Tracking of body mass index from childhood to adolescence: a 6-y follow-up study in China[1–3]

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ABSTRACT

Background: Although extensive descriptive research shows that childhood obesity predisposes a person to adult obesity, little is understood about the dynamics of weight during childhood and the predictors of weight tracking.

Objective: Our objective was to examine tracking patterns of body mass index (BMI) as well as their predictors between childhood and adolescence.

Design: A cohort of 975 Chinese children aged 6–13 y was followed for 6 y (1991–1997). Tracking of BMI was defined as an individual maintaining a certain status (overweight or underweight) or relative position (relative BMI quartile) over time. Relative BMI related BMI to age- and sex-specific BMI cutoffs.

Results: After 6 y, ≈40% of the subjects had maintained their relative positions, but 30% had moved into a lower or higher quartile. The BMIs of thin and fat children were more likely to track: 51% and 46% remained in the bottom and upper quartiles, respectively. Nearly one-third of the underweight children remained underweight in 1997. Overweight children were 2.8 times as likely as all other children to become overweight adolescents; underweight children were 3.6 times as likely to remain underweight as adolescents. Parental obesity and underweight, individuals' initial BMIs, dietary fat intake, and family income helped predict tracking and changes in BMI.

Conclusion: In a society undergoing enormous changes in diet and activity, BMI tracking is still very important between childhood and adolescence in China.   *Am J Clin Nutr* 2000;72:1018–24.

KEY WORDS   Child, adolescent, BMI, body mass index, body composition, body weight, obesity, overweight, underweight, tracking, China, dietary intakes

INTRODUCTION

Obesity, an emerging major public health problem throughout the world, occurs during 1 of 4 critical periods: infancy, early childhood, adolescence, and adulthood (1). In high-income countries, extensive evidence indicates that obesity during childhood is related to adult obesity (2–10). Epidemiologic literature shows that about one-third of obese preschool children and about one-half of obese school-age children become obese adults (8), but other studies showed that although fatter children are at elevated risk of becoming obese adults, the prediction of adult obesity from childhood and adolescent adiposity measures is only moderate (9).

The literature suggests that a series of biological factors, such as the timing of adiposity rebound and parental obesity, which might relate to both behavioral and biological causal mechanisms, affect carryover of fatness from childhood into adulthood (3, 7–11). Little research has focused on the dynamics of body composition in shorter periods, such as within childhood and adolescence, or on the effects of a wider range of social behavioral factors on the persistence of obesity (12). Understanding better the predictors of the dynamics of body mass index [BMI; weight (kg)/height (m)^2] between childhood and adolescence is an important step toward narrowing the gaps in our knowledge. Furthermore, much of the research has been undertaken in high-income countries, which face limited variability in diet, physical activity, and socioeconomic status factors relative to those found in low- and middle-income countries. Longitudinal research on this topic from a rapidly changing society might yield new insights.

This study focused on tracking of BMI patterns. Tracking is defined as the maintenance of a certain status (eg, obesity or underweight) or a relative position within a distribution of values in a population over time (13). Using longitudinal data from China, we ascertained tracking of overall patterns of BMI with an emphasis on both undernutrition and overnutrition and examined factors that predict tracking and changes in BMI. Longitudinal data from the China Health and Nutrition Survey (CHNS) collected between 1991 and 1997 were used.

SUBJECTS AND METHODS

Subjects

Children surveyed in the 1991 and 1997 CHNSs with complete anthropometric data in both years were selected at an age

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beyond the adiposity rebound period, which is ≈6 y of age (14, 15). This resulted in a total cohort of 975 children aged 6–13 y at baseline; the children were 12–19 y of age in 1997. All respondents provided informed consent according to the principles of the 2 collaborating parties. Both the University of North Carolina School of Public Health and the Chinese Academy of Preventive Medicine reviewed and approved the procedures used for data collection in the CHNS.

China Health and Nutrition Survey

This nationwide survey was conducted in 8 provinces, which varied significantly in geography, economic development, and health status (16). The CHNSs, started in 1989, covered ≈3800 households from 192 communities and 16000 individuals. Data were collected in 1989, 1991, 1993, and 1997. Dietary and anthropometric data for children >6 y of age were not collected in 1989, but after 1991 these data were collected for all family members. All data were collected by nutritionists following a well-developed protocol described in detail elsewhere (17, 18).

Anthropometry

Measurements of body weight, height, triceps skinfold thickness (TSFT), and arm circumference were obtained from all family members (children and their parents). Weight of subjects in light, indoor clothing was measured to the nearest 0.1 kg with a beam balance scale. Height of subjects without shoes was measured to the nearest 0.1 cm by using a portable stadiometer. All interviewers had to take interobserver reliability tests as part of their training.

Dietary intake

Detailed household food consumption data and individual dietary intake data were collected for 3 consecutive days. The start of the 3 d was randomly allocated from Monday to Sunday and almost equally balanced across the 7 d of the week from each sampling unit. Household food consumption was determined from the change in inventory from the beginning to the end of each day. Individual dietary intake data for the same 3 consecutive days were obtained from each family member on the basis of three 24-h recalls, except for young children, whose mothers responded for them. From the household dietary data, information on the added fat (cooking oil represents a significant proportion of the fat intake for this population) and other condiments was used to supplement the individual dietary intake data (17). The collection of household and individual dietary intake allowed us to check the quality of each against the other. At the time of data collection, the individual and household dietary data were compared and used to identify major discrepancies. Where significant discrepancies were found, the household and the individual in question were revisited and asked about food consumption to resolve these discrepancies. The 1991 Chinese food consumption table (19) was used to calculate nutrient intake from dietary data.

Sociodemographic data

Described in detail elsewhere, household income, area of residence, age, and other measures of relevance to this study were collected from key household informants (20).

Body-composition measures

Body composition was measured by using BMI and TSFT, with BMI as the principal measure. Because children's BMIs generally increase with age after age 6 y, to measure an individual's body weight status and to study the dynamics of BMI, some BMI standards (or references) are needed. We chose to use the International Obesity Task Force (IOTF; 21) age- and sex-specific BMI cutoffs to measure overweight and the World Health Organization (WHO; 22) reference for underweight. In the past, measures of stunting (low height-for-age) and wasting (low weight-for-height) were the main measurements of childhood undernutrition, and BMI focused on overweight status (22–24). Major initiatives in the United States and elsewhere are leading to a rethinking of this approach, and BMI is being proposed for use at both ends of the nutritional status spectrum.

Recently, the IOTF developed a set of international BMI standards (age- and sex-specific BMI cutoffs) for children and adolescents, which are based on 6 large data sets from several nations, including Brazil, the United Kingdom, Hong Kong, the Netherlands, Singapore, and the United States (21). The BMI cutoffs are linked to adult cutoffs for overweight (BMI ≥ 25) and obesity (BMI ≥ 30). These IOTF BMI cutoffs are derived from sex-specific curves that at age 18 y pass through the BMI values of 25 for overweight and 30 for obesity. On average, the BMI cutoffs for overweight approximately correspond to the 90th percentile in the 6 data sets. The IOTF reference is good for international use because of its unique strengths.

Although the IOTF experts led by Cole et al (21) initially proposed to define child and adolescent underweight using the BMI cutoffs linked to adult underweight (BMI < 18.5), they did not provide that reference because of their concerns about its low specificity. Therefore, to measure underweight we chose to use the age- and sex-specific 5th percentile for BMI developed by Must et al (23) on the basis of the first US National Health and Nutrition Examination Survey data collected from 1971 to 1975. These cutoffs were also recommended by the WHO for international use to define adolescent "thinness or low BMI-for-age" (22).

The IOTF and WHO references were used for children and adolescents aged 6–18 y in this study. To follow the widely used standard, we classified adolescents aged 19 y as overweight if their BMI was ≥25 and underweight if their BMI was <18.5. The IOTF and WHO references are provided only for 6-mo or 1-y age intervals. To provide a more precise fit, we used an approach developed by C Doak, L Adair, C Monteiro, and B Popkin (unpublished observations, 1999). A polynomial specification of the BMI curves was fitted to the ages of the boys and girls. Each curve had an almost perfect fit ($R^2 > 0.999$; the sum of squared residuals was <0.07 for overweight and <0.02 for underweight) and the predicted cutoffs and the original IOTF and WHO cutoffs matched perfectly. An important advantage we derived from using the predicted values was that we could use ages rounded to 0.1.

Relative BMI

To apply a new approach to study tracking of BMI, we computed relative BMI, that is, the individual's BMI divided by a standard BMI for his or her age and sex (100% × individual's BMI/sex- and age-specific BMI cutoffs from a reference population) as a measure of body composition. The meaning of relative BMI is easily understood. If a child's body weight status tracks, his or her relative BMI will be stable over time. This approach has 3 main advantages: 1) although BMI increases with age, relative BMI should not change with age, ie, this approach can help standardize BMI across age and sex; 2) relative BMI allows us to study tracking and change in BMI as a continuous variable more meaningfully; and 3) relative BMI provides a way to combine children

across age and sex groupings to increase the sample size of the subpopulation groups studied because age- and sex-specific cutoffs are needed to examine each individual's relative position to define tracking and change (addressed below). To our knowledge, no other study has used this approach, although the European Childhood Obesity Group suggested using relative BMI to define childhood obesity as well as to study tracking (25).

To compute the relative BMI, we selected as our BMI reference a series of local sex- and age-specific BMI medians derived from the 1992 China National Nutrition Survey data (CNNS; a large, representative survey of all provinces in mainland China that included ≈27 000 children and adolescents; 26). Other options we considered included internal BMI medians, the National Center for Health Statistics BMI medians from the first US National Health and Nutrition Examination Survey data (23), and the IOTF BMI cutoffs for overweight. We chose the 1992 CNNS BMI medians because, first, they are likely to represent healthy BMI values because the prevalences of obesity and underweight were low in the population (26) and, second, because they provide the real relations between BMI, age, and maturation in Chinese children. As above, the perfectly fitted sex-specific BMI median curves were used.

Although it is a concern that the SD of the BMI may change remarkably with age and as a result relative BMI may mean different things across different ages, we found that the variations in boys' SDs of BMI across ages were small, ranging from 2.3 to 3.5, whereas the variations in girls' SDs were larger. Girls' SDs first increased with age and then decreased at age 15 y, but most were around 2.5. We also tried an alternative approach by calculating a z score [(BMI $-$ age- and sex-specific BMI median)/age- and sex-specific SD] for each child. We found good agreement between the 2 measures (relative BMI and z score) for classifying individual's BMI pattern dynamics (ie, tracking, moving up, and moving down, which are addressed below): the BMIs of 40% and 37% of the subjects were classified as tracking by the 2 methods, respectively, and κ equaled 0.73 (27). The relative BMI was finally chosen because it is more easily understood and applied than is the z score approach. Because the relative-BMI variable produced results similar to the direct BMI and to the TSFT measures and the z score approach, we present only the results based on relative BMI.

Tracking and changes in BMI

Specifically, tracking was defined as the maintenance of a relative position in the population over time. If individuals remained overweight (or underweight) between 1991 and 1997, this was defined as tracking of overweight (or underweight). We examined each individual's relative position in the cohort on the basis of the sex-, age-, and group-specific (6–9 and 10–13 y) relative-BMI quartiles. If a child remained in the same quartile between 1991 and 1997, he or she was fitted into the tracking group. He or she was placed in the move-up group if he or she moved to a higher quartile by 1997 compared with his or her initial position in 1991. Otherwise, he or she was placed in the move-down group.

Independent variables

For the analysis of the predictors of tracking, children's initial characteristics, such as age, sex, BMI, residence (urban or rural), dietary intakes, and parental nutritional status, were studied. Children were separated into 2 age groups: 6–9 y (children) and 10–13 y (young adolescents). In 1997, the children were 12–15 y

(midadolescents) and 16–19 y (late adolescents) of age. The WHO defines adolescence as ages 10–19 y (28). Family income per capita was separated into tertiles. Dietary intakes, including the 3-d average total energy [% of the recommended dietary allowance (RDA)] and dietary fat (% of energy) intakes, were examined. These dietary intakes are comparable across sex and age groups because they are in percentages of sex- and age-specific Chinese RDA (19) or energy intake. On the basis of percentage of energy from dietary fat, each individual's diet was classified as a low-fat (≤10% of energy), medium-fat (10–30% of energy), or high-fat (≥30% of energy) diet. Also, parents' nutritional status at baseline (in 1991), classified as obese if their BMI was ≥25 and as underweight if their BMI was <18.5, was used.

Statistical analysis

Two statistics useful for examining tracking, the correlation coefficient and the κ statistic, were calculated (13, 27). κ equals 0 when the observed agreement equals that expected by chance and 1 when the agreement is perfect (27). Second, we examined the tracking and change patterns of BMI between 1991 and 1997 by using contingency tables. Greater correlation coefficients, κ values, and proportions of individuals who remained in the same quartiles suggest tracking. Then, using logistic regression models, we studied the predictors of tracking of underweight and tracking of fatness (remaining in the upper BMI quartile between 1991 and 1997). The small number of children for whom overweight tracked did not fit meaningful logistic models. All odds ratios (ORs) presented were adjusted for potential confounders. Finally, multiple linear regression analyses were conducted to study which factors may affect changes in relative BMI over time. These were performed by using the 1997 relative BMI (controlling for 1991 relative BMI) and the change in relative BMI between 1991 and 1997 as our outcome variables. These regression analyses generated consistent results. To avoid regression to the mean, results from the first approach were presented. All analyses were performed by using SAS (version 6.12; SAS Institute, Cary, NC).

RESULTS

Baseline characteristics of the study sample

Children's baseline characteristics are presented in **Table 1**. About one-half (46.3%) were girls, 59.8% were aged 6–9 y, and 19.2% lived in urban areas. These children's dietary intakes were almost adequate because their average energy, protein, and iron intakes all reached the relevant Chinese RDAs. At baseline, 9.2% and 17.3% of the children were overweight and underweight, respectively.

Tracking of BMI

The correlation coefficient (r) between the 1991 and 1997 measures was 0.39 for BMI (0.42 for boys and 0.36 for girls) and 0.40 for TSFT (0.36 for boys and 0.45 for girls). We also calculated weighted κ, which measures agreement between individuals' relative positions in 1991 and 1997 and considers disagreement close to the diagonal less heavily than disagreement farther away from the diagonal (27). The weighted κ was 0.31, which suggests a moderate tracking pattern.

As shown in **Table 2**, on the basis of the relative-BMI quartiles, tracking and changes in children's BMI coexisted. After 6 y of follow-up, 40.2% of these children remained in the same

TABLE 1
Baseline characteristics of the children aged 6–13 y in the China Health and Nutrition Survey, 1991

Characteristic	Value
Sociodemographic characteristics	
Age (y)	9.5 ± 2.2
Age group, 6–9 y (%)	59.8
Sex (% girls)	46.3
Urban or rural residence (% urban)	19.2
Anthropometric measures	
Weight (kg)	25.8 ± 7.9
Height (cm)	125.4 ± 14.4
BMI (kg/m^2)	14.9 ± 13.0
Triceps skinfold thickness (mm)	7.5 ± 3.5
Percentage overweight (%)[2]	9.2
Percentage underweight (%)[3]	17.3
Dietary intakes	
Energy (% of RDA)[4]	104.7 ± 28.7
Fat (% of energy)	22.3 ± 10.4
Percentage of children who had a low-fat diet ($\leq 10\%$ of energy)	11.4
Percentage of children who had a high-fat diet ($\geq 30\%$ of energy)	23.6
Protein (% of RDA)[4]	96.0 ± 32.4
Iron (% of RDA)[4]	155.5 ± 77.0
Parents' nutritional status[5]	
Father obese (%)	7.7
Mother obese (%)	9.5
≥ 1 obese parent (%)	15.1
Father underweight (%)	7.3
Mother underweight (%)	9.1
≥ 1 underweight parent (%)	14.9

[1] $\overline{x} \pm$ SD.

[2] Defined according to the International Obesity Task Force reference (21).

[3] Defined according to the National Center for Health Statistics based on the age- and sex-specific 5th percentile of BMI (23).

[4] Chinese recommended dietary allowance (19).

[5] Parental obesity was defined as BMI ≥ 25; underweight as BMI < 18.5.

only 6.7% of overweight children remained overweight after 6 y. Moreover, only 2.4% of the children who were not overweight in 1991 became overweight by 1997, and only 8.9% of those who were not overweight in 1997 were initially overweight in 1991.

Furthermore, our logistic regression analyses showed that after covariates such as age, sex, parental overweight and underweight, fat intake, and family income were controlled for, an individual's baseline body weight status was a strong predictor of the child's risks of later becoming an overweight or underweight adolescent, which further supported the tracking of children's body weight. Overweight children were 2.8 times as likely to become overweight adolescents than nonoverweight children [OR(95% CI): 2.8 (1.1, 7.0)]. Underweight children were 3.6 times as likely to become underweight adolescents than other children [OR(95% CI): 3.6 (2.3, 5.5)].

The predictors of tracking of fatness and underweight

Our study sample did not allow us to conduct meaningful regression analysis of the predictors of tracking of overweight because of the small number of children whose overweight tracked over time. Instead, we studied the predictors of tracking of fatness (ie, being in the upper quartile in both 1991 and 1997). As shown in **Table 4**, using the same approach with identical regressors in the models, we found that an individual's initial relative BMI, parental nutritional status (obesity and underweight), and fat intake were predictors of tracking of both fatness and underweight. Children with higher initial relative-BMI values were more likely to show tracking of fatness but less likely to show tracking of underweight. Children who had ≥ 1 obese parent were more likely to show tracking of fatness, whereas those with ≥ 1 underweight parent were more likely to show tracking of underweight. A low-fat diet at baseline predicted a higher likelihood of tracking of fatness but a lower likelihood of tracking of underweight. In addition, girls and children from high-income families were less likely to show tracking of under-

quartiles. Girls were less likely than boys to remain in the same quartile over time. The proportion was 38.1% compared with 42.0%, and weighted κ was 0.29 compared with 0.33 for girls and boys, respectively. An individual's initial BMI affected the patterns of tracking and change. The BMIs of children from high-income (by tertile) families were less likely to track but more likely to increase (ie, the children became fatter) than were those of low- and medium-income children ($P < 0.05$). Thin and fat children (those who were in the lowest and the highest quartiles, respectively) were more likely to remain in those quartiles than others ($P < 0.05$). Tracking patterns were similar in urban and rural children.

Using the WHO and IOTF references, we examined tracking of underweight and overweight both prospectively (eg, to examine how many children who were underweight in 1991 were still underweight by 1997) and retrospectively (eg, to see how many underweight adolescents in 1997 were originally underweight in 1991). There was an identifiable tracking pattern of underweight: 32.5% of underweight children remained underweight after 6 y and 36.9% of those who were underweight in 1997 were underweight in 1991 (**Table 3**). In contrast, the tracking of overweight was much weaker. Although 22.2% of those who were overweight in 1997 were originally overweight in 1991,

TABLE 2
BMI tracking patterns: percentage of children who remained in the same quartile, moved to a lower quartile, or moved to a higher quartile during 1991–1997[1]

	Tracked	Moved down	Moved up
		%	
All ($n = 975$)	40.2	28.9	30.9
Boys ($n = 524$)	42.0	28.1	30.0
Girls ($n = 451$)	38.1	29.9	31.9
Young children (6–9 y) ($n = 583$)	41.2	28.6	30.2
Older children (10–13 y) ($n = 392$)	38.8	29.3	31.9
Low income ($n = 325$)	41.1	32.5	26.4
Medium income ($n = 325$)	43.8	25.6	30.6
High income ($n = 325$)	35.7	28.6	35.7
Stratified by initial body composition			
1st quartile (lowest, thinnest group) ($n = 243$)	50.8	0	49.2
2nd quartile ($n = 244$)	32.8	22.9	44.3
3rd quartile ($n = 244$)	31.0	38.8	30.2
4th quartile (highest, fattest group) ($n = 244$)	46.3	53.7	0

[1] Based on relative-BMI quartiles in each year. Tracked, remained in the same quartile in both years; moved down, moved to a lower quartile by 1997; moved up, moved to a higher quartile by 1997.

TABLE 3
Tracking patterns of overweight and underweight[1]

	Tracked from 1991 to 1997 (prospectively)		Tracked from 1997 to 1991 (retrospectively)	
	Underweight (*n* = 169)	Overweight (*n* = 90)	Underweight (*n* = 149)	Overweight (*n* = 27)
	%		*%*	
All	32.5	6.7	36.9	22.2
Boys	39.1	10.8	37.5	35.7
Girls	24.7	2.3	35.9	7.7
Younger children (6–9 y)	40.0	3.1	30.0	11.1
Older children (10–13 y)	26.6	15.4	51.2	44.4
Rural residence	32.4	5.6	35.8	20.0
Urban residence	33.3	11.1	42. 3	28.6

[1] Overweight was defined according to the International Obesity Task Force reference (21); underweight was defined according to the National Center for Health Statistics age- and sex-specific 5th percentile of BMI (23). In 1997, for adolescents aged ≥18, BMI cutoffs of 25 (for overweight) and 18.5 (for underweight) were used. Percentages given are of children who maintained their initial status (underweight or overweight) over time. For example, 169 children were underweight in 1991, and 32.5% of them remained underweight in 1997; 149 children were underweight in 1997, and 36.9% of them were initially overweight in 1991.

weight; the ORs(95% CIs) were 0.3 (0.1, 0.6) and 0.4 (0.2, 0.8), respectively. Urban or rural residence, energy intake, and dietary quality did not predict tracking of fatness or underweight. Moreover, because family income was likely an important determinant of diet, we examined the effects of dietary intakes and dietary quality by excluding the income variables from our models. This did not change our results significantly, and the results are not presented.

The predictors of changes in relative BMI

We also studied the predictors of changes in relative BMI by using multiple linear regression models. An individual's 1997 relative BMI was regressed on baseline relative BMI and other covariates. After baseline relative BMI, age, sex, and energy and dietary fat intakes were controlled for, those children with ≥1 obese parent and those from higher-income families were likely to have an increase in their relative BMI (ie, to become fatter), but those with ≥1 underweight parent had a decrease in their relative BMI (ie, became thinner) (**Table 5**). These results were consistent with those achieved by our change model (in which change in an individual's relative BMI was used as the outcome variable), which explained 66.0% of the variation in the changes over a 6-y period.

DISCUSSION

This study fits into the literature on the tracking of body weight which has mainly focused on overweight status and the tracking patterns of overweight status of children or adolescents into adulthood. By examining the tracking of overweight status in a rapidly changing society, we have offered new insights into factors that might affect the dynamics of children's body weight status. We showed that, at the extreme classification of overweight status, a smaller proportion of Chinese children continue to be overweight than we find in higher-income countries. In addition, we examined tracking across the spectrum of BMI patterns and showed that about one-half of these Chinese children remained in either the lowest or the highest BMI quartile.

Compared with similar studies conducted over a much longer period, this study found that disproportionately fewer overweight children in China followed a trajectory to overweight status 6 y later. Although about one-half of these Chinese children

showed tracking of fatness (ie, they remained in the upper BMI quartiles) on the basis of the IOTF standard, of those initially overweight, only 7% remained overweight 6 y later. Studies in the United States and Europe that tracked obesity from childhood to adulthood from the 1960s to the present generally found that about one-third of overweight children remained overweight as adults, but the rate varies dramatically because of differences in how obesity is defined, the children's initial age, the length of follow-up, and parental obesity (2–11). The tracking patterns in this cohort may have been weakened by dramatic socioeconomic changes in China during the past 2 decades (29–32). The difference between the Chinese and the US and European tracking patterns may suggest that socioenvironmental factors affect the tracking of obesity in important ways.

TABLE 4
Logistic regression modeling: baseline predictors of tracking of fatness and underweight[1]

Predictors	OR (95% CI)
Tracking of fatness[2]	
Baseline relative BMI (per 10 percentage points of increase)	1.5 (1.4, 1.6)[3]
At least 1 obese parent (yes or no)	1.9 (1.1, 3.1)[4]
At least 1 underweight parent (yes or no)	0.8 (0.3, 1.6)
Low-fat diet (≤10% of energy)	2.2 (1.2, 4.0)[3]
Tracking of underweight[5]	
Baseline relative BMI (per 10 percentage points of increase)	0.1 (0.1, 0.2)[3]
≥1 obese parent (yes or no)	0.7 (0.1, 2.3)
≥1 underweight parent (yes or no)	2.2 (1.1, 4.4)[3]
Low-fat diet (≤10% of energy)	0.1 (0.01, 0.6)[4]

[1] Identical independent variables were included in the logistic regression models as predictors of tracking of fatness and tracking of underweight; initial age, total energy intake, high-fat diet (≥30% of energy), and family income were controlled for. OR, odds ratio.

[2] Tracking of fatness was defined for individuals who remained in the upper relative-BMI quartile between 1991 and 1997.

[3] $P < 0.001$.

[4] $P < 0.05$.

[5] Tracking of underweight was defined for individuals who were underweight in both 1991 and 1997.

TABLE 5
Linear regression modeling: baseline predictors of children's 1997 relative BMI[1]

Variable	Parameter ± SE
Intercept	91.45 ± 3.48[2]
Baseline relative BMI	0.13 ± 0.02[2]
≥1 obese parent (yes or no)	4.65 ± 1.31[2]
≥1 underweight parent (yes or no)	-2.76 ± 1.32[3]
Baseline family income (tertile)	1.38 ± 0.61[3]

[1] The coefficient also means 1 unit change in the independent variables [except for baseline relative BMI ($100\% \times$ BMI/sex- and age-specific BMI medians)] was associated with a certain percentage change in a child's relative BMI 6 y later because baseline relative BMI was controlled for in the model. Age, sex, and baseline energy and dietary fat intakes were controlled for in the model.
[2] $P < 0.001$.
[3] $P < 0.05$.

We found that the status of 33% of underweight children tracked over a 6-y period. Most of the research on tracking of underweight in lower-income countries has focused on catch-up growth in height. This study focused on low BMI as our definition of undernutrition. The standard literature on growth suggests that children became stunted during the preschool period followed by more normal growth for their height (33, 34). There is little understanding of the dynamics of undernutrition. A study of a 1958 British birth cohort, which defined undernutrition in terms of low weight-for-age and sex (the 5th percentile of relative median weight was used as the cutoff point), found that 30% of the children who were underweight at 7 y of age were still underweight at 23 y of age (35), but to our knowledge, no reported studies have examined tracking of underweight in lower-income countries, although there is abundant literature on studies of stunting. Given the high prevalence of undernutrition among children in most developing countries (eg, 17% of our subjects were underweight at baseline) and its serious adverse consequences (35–38), our findings suggest that, even in a country experiencing remarkable reductions in poverty and improvements in nutrition, it is crucial to prevent early childhood undernutrition or the effects will persist.

Studies in higher-income countries have rarely tried to examine socioenvironmental factors associated with tracking. This study looked at the role of several factors, including detailed measures of diet and socioeconomic status along with parental obesity and underweight as determinants of tracking. The few studies that examined determinants or correlates of tracking of fatness in higher-income countries suggested that the degree of fatness, timing of occurrence, sex, early adiposity rebound, and parental obesity are related to tracking, but the use of different standards to define obesity also affect the findings (2–11, 39, 40). As we have shown, although parental obesity was predictive, other important factors, such as diet and family income, affected the dynamics of children's body weight status. Interestingly, we found that compared with children who had a medium-fat diet, children with a low-fat diet were twice as likely to show tracking of fatness but less likely to show tracking of underweight. This may be because it was more difficult for those children who already had a low-fat diet at baseline to modify the fat content of their diet to reduce their energy intake, whereas it is very likely that the underweight children increased their energy intake by increasing the fat content of their diets. Studies in China showed that fat intake has increased remarkably during the past 2 decades (26, 41).

In addition, we found that overweight tracks in boys more consistently than in girls. There are several possible reasons for this phenomenon. First of all, boys may not have as great a concern about their body weight as do girls. Body image is more likely to be an important factor to urban Chinese girls according to recent in-depth focus groups and other qualitative studies we undertook. For example, the 1992 CNNS found more boys were overweight than were girls (26). Furthermore, a follow-up study in Beijing found that weight tracked more consistently in boys than in girls over an 8-y period (42). Second, this result may be due to the greater variation in the onset of puberty and the closer association between sexual maturation and change in fatness in girls. Finally, given the reality in China, it is possible that rural girls (three-fourths of our subjects were from rural areas) are more likely to have younger siblings than are boys. As a result, their parents may have fewer resources with which to raise them than do families with boys.

Another possible factor that may help explain the weaker tracking pattern of obesity is our use of the IOTF standard. It is possible that this standard misclassifies some Chinese adolescents (ie, the IOTF standard may have a lower sensitivity among Chinese adolescents than children, which might also help explain why the prevalence of overweight dropped considerably in this cohort from childhood to adolescence), but little research has been conducted on this topic. First, despite the increasing support for the development of an international BMI reference to define adolescent obesity, concerns have arisen about the validity of using references based on data from wealthy populations in some developing countries (23). Second, we did not consider sexual maturation patterns in this analysis because they are omitted from BMI standards, including the IOTF standard. This omission is important—we and others suggested in related research that Chinese adolescents mature later than did the IOTF reference populations (43–46). Moreover, many studies in China that used local standards suggested an increase in obesity (42, 47, 48). Overall, this study clarifies the importance of lifestyle factors, such as diet, as key determinants of the overweight and BMI trajectories that children follow.

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