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Tracking of Obesity in Childhood into Adulthood: Effects on Body Mass Index and Fat Mass Index at Age 50

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Abstract

Background: Obesity is present in 17% of US youth, age 2–19 years, but the extent to which obesity in childhood is associated with higher BMI and fat mass in middle age is unclear. In this study, links between childhood body size and BMI and body composition at age ∼50 were assessed.

Methods: Child Health and Development Studies participants, born between 1960 and 1963 in Alameda County, and still living in California, from whom anthropometric data were collected at age 5, 9–11, and/or 15–17 years were followed-up at age ∼50 for anthropometric outcomes (251 women; 249 men). Linear regression analyses assessed whether overweight (85th to <95th BMI percentile) or obesity (≥95th BMI percentile) at age 5 were associated with BMI, fat mass index (FMI), and lean mass index (LMI) at age ∼50.

Results: At age 50, participants with obesity at age 5 had BMI scores that were 6.51 units higher [95% confidence interval (CI) = 3.67–9.35] than participants who were normal weight at age 5; FMI and LMI scores were 4.15 (95% CI = 1.98–6.32) and 2.36 (95% CI = 1.45–3.26) units higher, respectively. However, obesity experienced at age 5 had only a modest positive predictive value for predicting the presence of obesity at age 50 (67%), whereas obesity present at age 15–17 had a higher positive predictive value (86%).

Conclusions: The experience of obesity at age 5 for members of this birth cohort was associated with significantly higher BMI, FMI, and LMI at age ∼50.

Keywords: adult body composition; adult BMI; childhood obesity

Introduction

In the United States it is estimated that obesity is present in 35% of adults and 17% of youth, defined as individuals between the age of 2 and 19 years.[1] Simulation analyses of the effects of the obesity epidemic on health burdens and life expectancy often note the rise of childhood obesity over the past three decades and argue that as a result, recent generations will suffer the burden of obesity for a larger proportion of their lives than past generations.[2–5] This logic implies that a child's overweight or obesity status will continue into adulthood, and indeed there is a relatively large literature, 23 identified studies in the most recent meta-analysis, showing the tracking into adulthood of higher BMI, overweight, and obesity present in childhood.[6–9] However, the literature finds that the sensitivity and positive predictive value of the presence of childhood overweight and obesity as a predictor of the presence of

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obesity in adulthood is low, although the specificity and negative predictive value are high.[9,10]

In this study, we use the Child Health and Development Studies (CHDS), a birth cohort study that began in the 1960s, and its adult follow-up study, the CHDS Disparities Study, to expand upon this literature in several ways.[11] We assess how BMI, overweight, and obesity status at age 5 in this cohort is associated with BMI and fat mass index (FMI) at age ∼50 years. Most previous studies assessed obesity outcomes only until late teens years or relatively young adulthood and there are few studies where BMI or obesity were ascertained in middle or older ages, when obesity-related health conditions begin to manifest.[9,12] Second, the literature has focused on obesity in adulthood as defined by BMI-based cut-points and more health-relevant anthropometric outcomes such as body composition have not been assessed. Here we analyze how much of the additional adult BMI associated with the presence of obesity in childhood is the result of higher fat mass in adulthood.

Methods

The CHDS Disparities Study followed-up, at approximately age 50 years, the adult offspring of families enrolled in the CHDS. The CHDS and the Disparities Study were previously extensively described and key elements of this study are described here.[11,13] Virtually all pregnant women receiving prenatal care from the Kaiser Foundation Health Plan at its facilities in Alameda County, California, were recruited to the CHDS (19,044 live births 1959–1967).[13] Follow-up examinations of offspring occurred at age 5, 9–11, and 15–17 years and the CHDS The Adolescent Study, based on all CHDS births that occurred from 1960 to 1963, includes participants with the maximum number of time points of observation during childhood, 87% were observed at birth, and at age 5, 9–11, and 15–17.[13] Recruitment into the CHDS Disparities Study has been extensively described previously.[11] In brief, a preliminary eligibility pool of 3196 participants for the CHDS Disparities Study was defined as follows: (1) a 50% random sample of nonblack male and female participants in the CHDS Adolescent Study; (2) 100% of black male and female participants in the CHDS Adolescent Study; and (3) to meet enrollment targets a supplementary sample of 100% of black male and female participants in other CHDS follow-up studies with examination data at age 5 or age 9–11. Recruitment at age 50 was limited to those still living in California owing to the difficulty and cost of implementing home visits nationwide. From the preliminary edibility pool, 635 participants were excluded because they did not reside in California and 47 were excluded because they were deceased. Sex by race sampling strata were established from the remaining pool of 2514 participants, and individuals from these 4 strata were randomly selected for attempted contact and recruitment into the study until attaining the desired sample in each stratum. Target sample sizes of 350 (achieved = 353) adults born to nonblack CHDS mothers and 250 (achieved = 252) adults born to black CHDS mothers, distributed evenly by gender, were achieved after attempting to contact through telephone 985 of the 1633 who were sent a recruitment letter from among the 2514 in the eligible pool (Recruitment flow charts are provided in Link et al.).[11]

Of the 605 individuals who participated in the telephone interview, 510 (84%) completed a home visit and 497 (82%) a self-administered questionnaire containing extensive psychosocial assessments. Those who participated in the CHDS Disparities Study were similar in demographic characteristics to eligible CHDS participants who did not participate in CHDS Disparities Study, and health disparities observed in the CHDS Disparities Study are similar to those observed in National Health and Nutrition Examination Survey (NHANES) data.[11] This study was approved by the CHDS and Columbia University Medical Center IRB.

Archived data were available for participant's birth weight, paternal and maternal educational attainment at the time of the offspring's birth and maternal prepregnancy height and weight. During the CHDS Disparities Study telephone interview, the participants reported their own educational attainment. Archived clinically measured height and weight data and age at assessment from the CHDS follow-up studies were used to calculate BMI z-scores at age 5, 9–11, and 15–17 years using the CDC 2000 Growth Charts SAS Macro. Childhood obesity was defined as a BMI percentile at or above the 95th percentile and childhood overweight was defined as a BMI percentile at or above the 85th percentile and below the 95th percentile. Adult height and weight at age ∼50 years were measured during the CHDS Disparities Study home visit, with each measure taken in duplicate and the mean of those measures use to calculate BMI as weight in kg/height in meters squared. Obesity in adulthood was defined as a BMI of 30 or over and the presence of overweight was defined as a BMI from 25 to <30. Participant fat mass and lean mass were also measured during the home visit using a Tanita Bio-impedance scale. FMI was calculated as fat mass in kg/height in meters squared and lean mass index (LMI) was calculated as lean mass in kg/height in meters squared. In total, BMI data at age ∼50 years were available from 507 participants and of these participants, anthropometric data were available for at least one of the follow-ups during childhood (age 5, 9–11, or 15–17) for 500 (251 women and 249 men) and these 500 individuals constitute the analytical sample for this report.

Statistical Analyses

Among subjects for whom height and weight data were available at age ∼50, height and weight data were available for 400 subjects at age 5 and some data were missing for anthropometric measures collected at age 9–11 and 15–17 years and for the other covariates (Table 1). Using the imputation strategy developed for imputing BMI in this

Table 1. Sociodemographic and Anthropometric Characteristics of the Cohort

	Male ($n=249$)	Female ($n=251$)
	n (%)	
Mother's race		
Nonblack	145 (58)	148 (59)
Black	104 (42)	103 (41)
Participant's education		
Less than college	152 (61)	129 (52)
College or more	97 (39)	120 (48)
Paternal education		
Less than high school	38 (16)	49 (20)
High school or special schooling	85 (35)	67 (27)
Some college	63 (26)	55 (22)
College graduate	58 (24)	74 (30)
Body size at age 5 years		
Normal weight	166 (82)	159 (80)
Overweight	24 (12)	32 (16)
Obese	12 (6)	7 (4)
Body size at age 9–11 years		
Normal weight	181 (85)	198 (80)
Overweight	22 (10)	29 (12)
Obese	9 (4)	20 (8)
Body size at age 15–17 years		
Normal weight	161 (88)	174 (83)
Overweight	15 (8)	23 (11)
Obese	8 (4)	12 (6)
Body size at age ~50 years		
Normal weight	47 (19)	71 (28)
Overweight	105 (42)	69 (27)
Obese	97 (39)	111 (44)
	Mean (standard deviation)	
BMI (kg of weight/m^2) at age ~50 years	29.27 (5.34)	30.30 (7.91)
FMI (kg fat tissue/m^2) at age ~50 years	8.60 (4.39)	12.56 (5.83)
LMI (kg lean tissue/m^2) at age ~50 years	20.68 (1.90)	17.66 (2.28)

FMI, fat mass index; LMI, lean mass index.

data set, multiple imputations by chained equations (70 data sets) was used to impute missing values for BMI z-score data and covariate data for the 500 subjects.[14,15] The details and performance of the multiple imputation strategy have been reported extensively previously.[15]

Linear regression analyses were used to assess the associations between overweight and obesity present at age 5 and BMI at age ~50 years and the association between BMI z-score at age 5 and BMI at age ~50 years. Both paternal and maternal education were assessed as predictors of study participant BMI at age ~50 and paternal education was found to be a significant predictor while maternal education was not; thus, paternal education was used as the primary measure of family socioeconomic status. The primary analyses adjusted for paternal education at the time of the participant's birth, maternal prepregnancy BMI, maternal race, and the participant's gender, own educational attainment and age at adult follow-up. Additional models further adjusted for participant birth weight and maternal education. The children of black mothers were oversampled for follow-up; however, as making inferences regarding the entire CHDS was not one of the goals, sample weights were not used in analyses. The linear regression analyses of the association between age 5 body size and age ~50 BMI were repeated using FMI and LMI at age ~50 as the outcomes. The linear regression analyses were repeated for men and women separately. As this stratification resulted in small cell sizes for obesity at age 5, obesity or overweight present at age 5 were pooled and associations between being overweight/obese verses normal weight at age 5 and BMI at age ~50 were analyzed. Model residuals for each imputed data set were analyzed to assess possible nonheteroscedasticity, nonlinearity, and non-normality of the residuals, and linear regression model assumptions appear to have been met.[16] Results from each imputed data set were pooled following Rubin's Rules and pooled results were calculated using SPSS V24.[17]

Spearman correlation analyses were used to assess the association between body size categories in childhood and body size categories in adulthood. Pooled 2×2 table data from the multiple imputation data sets were used to estimate the sensitivity, specificity, and positive and negative predictive value of obesity status and combined overweight and obesity status at age 5, 9–11, and 15–17 to predict the presence of obesity at age ~50 years. For example, considering obesity present at age 5 as a predictor of obesity being present at age 50: sensitivity was defined as among those experiencing obesity at age ~50 years, the proportion with obesity at age 5; specificity was defined as among those who were not experiencing obesity at age ~50, the proportion who were not classified as obese at age 5; positive predictive value was defined as among those who experienced obesity at age 5, the proportion for whom obesity was present at age 50; and negative predictive value was defined as among those who were not experiencing obesity at age 5, the proportion for whom obesity was not present at age ~50 years.

All analyses were performed in SPSS V.24.

Results

Table 1 reports the sociodemographic characteristics and anthropometric outcomes available at each age for the cohort among the 500 participants for whom height and weight was measured at age ∼50 years and at least once during childhood. At age 5, 14% of the participants were experiencing overweight and 5% were experiencing obesity and at follow-up at age ∼50 years, overweight was present for 35% of the participants and obesity was present for 42% of the cohort. Table 2 provides data on the cross-classifications of participants into normal weight, overweight, and obese categories by age of assessment.

Covariate-adjusted linear regression analyses found that, per unit higher BMI z-score at age 5, BMI measured at age 50 was 2.02 units higher [95% confidence interval (CI) = 1.35–2.68]. Consonantly, as given in Table 3, compared with normal weight status at age 5, obesity experienced at age 5 was associated with a 6.51 units higher BMI at age ∼50 years (95% CI = 3.67–9.35) and overweight present at age 5 was associated with a 3.33 units higher BMI at age ∼50 years (95% CI = 1.58–5.07). Likewise, obesity and overweight present at age 5 were associated with significantly higher FMI and LMI at age ∼50 years.

Complete case analyses produced results that were similar to the results from multiple imputed data sets, although effect sizes were larger in the complete case analyses. Regression coefficients from complete case analyses for obesity present at age 5 were 10% higher for BMI, 18% higher for FMI, and 19% higher for LMI at age ∼50; and for overweight present at age 5 the coefficients were 4% higher for BMI, 2% higher for FMI, and 8% higher for LMI age ∼50. In further analyses, the addition to the model of variables for maternal education and participant birth weight did not materially alter the association between weight status observed at age 5 and BMI at age ∼50. In gender-specific analyses, the associations between overweight/obese versus normal weight status observed at age 5 and BMI, FMI, and LMI at age ∼50 years did not vary by sex (Table 4).

Although obesity present at age 5 was associated with large differences in BMI at age ∼50 years, the predictive value of obesity and overweight experienced during childhood for predicting the presence of obesity at age ∼50 years was modest (Table 5). Obesity present at age 15–17 compared with combined normal and overweight at age 15–17 years had the highest positive predictive value, 0.86 (95% CI = 0.73–1.00), for predicting the presence of obesity at age ∼50 years. The Spearman correlation coefficient for body size at age ∼50 and body size at age 5 was 0.19 ($p < 0.001$), at age 9–11 was 0.30 ($p < 0.001$), and at age 15–17 was 0.35 ($p < 0.001$).

Discussion

These analyses document the tracking of body size from age 5 to age ∼50 years in a birth cohort that entered their teen years as the obesity epidemic began in the United States. Compared with being normal weight at age 5,

Table 2. Body Size of Participants at Each Follow-up

	Body size at age 9–11			Body size at age 15–17			Body size at age ∼50		
	Normal weight	Overweight	Obese	Normal weight	Overweight	Obese	Normal weight	Overweight	Obese
Body size at age 5									
Normal weight (n = 325)[a]	270	21	3	246	19	1	84	128	113
Overweight (n = 56)	29	15	8	31	10	7	11	11	34
Obese (n = 19)	2	5	8	6	3	7	0	6	13
Body size at age 9–11									
Normal weight (n = 379)				303	20	4	106	142	131
Overweight (n = 51)				23	12	4	5	11	35
Obese (n = 29)				7	6	11	1	4	24
Body size at age 15–17									
Normal weight (= 335)							100	131	104
Overweight (n = 38)							1	5	32
Obese (n = 20)							0	3	17

[a]Numbers in brackets indicate the number of participants in each body size category at the age of measurement. In some instances, the numbers in the table cells at the subsequent follow-up period do not do up to the number in the brackets because of missing data at the follow-up.

Table 3. Results of Linear Regression Analyses Predicting Body Mass Index, Fat Mass Index, and Lean Mass Index at Age 50

	Difference in BMI at age 50 (95% CI), *p*-value *N* = 500	Difference in FMI at age 50 (95% CI), *p*-value *N* = 500	Difference in LMI at age 50 (95% CI), *p*-value *N* = 500
Body size at age 5			
Normal weight	Ref.	Ref.	Ref.
Overweight	3.33 (1.58 to 5.07), <0.01	2.10 (0.77 to 3.43), <0.01	1.23 (0.67 to 1.78), <0.01
Obese	6.51 (3.67 to 9.35), <0.01	4.15 (1.98 to 6.32), <0.01	2.36 (1.45 to 3.26), <0.01
Gender			
Male	Ref.	Ref.	Ref.
Female	1.16 (0.07 to 2.26), 0.04	4.14 (3.3 to 4.98), <0.01	−2.98 (−3.33 to −2.62), <0.01
Mother's race			
White	Ref.	Ref.	Ref.
Nonwhite	2.31 (1.09 to 3.54), <0.01	2.09 (1.15 to 3.04), <0.01	0.22 (−0.18 to 0.61), 0.28
Age at assessment (per year)	−0.09 (−0.52 to 0.35), 0.70	−0.02 (−0.35 to 0.31), 0.91	−0.07 (−0.21 to 0.07), 0.35
Maternal prepregnancy BMI (per unit)	0.19 (0.04 to 0.34), 0.01	0.13 (0.02 to 0.25), 0.02	0.05 (0.00 to 0.1), 0.03
Participant education			
Less than college education	Ref.	Ref.	Ref.
College education or more	−0.43 (−1.62 to 0.77), 0.48	−0.52 (−1.44 to 0.40), 0.26	0.1 (−0.29 to 0.48), 0.62
Paternal education			
Less than high school education	Ref.	Ref.	Ref.
High school graduate	−2.26 (−3.96 to −0.57), 0.01	−1.71 (−3 to −0.41), 0.01	−0.56 (−1.11 to 0.00), 0.05
Some college	−1.01 (−2.83 to 0.8), 0.27	−0.88 (−2.27 to 0.52), 0.22	−0.13 (−0.73 to 0.46), 0.66
College graduate	−2.86 (−4.81 to −0.92), <0.01	−2.29 (−3.78 to −0.79), <0.01	−0.58 (−1.21 to 0.06), 0.07

Estimates are mutually adjusted for all predictor variables in the table.

95% CI, 95% confidence interval.

overweight and obese present at age 5 were each associated with significantly higher BMI at age ∼50 years. The estimated 6.51 units difference in BMI at age ∼50 associated with the presence of obesity at age 5 can be decomposed into 4.15 units difference in FMI and a 2.36 units difference in LMI.

The results presented here are consistent with previous studies of the tracking of childhood body size into adolescence, the teen years, and into adulthood.[6–9] The study extends previous findings by providing follow-up to later age and by demonstrating that the excess BMI is largely because of increases in fat mass. Although overweight and obesity experienced at age 5 were associated with large differences in BMI at age ∼50, as noted previously, body size data in childhood was not highly sensitive for predicting obesity in adulthood[9,10]; obesity was not present for 95% of the children at age 5, whereas only 58% of the participants were not experiencing obesity at age ∼50. However, the positive predictive value of obesity experienced at age 15–17 for obesity at age 50 in this cohort was high. Although only 5% of the participants were obese at age 5 in this birth cohort, the prevalence of children experiencing obesity by age 5 has reached as high as 20% in some contemporary cohorts.[18,19] If contemporary cohorts experience a similar tracking of obesity from childhood into adulthood as observed in the CHDS-Disparities Cohort, then for today's children the predictive power of obesity present in childhood on the risk of obesity experienced at age ∼50 may be higher than observed here.

Although extensively validated, the Tanita Bio-Impedance scales used in this research are not a gold-standard measure of body composition such as magnetic resonance imaging or a four-compartment model.[20–24] It is difficult to argue that measurement error in the bio-impedance data would be differential by participant obesity status at age 5 and thus we expect that any

Table 4. Associations Between Body Size at Age 5 and Body Mass Index, Fat Mass Index and Lean Mass Index at Age 50 Stratified by Participant Sex

	Sex stratified models predicting BMI by age ~50, difference in BMI (95% CI)	
	Men ($n=249$)	**Women[a] ($n=251$)**
Body size at age 5		
Normal weight	Ref.	Ref.
Overweight or obese	3.46 (1.73–5.20)	4.25 (1.85–6.65)
	Sex stratified models predicting FMI at age ~50, Difference in FMI (95% CI)	
	Men ($N=249$)	**Women[b] ($N=251$)**
Body size at age 5		
Normal weight	Ref.	Ref.
Overweight or obese	2.13 (0.71–3.56)	2.70 (0.91–4.49)
	Sex stratified models predicting LMI at age ~50, difference in LMI (95% CI)	
	Men ($N=249$)	**Women[c] ($N=251$)**
Body size at age 5		
Normal weight	Ref.	Ref.
Overweight or obese	1.33 (0.70–1.95)	1.55 (0.84–2.26)

Adjusting for mother's race, age at assessment, maternal prepregnancy BMI, participant education, and paternal education.
[a] p for interaction between gender and age 5 body size predicting age ~50 BMI = 0.61.
[b] p for interaction between gender and age 5 body size predicting age ~50 FMI = 0.66.
[c] p for interaction between gender and age 5 body size predicting age ~50 LMI = 0.58.

measurement error of fat mass was random with regard to age 5 body size. Random measurement error in a dependent variable in a linear regression model does not bias the model's estimate of the beta coefficients for the predictor variables, instead it increases the standard error of the estimate and reduces statistical power. Thus, it is unlikely that any measurement error in the body composition data affects the interpretation of the results presented here.

Several additional factors that should be considered in interpreting the results of this study. In the CHDS the

Table 5. Sensitivity, Specificity, and Positive and Negative Predictive Value of Body Size in Childhood and Teen Years for Predicting the Presence of Obesity at Age ~50 Years ($N=500$)

Predictor	Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)
Presence of obesity compared with combined normal and overweight at age 5	0.08 (0.04–0.12)	0.97 (0.95–0.99)	0.67 (0.49–0.85)	0.60 (0.55–0.64)
Presence of overweight or obesity compared with normal weight at age 5	0.28 (0.22–0.34)	0.88 (0.84–0.91)	0.62 (0.52–0.72)	0.63 (0.58–0.68)
Presence of obesity compared with combined normal and overweight at age 9–11	0.13 (0.09–0.18)	0.98 (0.96–1.00)	0.83 (0.70–0.96)	0.61 (0.57–0.66)
Presence of overweight or obesity compared with normal weight at age 9–11	0.31 (0.25–0.38)	0.92 (0.89–0.95)	0.73 (0.64–0.83)	0.65 (0.61–0.70)
Presence of obesity compared with combined normal and overweight at age 15–17	0.11 (0.06–0.15)	0.99 (0.98–1.00)	0.86 (0.73–1.00)	0.61 (0.56–0.65)
Presence of overweight or obesity compared with normal weight at age 15–17	0.30 (0.23–0.36)	0.96 (0.94–0.98)	0.84 (0.76–0.92)	0.66 (0.61–0.70)

patterns of follow-up through various substudies, such as the CHDS Adolescent Cohort, and loss to follow-up over the years are complex. The analyses presented here do not include weights to relate our participants back to the eligible pool of participants, or back to the overall CHDS birth cohort. There were some missing data on BMI z-score at age 5, 9–11, and 15–17; however, anthropometric data were available at multiple ages to support multiple imputation procedures and we have previously shown the validity of our multiple imputation strategy.[15] Furthermore, complete case analyses produced results that were quite similar to the multiple imputed results, suggesting minimal bias because of missing data. The analyzed birth cohort has a relatively small sample size and its members entered adolescence and the teen years as the obesity epidemic in the United States was beginning and experienced the drivers of the obesity epidemic that were in place at that time. It is important to keep in mind that factors influencing the obesity epidemic today may differ from those experienced by this birth cohort and so the results may not be generalizable to contemporary birth cohorts. In addition, as the CHDS recruited from a single county in California and recruitment for this study was limited to CHDS offspring still living in California, the CHDS Disparities Study is not a nationally representative birth cohort and may possibly reflect unique circumstances found in California. However, health disparities observed in the CHDS Disparities Study are consistent with those observed in NHANES data.[11] This study has substantial strengths including the long-term follow-up of a cohort that came of age as the obesity epidemic unfolded in the United States and experienced the drivers of the first wave of this epidemic; the availability of body size data in childhood, adolescence, and the teen years; the availability of body composition data at age 50 and multiple measures on individual and familial socioeconomic status in childhood and adulthood.

Conclusion

Obesity present at age 5 years among cohort members was found to be associated with higher BMI, FMI, and LMI at age ~50 years. However, although overweight and obesity present at age 5 were associated with large differences in BMI at age ~50, these childhood health conditions had low sensitivity for predicting obesity at age ~50. The positive predictive value of obesity present at age 15–17 for predicting the presence of obesity at age ~50 was high. While confined to the experiences of a geographically constrained cohort from California born between 1960 and 1963, this work suggests that addressing overweight and obesity present in the mid- to late teen years may result in lower BMI, FMI, and LMI in later adulthood.

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Author Disclosure Statement

The authors have no competing financial interests to declare.

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