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PREDICTING OBESITY IN YOUNG ADULTHOOD FROM CHILDHOOD AND PARENTAL OBESITY

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ABSTRACT

Background Childhood obesity increases the risk of obesity in adulthood, but how parental obesity affects the chances of a child's becoming an obese adult is unknown. We investigated the risk of obesity in young adulthood associated with both obesity in childhood and obesity in one or both parents.

Methods Height and weight measurements were abstracted from the records of 854 subjects born at a health maintenance organization in Washington State between 1965 and 1971. Their parents' medical records were also reviewed. Childhood obesity was defined as a body-mass index at or above the 85th percentile for age and sex, and obesity in adulthood as a mean body-mass index at or above 27.8 for men and 27.3 for women.

Results In young adulthood (defined as 21 to 29 years of age), 135 subjects (16 percent) were obese. Among those who were obese during childhood, the chance of obesity in adulthood ranged from 8 percent for 1- or 2-year-olds without obese parents to 79 percent for 10-to-14-year-olds with at least one obese parent. After adjustment for parental obesity, the odds ratios for obesity in adulthood associated with childhood obesity ranged from 1.3 (95 percent confidence interval, 0.6 to 3.0) for obesity at 1 or 2 years of age to 17.5 (7.7 to 39.5) for obesity at 15 to 17 years of age. After adjustment for the child's obesity status, the odds ratios for obesity in adulthood associated with having one obese parent ranged from 2.2 (95 percent confidence interval, 1.1 to 4.3) at 15 to 17 years of age to 3.2 (1.8 to 5.7) at 1 or 2 years of age.

Conclusions Obese children under three years of age without obese parents are at low risk for obesity in adulthood, but among older children, obesity is an increasingly important predictor of adult obesity, regardless of whether the parents are obese. Parental obesity more than doubles the risk of adult obesity among both obese and nonobese children under 10 years of age. (N Engl J Med 1997;337:869-73.)

THE prevalence of obesity has increased in both children and adults.[1,2] The medical illnesses associated with obesity[3] usually occur in adulthood, but adults rarely achieve sustained weight loss.[4] Therefore, prevention of obesity in childhood and effective treatment of overweight children are essential. Although several studies have tracked fatness from childhood to adulthood,[5-11] only one study contained data on subjects' height and weight throughout childhood.[11] Whether parental obesity alters the probability that a child will become an obese adult is not known.

The purpose of this study was to determine the probability of obesity in young adulthood in relation to the presence or absence of obesity at various times throughout childhood and the presence or absence of obesity in the child's parents. We hypothesized that the probability that a child would become an obese adult depends on the presence of both childhood and parental obesity and that the effects of these two factors on the risk of obesity in adulthood differ according to the age of the child.

METHODS

In this retrospective cohort study, we abstracted height and weight measurements from the outpatient medical records of a cohort of young adults and their parents who were long-term members of Group Health Cooperative of Puget Sound, a staff-model health maintenance organization established in 1947 in Washington State.

Selection of Subjects

Using computerized enrollment and outpatient-visit data bases, we identified all 1333 members who were born at the cooperative

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in 1965 through 1970 and who had at least one outpatient visit each after the age of 21 years. The majority of the subjects had received health care at the cooperative all their lives, and most outpatient visits were for routine health care and minor illnesses. The medical records of eight subjects could not be located or were partially missing. Among the remaining 1325 subjects, 854 (64 percent) met the following criteria for inclusion in the study cohort: at least one weight measurement at the age of 21 years or older, at least one height measurement at the age of 18 years or older for men and at the age of 16 years or older for women, no chronic condition that might affect stature or weight (e.g., cancer or inflammatory bowel disease), and birth at a gestational age of 36 weeks or more. The parents of all 854 subjects were Group Health Cooperative members. Two pairs of parents each had three adult children in the cohort, and 56 pairs of parents each had two. Thus, 118 subjects (14 percent) had at least one sibling each in the cohort. Among the 794 pairs of parents, we located records for 747 mothers (94 percent) and 699 fathers (88 percent).

Outcome Measures

All height and weight measurements recorded before January 1, 1994, were abstracted unless these measurements were from a visit to the emergency department or the subject was pregnant. For each subject, we calculated the average body-mass index (the weight in kilograms divided by the square of the height in meters) between 21 and 29 years of age. Adult obesity was defined as an average body-mass index ≥27.8 for men and ≥27.3 for women.[12]

Obesity in Childhood

We also defined childhood obesity in terms of the body-mass index, because it is the best and most widely used surrogate measure of adiposity among indexes derived from height and weight measurements.[13,14] The body-mass index in children is correlated with direct measures of adiposity,[15] blood pressure,[16] and serum concentrations of lipids[17] and insulin.[18] Although there is no established cutoff point for childhood obesity,[19] we classified subjects with a body-mass index at or above the 85th percentile for age and sex as obese and those with a body-mass index at or above the 95th percentile as very obese. We used as reference standards the 85th and 95th percentiles for body-mass index in the combined data of the First and Second National Health and Nutrition Examination Surveys.[20]

We defined five consecutive age intervals from 1 to 18 years of age (Table 1). The first interval, for example, included all measurements between the first and third birthdays. For each subject, all body-mass-index values (calculated from height and weight recorded on the same date) were standardized for age and sex by conversion to a z score. The z score was calculated as follows: (body-mass index − mean)/standard deviation; the mean and standard deviation for the body-mass index were from the chosen reference population of the same age and sex as the subject.[20] Means and standard deviations for the body-mass index at specific ages (e.g., 3.2 years) were found by linear interpolation between the discrete ages (e.g., 3 years and 4 years) given in the reference data. We calculated the average z score for the body-mass index for each subject during each interval by the method described below. We classified a subject as obese during an interval if the average z score for the body-mass index was ≥1.036 and as very obese if the average was ≥1.645. These z scores correspond to the 85th and 95th percentiles, respectively, of a normal distribution.

Parental Obesity

If a parent's record contained an adult height, then that height was used to calculate the body-mass index for all recorded parental weights. The parent's body-mass index was then estimated on the five dates when the subject reached the midpoint in each of the five age intervals. For the age interval one through two years, for example, we estimated each parent's body-mass index on the date of the subject's second birthday. To estimate the body-mass index, we used linear interpolation between values calculated for the parent before and after that date. Parental obesity was defined as a body-mass index ≥27.8 for fathers and ≥27.3 for mothers.

Statistical Analysis

We computed a weighted average of the body-mass-index values for each subject during each childhood age interval and in adulthood (at 21 through 29 years of age). The weighting was based on the time between the available values. Values closely spaced in time received less weight than widely spaced values, so that the average would not be unduly influenced by the values clustered close together in time. The formula used for the average was as follows:

$$\sum_{i=1}^{K+1} \frac{1}{2}(\mathrm{BMIz}(t_i) + \mathrm{BMIz}(t_{i-1}))(t_i - t_{i-1})/(t_{K+1} - t_0),$$

when the ages at which body-mass indexes were measured were $t_i, \ldots t_K$ and where t_0 and t_{K+1} denoted the end points of the time interval.

For each age interval, associations between obesity in young

Table 1. Availability of Data on Body-Mass Index (BMI) and the Prevalence of Obesity in 854 Subjects at Various Ages, Their Mothers, and Their Fathers.*

Age Category	Age Interval (yr)	Subjects			Mothers		Fathers	
		No. (%) with BMI values	Median no. of BMI values (range)	No. (%) obese	No. (%) with BMI data	No. (%) obese	No. (%) with BMI data	No. (%) obese
Toddler	1–2	775 (91)	3 (1–8)	73 (9)	660 (77)	85 (13)	553 (65)	98 (18)
Preschool	3–5	750 (88)	2 (1–16)	86 (11)	701 (82)	104 (15)	598 (70)	123 (21)
Before puberty	6–9	638 (75)	2 (1–9)	80 (13)	742 (87)	131 (18)	646 (76)	149 (23)
Puberty	10–14	695 (81)	2 (1–13)	61 (9)	771 (90)	177 (23)	689 (81)	184 (27)
After puberty	15–17	577 (68)	2 (1–11)	55 (10)	782 (92)	233 (30)	712 (83)	221 (31)
Young adulthood	21–29	854 (100)	3 (1–29)	135 (16)	—	—	—	—

*In calculating numbers and percentages for mothers and fathers, each subject's parents were counted; thus, some mothers and fathers with more than one child in the cohort were counted more than once.

TABLE 2. ODDS RATIOS FOR OBESITY IN YOUNG ADULTHOOD ACCORDING TO THE CHILD'S AGE AND THE OBESITY STATUS OF THE CHILD AND THE PARENTS.

VARIABLE	NO. OF SUBJECTS OBESE AS ADULTS/ TOTAL NO. (%)	ODDS RATIO (95% CI)*
Subject's age and obesity status		
1–2 yr		
Not obese	106/702 (15)	1.0
Obese or very obese	14/73 (19)	1.3 (0.7–2.5)
Very obese	5/19 (26)	2.0 (0.7–5.7)
3–5 yr		
Not obese	80/664 (12)	1.0
Obese or very obese	31/86 (36)	4.1 (2.5–6.7)
Very obese	14/27 (52)	7.9 (3.6–17.3)
6–9 yr		
Not obese	59/558 (11)	1.0
Obese or very obese	44/80 (55)	10.3 (6.2–17.3)
Very obese	24/35 (69)	18.5 (8.8–38.8)
10–14 yr		
Not obese	62/634 (10)	1.0
Obese or very obese	46/61 (75)	28.3 (15.0–53.5)
Very obese	24/29 (83)	44.3 (16.3–120)
15–17 yr		
Not obese	48/522 (9)	1.0
Obese or very obese	37/55 (67)	20.3 (10.4–39.6)
Very obese	23/30 (77)	32.5 (13.1–80.6)
Subject's age and mother's obesity status		
1–2 yr		
Mother not obese	73/575 (13)	1.0
Mother obese	29/85 (34)	3.6 (2.1–5.9)
3–5 yr		
Mother not obese	77/597 (13)	1.0
Mother obese	36/104 (35)	3.6 (2.2–5.7)
6–9 yr		
Mother not obese	76/611 (12)	1.0
Mother obese	42/131 (32)	3.3 (2.2–5.1)
10–14 yr		
Mother not obese	73/594 (12)	1.0
Mother obese	53/177 (30)	3.1 (2.0–4.6)
15–17 yr		
Mother not obese	65/549 (12)	1.0
Mother obese	64/233 (27)	2.8 (1.9–4.1)
Subject's age and father's obesity status		
1–2 yr		
Father not obese	55/455 (12)	1.0
Father obese	28/98 (29)	2.9 (1.7–4.9)
3–5 yr		
Father not obese	56/475 (12)	1.0
Father obese	34/123 (28)	2.9 (1.8–4.6)
6–9 yr		
Father not obese	60/497 (12)	1.0
Father obese	40/149 (27)	2.7 (1.7–4.2)
10–14 yr		
Father not obese	62/505 (12)	1.0
Father obese	46/184 (25)	2.4 (1.6–3.7)
15–17 yr		
Father not obese	54/491 (11)	1.0
Father obese	56/221 (25)	2.7 (1.8–4.1)

*For all odds ratios, the nonobese group served as the reference group. CI denotes confidence interval. The subject's obesity status during childhood is based on the mean z score for the child's body-mass index during the age interval, as follows: not obese, $z<1.036$ (corresponding to the 85th percentile for a normal population of the same age and sex); obese, $z\geq1.036$ (85th percentile); and very obese, mean $z\geq1.645$ (95th percentile).

adulthood and both childhood and parental obesity were tabulated and analyzed by logistic-regression analysis. Regression parameters for these models were estimated with the generalized-estimating-equation method of Liang and Zeger,[21] which incorporates adjustments for correlations between data from siblings.

RESULTS

Ninety-four percent of the 854 subjects were non-Hispanic whites, 64 percent were female, and 93 percent were born to married mothers. More women than men met the inclusion criteria for the study, because in young adulthood women are more likely to use health care services.[22] At the time of the subjects' births, the mean ages of their mothers and fathers were 29 and 32 years, respectively.

The 854 subjects had a median of nine body-mass-index values from 1 through 17 years of age; the last value was at a mean age of 24.5 years. The prevalence of adult obesity in the cohort (16 percent) (Table 1) was near the current value for the prevalence of obesity in 20-to-29-year-old non-Hispanic white subjects in the United States (18 percent).[1] The prevalence of obesity in the parents increased with age and reached 30 percent when their children were 15 to 17 years of age; this figure is near the current prevalence of obesity in older U.S. adults.[1]

The probability of being obese as a young adult increased with the age of the obese child and was higher at all ages for the group of very obese children (Table 2). After six years of age, the probability of obesity in adulthood exceeded 50 percent for obese children, as compared with about 10 percent for nonobese children. Obesity at one or two years of age was not associated with an increased risk of adult obesity. Overall, there were no significant differences between the sexes in the risk of adult obesity associated with childhood obesity (data not shown). The risk of adult obesity was significantly greater if either the mother or the father was obese (Table 2). There were no significant differences in these risk estimates between boys and girls (data not shown). Although the odds ratios for obesity associated with maternal obesity were slightly higher than was the case for paternal obesity, the differences between these risk estimates were not statistically significant for any age interval.

Subjects were included in Tables 3 and 4 only if data on obesity were also available for their parents. There was no significant difference in the rates of obesity in adulthood between subjects with and those without data on parental obesity. At every age interval, both obese and nonobese children were at greater risk for obesity as adults if at least one parent was obese. The effect of parental obesity on the risk of obesity in adulthood was most pronounced among obese and nonobese children under 10 years of age. For example, among nonobese one- and two-year-olds, those with at least one obese parent had a

TABLE 3. PREVALENCE OF OBESITY IN YOUNG ADULTHOOD ACCORDING TO SUBJECTS' OBESITY STATUS IN CHILDHOOD AND THEIR PARENTS' OBESITY STATUS.*

AGE (YR)	SUBJECT NOT OBESE IN CHILDHOOD		SUBJECT OBESE OR VERY OBESE IN CHILDHOOD		SUBJECT VERY OBESE IN CHILDHOOD	
	NEITHER PARENT OBESE	≥1 PARENT OBESE	NEITHER PARENT OBESE	≥1 PARENT OBESE	NEITHER PARENT OBESE	≥1 PARENT OBESE
	number of obese subjects/total number of subjects (percent)					
1–2	30/298 (10)	28/101 (28)	2/25 (8)	6/15 (40)	1/7 (14)	2/5 (40)
3–5	23/298 (8)	29/125 (23)	8/34 (24)	13/21 (62)	4/12 (33)	5/6 (83)
6–9	21/281 (7)	23/132 (17)	10/27 (37)	20/28 (71)	6/11 (55)	10/13 (77)
10–14	24/317 (8)	28/188 (15)	7/11 (64)	31/39 (79)	3/4 (75)	18/22 (82)
15–17	12/248 (5)	26/187 (14)	7/13 (54)	24/33 (73)	3/5 (60)	17/21 (81)

*Young adulthood was defined as 21 to 29 years of age. Subjects were included in this analysis only if data on obesity were available for both their parents.

TABLE 4. ODDS RATIOS FOR OBESITY IN YOUNG ADULTHOOD ACCORDING TO SUBJECTS' OBESITY STATUS IN CHILDHOOD AND THEIR PARENTS' OBESITY STATUS, FROM MULTIVARIATE LOGISTIC-REGRESSION MODELS.*

AGE (YR)	SUBJECT OBESE AS A CHILD	NO. OF OBESE PARENTS	
	YES VS. NO	1 VS. 0	2 VS. 0
	odds ratio (95% confidence interval)		
1–2	1.3 (0.6–3.0)	3.2 (1.8–5.7)	13.6 (3.7–50.4)
3–5	4.7 (2.5–8.8)	3.0 (1.7–5.3)	15.3 (5.7–41.3)
6–9	8.8 (4.7–16.5)	2.6 (1.4–4.6)	5.0 (2.1–12.1)
10–14	22.3 (10.5–47.1)	2.2 (1.2–3.8)	2.0 (0.8–5.2)
15–17	17.5 (7.7–39.5)	2.2 (1.1–4.3)	5.6 (2.5–12.4)

*Young adulthood was defined as 21 to 29 years of age. The variables included in the model were childhood obesity status (obese or not obese) and the number of obese parents (0, 1, or 2). See the Methods section for an explanation of adjustments for siblings.

greater chance of being obese as adults than those without an obese parent (28 percent vs. 10 percent), and among obese three-to-five-year-olds, the chance of adult obesity increased from 24 percent if neither parent was obese to 62 percent if at least one parent was obese (Table 3). Very obese children with at least one obese parent had the highest risk of adult obesity.

Before three years of age, the primary predictor of obesity in adulthood was the parents' obesity status; the child's obesity status was not an indicator of the risk of adult obesity (Table 4). For children three through nine years of age, the child's and the parents' obesity status were both important predictors, but as the child aged, the child's obesity status became the more important predictor. Especially before six years of age, obesity in both parents substantially increased the odds of the child's becoming an obese adult.

Among children who were obese in any age interval, neither the age of onset nor the duration of obesity increased the risk of adult obesity after adjustment for parental obesity and for whether or not the child was very obese (data not shown).

DISCUSSION

Advancing knowledge about the molecular mechanisms and genetics of obesity[23] supports the results of observational studies that have revealed an inherited susceptibility to obesity.[24,25] Although the parents' body-mass indexes are a readily available marker for the susceptibility to obesity, the probability that a child will become an obese adult if at least one parent is obese has not previously been estimated. We found that parental obesity significantly alters the risk of obesity in adulthood for both obese and nonobese children, especially those under 10 years of age. Obesity in one or both parents probably influences the risk of obesity in their offspring because of shared genes or environmental factors within families.

Direct comparison of our results with those of other studies[5-11] is difficult because of differences in the birth years of the cohorts, the ages at which examinations were performed, the methods used for the measurement of adiposity, the definitions of obesity, and the reference populations used to adjust measurements for age and sex.[26] Because our height and weight measurements were obtained from clinical records, they lack the precision that could be obtained in a prospective study. However, any errors in these measurements are likely to have been random.

We caution against interventions to treat overweight children under three years of age who do not have obese parents. Physicians should avoid labeling these children as being at risk for later obesity, because few of them will become obese adults. In contrast, any one- or two-year-old who has an obese

parent, especially any who has two obese parents, appears to be susceptible to obesity in young adulthood. One- and two-year-olds with an obese parent may benefit most from efforts to prevent obesity, but it remains unclear what factors in the environments of these children contribute to the expression of obesity. These factors, once identified, may present reasonable targets for prevention trials.

Obese three-through-nine-year-olds with obese parents may be ideal candidates for treatment because the parents still have the opportunity to influence their children's activity and diet positively.[27] However, because many obese children, if left untreated, will not become obese adults, treatment trials should be designed to consider the benefits and risks, both physical and psychological, of any interventions. Between 10 and 17 years of age, parental obesity has a much more limited effect on a child's risk of future obesity. Decisions to treat overweight children after they reach 10 years of age can be made primarily on the basis of the child's obesity status.

This study demonstrates the importance of parental obesity in predicting children's risk of obesity in adulthood. Several studies now indicate that obesity in young adult life is associated with increased morbidity[28,29] and mortality.[30,31] Furthermore, excessive weight during adolescence predicts a number of adverse effects on health later in life, including increased mortality among men.[32]

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