

Epidemics of overweight and obesity among growing childhood in China between 1997 and 2009: Impact of Family Income, Dietary Intake, and Physical Activity Dynamics

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Abstract

Background: Obesity has become a major health problem among children and adolescents worldwide. This study aimed to examine the trends of overweight and obesity among childhood in China and assess their associations with family income, dietary intake, and physical activity (PA) between 1997 and 2009.

Methods: Two waves of cross-sectional data of Chinese children and adolescents aged 7–17 years from the China Health and Nutrition Survey were used. Weight and height were measured following standardized procedures. Dietary intake was assessed by 3 consecutive 24-h recalls. Childhood overweight and obesity were defined using the International Obesity Task Force-recommended body mass index cut-offs. Multivariate linear regression analysis was used to examine the associations of family income with diet intakes and PA. Multivariate logistic regression analysis was conducted to assess the associations of overweight and obesity with family income, dietary intake, and PA.

Results: The prevalence of childhood overweight and obesity increased from 12.6% in 1997 to 22.1% in 2009, particularly in the medium- and high-family income groups, which increased by 102.7% and 90.3%, respectively. Higher fat intake (% energy), and moderate and vigorous PA were significantly associated with overweight and obesity in final model (odds ratio [OR] = 1.01, 95% confidence interval [CI]: 1.00–1.02, $P = 0.004$; and OR = 0.99, 95% CI: 0.98–1.00, $P = 0.036$, respectively).

Conclusions: The prevalence of overweight and obesity among Chinese children and adolescents has increased between 1997 and 2009. Reducing fat intake and increasing PA may help obesity prevention.

Key words: Adolescent; Child; Dietary Intake; Income; Obesity; Overweight; Physical Activity

INTRODUCTION

Overweight and obesity have become a major health problem among children and adolescents worldwide and are more prevalent than underweight.^[1,2] Childhood obesity could induce adverse health and social consequences, such as adult obesity, cardiovascular diseases, and type 2 diabetes mellitus.^[3]

Cumulative researches from developed countries have shown a significantly negative association between household income level and prevalence of obesity among children and adolescents, but the results were inconsistent with those in developing nations.^[4,5] In 27 of 37 developing countries, higher socioeconomic status was associated with higher gains in overweight and obesity prevalence; in the remaining

10 countries, lower socioeconomic status was associated with higher gains in overweight and obesity prevalence.^[6] The income is associated with altered dietary intakes and levels of physical activity (PA), as a result of which the incidence of obesity may be affected.^[7]

The evidence linking dietary intakes and PA with obesity among children and adolescents is inconclusive and contradictory.^[8-10] Energy intakes in children and adolescents have shown a small or no association with weight status in previous epidemiologic studies, partly because of a possibly underreported dietary intake.^[11,12] Several studies on overweight and obesity among children and adolescents indicate a significant association between weight status and PA.^[13] To date, most studies focused on either PA or dietary intakes, and few took both into account. The relationships of overweight and obesity with PA and dietary intakes in children and adolescents have seldom been examined by combining household income using a large sample size, nor

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have they been specifically focused in developing nations. China, where economic reforms were initiated in the late 1970s, has become the largest developing nation and the second largest economy globally and is undergoing nutrition and lifestyle transitions characterized by ample food supply and higher living standards, as described elsewhere.^[14] To our knowledge, there are few epidemiological studies exploring the status of overweight and obesity in Chinese children and adolescents along with their dietary intakes and PA, setting these data against the background of widespread nutritional and lifestyle transitions. To mitigate the potentially harmful effects and to optimize the potential benefits of this transition, it is important to address this issue, taking care to delineate any differences from western developed countries.

The purpose of this present study was to examine the prevalence of overweight and obesity among Chinese children and adolescents between 1997 and 2009, and the associations of household income with dietary intakes and PA behaviors. We also investigate the effects of both dietary intakes and PA combined with household income on overweight and obesity.

METHODS

Study design and subjects

The China Health and Nutrition Survey (CHNS) is a representative cross-sectional survey (with a nested longitudinal cohort) that covers nine diverse provinces and autonomous regions from south to north (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning and Shandong) and was performed eight rounds between 1989 and 2009. Details of the study design have been described elsewhere.^[15,16] The present study was based on two cross-sectional samples collected in 1997 and 2009 of the CHNS. Because the sedentary time of children and adolescents was not collected in 1989, 1991, and 1993, we chose 1997 as the reference. Of the total 3391 children and adolescents aged 7–17 years who attended school, 3221 (95%) subjects (2275 in 1997 and 946 in 2009) had complete and reasonable measurements of weight and height. The 155 subjects were excluded because of missing data, including household income ($n = 53$), anthropometric measurements ($n = 25$), or PA ($n = 77$). Another 15 subjects were excluded because of extreme body mass index (BMI) (z -scores >5 or <-5) or impossible time spent in PA (e.g., 25 h/day). It is worthy to address that there was much smaller sample size in 2009 compared to that in 1997, which resulted from migration of new established households with newborns and/or children during 1997–2009 into other communities, out of targeted communities; lower birth rate from 1997 (16.57%) to 2009 (11.95%);^[17] and lost to follow-up some teenagers during survey period as attending boarding school.

Written informed consent was provided by parents or guardians of each participant. The institutional review boards of University of North Carolina at Chapel Hill, and National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention approved the survey.

Key measurements

Body mass index measurement

Anthropometric measurements were performed by trained health workers following standardized procedures. Weight was measured to the nearest 0.1 kg with SECA 880 scales while the participants were wearing light clothing. Height was measured to the nearest 0.1 cm using SECA 206 wall-mounted metal tapes for bare-footed participants. BMI was calculated as weight (kg) divided by the squared height (m^2). Overweight and obesity was defined using age- and sex-specific BMI cut-offs recommended by the International Obesity Task Force (IOTF).^[18]

Family income

Income measures were based on per capita annual income of household by dividing gross annual income of the family by household size. The per capita annual income of the family was inflated to that of 2009 by adjusting for the consumer price index and was categorized into tertiles (high-, middle- and low-income levels).

Dietary intakes

Detailed information on dietary consumption at the household and individual levels were collected using a weighing method in combination with 3 consecutive 24-h recalls, including 1 weekend day and 2 weekdays. Details have been introduced elsewhere.^[15,16] The energy and nutrient intake levels for dietary data were calculated using the China Food Composition Table. Nutrient variables including total energy per day, percentages of calories from total fat, total carbohydrate and total protein were calculated. Considering the differences in energy requirements of children and adolescents based on body size, we added the ratio of energy/subjects' height (cm) as a nutrient variable. Energy/height (cm) was chosen as both total energy and energy/height (cm) gave similar results.

Physical activity assessment

Physical activity was measured using metabolic equivalents of task (MET)-hours per week that account for both the average intensity of each activity and the time spent. MET is defined as the ratio of a person's working metabolic rate to his/her resting (basal) metabolic rate,^[19] and any given activity is classified as moderate and vigorous (≥ 3 METs) by referring to the Compendium of Physical Activities.^[20]

Information on PA being collected included the participation in in-school and outside school sports, commuting type and required time to school, domestic activities (e.g., buying food, preparing food, doing laundry, and childcare), and time spent in sedentary activities (e.g., reading, watching TV, DVDs, videos, and using computers). Details on survey questions, coding, and the method of MET-hours per week calculation have been published elsewhere.^[21,22]

Covariates

Other factors such as surveyed year, gender, and age were used in the analysis. Subjects' age was divided into two categories (7–12 and 13–17 years).

Statistical analysis

Data were expressed as mean \pm standard deviation (SD) for continuous variables and as percentages for categorical variables. The differences between 1997 and 2009 or among groups in the same year were assessed using analysis of variance or Kruskal–Wallis rank-sum tests depending on assumption of parametric test for continuous variables, and using Chi-squared test for categorical variables. We reported statistically significance at $P < 0.05$.

Multivariate linear regression models were fit to examine the associations of income with diet intakes and PA. Interactions among different income levels and surveyed year were used to test the difference in income effects between 1997 and 2009. Potential confounders such as gender, age, and surveyed year were also taken into account in the models. In order to interpret the coefficients of the models, we simulated the predicted level of each diet and PA outcome by income group by year.

Finally, we used multivariate logistic regression to examine the combined effects of household income, diet intakes, and PA on overweight and obesity. Four models were performed by consecutively including predictors of overweight and obesity. Firstly, we included household income and year (Model 1). Subsequently, dietary energy intake was added (Model 2). Next moderate and vigorous PA was also included (Model 3). Sedentary activity was finally included (Model 4). To interpret odds ratios (ORs), we simulated the predicted prevalence of overweight and obesity if all subjects had the diet and PA profiles of the low-, medium-, or high-income levels in 1997 and 2009. Although the CHNS is longitudinal in nature, the present study focused on cross-sectional analysis of data in 1997 and 2009. All analyses were conducted using SAS software (Version 9; SAS Institute, Cary, NC, USA).

RESULTS

Sample characteristics

There were 2275 and 946 children and adolescents in 1997 and 2009, respectively [Table 1]. No significant difference was found using Chi-square analysis in the proportions of sex ($P = 0.265$) and age ($P = 0.195$) groups. Mean height ($P < 0.001$), weight ($P < 0.001$), BMI ($P = 0.006$), and income level ($P < 0.001$) increased from 1997 to 2009. A similar increasing trend was found in the percentage of energy derived from fat ($P < 0.001$) and MET-hours/week expended in sedentary activity ($P < 0.001$), but there was a decline in the total energy intake ($P < 0.001$), the ratio of energy/height ($P < 0.001$), the percentage of energy from carbohydrate ($P < 0.001$), and MET-hours/week spent in moderate and vigorous activity ($P < 0.001$) from 1997 to 2009. An increase of over three-fourths in overweight and obesity prevalence ($P < 0.001$) from 1997 (12.6%, 287) to 2009 (22.1%, 209) was observed. In addition, overweight and obesity prevalence in younger subjects (7–12 years, 197, 14.0% and 144, 23.7%) was higher than that in older subjects (13–17 years, 89, 10.3% and 65, 19.2%) in 1997 ($P = 0.022$) and 2009 ($P = 0.006$), respectively (data not shown in Table 1).

Changes in the prevalence of overweight and obesity, diet intake, and physical activity of subjects by income level

Table 2 presents an increase in the prevalence of overweight and obesity ($P < 0.001$) by income levels between 1997 and 2009. Particularly, the prevalence of overweight/obesity increased by 102.7% and 90.3% in the medium- and high-family income groups. As compared to 1997, three income groups displayed less total energy intake (all $P < 0.001$) in 2009, a smaller ratio of energy/height ($P < 0.001$), less percentage of energy from carbohydrate ($P < 0.001$) and fewer MET-hours/week spent in moderate and vigorous activity ($P < 0.001$), along with a greater percentage of energy from fat ($P < 0.001$) and MET-hours/week spent in sedentary activity ($P < 0.001$). Medium- and high-income groups presented a greater percentage of energy from protein in 2009 compared to 1997.

Association of household income with dietary intake and physical activity

We tested the main effects of income and year, interaction effects between income and year, and the combined main effect and interaction effect of income with year using the multivariate linear model to assess how income affects dietary intake and PA. High-income group had a higher percentage of energy from fat ($P < 0.001$) and more MET-hours/week in sedentary activity ($P < 0.001$), but fewer MET-hours/week spent in moderate and vigorous activity ($P < 0.001$), compared with low-income group [Table 3]. The high-income group consumed about 2% ($P = 0.249$) and 6% ($P = 0.029$) more energy/height and about 46% ($P < 0.001$) and 16% ($P = 0.005$) more energy from fat than the low-income group in 1997 and 2009, respectively [Figure 1a and b]. Consistently, predicted value for MET-hours/week of sedentary activity in high-income group was also higher than low-income group in both time periods ($P = 0.046$ and 0.039 , respectively), but the predicted value for moderate-vigorous activity in high-income group was lower than low-income group in both time periods [$P < 0.001$ and $P = 0.004$, respectively, Figure 1c and d].

Association of household income, dietary intake and physical activity with overweight and obesity

Association of household income, dietary intake and PA with overweight and obesity were tested by multivariate logistic regression models. The percentage of energy from fat was positively related to overweight and obesity (OR = 1.01, 95% confidence interval [CI]: 1.00, 1.02) in Model 2 ($P = 0.006$), Model 3 ($P = 0.005$), and Model 4 ($P = 0.004$); and MET-hours/week spent in moderate and vigorous PA had an inverse relationship with overweight and obesity (OR = 0.99, 95% CI: 0.98, 1.00) in Model 3 ($P = 0.044$) and Model 4 [$P = 0.036$, Table 4]. The risk for being overweight and obese was not significantly associated with income, energy intake, and MET-hours/week spent in sedentary activity. Figure 2 shows a U-shaped distribution of predicted prevalence of overweight and obesity by different income levels among

Table 1: Sample characteristics of children and adolescents aged 7–17 years old in China

Characteristics	Year 1997 (n = 2275)	Year 2009 (n = 946)	P
Sex (male/female, n (%))	1203 (52.9)/1072 (47.1)	521 (55.1)/425 (44.9)	0.265
Age group (7–12 years/13–17 years, n (%))	1407 (61.8)/868 (38.2)	608 (64.3)/338 (35.7)	0.195
Height (cm)	141.9 ± 16.0	145.5 ± 16.1	<0.001
Weight (kg)	36.0 ± 12.0	38.5 ± 13.1	<0.001
BMI (kg/m ²)	17.3 ± 2.8	17.7 ± 3.3	0.006
Income (RMB)*			
Low	1150.3 ± 555.6	2261.8 ± 1421.8	<0.001
Medium	2820.7 ± 545.6	6336.4 ± 1324.5	<0.001
High	6469.0 ± 29.01.4	18255.5 ± 13973.6	<0.001
Energy (kcal/day)	2078.9 ± 693.3	1815.1 ± 632.4	<0.001
Fat (% energy)	24.9 ± 12.4	32.2 ± 12.9	<0.001
Carbohydrate (% energy)	63.1 ± 12.3	53.0 ± 11.9	<0.001
Energy/height (kcal/cm)	14.7 ± 4.6	12.5 ± 4.1	<0.001
MVA (MET-hours/week)	43.5 ± 52.2	24.0 ± 32.6	<0.001
SA (MET-hours/week)	13.7 ± 12.0	22.3 ± 13.4	<0.001
Overweight + obesity (n (%))†	287 (12.6)	209 (22.1)	<0.001

*RMB denotes Chinese currency; the per capita annual income of family was inflated to that in 2009 by adjusting for consumer price index; †Overweight and obesity was identified based upon age- and sex-specific BMI cut-off points of the IOTF. Values were expressed as percentages (n) or mean ± SD. BMI: Body mass index; MET: Metabolic equivalents of task; MVA: Moderate and vigorous activity; SA: Sedentary activity; IOTF: International Obesity Task Force; SD: Standard deviation.

Table 2: Shifts over time in the prevalence (%) of overweight and obesity, diet intake, and physical activity of children and adolescents by income level in China: 1997 and 2009

Items	Low income level			Medium income level			High income level		
	1997	2009	P	1997	2009	P	1997	2009	P
Overweight + obesity (n (%))	92 (12.1)	51 (16.2)	<0.001	84 (11.1)	71 (22.5)	<0.001	110 (14.5)	87 (27.5)	<0.001
MVA (MET-hours/week)	47.7 ± 57.1	25.0 ± 34.9	<0.001	44.3 ± 54.5	24.5 ± 30.2	<0.001	38.5 ± 43.6	22.4 ± 32.5	<0.001
SA (MET-hours/week)	11.8 ± 11.5	21.7 ± 12.8	<0.001	14.2 ± 12.1	21.0 ± 11.6	<0.001	15.0 ± 12.1	24.4 ± 15.5	<0.001
Energy (kcal/day)	2018.8 ± 700.1	1734.1 ± 619.3	<0.001	2073.5 ± 652.0	1787.3 ± 572.0	<0.001	2145.0 ± 720.3	1922.3 ± 686.8	<0.001
Energy/height (kcal/cm)	14.4 ± 4.7	12.2 ± 4.2	<0.001	14.7 ± 4.3	12.3 ± 3.8	<0.001	14.8 ± 4.7	13.0 ± 4.4	<0.001
Fat (% energy)	20.8 ± 10.2	31.5 ± 17.5	<0.001	23.9 ± 11.8	31.0 ± 9.9	<0.001	30.0 ± 13.1	34.1 ± 9.5	<0.001
Protein (% energy)	11.7 ± 2.4	12.0 ± 2.6	0.069	11.8 ± 2.2	12.6 ± 2.9	<0.001	12.3 ± 2.6	12.8 ± 2.9	0.006
Carbohydrate (% energy)	67.5 ± 10.1	56.5 ± 11.7	<0.001	64.3 ± 12.0	56.4 ± 12.0	<0.001	57.7 ± 12.8	53.1 ± 11.4	<0.001

Values were expressed as percentages (n) or mean ± SD. MET: Metabolic equivalents of task; MVA: Moderate and vigorous activity; SA: Sedentary activity; SD: Standard deviation.

children and adolescents shifted to a stair-shaped distribution from 1997 to 2009. In addition, the predicted prevalence in 2009 increased from that in 1997 for all income groups (all $P < 0.001$).

DISCUSSION

Our study presented an increment of 9.5% in prevalence of overweight and obesity in Chinese 7–17 year-old children from 1997 to 2009, rising 0.79% annually in average, which was similar to the increment of 9.6% in overweight and obesity among Chinese 7–18 year-old children during 1995–2010, annual growth rate of 0.64%.^[23] Although the previous study was more representative,^[23] our study still could reflect the trends of overweight and obesity in Chinese children. Present study used the latest IOTF criteria^[18] to define childhood overweight and obesity, which is an important aspect, and covered many Eastern developed

provinces, which may have higher overweight and obesity prevalence, as indicated by previous study.^[23] Additionally, the effects of household income on dietary intakes, PA, and overweight and obesity prevalence were enhanced in 2009 compared to 1997.

Further, there was a significant association between MET-hours/week spent in moderate and vigorous activity and a decrease in overweight and obesity prevalence, but the effect was small. The increase in the prevalence of overweight and obesity among children and adolescents was consistent with that in other countries,^[24,25] and was accompanied by a concurrent increasing prevalence of overweight and obesity among Chinese adults.^[26] An overall increasing trend toward obesity had been found in the study of childhood obesity from the US and Brazil, which was dramatically similar to our results.^[24,25] In addition, our results showed that overweight and obesity of children and

Table 3: Coefficients and intercepts from multivariate linear regression models used to predict dietary intakes and physical activity by household income levels

Items	Energy/height (kcal/cm)		Fat (% energy)		MVA (MET-hours)		SA (MET-hours)	
	Coefficients (95% CI)	P	Coefficients (95% CI)	P	Coefficients (95% CI)	P	Coefficients (95% CI)	P
Intercept	13.48 (12.83, 14.13)	<0.001	22.10 (20.19, 24.01)	<0.001	38.36 (31.25, 45.47)	<0.001	17.36 (15.54, 19.18)	<0.001
Income level								
Low-income (ref)	NA	–	NA	–	NA	–	NA	–
Medium-income	0.27 (–0.13, 0.68)	0.343	2.87 (1.69, 4.05)	<0.001	–3.35 (–9.46, 2.75)	0.360	2.37 (1.25, 3.49)	<0.001
High-income	0.29 (–0.11, 0.69)	0.142	9.18 (8.01, 10.36)	<0.001	–8.51 (–14.61, –2.41)	<0.001	3.56 (2.44, 4.69)	<0.001
Year								
1997 (ref)	NA	–	NA	–	NA	–	NA	–
2009	–2.20 (–2.72, –1.68)	<0.001	9.15 (7.63, 10.67)	<0.001	–22.74 (–27.87, –17.60)	<0.001	9.22 (7.76, 10.69)	<0.001
Interaction terms								
Low-income × year (ref)	NA	–	NA	–	NA	–	NA	–
Medium-income × year	–0.11 (–0.84, 0.62)	0.561	–1.27 (–3.42, 0.88)	0.003	3.01 (–4.25, 10.27)	0.370	–2.74 (–4.81, –0.67)	0.011
High-income × year	0.40 (–0.33, 1.13)	0.411	–4.40 (–6.54, –2.26)	<0.001	6.33 (–0.93, 13.58)	0.277	–1.84 (–3.91, 0.23)	0.699
Main effect and interaction effect								
Low-income + low-income × year (ref)	NA	–	NA	–	NA	–	NA	–
Medium-income + medium-income × year	0.16 (–0.45, 0.77)	0.940	1.60 (–0.20, 3.40)	0.686	–0.35 (–4.28, 3.59)	0.098	–0.37 (–2.11, 1.37)	0.532
High-income + high-income × year	0.68 (0.07, 1.29)	0.042	4.78 (2.99, 6.58)	0.005	–2.18 (–6.12, –1.75)	0.006	1.72 (0.01, 3.47)	0.004
Age	0.09 (0.04, 0.14)	0.005	–0.17 (–0.31, –0.03)	0.003	–1.04 (–1.51, –0.58)	<0.001	0.56 (0.42, 0.69)	<0.001
Gender								
Boy (ref)	NA	–	NA	–	NA	–	NA	–
Girl	–1.30 (–1.57, –1.02)	<0.001	0.37 (–0.43, 1.18)	0.437	–7.15 (–9.86, –4.44)	<0.001	0.23 (–0.54, 1.00)	0.676

Ref indicates the group as reference. MET: Metabolic equivalents of task; CI: Confidence interval; NA: Not applicable; MVA: Moderate and vigorous activity; SA: Sedentary activity.

adolescents in China increased as income has increased; in contrast, only children and adolescents from low- or high-income groups had a higher prevalence of obesity in other countries.^[24,25]

A striking association of household income with dietary intakes and PA in our study was consistent with the findings from other studies, which have found differences in nutrient intakes by income.^[7,27] We found more energy intake, higher fat intake, and more MET-hours/week spent in sedentary activity in the higher-income group, and that high-income group also had a higher prevalence of overweight and obesity, which was similar to findings from Brazil.^[25]

Traditionally, research into weight status and its influencing factors has only focused on a single behavior. However, obesity development in childhood and adolescence is associated with a complex behavioral pattern of energy intake and energy expenditure. Evidence about the association of overweight and obesity with multiple variables such as income, diet, and PA is still scarce. This is one of the first studies from Asia to specifically test the effects of the combination of income, diet, and activity on overweight and obesity among Chinese children and adolescents. Our results were consistent with a recent study conducted in American children and adolescents that examined diet and

PA as risk factors for overweight and obesity.^[28] However, some issues need to be clarified by additional studies. We found that only MET-hours/week spent in moderate and vigorous PA and energy derived from fat appeared to have independent associations with overweight and obesity for Chinese children and adolescents, which is novel and gives interesting implications for research and intervention.

Similar to the results in most previous researches,^[11,26,28] the present study also did not find an observed effects of household income or total energy intakes on overweight and obesity. In addition, our results, including the inverse effect of moderate and vigorous PA, were consistent with other studies summarized in a recent literature review showing a negative relationship between moderate and vigorous activity and risk of obesity.^[8]

Although conclusions supporting an association between sedentary behavior and obesity have not been found, our results have indicated that MET-hours/week spent in sedentary activity had a marked increase. Strong national economic drivers increased the opportunities of Chinese children and adolescents for access to screen-based devices such as computers and video games, and in the unique Chinese cultural setting, most children and adolescents had more extracurricular academic activities such as homework

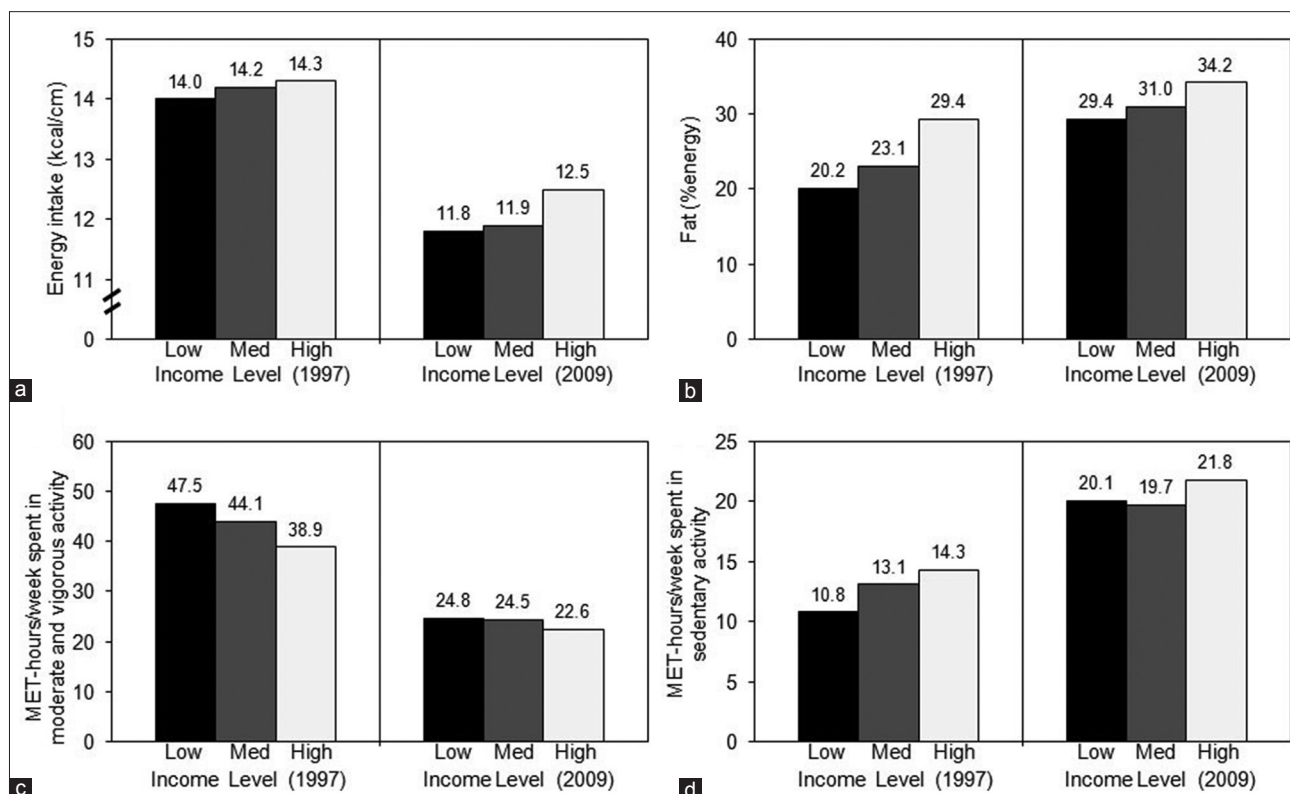


Figure 1: Prediction of dietary intake and physical activity by family income in 1997 and 2009. (a) Energy intake presented as energy/height; (b) percentage of energy from fat; (c) metabolic equivalents of task (MET)-hours/week spent in moderate and vigorous activity; (d) MET-hours/week spent in sedentary activity.

Table 4: The results of multivariate logistic regression models of predictors of overweight and obesity in children and adolescents*

Items	Model 1		Model 2		Model 3		Model 4	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Income level								
Low-income (ref)	NA	–	NA	–	NA	–	NA	–
Medium-income	0.88 (0.65, 1.21)	0.446	0.85 (0.61, 1.18)	0.331	0.85 (0.61, 1.19)	0.341	0.84 (0.61, 1.17)	0.313
High-income	1.22 (0.91, 1.65)	0.179	1.12 (0.82, 1.54)	0.538	1.12 (0.82, 1.54)	0.484	1.11 (0.81, 1.53)	0.479
Year								
1997 (ref)	NA	–	NA	–	NA	–	NA	–
2009	1.36 (0.94, 1.98)	0.100	1.25 (0.83, 1.87)	0.379	1.21 (0.81, 1.81)	0.351	1.18 (0.78, 1.77)	0.280
Interaction terms								
Low-income × year (ref)	NA	–	NA	–	NA	–	NA	–
Medium-income × year	1.69 (1.02, 2.82)	0.043	1.85 (1.09, 3.14)	0.022	1.87 (1.10, 3.17)	0.021	1.87 (1.10, 3.18)	0.018
High-income × year	1.62 (0.99, 2.64)	0.055	1.74 (1.04, 2.89)	0.034	1.74 (1.04, 2.89)	0.029	1.77 (1.06, 2.95)	0.028
Diet								
Energy/height (kcal/cm)	NA	–	1.01 (0.99, 1.03)	0.494	1.01 (0.99, 1.03)	0.473	1.01 (0.99, 1.03)	0.470
Fat (% energy)	NA	–	1.01 (1.00, 1.02)	0.006	1.01 (1.00, 1.02)	0.005	1.01 (1.00, 1.02)	0.004
Physical activity (MET-hours/week)								
MVA	NA	–	NA	–	0.99 (0.98, 1.00)	0.044	0.99 (0.98, 1.00)	0.036
SA	NA	–	NA	–	NA	–	1.00 (0.99, 1.01)	0.248

*All models were adjusted for age and sex. Ref indicates the group as reference. MET: Metabolic equivalents of task; CI: Confidence interval; NA: Not applicable; OR: Odds ratio; MVA: Moderate and vigorous activity; SA: Sedentary activity.

and night classes, all of which may contribute to rising sedentary activity time. Adopting measures to increase PA for Chinese children and adolescents at school as well as control sedentary activity time are critical and noticeable.

In addition, with the development of Chinese urbanization, consumption of “junk food” and foods rich in energy and fat has rapidly increased, and snacking and away from home eating behaviors have changed dramatically. Therefore,

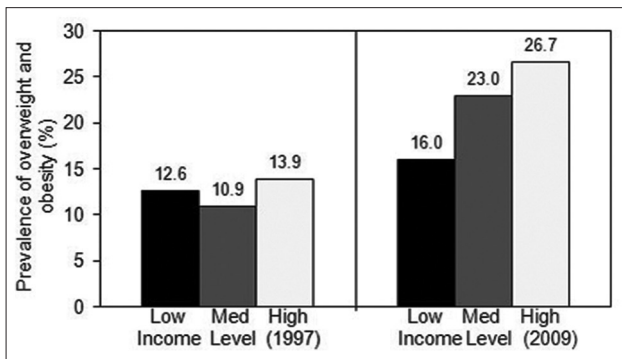


Figure 2: Predicted prevalence of overweight and obesity by family income using multivariate logistic regression models in 1997 and 2009. Overweight and obesity was defined using age- and sex-specific cut-off points for body mass index recommended by the International Obesity Task Force.

making appropriate health-related policies and providing better nutritional knowledge from parents or schools would also play pivotal roles in interventions for overweight and obesity in Chinese children and adolescents.

This study has some limitations. First, we were unable to assess causality because of the cross-sectional analysis. Second, recall and social desirability biases existed in self-reported PA and dietary data, although whether over-estimated PA or dietary intakes due to social desirability bias in some developed countries^[29] occurs in developing countries is not clear. Third, the collection methods of PA and dietary data in children and adolescents varied slightly by age groups, with assistance from caregivers for children <10 years. While different data collection methods were used for improving accuracy of PA or dietary data,^[30] comparison of CHNS PA and dietary data in children based on parent-assisted self-report and self-report has not yet been conducted.

In conclusion, to the best of our knowledge, this is the first study to assess the shifts over time in household income, dietary intake and PA, and their associations with overweight and obesity among Chinese children and adolescents using nationwide survey data. These findings suggest that household income, dietary intake, and PA have changed dramatically over time, and prevalence of overweight and obesity has increased. Sedentary behaviors are more common while moderate and vigorous PA is inadequate. Lower fat intake and frequent participation in moderate and vigorous PA may be protective against overweight and obesity.

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