www.who.int/growthref/who2007_bmi_for_age/en/.
13. Rosenbloom JI, Kaluski DN, Berry EM. A global nutritional index. Food Nutr Bull. 2008;29:266–77.
14. Perignon M, Fiorentino M, Kuong K, et al. Stunting, poor iron status and parasite infection are significant risk factors for lower cognitive performance in cambodian school-aged children. PLOS ONE. 2014;9:e112605.
15. Zhang N, Bécares L, Chandola T. Patterns and determinants of double-burden of malnutrition among rural children: evidence from China. PLOS ONE. 2016;8:e0158119.
16. Bovet P, Kizirian N, Madeleine G, Blössner M, Chiolero A. Prevalence of thinness in children and adolescents in the Seychelles: comparison of two international growth references. Nutr J. 2011;10:65.
17. Song Y, Wang H-J, Ma J, Wang Z. Secular trends of obesity prevalence in urban Chinese children from 1985 to 2010: Gender disparity. PLOS ONE. 2013;8:e53069.
18. Song Y, Wang HJ, Dong B, Ma J, Wang Z, Agardh A. 25-year trends in gender disparity for obesity and overweight by using WHO and IOTF definitions among Chinese school-aged children: a multiple-cross-sectional study. BMJ Open. 2016;6:e011904.
19. Dearth-Wesley T, Wang H, Popkin BM. Under- and overnutrition dynamics in Chinese children and adults (1991–2004). Eur J Clin Nutr. 2008;62:1302–7.
20. Popkin BM. Synthesis and implications: China's nutrition transition in the context of changes across other low and middle income countries. Obes Rev. 2014;15:10.
21. CNSSCH Association. Report on the 1985th National Survey on Students' Constitution and Health. Beijing: People's Education Publishing; 1987. (in Chinese).
22. CNSSCH Association. Report on the 1995th National Survey on Students' situation and Health. Changchun: Jilin Technical and Science Publication; 1997. (in Chinese).
23. CNSSCH Association. Report on the 2000th National Survey on Students' Constitution and Health. Beijing: China College & University Press; 2002. (in Chinese).
24. CNSSCH Association. Report on the 2005th National Survey on Students' Constitution and Health. Beijing: China College & University Press; 2007. (in Chinese).
25. CNSSCH Association. Report on the 2010th National Survey on Students' Constitution and Health. Beijing: China College & University Press; 2012. (in Chinese).
26. CNSSCH Association. Report on the 2014th National Survey on Students' Constitution and Health. Beijing: China College & University Press; 2016. (in Chinese).
27. Song Y, Wang HJ, Ma J, Patrick WC, Hu P, Zhang B, Wang Z. BMI-for-age *Z*-score distribution shifts among Chinese children: Gender disparity. Obesity. 2014;22:1187–93.
28. World Health Organization. WHO reference 2007 SPSS macro package [WWW document]. 2007. http://www.who.int/entity/growthref/tools/readme_spss.pdf.
29. Song Y, Ma J, Wang HJ, Wang Z, Hu P, Zhang B, Agardh A. Secular trends of obesity prevalence in Chinese children from 1985 to 2010: Urban-rural disparity. Obesity. 2015;23:448–53.
30. Zong XN, Li H. Physical growth of children and adolescents in China over the past 35 years. Bull World Health Organ. 2014;92:555–64.
31. Liang YJ, Xi B, Song AQ, Liu JX, Mi J. Trends in general and abdominal obesity among Chinese children and adolescents 1993-2009. Pediatr Obes. 2012;7:355–64.
32. Subramanyam MA, Kawachi I, Berkman LF, Subramanian SV. Socioeconomic inequalities in childhood undernutrition in India: analyzing trends between 1992 and 2005. PLoS One. 2010;5:e11392.
33. Ji CY, Cheng TO. Epidemic increase in overweight and obesity in Chinese children from 1985 to 2005. Int J Cardiol. 2009;132:1–10.
34. Jaacks LM, Slining MM, Popkin BM. Recent trends in the prevalence of under- and overweight among adolescent girls in low- and middle-income countries. Pediatr Obes. 2015;10:428–35.
35. Popkin BM, Richards MK, Montiero CA. Stunting is associated with overweight in children of four nations that are undergoing the nutrition transition. J Nutr. 1996;126:3009–16.
36. National Bureau of Statistics of China. Per capita annual income and engel's coefficient of urban and rural households [WWW document]. http://data.stats.gov.cn/english/easyquery.htm?cn=C01.
37. He Y, Yang X, Xia J, Zhao L, Yang Y. Consumption of meat and dairy products in China: a review. Proc Nutr Soc. 2016;75:385–91.
38. The central People's Government of the People's Republic of China. The inform of interim measures on management of special funds targeted on rural compulsory schools to improve student nutrition program issued by Ministry of Finance and Ministry of Education [WWW document]. 2012. http://www.gov.cn/gongbao/content/2012/content_2256575.htm.
39. Department of Disease Control and Prevention, Ministry of Health; National Institute for Nutrtion and Health, Chinese Center for Disease Control and Prevention; Chinese Nutrition Society. Guidelines on snacks for Chinese children and adolescents. *Acta Nutrimenta Sinica* 2008; **30**:123–4 [in Chinese].
40. Wang H, Zhai F. Programme and policy options for preventing obesity in China. Obes Rev. 2013;14(Suppl 2):134–40.