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# Body mass index across the life course: emergence of race-by-sex disparities in early childhood

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ABSTRACT

*Purpose:* The purpose of this study was to assess when in the life-course race-by-sex disparities in body mass index (BMI) emerge.
*Methods:* Child Health and Development Studies participants, from whom height and weight data were collected at ages 5, 9–11, and 15–17 years, were followed up at the age of 50 years for anthropometric outcomes. Follow-up was completed for 605 subjects, 460 of whom were assessed for height and weight at the age of 50 years, had at least one available childhood BMI measure, and self-identified as either non-Hispanic black or non-Hispanic white. Linear regression analyses were conducted to determine whether interactions existed between race (black vs. white) and sex for predicting BMI at ages 5, 9–11, 15–17, and 50 years.
*Results:* At age 5 years, BMI was independent of sex for both blacks and whites, but by the age of 9–11 years, BMI was sex-dependent in blacks, with higher BMI observed among black females. This sex dependence for BMI among blacks persisted at ages 15–17 years and age 50 years. The race-by-sex interaction was significant at ages 9–11, 15–17, and 50 years (*P* for interaction = 0.001, 0.002, and 0.01, respectively).
*Conclusions:* Race-by-sex disparities in body size were observed by the age of 9–11 years and persisted until the age of 50 years.



## Introduction

In the United States, 35% of adults aged 20 years or older are obese and the obesity epidemic represents a critical public health issue [1]. There are marked disparities in body mass index (BMI) and obesity prevalence by race/ethnicity and sex [1–3]. Among men, the age-adjusted prevalence of obesity is modestly higher among non-Hispanic blacks and Hispanics than among non-Hispanic whites, whereas among women, the prevalence of obesity is substantially higher among non-Hispanic blacks and Hispanics than among non-Hispanic whites [1]. Non-Hispanic black women have the highest prevalence of obesity of any racial, ethnic, sex group, a disparity that has been in place for several decades, with an age-adjusted obesity prevalence of 57% in 2011–2012 [1,3–5].

It is not clear when in the life-course sex-by-race disparities in body size originate and how much of the disparity observed in middle age can be explained by disparities in adolescence or childhood. Past work has shown that differences in BMI between

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blacks and whites track from childhood into young adulthood and that age-related BMI gains were larger among black than white girls [6]. A report from the National Longitudinal Study of Adolescent Health showed that the higher prevalence of obesity seen in adolescent black girls tracked into late 20s and early 30s [7]. Similarly longitudinal analyses of the National Longitudinal Survey of Youth 1979 found that race and sex disparities in body size present at age 17–24 years persisted to age 34–41 years [8].

Knowing when in the life course the gender-by-race interaction emerges will provide critical information for public health interventions as it will suggest when its emergence might most effectively be blocked. Using a birth cohort study that has recently been followed up as the participants approach the age of 50 years and has assessments of height and weight in childhood (5 and 9–11 years), and adolescence (15–17 years), we assessed the development of gender-by-race disparities in BMI over the life course. We also assessed whether gender-by-race disparities in BMI observed in midlife are explained by disparities in body size observed in childhood or adolescence.

**Methods**

The Child Health and Development Studies (CHDS) Disparities Study followed up, at approximately the age of 50 years, the adult offspring of families enrolled in the CHDS. Both studies have been previously extensively described, and key elements of this work will be described here [9]. 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) [10]. Childhood examinations based primarily on CHDS births that occurred from 1960 to 1963, followed up CHDS participants at ages 5, 9–11, and 15–17 years. The CHDS Disparities Study builds on the childhood examinations to follow-up, at age 50 years, the children of black and nonblack women who participated in the CHDS [9]. Recruitment for the CHDS Disparities Study was limited to California residents (79% of the eligible pool, $n = 2514$) because of the difficulty and cost of implementing home visits nationwide. We obtained phone numbers for 1,073 of the eligible pool and slightly surpassed our 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, after contacting 985 of them [9]. 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 [9]. This study was approved by the CHDS and Columbia University Medical Center Institutional Review Board.

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 participant reported their own race and ethnicity, which was coded as non-Hispanic black, non-Hispanic white, and other, and reported their own educational attainment, which was coded as completing a college education or more verses not completing a college education.

Archived height, weight, and age at assessment data from the CHDS follow-up studies were used to calculate BMI z-scores at ages 5, 9–11 and 15–17 years using the CDC 2000 Growth Charts SAS Macro. Adult height and weight at the age of 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. In total, BMI data at the age of 50 years were available from 507 participants and 467 of these participants self-identified as non-Hispanic black or non-Hispanic white and with the rest choosing some other racial identification. Of these 467 participants, anthropometric data were available for at least one of the follow-ups during childhood (age 5, 9–11, or 15–17 years) for 460, and these 460 individuals constitute the analytical sample for this report.

*Statistical analyses*

Among subjects for whom height and weight data were available at the age of 50 years, height and weight data were available for 400 subjects at the age of 5 years and some data were missing for anthropometric measures at each age between age 5 and 50 years and for the other covariates (see Table 1). Multiple imputation by chained equations (70 data sets) was used to impute missing values for anthropometric and covariate data for the 460 non-Hispanic black or non-Hispanic white subjects for whom age 50 years, height and weight, and at least one height and weight measure during childhood were available [11]. The multiple imputation strategy is discussed in detail in the online supplement and analyses of the validity of the imputation model are presented. The results of the analyses in each of the 70 data sets were pooled using Rubin's rules, and the pooled results are presented [11].

One of the analytical goals was to test for associations between sex and body size in childhood, and the calculation of childhood BMI z-scores and percentiles involves standardization for child sex, so instead BMI scores were used as outcome variables in all analyses. A series of linear regression models were fit with race (non-Hispanic black compared with non-Hispanic white), sex (female compared with male), and a race-by-sex interaction term as predictor terms and BMI score at ages 5, 9–11, 15–17, and 50 years as the outcome variables. The interaction term was coded such that the interaction describes the additional BMI observed among non-Hispanic black girls or women. To address relatively small differences in age at the time of the CHDS Disparities Study, the model assessing associations between sex and race and BMI additionally controlled for age at follow-up in midlife.

An additional series of three models was fit assessing the association between sex and race and BMI at the age of 50 years with adjustment for BMI at ages 5, 9–11, and 15–17 years. These additional models assessed the extent to which BMI score in childhood, adolescence, and teen years explained interactions between race and sex in predicting BMI at the age of 50 years. A subsequent model was fit predicting BMI at the age of 50 years that adjusted for BMI score in adolescence and further adjusted for paternal and maternal educational attainment, maternal prepregnancy BMI, the participant's own educational attainment, and for whether the participant smoked at the time of follow-up. This subsequent model assessed the extent to which these sociodemographic and behavioral variables explained remaining race, sex, and race-by-sex interaction effects after adjustment for adolescent BMI score.

In post hoc analyses among women, linear regression analyses were used to assess whether associations between race and BMI at the age of 50 years remained after adjustment for participant-reported age at menarche. Age at menarche data reported during the age 15- to 17-year follow-up ($n = 192$) were analyzed, and if data were not available from the age 15- to 17-year follow-up, age at menarche reported on the age 50 survey ($n = 184$) were analyzed. Combining the data from these two self-reports of age at menarche, data were available for 224 women and missing for eight

**Table 1**
Anthropometric and sociodemographic characteristic of the study participants by race and sex

| Participant characteristics | Black women $n = 100$ | Black men $n = 102$ | White women $n = 132$ | White men $n = 126$ |
|---|---|---|---|---|
| Maternal prepregnancy BMI | 24.58 (4.12) 98 | 25.07 (4.61) 98 | 22.27 (3.13) 130 | 22.76 (3.27) 123 |
| Birth weight (ounces) | 111.75 (19.76) 100 | 112.63 (17.25) 102 | 115.28 (18.28) 132 | 123.03 (17.56) 126 |
| BMI at age 5 y | 15.81 (1.48) 72 | 16.13 (1.48) 80 | 15.71 (1.27) 113 | 16.02 (1.2) 105 |
| BMI at age 9–11 y | 19.13 (3.77) 96 | 17.29 (2.53) 68 | 17.21 (2.4) 132 | 17.34 (1.9) 123 |
| BMI at age 15–17 y | 24 (5.85) 61 | 21.84 (3.61) 38 | 21.32 (3.04) 131 | 21.48 (2.75) 126 |
| BMI at age 50 y | 33.51 (7.94) 100 | 30.38 (6.22) 102 | 28.22 (7.13) 132 | 28.5 (4.47) 126 |
| Paternal education | | | | |
| Less than high school | 29 (31) | 27 (28) | 16 (12) | 7 (6) |
| High school | 34 (36) | 37 (38) | 28 (21) | 40 (32) |
| Some college | 25 (26) | 27 (28) | 29 (22) | 33 (26) |
| College | 7 (7) | 6 (6) | 58 (44) | 46 (37) |
| Participant has a college degree | | | | |
| No | 63 (64) | 79 (77) | 61 (47) | 62 (49) |
| Yes | 36 (36) | 23 (23) | 70 (53) | 64 (51) |
| Participant smokes at age 50 y | | | | |
| No | 68 (68) | 64 (64) | 110 (83) | 96 (81) |
| Yes | 32 (32) | 36 (36) | 22 (17) | 23 (19) |

women; for these eight women, age at menarche was imputed (see Online Supplement).

## Results

Table 1 displays the anthropometric outcomes and sociodemographic characteristics of the study population by sex and race.

Table 2 shows the association between race, sex, the interaction term for race and sex and BMI at ages 5, 9–11, 15–17, and ~50 years. At the age of 5 years, a race-by-sex interaction was not observed, whereas from age 9–11 onward, there was a significant race-by-sex interaction for predicting BMI. The interactions reflect the significantly higher BMI among black females as compared with black males, and the lack of difference in BMI scores between white females and white males. At the age of 11 years, blacks girls were 1.53 BMI units heavier than black boys (95% CI: 0.76, 2.29, $P < 0.001$), whereas white boys and girls had equivalent BMI scores. By the age of 15–17 years, the difference in BMI between black girls and boys had increased to 1.79 units (95% CI: 0.65, 2.92, $P = 0.002$), and by the age of 50 years, the difference had increased to 2.79 units (95% CI: 1.00, 4.57, $P = 0.002$). Differences in BMI between white females and white males were minimal and nonsignificant at ages 15–17 and 50 years.

Table 3 compares the associations between sex, race, and the sex-by-race interaction term and BMI at the age of 50 years, after adjustment for BMI at the age of 5 years (model 1), 9–11 years (model 2), and 15–17 years (model 3). Adjustment for BMI at the age of 5 years did not substantially alter the race-by-sex interaction term for predicting BMI at the age of 50 years. However, adjustment for BMI at the age of 9–11 years substantially attenuated (58%) the magnitude of the race-by-sex interaction term and rendered it nonsignificant. Adjustment for BMI at the age of 15–17 years attenuated the race-by-sex interaction term to a similar extent as adjustment for BMI at the age of 9–11 years did.

The cause of the diminution of the race-by-sex interaction term on conditioning the analyses for BMI at the age of 9–11 years can be seen when sex stratified analyses are conducted. Among women, in analyses that did not condition on BMI at the age of 9–11 years, BMI was 5.29 units (95% CI: 3.61, 6.97) higher among black women than among white women, and after conditioning the analyses on BMI score at the age of 9–11 years, the difference in BMI between black and white women decreased to 3.23 units (95% CI: 1.69, 4.78) (see Fig. 1). While among men, the estimated difference in BMI between blacks and whites was less affected by adjustment for BMI at the age of 9–11 years. There was a 1.81 unit difference in BMI by race among men before adjustment (95% CI: 0.07, 3.54) and a 1.61 unit difference after adjustment (95% CI: 0.05, 3.17). Thus, the race-by-sex interaction term diminishes on adjustment for BMI at the age of 9–11 years because the association between race and BMI in middle age decreases substantially among women and only slightly among men after this adjustment (see Fig. 1).

Further covariates were added to the model that adjusted for BMI at the age of 15–17 years to assess whether paternal and maternal educational attainment, maternal prepregnancy BMI, the participant's own educational attainment, and smoking at the age of 50 years further diminished the race-by-sex interaction term (Table 3, model 4). The addition of these variables to model 3 did not materially alter the race-by-sex interaction term (1.39 in model 3 and 1.47 in model 4). However, the addition of these variables to the model 3 did diminish the association between race and BMI at the age of 50 years, and to a similar extent, among men and women (0.90 BMI units among men and 0.82 among women). In men, the difference in BMI by race went from 1.73 BMI units (95% CI: 0.17,

**Table 2**
Association between BMI at ages 5, 9–11, 15–17, and 50 years and race and sex

| Predictor | Difference in BMI at age 5 y (95% CI) | Difference in BMI at age 9–11 y (95% CI) | Difference in BMI at age 15–17 y (95% CI) | Difference in BMI* at age 50 y (95% CI) |
|---|---|---|---|---|
| | *P*-value | *P*-value | *P*-value | *P*-value |
| Black compared with white | .10 (−.28, .47)<br>.62 | .05 (−.72, .82)<br>.65 | .02 (−1.15, 1.10)<br>.97 | 1.81 (.07, 3.54)<br>.04 |
| Female compared with male | −.24 (−.58, .11)<br>.18 | −.16 (−.82, .50)<br>.63 | −.15 (−1.05, .76)<br>.75 | −.27 (−1.88, 1.33)<br>.74 |
| Black * female† | .00 (−.53, .53)<br>.99 | 1.83 (.79, 2.86)<br>.001 | 2.36 (.85, 3.86)<br>.002 | 3.31 (.88, 5.74)<br>.01 |

* Model also adjusts for age at assessment of height and weight.
† The interaction term is coded such that the coefficient estimates the difference in BMI for black compared with white girls/women.

**Table 3**
Associations between BMI at the age of 50 years and race and sex after covariate adjustments

| Predictor | Model 1* | Model 2† | Model 3‡ | Model 4§ |
|---|---|---|---|---|
| | Difference in BMI at age 50 y (95% CI) | Difference in BMI at age 50 y (95% CI) | Difference in BMI at age 50 y (95% CI) | Difference in BMI at age 50 y (95% CI) |
| | *P*-value | *P*-value | *P*-value | *P*-value |
| Black compared with white | 1.62 (−.04, 3.28) | 1.61 (.05, 3.17) | 1.73 (.17, 3.29) | .83 (−.82, 2.48) |
| | .06 | .04 | .03 | .32 |
| Female compared with male | .07 (−1.45, 1.58) | −.10 (−1.51, 1.31) | −.14 (−1.48, 1.20) | −.23 (−1.55, 1.09) |
| | .93 | .89 | .84 | .73 |
| Black * Female‖ | 3.53 (1.21, 5.84) | 1.62 (−.57, 3.82) | 1.39 (−.77, 3.55) | 1.47 (−.66, 3.60) |
| | .003 | .15 | .21 | .18 |

* Adjusts for participant age at assessment and BMI at age 5 years.
† Adjusts for participant age at assessment and BMI at age 9–11 years.
‡ Adjusts for participant age at assessment and BMI at age 15–17 years.
§ Adjusts for BMI at the age of 15–17 years, and paternal and maternal education, maternal prepregnancy BMI, participant obtained a college degree, participant's smoker/nonsmoker status at age 50 years and participant age of assessment.
‖ The interaction term is coded such that the coefficient estimates the difference in BMI black compared with white girls/women.

3.29) in model 3 to 0.83 BMI units (95% CI: −0.82, 2.48) in model 4. Among women, the difference in BMI by race went from 3.12 BMI units (95% CI: 1.62, 4.62) in model 3 to 2.30 BMI units (95% CI: 0.74, 3.87) in model 4. The change in the magnitude of the associations between race and BMI at the age of 50 years, on adjustment for the additional covariates, primarily resulted from the adjustment for paternal education.

In post hoc analyses among women only, adjustment for age at menarche only marginally altered the association between race and BMI at the age of 50 years. Before adjustment, black women had a BMI at the age of 50 years that was 5.29 (95% CI: 3.35, 7.23) units higher than white women, whereas the age at menarche–adjusted difference in BMI by race was 4.98 (95% CI: 3.01, 6.96) units. After adjustment for BMI at the age of 9–11 years, black women had a BMI at the age of 50 years that was 3.13 (95% CI: 1.34, 4.92) units higher than white women, and after further adjustment for age at menarche, the difference in BMI at the age of 50 years by race was 3.12 (95% CI: 1.31, 4.93) units.

Across the analyses presented here, analyses of multiple imputed data sets and complete cases produced essentially identical results.

## Discussion

Disparities in obesity prevalence by race and sex have been apparent for several decades with black women consistently having the highest prevalence of obesity. Here using a birth cohort that came of age as the obesity epidemic unfolded in the United States, we find that race-by-sex disparities were present by age 9–11 years and continued into middle age. The race-by-sex disparities in BMI scores at the age of 50 years were largely accounted for by differences in participant's BMI scores at the age of 9–11 years. These findings emphasize the importance of early prevention of obesity and unhealthy weight gain trajectories in childhood and suggests that such prevention programs could have lasting beneficial consequences.

The presence of the race-by-sex interaction being apparent by age 9–11 years and being largely driven by differences in BMI by race among girls suggests that differences in pubertal timing by race among girls may explain the disparity. Research has found the onset of puberty to be earlier in African American than in white girls [12–15] and earlier pubertal timing among girls has been associated with higher BMI in adolescence and adulthood [15–17].

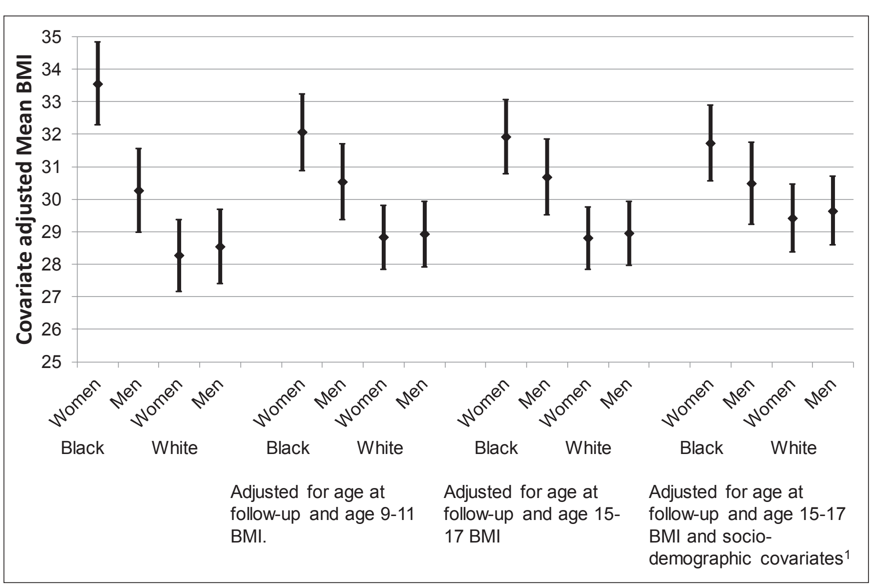


**Fig. 1.** Covariate-adjusted mean and 95% confidence interval for body mass index at the age of 50 years by sex and race. [1]Sociodemographic covariates were paternal and maternal education, maternal prepregnancy BMI, participant obtained a college degree, participant's smoker/nonsmoker status at the age of 50 years, and participant age of assessment.

However, there is some evidence that childhood obesity itself is associated with earlier onset of puberty in girls [18]. Thus from the literature, it is unclear whether obesity before the onset of puberty predicts future risk for higher BMI throughout the life course, and early onset of puberty is incidental to this overall trajectory, or if early onset of puberty predicts future obesity risk independent of early childhood body size. In post hoc analyses among women in this cohort, adjustment for self-reported age at menarche only minimally reduced the racial disparity in BMI at the age of 50 years. The results presented here and the literature on race, obesity, and pubertal timing indicates that the collection of better pubertal development data and anthropometric data in early and middle childhood, around pubertal onset, during adolescence and the teen years is required to understand the role of pubertal timing in the differences in BMI between African American and white girls and women.

Adjustment for BMI at the age of 15–17 years diminished the race*sex interaction term for predicting BMI at the age of 50 years and made the term nonsignificant. Further adjustment for covariates only marginally affected the race*sex interaction term, but it diminished the difference in BMI by race and equivalently so among men and women. Among the covariates, paternal education accounted for almost all of the observed changes in the association between race and BMI at the age of 50 years. Considering paternal education in the 1960s to be a marker of familial socioeconomic status, these analyses suggest that socioeconomic conditions experienced during childhood have persistent effects on BMI that account for some of the differences in BMI associated with race.

This study has several limitations that should be considered in interpreting the results. The results are based on a cohort that entered its adolescence and teen years as the obesity epidemic was beginning and may have experienced an obesogenic environment that differs from the one that exists today. The patterns of follow-up in this cohort are complex and there were missing data on BMI at ages 5, 9–11, and 15–17 years. However, the multiple imputation model for missing BMI and covariate data appears valid and robust (see Supplement). However, it is not possible to prove that an imputed data set meets the assumptions of missing at random. It is possible that even with the multiple imputation model accounting for interactions between sex and race and maternal BMI, birth weight, and BMI at ages 5, 9–11, 15–17, and 50 years, the pattern of missing data caused the spurious appearance of race-by-sex interactions in the MI-based analyses. But this is thought to be unlikely as the findings of interactions at ages 9–11, 15–17, and 50 years presented here are consistent with cross-sectional analyses in recent NHANES data and analyses of NHANES I and II data from children and adolescents [19,20].

The strengths of this study include the following: the long-term follow-up of a cohort that experienced the drivers of the first wave of this epidemic; data on prenatal and earliest life risk factors and birth weight; and the availability of body-size data in childhood, adolescence, and the teen years; and multiple measures on individual and familial socioeconomic status in adulthood.

In conclusion, we find in this cohort that race-by-sex disparities were present by 9–11 years of age and continued into middle age, and that the higher BMI scores observed among black women compared with black men in midlife was largely explained by differences in BMI scores at the age of 9–11 years. This research suggests that race-by-sex disparities in adult BMI can be reduced by interventions during childhood and/or adolescence, particularly by interventions that support healthy weight among black girls. However, as modest differences in BMI by race and gender persist into adulthood even after accounting for BMI in adolescence, additional interventions in early adulthood are likely needed to reduce the overall racial disparity in BMI at midlife.

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## Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.annepidem.2019.03.001.

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