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Trends of obesity and underweight in older children and adolescents in the United States, Brazil, China, and Russia[1–3]

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ABSTRACT

Background: Few studies have used the same references across countries to examine the trends of over- and underweight in older children and adolescents.

Objective: Using international references, we examined the trends of overweight and underweight in young persons aged 6–18 y from 4 countries.

Design: Nationally representative data from Brazil (1975 and 1997), Russia (1992 and 1998), and the United States (1971–1974 and 1988–1994) and nationwide survey data from China (1991 and 1997) were used. To define overweight, we used the sex- and age-specific body mass index cutoffs recommended by the International Obesity Task Force. The sex- and age-specific body mass index fifth percentile from the first US National Health and Nutrition Examination Survey was used to define underweight.

Results: The prevalence of overweight increased during the study periods in Brazil (from 4.1 to 13.9), China (from 6.4 to 7.7), and the United States (from 15.4 to 25.6); underweight decreased in Brazil (from 14.8 to 8.6), China (from 14.5 to 13.1), and the United States (from 5.1 to 3.3). In Russia, overweight decreased (from 15.6 to 9.0) and underweight increased (from 6.9 to 8.1). The annual rates of increase in the prevalence of overweight were 0.5% (Brazil), 0.2% (China), −1.1% (Russia), and 0.6% (United States).

Conclusions: The burden of nutritional problems is shifting from energy imbalance deficiency to excess among older children and adolescents in Brazil and China. The variations across countries may relate to changes and differences in key environmental factors. *Am J Clin Nutr* 2002;75:971–7.

KEY WORDS Obesity, underweight, children, adolescents, United States, Brazil, China, Russia

INTRODUCTION

Over the past century, most nutrition research and policy concerning the developing world focused on poverty and undernutrition. Now there is growing evidence of a major shift toward overweight and obesity in these societies. Many studies have documented the increases in overweight among adults (1, 2), and most recently 2 comprehensive studies examined obesity in preschool children from developing countries (3, 4), but few efforts have been made to address this issue among older children and adolescents worldwide. Several reports discussed the rapid increase in childhood obesity in higher-income countries (1, 5–7). In contrast, no large-scale representative samples have been studied in transitional nations, but a series of smaller, nonrepresentative studies showed a rapid increase in obesity among children and adolescents (1, 8). An added complexity was the lack of consistent references for measuring childhood and adolescent obesity before acceptance of the use of body mass index [BMI; weight (kg)/height (m)^2] and then the development of an international reference (9–14). Understanding the trends in childhood obesity is important because obesity in childhood has many adverse effects on health in both childhood and adulthood (1, 10, 15). Of equal importance is tracking childhood obesity into adulthood (16).

We attempted to fill a gap by exploring the trends in the shift from underweight to overweight among older children (aged 6–9 y) and adolescents (aged 10–18 y) by using a proposed new international reference (11) and nationally representative survey data from Brazil, Russia, and the United States and nationwide survey data from China collected over the past 2–3 decades. These 4 countries from different continents include developing and industrialized countries. Their total populations account for approximately one-third of the global population (17). These countries experienced different socioeconomic development processes and social environmental changes during the past 2 decades (18) that provided us a great opportunity to understand the range of shifts in childhood nutritional status being experienced by large segments of the world.

SUBJECTS AND METHODS

Data and study populations

Brazil

The data came from 2 random nationally representative samples undertaken by the Brazilian agency in charge of national

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statistics in 1974–1975 and 1996–1997. Similar sampling procedures and data collection processes were used in both surveys (19). The 1974 survey covered the whole country; the 1997 survey was restricted to the northeastern and southeastern regions, where more than two-thirds of the Brazilian population is concentrated. To allow for proper comparisons, we included only children and adolescents in these 2 regions. Trained teams used calibrated portable scales to measure weight while the subjects were wearing lightweight clothing and no shoes. Height was measured with metal tapes in barefooted subjects with their heads held in the Frankfort plane.

China

We used data from the longitudinal China Health and Nutrition Surveys conducted in 1991 and 1997. These surveys covered 8 provinces that vary substantially in geography, economic development, and health indicators and provide a broad-based indication of the trends China is facing. Although these surveys were not nationally representative, their previous findings regarding the patterns and trends in diet and body composition were almost identical with those from national surveys and the China National Bureau of Statistics (20–22). Anthropometric measurements were carried out by well-trained health workers who followed a reference protocol (23). Weight was measured to the nearest 0.10 kg with a balance-beam scale while the subjects were wearing lightweight clothing. Height was measured to the nearest 0.10 cm with a portable stadiometer in barefooted subjects.

Russia

The Russian Longitudinal Monitoring Survey was the first nationally representative household survey in the Russian Federation. All members of >6400 households from all regions of Russia were surveyed 8 times in 1992–1998. The 1992 (round 1) and 1998 (round 8) data were used for the present study. Details of this survey were described previously (24). Weight and height measurements followed a protocol similar to that of the US National Health and Nutrition Examination Surveys (NHANES).

United States

NHANES I (1971–1974) and NHANES III (1988–1994) were cross-sectional representative samples of the US civilian noninstitutionalized population. Both surveys used standardized protocols for all interviews and examinations. Data on weight and height were collected for each individual in a fully equipped mobile examination center through direct physical examinations. Detailed descriptions of the surveys were published previously (25).

Measures

The main variables we studied were the subjects' weight, height, age, sex, residence, and socioeconomic status (SES). Body composition was estimated by using BMI. Among the key reasons for excluding preschoolers from the present study were the exclusion of children ≤2 y of age from the International Obesity Task Force (IOTF) reference (11) and the difficulty of accurately measuring preschooler overweight status, because it appears that adiposity rebound may occur in different ways in each population. In addition, 2 recently published comprehensive studies focused on preschool children (3, 4), and we were trying to provide insights into school-age children.

Definition of overweight

Until the past decade no widely accepted BMI-based reference existed for childhood and adolescent underweight or overweight or obesity. An interim reference (sex- and age-specific 85th percentiles) was initially developed from the US NHANES I data to define adolescent overweight with what we termed the WHO-NCHS (World Health Organization–National Center for Health Statistics) reference (12, 13). A WHO expert committee recommended these BMI 85th percentiles for international use to classify adolescent overweight, but they recommended use of a weight-for-height z score (ie, a z score of 2, which corresponds to the 97.7th percentile) for children aged <10 y (13). Recently, the Childhood Obesity Working Group of the IOTF proposed a new international reference, age- and sex-specific BMI cutoffs, to define childhood and adolescent obesity (11, 14). Previous research by one of the authors (YW) showed that, in general, the WHO-NCHS 85th BMI percentiles and the IOTF reference produced similar estimates of the overall prevalence of overweight, although there were considerable differences between the 2 references for some age groups (26, 27).

We chose to use the IOTF reference because it has several advantages for international use. First, it was developed based on data from many nations, including Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. Second, unlike the WHO reference, BMI is used for both children and adolescents. In addition, the BMI cutoffs are linked to adult cutoffs for overweight and obesity, which are good indicators of risks for adverse health outcomes (1, 13). They are achieved from sex-specific curves that pass through a BMI of 25 and 30 by age 18 y for overweight and obesity, respectively. However, concerns were recently raised about using the IOTF reference internationally, especially in developing countries (26, 28). There is a great variation in the prevalence of overweight in the countries that made up the IOTF reference population. Development of BMI cutoffs by averaging across such a heterogeneous mix of surveys may need to be further justified. In addition, further research is needed to study the health consequences for children with values greater than these cutoffs and to test whether ethnic differences should be considered. Nevertheless, we felt that despite its limitations, the IOTF reference is better than other existing references or approaches for making cross-national comparisons. We chose to examine the combined prevalence of overweight and obesity because the prevalence of obesity was very low in China and Russia and in the Brazil 1974 survey.

Definition of underweight

We used the BMI fifth percentiles developed by Must et al (12) on the basis of the US NHANES I data for all subjects aged 6–18 y. These BMI cutoffs have been widely used to define childhood and adolescent underweight, and they were also recommended for international use for adolescents aged 10–19 y by a WHO expert committee (13).

Age, residence, and socioeconomic status

Subjects were separated into 2 age groups: children (6–9 y) and adolescents (10–18 y). Urban or rural residence was determined according to standards that each country developed and that were the only measures available. As a result, the definition and meanings of urban and rural residence may vary across countries. Tertiles of per capita family income were used to indicate low, medium, and high SES.

TABLE 1
Prevalence of overweight and underweight in 4 countries by age, sex, and urban or rural residence[1]

	Brazil		China		Russia		United States	
	1974 (n = 56295)	1997 (n = 4875)	1991 (n = 3014)	1997 (n = 2688)	1992 (n = 6883)	1998 (n = 2152)	1971–1974 (n = 4472)	1988–1994 (n = 6108)
	%							
Overweight[2]								
All	4.1 ± 0.10[3]	13.9 ± 0.66[3]	6.4 ± 0.44[3]	7.7 ± 0.51[3]	15.6 ± 0.45[3]	9.0 ± 0.65[3]	15.4 ± 0.75[3]	25.6 ± 1.22[3]
Children (6–9 y)	4.9 ± 0.18[3]	17.4 ± 1.35[3]	10.5 ± 1.00	11.3 ± 1.11	26.4 ± 1.05[3]	10.2 ± 1.31[3]	11.8 ± 1.16[3]	22.0 ± 1.46[3]
Adolescents (10–18 y)	3.7 ± 0.11[3]	12.6 ± 0.76[3]	4.5 ± 0.46[3]	6.2 ± 0.56[3]	11.5 ± 0.46[3]	8.5 ± 0.74[3]	16.8 ± 0.86[3]	27.3 ± 1.47[3]
Males	2.9 ± 0.12[3]	13.1 ± 0.91[3]	6.3 ± 0.61[3]	8.4 ± 0.73[3]	15.5 ± 0.64[3]	9.6 ± 0.95[3]	14.5 ± 1.00[3]	25.0 ± 1.35[3]
Females	5.3 ± 0.15[3]	14.8 ± 0.97[3]	6.5 ± 0.64[3]	7.0 ± 0.72[3]	15.8 ± 0.63[3]	8.3 ± 0.89[3]	16.3 ± 1.10[3]	26.3 ± 1.55[3]
Rural	3.1 ± 0.12[3]	8.4 ± 0.68[3]	5.9 ± 0.49[3]	6.4 ± 0.54[3]	17.7 ± 0.87[3]	11.2 ± 1.30[3]	16.6 ± 1.59[3]	26.6 ± 1.73[3]
Urban	4.9 ± 0.14[3]	18.4 ± 1.06[3]	7.7 ± 0.99[3]	12.4 ± 1.36[3]	14.7 ± 0.52[3]	8.1 ± 0.75[3]	14.7 ± 0.91[3]	24.6 ± 1.50[3]
Underweight[4]								
All	14.8 ± 0.17[3]	8.6 ± 0.52[3]	14.5 ± 0.64	13.1 ± 0.65	6.9 ± 0.31	8.1 ± 0.63	5.1 ± 0.40[3]	3.3 ± 0.36[3]
Children (6–9 y)	12.3 ± 0.27[3]	6.1 ± 0.79[3]	12.5 ± 1.08[3]	9.4 ± 1.03[3]	7.1 ± 0.62	8.0 ± 1.19	4.1 ± 0.54	3.4 ± 0.67
Adolescents (10–18 y)	16.1 ± 0.26[3]	9.6 ± 0.65[3]	15.4 ± 0.79	14.7 ± 0.82	6.8 ± 0.37	8.2 ± 0.74	5.5 ± 0.51[3]	3.3 ± 0.42[3]
Males	18.3 ± 0.26[3]	10.6 ± 0.82[3]	16.9 ± 0.95	14.4 ± 0.93	9.0 ± 0.51	7.7 ± 0.86	5.2 ± 0.53[3]	3.6 ± 0.50[3]
Females	11.4 ± 0.21[3]	6.5 ± 0.63[3]	12.0 ± 0.85	11.5 ± 0.90	4.9 ± 0.38[3]	8.6 ± 0.93[3]	5.0 ± 0.53	3.0 ± 0.48
Rural	15.4 ± 0.25[3]	9.6 ± 0.73[3]	15.2 ± 0.75	13.9 ± 0.77	5.4 ± 0.53	7.6 ± 1.10	4.3 ± 0.64	3.6 ± 0.55
Urban	14.4 ± 0.22[3]	7.7 ± 0.72[3]	12.4 ± 1.22	10.0 ± 1.24	7.5 ± 0.39	8.4 ± 0.76	5.5 ± 0.50[3]	3.0 ± 0.57[3]

[1] $\bar{x}$ ± SEM.

[2] Defined as the combined prevalence of overweight and obesity. It was calculated by using the International Obesity Task Force standards, which were age- and sex-specific BMI cutoffs that corresponded to a BMI of 25 at age 25 y. They were developed with the use of data from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States.

[3] Significant difference between the 2 surveys within the country, $P < 0.05$ (chi-square test).

[4] Defined on the basis of the age- and sex-specific BMI fifth percentiles developed by Must et al (12) with the use of data from the first National Health and Nutrition Examination Survey.

Statistical analysis

First, we examined the prevalence of over- and underweight in each country in each year by age group, sex, urban or rural residence, and SES. Then we calculated the average annual percentage increase in prevalence in each country during the periods covered by the surveys. Sample weights were used to produce population-representative estimates for Brazil, Russia, and the United States but not for China, where sample weights were not available. Chi-square tests were conducted to test the differences in prevalence between surveys within each country. SEMs for annual rates of change in prevalence were calculated with the following equation:

$$\mathrm{SEM} = \{\text{variance}\ [(p1 - p2)/n]\}^{1/2} = 1/n \times [\text{variance}\ (p1) + \text{variance}\ (p2) - 2 \times \text{covariance}\ (p1, p2)]^{1/2} \quad (1)$$

where $p1$ and $p2$ are the prevalence of overweight (or underweight) in surveys 1 and 2, respectively, and n is the number of years between the 2 surveys in each country. For practical reasons (eg, sample weights) and to be consistent, we assumed that the covariance between $p1$ and $p2$ was 0. This assumption was well justified for the data from Brazil, Russia, and the United States, because the data were from independent cross-sectional surveys. In the data from China, there was only a small overlap in the samples we studied between the 2 surveys. To test for the statistical significance of the differences in annual rates of change, we calculated 95% CIs. Data management and data analysis were performed by using SAS (version 6.12; SAS Institute, Cary, NC) and STATA (version 6.0; Stata Co, College Station, TX). The "svy" commands in STATA were used to account for sampling designs. A P value < 0.05 was consider significant.

RESULTS

Changes in the prevalence of overweight

The prevalence of overweight increased in 3 of the 4 countries between the survey periods (**Table 1**), tripling in Brazil, almost doubling in the United States, and increasing by one-fifth in China. In contrast, the prevalence of overweight in Russia decreased from 15.6% to 9.0% during a period of tremendous economic stress and a large reduction in the energy density of the typical diet (18, 24, 29, 30). All the changes were significant except for the increase among Chinese children, although the increase among Chinese adolescents was significant.

The prevalence of overweight was considerably higher in children than in adolescents in China, Brazil, and Russia but was lower in children than in adolescents in the United States. In addition, the prevalence of overweight was much higher in urban areas than in rural areas in Brazil and China but slightly lower in urban than in rural areas in Russia and the United States. Over the past 2 decades, the prevalence of overweight in Brazil increased most quickly in high-SES groups, but in the United States the increase was greatest in low-SES groups (**Figure 1**).

Changes in the prevalence of underweight

During the survey periods, the prevalence of underweight decreased in Brazil, China, and the United States but increased in Russia. However, the differences in the prevalence of underweight between the 2 surveys in China and Russia were not statistically significant, which may be the result of the shorter survey intervals. China had the highest and the United States the lowest prevalence of underweight. Except for the United States, the prevalence of underweight was lower in children than in ado-

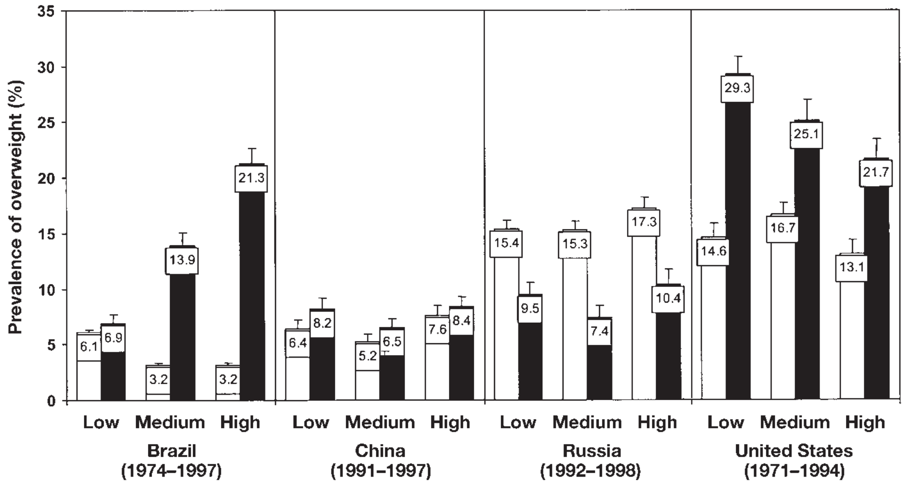

FIGURE 1. Relation between per capita household income and the prevalence of overweight. Income tertiles were used for each country to indicate low, medium, and high levels. For the first (□) and second (■) surveys, respectively, n = 56295 and 4875 for Brazil, 3014 and 2688 for China, 6883 and 2152 for Russia, and 4472 and 6108 for the United States. References for the prevalence of overweight are from Cole et al (11).

lescents. The prevalence of underweight was greater in rural than urban areas in Brazil and China, but these urban-rural differences were much smaller than those for overweight. The prevalence of underweight was lower in higher-SES groups in all countries except for the United States in the most recent surveys.

Shift from an under- to an overnutrition problem in Brazil and China

As shown in Table 1, we observed a clear shift from an under- to an overnutrition problem in Brazil over the past 2 decades and a moderate shift in China over a 6-y period in the 1990s. The shifts were more dramatic in urban areas than in rural areas in both countries.

Average annual changes in the prevalence of over- and underweight

To further examine the magnitude of change considering the length of the interval between surveys, we calculated the annual change in the percentage of overweight and underweight subjects in each country (**Table 2**). Although the rates of change varied during different periods in each country, annual rates provide an easier way to make comparisons across countries. The annual increase in the prevalence of overweight was the highest in the United States, followed by Brazil and China. In contrast, the prevalence of overweight in Russia decreased >1%/y during 1992–1998 and much more quickly in children than in adolescents.

The annual rates of change tended to differ by residence, sex, and age group, although most of these differences were not significant. Both Brazil and China recorded a larger increase in the prevalence of overweight in urban areas than in rural areas, but the difference was only significant for Brazil. In Brazil, the annual percentage increase in the prevalence of overweight in urban areas was more than double that for rural areas. The annual increase was minuscule in rural areas in China compared with urban areas. No significant difference between urban and rural areas was found in the United States or Russia. A sex difference was found in China, although it was not significant (because on the basis of our data the estimated SEMs for the annual increase rates were large). The rate of increase in boys was 4 times higher that in girls.

The annual reduction in the prevalence of underweight was greatest in Brazil, followed by that in China and the United States. In Brazil, males enjoyed a greater reduction than did females. In the Chinese sample, children aged 6–9 y, boys, and urban residents experienced greater reductions than their older, female, and rural counterparts, although the differences were not significant. Russia had an annual increase in the prevalence of underweight, but there was a remarkable sex difference: although the prevalence of underweight increased among females, it decreased among males.

DISCUSSION

This study presents unique comparative information on trends in childhood and adolescent underweight and overweight status from 4 countries representing approximately one-third of the global population (17). An important aspect of our study is that we used the IOTF reference, an international reference developed from data from multiple nations worldwide (11), to define childhood and adolescent overweight. Overall, we found a notable shift away from undernutrition toward overnutrition in all countries except Russia and a remarkably similar average annual increase in the prevalence of overweight in Brazil and the United States. The patterns of change in over- and underweight vary across countries and differ by age group, sex, rural or urban residence, and SES within countries. The dramatic shifts in the urban areas of Brazil and China may have been the result of greater improvements in the diets of these populations and to a greater reduction in physical activities during the survey periods. Differences in body image and access to energy-dense diets across different SES groups between developing countries and industrialized countries may help to explain the different shift patterns across SES groups that we observed between Brazil and the United States.

The finding that only the United States has a far greater proportion of adolescent than childhood overweight is striking. It is possible that this relates partly to our use of the IOTF reference (26, 27), but these differences may be far too great to be explained by this reference. Differences in sexual maturation

TABLE 2
Annual change in the prevalence of over- and underweight by age, sex, and urban or rural residence[1]

	Brazil		China		Russia		United States	
	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight	Overweight	Underweight
				%				
All	0.46 ± 0.03	−0.29 ± 0.02	0.22 ± 0.11	−0.23 ± 0.15	−1.10 ± 0.13	0.20 ± 0.12	0.57 ± 0.08	−0.10 ± 0.03
Children (6–9 y)	0.58 ± 0.06	−0.28 ± 0.04	0.13 ± 0.17	−0.52 ± 0.25	−2.70 ± 0.28[2]	0.15 ± 0.22	0.57 ± 0.10	−0.04 ± 0.04
Adolescents (10–18 y)	0.42 ± 0.03	−0.30 ± 0.03	0.28 ± 0.12	−0.12 ± 0.19	−0.50 ± 0.15[2]	0.23 ± 0.14	0.58 ± 0.09	−0.12 ± 0.04
Males	0.47 ± 0.04	−0.35 ± 0.04[2]	0.35 ± 0.16	−0.42 ± 0.22	−0.98 ± 0.19	−0.22 ± 0.17[2]	0.58 ± 0.09	−0.09 ± 0.04
Females	0.45 ± 0.04	−0.22 ± 0.03[2]	0.08 ± 0.16	−0.08 ± 0.21	−1.25 ± 0.18	0.62 ± 0.17[2]	0.56 ± 0.11	−0.11 ± 0.04
Rural	0.24 ± 0.03[2]	−0.26 ± 0.04	0.08 ± 0.12	−0.22 ± 0.18	−1.08 ± 0.26	0.37 ± 0.20	0.56 ± 0.13	−0.04 ± 0.05
Urban	0.63 ± 0.05[2]	−0.33 ± 0.03	0.78 ± 0.28	−0.40 ± 0.29	−1.10 ± 0.15	0.15 ± 0.14	0.55 ± 0.10	−0.14 ± 0.04

[1] ± SEM. Surveys in Brazil were conducted in 1974 (n = 56 295) and 1997 (n = 4875), in China, in 1991 (n = 3014) and 1997 (n = 2688), in Russia, in 1992 (n = 6883) and 1998 (n = 2152), in the United States, in 1971–1974 (n = 4472) and 1988–1994 (n = 6108). Overweight was defined as the combined prevalence of overweight and obesity was calculated by using the Interanational Obesity Task Force standard, which designates age- and sex-specific BMI cutoffs that correspond to a BMI of 25 at age 25 y. They were developed with the use of data from Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States. Underweight was defined on the basis of the age- and sex-specific BMI fifth percentiles developed by Must et al (12) with the use of data from the first National Health and Nutrition Examination Survey. Annual change rates were calculated based on the difference in the prevalence of overweight (or underweight) between surveys within each country.

[2] Significant difference within the country, $P < 0.05$ (chi-square test).

patterns between the reference and study populations are one issue worthy of further consideration (13, 26, 31).

Note that although urban-rural and sex differences in China were not significant, as epidemiologists we believe that these patterns and their underlying causes should be examined in future studies. These differences may be related to unbalanced economic development between rural and urban areas, China's one-child policy, and the society's tradition of son preference, particularly in rural areas. In general, urban residents have better living standards and less physical activity than do their rural counterparts (20–22). Under the one-child policy, rural parents whose first child is a daughter are allowed to have a second child. Boys are likely to enjoy more of the family's resources and to be better raised than girls. In addition, the sex difference in overweight trends may relate to the emerging body image (preference of thinness) among Chinese adolescent females.

In general, our findings are consistent with those of several smaller studies of children and adolescents and with related adult studies in these countries that showed an increase in overweight in Brazil, China, and the United States, although they used different references to define overweight. The trends we observed in older children and adolescents in Brazil agree with studies involving adults (16, 32), although other researchers recently found that the prevalence of overweight among preschoolers decreased when overweight was defined on the basis of weight-for-height z scores (3, 4). In China, the 1982 and 1992 China National Nutrition Survey data showed an increase in the prevalence of overweight and a remarkable decrease in undernutrition in children (20). In the United States, the prevalence of overweight in children and adolescents increased ≈2-fold between the early 1970s and early 1990s (5). A Centers for Disease Control and Prevention report, based on the 1999 NHANES data, found that the prevalence of overweight and obesity among American children and adults continues to increase (33). This trend of increasing childhood obesity is also found in other industrialized and developing countries (7, 8). The present study showed that the rapid increases in late childhood and adolescent obesity found in the United States are not restricted to high-income countries; this is most pointedly shown by the similarity in the increases in childhood obesity in the United States and Brazil. An exploration of shifts in the environment and related socioeconomic and behavioral factors common to these countries is needed.

We cannot fully explore these shifts in this paper, but the key question is, Why are they occurring? Clearly this is ultimately a question of energy imbalance, possibly interacting with genetic susceptibility, and hence, dietary intake and physical activity pattern changes that must be understood. Underlying these shifts are important changes in environmental factors related to socioeconomic and behavioral changes. First, there are the remarkable shifts in the economies and the social welfare of these 4 countries (18, 22, 29, 30, 34). Large proportions of the populations of Brazil, China, and the United States have benefited from improved economic and social conditions, whereas Russia faced severe economic setbacks in the 1990s. Over the past 2 decades, the per capita gross domestic product has tripled in Brazil and the United States and has increased by >10-fold in China (**Figure 2**). In contrast, in Russia, it decreased from \$6230 in 1990 to \$4370 in 1997 (18).

With this shift in economic welfare has come a shift toward more secure food supplies and increased dietary intakes, particularly a more nutrient-dense and energy-dense diet; reduced energy expenditure in transportation; and more leisure time, especially inactive leisure time (18, 22, 30, 34–36). Clearly, a large component of the change was due to the decrease in physical activity, as is documented elsewhere (18, 35, 36). In particular, ownership and use of television is linked with the shift toward much greater inactivity. Television watching is a major cause of children's inactivity and has been linked to childhood obesity (37, 38). Television ownership has increased remarkably in Brazil, China, and the United States (Figure 2). The weight trends in Russia are very different from those of the other 3 countries, and we have written elsewhere about the economic shifts underlying this change (29). The sex difference we found in the changing prevalence of underweight may suggest that Russian males and females have been influenced differently by the socioeconomic difficulties in the society.

The transition in weight trends shown by the present study poses a major challenge for lower-income countries. For example,

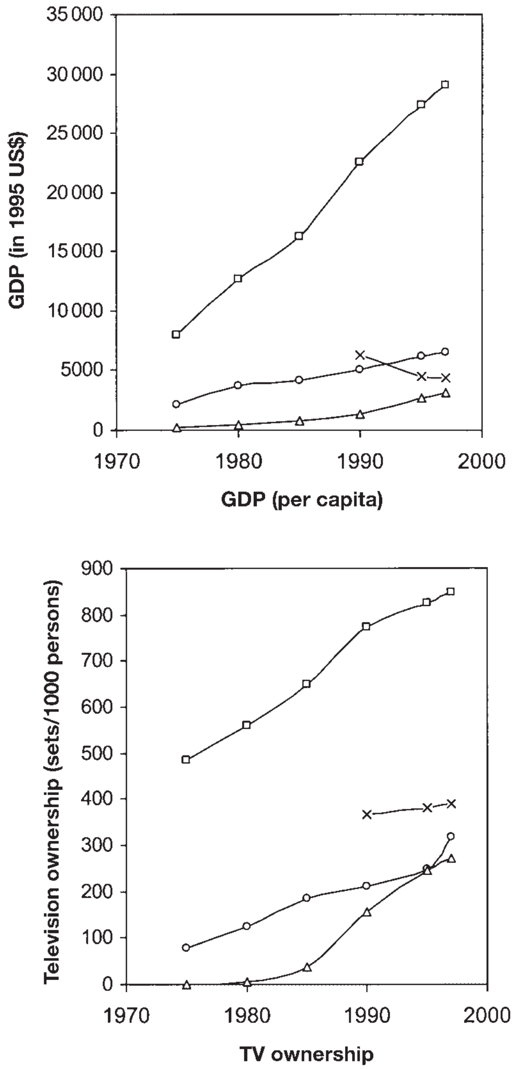

FIGURE 2. Trends in the gross domestic product (GDP) and in television ownership in the United States (□), Brazil (○), China (△), and Russia (×). Data come from public use sources (18).

if countries facing this shift toward greater obesity continue to focus their feeding programs on undernutrition, they may actually increase the prevalence of obesity among those with marginal undernutrition, as occurred in Chile (39). Current nutrition programs for children and adolescents should be reviewed and revised to consider these rapidly emerging concerns. Furthermore, few countries are aggressively addressing obesity among schoolchildren in an active, systematic manner. Singapore has reduced obesity among school-age children significantly and enhanced their fitness. The concerted Singaporean effort includes systematic education of administrators and teachers, better physical education, and nutritional improvement in the beverages and food products available in schools (40). Similar efforts are clearly needed worldwide. It is important to note that shifts toward reduced adult obesity in Brazil do not appear to have reached older children and adolescents yet (41).

Clearly, our results show that countries of different economic development levels are facing considerable increases in obesity among older children and adolescents. This must alert scholars, program directors, and policymakers that broad international trends in socioeconomic and environmental factors as well as technology related to food supply and physical activity may be critical components of the global increase in childhood obesity. These trends pose many critical public health challenges in the new millennium. These changes are particularly challenging for countries facing shifts from under- to overnutrition problems; it is highly recommended that they adjust their national efforts in the food and nutrition area to consider these new realities.

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