Tracking of body mass index in children in relation to overweight in adulthood[1–3]

Shumei S Guo and William Cameron Chumlea

ABSTRACT   Body mass index (BMI; in kg/m^2) values at or above the 75th percentile are associated with increased morbidity and mortality in adulthood, and there are significant correlations between BMI values in childhood and in adulthood. The present study addresses the predictive value of childhood BMI for overweight at 35 ± 5 y, defined as BMI >28 for men and BMI >26 for women. Analyses of data from 555 white children showed that overweight at age 35 y could be predicted from BMI at younger ages. The prediction is excellent at age 18 y, good at age 13 y, but only moderate at ages <13 y. For 18-y-olds with BMIs above the 60th percentile, the probability of overweight at age 35 y is 34% for men and 37% for women. A clinically applicable method is provided to assign an overweight child to a group with a known probability of high BMI values in adulthood.   *Am J Clin Nutr* 1999;70(suppl):145S–8S.

KEY WORDS   Childhood BMI, adulthood overweight, body mass index, tracking

INTRODUCTION

The first, second, and third US National Health and Nutrition Examination Surveys (NHANES I, II, and III) indicate that a large number of Americans are obese (1–3). These national cross-sectional surveys revealed that overweight occurs at all ages, in men and women, and across ethnic groups. The prevalence of overweight is generally higher in blacks than whites (3). Overweight is related to cardiovascular disease, hypertension, and diabetes (the leading causes of morbidity and mortality in the United States) in adulthood (4–8). Overweight in childhood is also related to morbidity and mortality rates in adulthood (6) because both body weight and body composition in childhood are important determinants of overweight in adulthood (9, 10). The management of overweight and obesity in children should not be delayed until adulthood because then it is even more difficult to achieve lasting weight reductions (11, 12). The prevention or treatment of obesity requires the identification of individual children who would likely become overweight or obese in adulthood. The predictive value of overweight in childhood for overweight in adulthood helps in identifying children with a high probability of becoming overweight adults (13). This article discusses the use of body mass index (BMI; in kg/m^2) as an index of obesity, the tracking and predictive value of childhood BMI in adulthood, and the clinical and public health applications of tracking BMI.

BMI AS AN INDEX OF OBESITY

BMI is the most commonly used index of obesity and overweight. Weight and height are simple, reliable, and suitable measures for field studies and are included in almost all population and epidemiologic studies. BMI is closely related to body fatness in whites and in children and adults (14). Values for this index were compared with national reference data from NHANES II and the 85th percentile for BMI in these data during young adulthood has been recommended as the upper limit of normal for adults (15, 16). This corresponds to a BMI of 27.8 for males and 27.3 for females. Use of the 95th percentile to define obesity and the 85th to define overweight impose prevalence rates of 5% for obesity and 15% for overweight regardless of changes in body composition in the population. Most importantly, the choice of the 85th percentile is based neither on body-composition data nor on evidence that this is a threshold beyond which high BMI values are more closely associated with disease.

Definition of tracking

The concepts of tracking are summarized by Foulkes and Davis (17). The first concept refers to the prediction of future measures from earlier values (18, 19). The second is related to the constancy of an individual's expected measures relative to population percentiles (20–22). Tracking is determined by correlations between values at pairs of ages for the same individuals. Other tracking analyses concern "canalization," in which a canal is a zone between adjacent cross-sectional percentiles for a representative population plotted against chronologic age. *Canalization* is the tendency of all of an individual's serial measurements to be in the same canal of the population distribution. The significance of canalization can be determined for different canals, eg, the 75–95th percentile, by using a κ coefficient (23–24). For BMI, the population values can be obtained from National Center for Health Statistics surveys. Tracking can also

TABLE 1
Participants in 4 longitudinal studies categorized by BMI as low risk (BMI <28) or high risk (BMI ≥28) at age 35 y

Study and reference	Men		Women	
	Low risk	High risk	Low risk	High risk
The Fels Longitudinal Study (27)	92	20	93	18
Guidance (28)	53	2	52	3
Harvard (28)	43	8	46	6
Oakland (28)	54	5	54	4
Total	242	35	247	31

TABLE 2
Mean BMI values of participants in 4 longitudinal studies at ages 3, 8, 13, 18, and 35 y by sex and risk categories

| Age (y)	Males		Females	
	Low risk ($n = 242$)	High risk ($n = 35$)	Low risk ($n = 247$)	High risk ($n = 31$)
3	16 ± 1.2	17 ± 1.0	16 ± 1.4	17 ± 1.3
8	16 ± 1.9	17 ± 2.0	16 ± 1.6	18 ± 2.6
13	18 ± 2.4	22 ± 3.5	19 ± 2.6	22 ± 3.8
18	21 ± 2.1	25 ± 3.4	21 ± 2.1	26 ± 5.0
35	24 ± 2.2	30 ± 2.9	21 ± 2.0	30 ± 4.6

[1] $\overline{x}$ ± SD. Risk categories were assigned on the basis of BMI values at age 35 y, with BMIs <28 and <26 considered as low risk for males and females, respectively, and ≥28 and ≥26 considered as high risk in males and females, respectively. Data from references 27–29.

be measured by a *U* statistic based on a chi-square test of individual growth curves (17). This involves fitting a family of mathematical models to serial data for individuals, assuming that the individuals' true curves have a functional form. If the curves for all individuals are parallel within the time span of interest, there is perfect tracking. The fitted models can be used to calculate a future value or to predict risk of category membership. The accuracy of these predictions is an index of tracking.

Tracking BMI from childhood to adulthood

Correlation

In published studies, the tracking of BMI has emphasized correlations between childhood and adulthood values. BMI values during adulthood are largely independent of values during infancy, but they are related to BMI patterns of change by ≈6 y of age (8–10). A rapid change in BMI at ≈6 y of age is associated with high BMI values at 16 y of age (25). Other analyses have shown that patterns of change in BMI during later childhood and adolescence are closely related to those during early childhood (26).

Childhood BMI in relation to adulthood risk of obesity

Tracking in this article refers specifically to the prediction of future measures from earlier values (18, 19) by using data obtained from 277 white male and 278 white female participants in the Fels, Guidance, Harvard, and Oakland longitudinal studies (27–29). The number of participants in each study is given in **Table 1**. Annual data for height or recumbent length and weight from age 1 to 18 y and from age 30 to 39 y were included in the analysis. Recumbent length was used in place of height from age 1 to 3 y. Pooling of the 4 longitudinal studies was justified by the absence of significant differences between the coefficients of the study-specific logistic regressions. Childhood BMI values were converted to percentile levels for age and sex by using data from NHANES II (30). An average BMI value at age 35 y for an individual was obtained by averaging all available BMI values from 30 to 39 y of age. At age 35 y, BMIs ≥28 for men and ≥26 for women were the criteria for overweight.

The sample sizes and BMI means and SDs for each risk category at ages 3, 8, 13, 18, and 35 y are shown in **Table 2**. These ages were selected to represent early and late childhood, puberty, postpuberty, and adulthood. Risk categories were assigned on the basis of BMI values at age 35 y with BMI values <28 and <26 defined as low risk for men and women, respectively, and ≥28 and ≥26 considered as high risk in men and women, respectively. In both sexes, BMI values tended to increase with age in each risk category. In both risk categories in males and females

the high-risk group tended to have higher BMI values in childhood than did the low-risk group.

A logistic regression of overweight at age 35 y (BMI > recommended range) on BMI for each annual childhood age was performed separately for males and females. The predicted probabilities of overweight at age 35 y were calculated for childhood BMI values at the 95th percentile and are shown in **Figure 1**. For childhood BMI values at the 95th percentile, the probabilities of overweight at age 35 y increased by age. The probabilities were higher for boys than for girls until ≈8 y of age. The sex-associated differences in the probability of overweight at age 35 y were slight after age 8 y but varied with age.

The odds ratios of overweight for males at age 35 y with childhood BMI values at the 95th percentile compared with those with BMI values at the 75th percentile varied with age and doubled after ≈10 y of age (**Figure 2**). The corresponding odds ratio for girls doubled after ≈8 y of age. The odds of overweight at age 35 y of male and female participants who were at the 75th
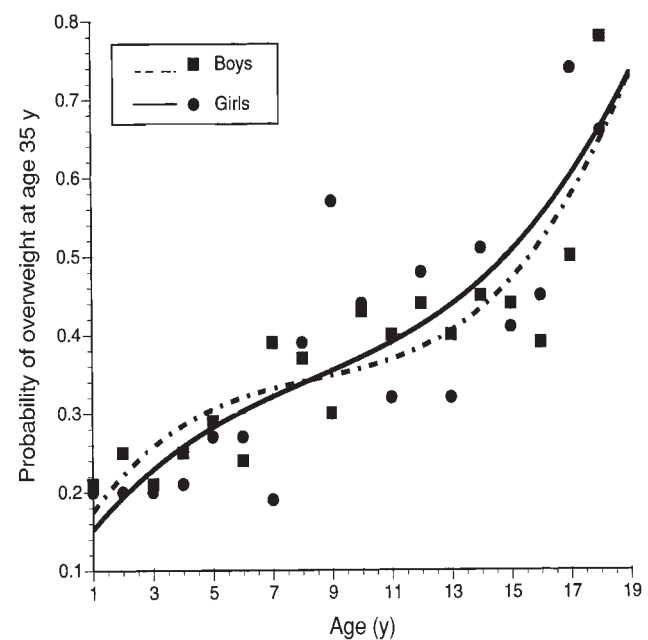
FIGURE 1. Probability of overweight at age 35 y predicted from childhood BMI at the 95th percentile.
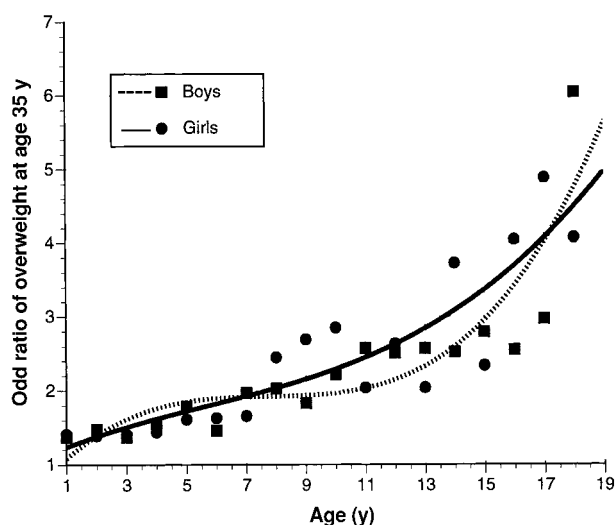
FIGURE 2. Odds ratios of overweight at age 35 y for boys and girls with BMIs at the 95th percentile compared with those of boys and girls with BMIs at 75th percentile.

percentile at the ages of 8–18 y were at least double those of participants with BMI values at the 50th percentile.

Sensitivity refers to the percentage of participants who were correctly predicted to be in the overweight group. *Specificity* refers to the percentage of participants who were correctly predicted to be in the remaining group. BMI values at the 60th percentile for age 18 y were chosen as cutoff points for identifying overweight at age 35 y because they had greater sensitivity and specificity than other percentiles in predicting adult obesity (13). The probability of overweight at age 35 y, predicted from BMI values at or above the 60th percentile at age 18 y, was 0.34 for males (22 of 64 subjects) and 0.37 for females (19 of 51 subjects) (**Table 3**). The sensitivities were 0.81 for males and 0.86 for females, and the specificities were 0.77 for males and 0.81 for females (Table 3). With use of the cutoff point of the 60th percentile at age 18 y, the odds ratios of overweight at age 35 y were ≈15 for males and 27 for females, and corresponding SEs were 1.9 and 3.5, respectively.

Applications of findings

The odds of overweight in adulthood for those with childhood BMI values at the 95th percentile were ≈1.3–6.1 and 1.4–4.9 times as great as for those with BMI values at the 75th percentile for males and females, respectively. The sensitivity and specificity of selected childhood cutoff points in relation to adulthood overweight were analyzed for age at 18 y; the same method could be applied to establish the cutoff points for other ages. This cutoff point could facilitate public health screening programs by detecting children with a high probability of being overweight at age 35 y.

Reference percentiles (75th, 85th, and 95th) from NHANES II data for BMI at ages 2–18 y for white girls and boys are shown in **Figure 3** (30), as well as the likelihood of being overweight at age 35 y based on their BMI percentile level during childhood. The lines indicating the 75th, 85th and 95th percentiles in these figures are shaded differentially to indicate age ranges during which the probability of overweight at 35 y was either <20%, 20–29.9%, 30–39.9% or 40–80%. For example, a 12-y-old girl with a BMI of 26.5 is at the 95th percentile for national data. Her BMI value is near the upper end of the distribution for the general US population of white girls. Only 5 of 100 girls her age have BMI values higher than 26.5, and this group of overweight girls has a 40–80% probability of being overweight at age 35 y.

Future research directions

The present study discussed tracking in BMI from early childhood into adulthood and subsequent risk of obesity in white populations. Extension of this study to other populations such as African American, Asian, and Hispanic populations deserves a high priority. There is general agreement on the use of BMI with selected cutpoints as guidelines for desirable weight, and this consensus will provide a basis for assessment of overweight and obesity, which is important in scientific research and in public health programs.

BMI is a simple, reliable measure of levels of body fatness. However, the correlations between BMI and amount or percentage of body fat vary among studies and ethnic groups. Because of the difficulty in obtaining long-term values for body fatness collected using direct body-composition methods, longitudinal studies for tracking body fat are few. Further research in all these areas is needed.

TABLE 3
Sensitivity, specificity, and odds ratios of the selected cutoff point for BMI values at the 60th percentile at age 18 y for identifying overweight at age 35 y[1]

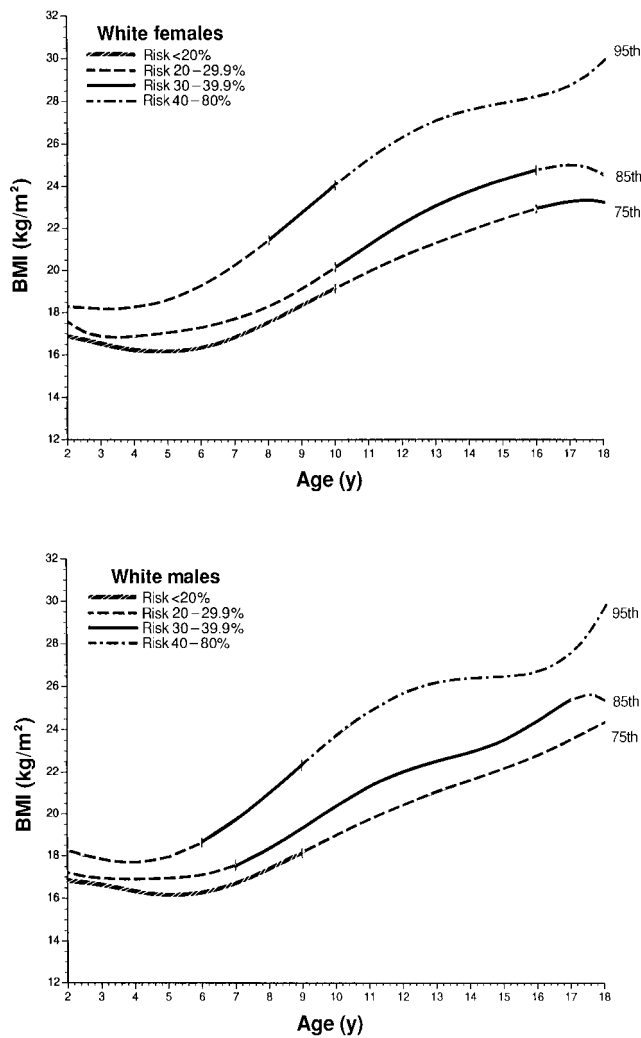| BMI at age 35 y | BMI percentile at age 18 y | | Sensitivity | Specificity | Odds ratio |
	<60th	≥60th			
Males					
<28 (n = 184)	142	42		0.77[2]	
≥28 (n = 27)	5	22	0.81[3]		
Total (n = 211)	147	64			14.9
Females					
<26 (n = 172)	140	32		0.81[4]	
≥26 (n = 22)	3	19	0.86[5]		
Total (n = 194)	143	51			27.2

[1] Data from references 27–29.
[2] 142 of 184 subjects.
[3] 22 of 27 subjects.
[4] 140 of 172 subjects.
[5] 19 of 22 subjects.

FIGURE 3. Selected percentiles of BMI from the second National Health and Nutrition Examination Survey (30). Segments of the 75th, 85th and 95th percentile lines are shaded differentially to indicate differences in the risk of overweight, ie, that BMI at 35 y will be ≥26 and ≥28 in females and males, respectively.

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