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Longitudinal trends in obesity in the US from adolescence to the third decade of life

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Abstract

No longitudinal analyses using national data have evaluated the increase in obesity from adolescence into early adulthood. We examined obesity incidence, **persistence, and reversal** in a nationally representative cohort of US teens followed into their early 30's, using measured height and weight data, in individuals enrolled in wave II (1996; 12–21 years), wave III (2001; 17–26 years), and wave IV (2008 early release data; 24–32 years) of the National Longitudinal Study of Adolescent Health [N=8,675]. Obesity was defined as a BMI≥95th percentile of the 2000 CDC/NCHS growth charts for adolescents or ≥30 kg/m^2 **for individuals ≤20 years and ≥30 kg/m^2 in individuals>20 years**. In 1996, 13.3% of adolescents were obese. By 2008, obesity prevalence increased to 36.1%, and was highest among non-Hispanic black females (54.8%). **Ninety percent of the obese adolescents remained obese in 2008**. While annual obesity incidence did not decline in the total sample across the 2 study intervals (2.3% per year 1996–2001 vs. 2.2% per year 2001–2008), rates among white females declined (2.7% to 1.9% per year) and were highest among non-Hispanic black and Hispanic females (3.8% and 2.7% per year, 1996–2001 vs. 3.0% and 2.6% per year, respectively, 2002–2008). Obesity prevalence doubled from adolescence to the early 20's, and doubled again from the early to late 20's or early 30's, with strong tracking from adolescence into adulthood. This trend is likely to continue owing to high rates of pediatric obesity. Effective preventive and treatment efforts are critically needed.

Keywords

longitudinal data analysis; minority population

INTRODUCTION

Obesity remains a major public health issue, particularly in terms of its inequitable distribution and high risk for minority subpopulations in the US.(1) The most recent national cross-sectional estimates show no declines in obesity in any US subpopulation.(2) Yet there is a paucity of nationally representative longitudinal data capturing the transition from adolescence to adulthood. Longitudinal data are needed to better understand the patterns of obesity development over time, the permanency of obesity at each age, and the ideal points for intervention. We examine trends in obesity persistence, incidence, and reversal in adolescents followed for 12 years from the mid-1990's to 2008 using nationally representative data from the National Longitudinal Study of Adolescent Health (Add Health).

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METHODS AND PROCEDURES

Survey Design

The study population initially consisted of 20,745 adolescents enrolled in Add Health, a longitudinal, nationally representative, school-based study of US adolescents in grades 7–12, supplemented with minority special samples and collected under protocols approved by the Institutional Review Board of the University of North Carolina-Chapel Hill. A sample of 80 high schools and 52 middle schools from the US was selected to ensure this sample is representative of US schools with respect to region of country, urbanicity, school size, school type, and ethnicity.

Wave II included 14,438 eligible wave I (1994–1995) adolescents (aged 12–21 years) who would still be enrolled in high school during 1996, including dropouts, measured between April and August, 1996. In waves III and IV, all wave I respondents were followed regardless of wave II participation. Wave III included 15,197 eligible original wave I respondents (aged 17–26 years), measured in April 2001 and between August 2001 and April 2002. Wave IV included 15,608 eligible original wave I respondents (aged 24–32 years), measured April to June 2007 and between January 2008 and January 2009. Our final analytic sample included 8,675 respondents with complete measured height and weight data at waves II, III and IV (early release data). Those excluded from the sample (pregnant females, and individuals lost to follow-up or lacking complete data) were more likely to be Asian, older and from the lowest parental income tertile based on wave I data. However, obesity prevalence based on wave I self-reported weight and height was not statistically different for those included (10.8%) versus excluded (10.4%). The survey design and sampling frame have been described elsewhere.(3, 4)

Study Variables

Height and weight were measured at waves II, III, and IV during in-home surveys using standardized procedures. Using the recommended definition for comparability from adolescence to adulthood,(5) obesity was defined in individuals ≤20 years as BMI≥ 95th percentile of the age-and sex-specific Centers for Disease Control (CDC) growth reference or BMI ≥30 kg/m^2 and in adults >20 years: BMI≥30kg/m^2. Respondents who exceeded scale capacity (wave II: 350 lbs; wave III: 330 lbs; wave IV: 440 lbs) were coded as obese.

A combination of in-home surveys of parents and adolescents provided race/ethnicity data, which was categorized as Hispanic (Cuban, Puerto Rican, Central/South American, Mexican, Other Hispanic), non-Hispanic white, non-Hispanic black, or Asian-American (Chinese, Filipino, Other Asian). Age at last birthday was reported.

Statistical Analysis

Statistical analysis was carried out using Stata Version 10.0.(6) For incidence and prevalence estimates, we used survey (SVY) procedures to correct for multiple stages of cluster sample design and unequal probability of selection to ensure that our results were nationally representative. Longitudinal sample weights for waves I–III were used in the analysis, to provide correction for non-response bias over time.(7) Data limitations precluded the use of sample weights for wave IV, but the longitudinal sample weights are likely to provide acceptable estimates given that the analytic sample includes individuals present across all measurement occasions. Since the time periods between survey waves were not the same (1996 to 2001 and 2001 to 2008), we present overall and annual incidence rates (new cases between survey waves/number of years between surveys). This approach assumes a constant rate of increase across the observed time period. We used an F-statistic and t-test to compare group means of obesity prevalence across the three measurement periods and incidence across the

two time intervals. For race/ethnic differences within sex and within age, the Bonferroni correction for multiple comparisons was applied. To explore possible cohort effects, we defined three age groups based on age at wave I (12–14,15–16,[17] and older) and tested age differences where there was overlap (e.g., obesity rates for individuals aged 19 years at wave II versus those 19 years at wave III) using 2 sided t-tests.

RESULTS

In 2008, 36.1% of the sample was obese, with variation across sex and ethnicity (Persistent and Incident Obesity Columns, Table 1). The vast majority (90%) of obese adolescents remained obese into their 30's: 94% of females overall, 95% of black females, and 88% of males remained obese. Obesity prevalence was highest in the oldest age groups across all race/ethnic categories. Less than 2% of individuals who were initially obese at wave II became non-obese by wave IV.

Obesity prevalence more than doubled from 1996 to 2001 and again from wave 2001 to 2008. Incidence was higher for females from 1996–2001, but not from 2001–2008 (Table 2). Annual obesity incidence was highest among black females and lowest among Asian females. There were no statistically significant differences by baseline age group across any of the obesity transitions.

In Figure 1 we provide an example of the differences in blacks versus whites across baseline age cohort. For females in each baseline cohort group we find statistically significant black-white differences except at wave II in the 18–21 year old baseline cohort group (borderline significant p=0.0683). In contrast, we found no evidence of cohort effects within any of the gender and race/ethnicity groups. Within sex and race/ethnicity groups, all three age groups experienced similar increases in obesity with age.

DISCUSSION

We observed a dramatic increase in obesity prevalence from adolescence into adulthood., (4) Our sample represents a cohort of more than 15 million 13–20 year old students at public and private schools in the US, followed over a 12-year period and shows that an estimated 5.5 million adolescents are obese by the time they reached their early 30's. With the trend towards increasing obesity in younger US children,(2) these numbers will likely be higher for the cohorts to come.(8)

As longitudinal studies have shown, a substantial amount of weight is gained during the transition from adolescence to young adulthood,(4,9) with strong tracking from adolescence into adulthood.(10–12) The longitudinal and racial/ethnically diverse Add Health cohort uniquely captures longitudinal trends in the understudied period from adolescence in the 1990's to the third decade of life. Using these data, we find interesting racial differences. While the ratio of obese black to white females drops from 1.84 to 1 in 1996 and 1.66 to 1 in 2008, we see persistent disparity in obesity prevalence by year (1996: 19.3% blacks, 10.5% whites; 2001: 35.9% blacks, 22.5% whites; 2008: 54.8% blacks, 33.1% whites), representing a prevalence difference of 8.8% at 1996 and 21.7% at 2008 (Table 1 and Table 2).

NHANES data capture changes in rates by age group using repeated cross-sections, showing a leveling off of obesity rates in women.(2) The NHLBI Growth and Health Study followed a multicenter biracial cohort (N=2379) of 9–10 year old females (1985) over 10 years documenting doubling of obesity prevalence into adulthood (blacks: 17.7% to 36.9%; whites: 7.7% to 18.0%), with relatively stable racial differences in prevalence.(13) In the biracial Bogalusa cohort (N=2,392) of 5–14 year olds (1973-74) followed over a mean of 17.1 years, annual BMI increases were approximately 30–40% higher in black versus white females.(14)

Our data show that black females start off with higher proportion of obesity, have higher annual incidence rates, but the ratio of obesity prevalence in black versus white r females reduces over time.

Our longitudinal, nationally representative and ethnically-diverse data capture the transition from adolescence to middle adulthood over multiple measurement occasions. We find that the upward trend in obesity continues into the adult years and is evident in both males and females and in all major US ethnic groups. The public health implications of this upward trend in obesity prevalence are substantial. This early development, persistence, and incidence of obesity foreshadows increased mortality and morbidity (and potentially earlier onset) related to a variety of chronic diseases later in life.(15–17) While all groups are affected, black and Hispanic females seem particularly at risk. Our findings emphasize the critical need for focus on obesity prevention prior to adulthood.

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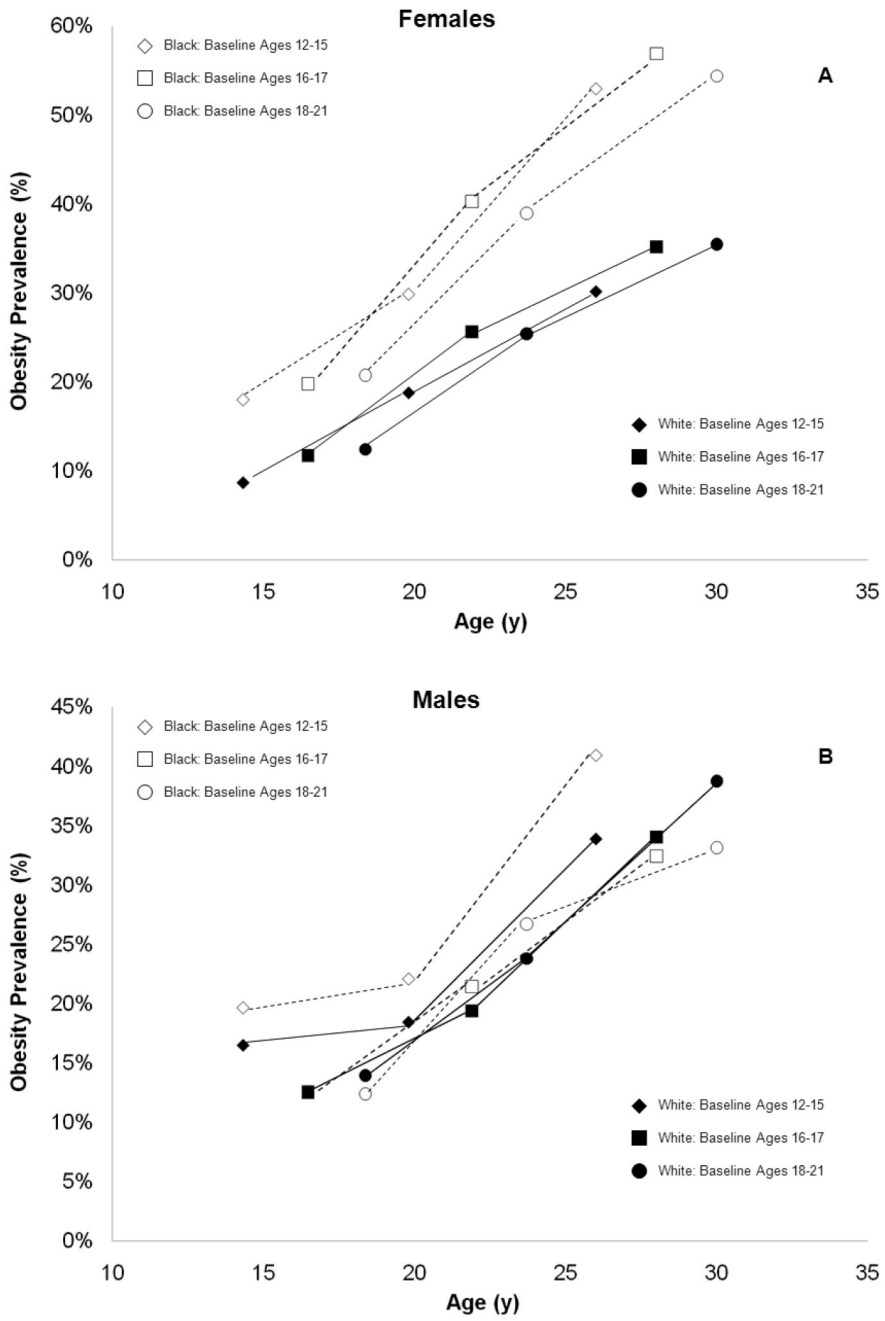

Figure 1.
Obesity prevalence for blacks and whites by baseline age cohort across three measurement occasions from 1996 to 2008 for females (A) and males (B) by race/ethnicity, The National Longitudinal Study of Adolescent health (N=6,791 respondents (4,962 white, 1,789 black) measured at all survey periods).

Table 1

Shifts in obesity between wave II (1996; ages 12–21 y) and wave IV (2008; ages 24–33 y) by gender race/ethnicity and age in participants of the National Longitudinal Study of Adolescent Health[a]

	Persistent Non-Obesity (wave II: non-obese wave IV: non-obese)	Incident Obesity (wave II: non-obese wave IV: obese)	Reversal of Obesity (wave II: obese wave IV: non-obese)	Persistent Obesity (wave II: obese wave IV: obese)
Total (*n = 8,675*)	62.6 (60.8, 64.4)	24.1 (22.9, 25.4)	1.3 (1.0, 1.6)	12.0 (10.8, 13.2)
Males (*n = 4,122)*	62.9 (60.7, 65.1)	22.7 (20.9, 24.4)[b]	1.8 (1.3, 2.3)[b]	12.6 (11.0, 14.2)
White (*n = 2,390*)	63.1 (60.4, 65.9)	22.4 (20.2, 24.6)	1.9 (1.3, 2.5)[e]	12.6 (10.6, 14.6)
Black (*n = 762*)	62.7 (57.3, 68.0)	22.2 (17.7, 26.7)	1.6 (0.4, 2.8)	13.5 (9.9, 17.2)
Hispanic (*n = 667*)	59.2 (52.3, 66.0)	26.8 (21.2, 32.3)	1.8 (0.5, 3.1)	12.3 (8.7, 15.9)
Asian (*n = 303*)	72.1 (63.5, 80.7)	17.2 (11.3, 23.2)	0.1 (0.0, 1.2)	10.1 (4.3, 16.0)
Females (*n = 4,553)*	62.2 (59.9, 64.6)	25.6 (23.9, 27.3)	0.7 (0.4, 1.1)	11.3 (9.8, 12.8)
White (*n = 2,572*)	66.3 (63.7, 69.0)[cde]	23.2 (21.3, 25.0)[c]	0.6 (0.3, 1.0)	9.9 (8.1, 11.6)[ce]
Black (*n = 1,027*)	44.2 (40.4, 48.0)[fg]	36.5 (33.0, 40.0)[g]	1.0 (0.4, 1.6)	18.3 (15.2, 21.4)[g]
Hispanic (*n = 691*)	56.4 (51.3, 61.5)[h]	29.2 (23.7, 34.7)[h]	1.0 (0.0, 2.4)	13.2 (9.1, 17.3)[h]
Asian (*n = 263*)	82.1 (71.6, 92.5)	14.3 (7.0, 21.6)	0.7 (−0.1, 2.2)	2.9 (−0.1, 5.8)
Total Population by Age at Baseline (wave II)				
12 – 15 y (*n* = 2,984)	64.1 (61.6, 66.6)	22.6 (20.9, 24.4)	1.6 (1.1, 0.0)	11.6 (10.0, 0.0)
16 – 17 y (*n* = 3,657)	62.2 (59.7, 64.8)	24.6 (22.3, 27.0)	1.2 (0.7, 0.0)	11.9 (10.3, 0.0)
18 – 21 y (*n* = 2,034)	60.1 (56.4, 63.8)	26.3 (23.5, 29.2)	0.7 (0.2, 0.0)	12.8 (10.8, 0.0)

[a] 95% Confidence Intervals in parentheses. Adolescent obesity (< 20 y) defined using the 2000 NCHS/CDC growth chart age- and sex-specific BMIs ≥ 95th percentile cut point or BMI ≥ 30. Adult obesity (≥ 20 y) defined as BMI ≥ 30. All results were weighted for national representation, and the standard errors were corrected for multiple stages of cluster sample design and unequal probability of selection.
NOTE: Incident Obesity and Persistent Obesity Columns total to equal Obesity Prevalence at wave IV (i.e., obesity prevalence at wave IV in the total sample is 36.1%).

[b] Male and female differences, $p \leq 0.05$

[c] Within-sex, white and black differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[d] Within-sex, white and Hispanic differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[e] Within-sex, white and Asian differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[f] Within-sex, black and Hispanic differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[g] Within-sex, black and Asian differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[h] Within-sex, Hispanic and Asian differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

Table 2

Shifts in obesity incidence in the National Longitudinal Study of Adolescent Health, 1996 to 2008[a]

	1996 Prevalence	1996–2001 incidence	1996–2001 annual incidence	2001 Prevalence	2001–2008 incidence	2001–2008 annual incidence
Total (*n = 8,675*)	13.3 (12.0, 14.5)	11.6 (10.5, 12.6)	2.3 (2.1, 2.5)	22.6 (21.0, 24.2)	15.7 (14.7, 16.7)	2.2 (2.1, 2.4)
Males (*n = 4,122)*	14.4 (12.6, 16.1)[b]	9.2 (7.9, 10.4)[b]	1.8 (1.6, 2.1)	20.4 (18.6, 22.3)[b]	16.6 (15.0, 18.2)	2.4 (2.1, 2.6)[k]
White (*n = 2,390*)	14.5 (12.4, 16.7)	8.7 (7.2, 10.2)	1.7 (1.5,2.0)	19.9 (17.7, 22.2)	17.0 (15.0, 18.9)[d]	2.4 (2.2, 2.7)[k]
Black (*n = 762*)	15.1 (11.2, 19.1)	10.5 (7.4, 13.7)	2.1 (1.5,2.8)	23.9 (18.9, 27.0)	14.7 (11.2, 18.1)	2.1 (1.6, 2.6)
Hispanic (*n = 667*)	14.1 (10.1, 18.1)	10.5 (7.0, 14.0)	2.1 (1.4, 2.8)	21.3 (16.1, 26.5)	18.6 (13.6, 23.5)	2.7 (1.9, 3.4)
Asian (*n = 303*)	10.7 (4.8, 16.5)	8.0 (3.1, 12.9)	1.6 (0.6, 2.6)	18.2 (9.7, 26.7)	10.0 (6.0, 14.0)	1.4 (0.9, 2.0)
Females (*n = 4,553)*	12.1 (10.6, 13.7)	14.1 (12.5, 15.7)	2.8 (2.5, 3.1)	24.7 (22.5, 27.0)	14.8 (13.4, 16.1)	2.1 (1.9, 2.3)[k]
White (*n = 2,572*)	10.5 (8.7, 12.3)[cd]	13.3 (11.2, 15.3)[d]	2.7 (2.3, 3.1)	22.5 (19.8, 25.3)[cd]	13.1 (11.7, 14.5)[cd]	1.9 (1.7, 2.1)[k]
Black (*n = 1,027*)	19.3 (16.1, 22.6)[f]	19.1 (15.7, 22.3)[f]	3.8 (3.1, 4.5)	35.9 (31.2, 40.6)[ef]	21.3 (18.2, 24.5)[f]	3.0 (2.6, 3.5)
Hispanic (*n = 691*)	14.4 (10.1, 18.8)[g]	13.7 (9.5, 17.9)	2.7 (1.9, 3.6)	26.7 (22.4, 21.0)[g]	18.2 (13.4, 22.9)[g]	2.6 (1.9, 3.3)
Asian (*n = 263*)	3.7 (−0.4, 7.7)	8.5 (2.3, 14.7)	1.7 (0.4, 3.0)	11.0 (3.2, 18.9)	6.1 (2.2, 10.1)	0.9 (0.3, 1.4)
Total population by Age at baseline[j]						
12 – 15 y (*n = 2,984)*	13.2 (11.4, 15.1)	9.6 (8.2, 10.9)[hi]	1.9 (1.7, 2.2)	20.0 (17.9, 22.1)[i]	15.9 (14.3, 17.6)	2.3 (2.0, 2.5)[k]
16 – 17 y (*n = 3,657)*	13.1 (11.5, 14.8)	12.7 (10.8, 14.5)	2.5 (2.2, 2.9)	23.6 (21.4, 25.8)	15.0 (13.5, 16.5)	2.1 (1.9, 2.4)
18 – 21 y (*n = 2,034)*	13.6 (11.3, 15.8)	13.7 (11.4, 15.8)	2.7 (2.3, 3.2)	25.9 (22.6, 29.2)	16.5 (14.5, 18.6)	2.4 (2.1, 2.7)

[a] Wave II (1996; ages 12–21 y), wave III (2001; ages 17–26 y), and wave IV (2008; ages 24–33 y) of the National Longitudinal Study of Adolescent Health, 95% Confidence Intervals in parentheses. Adolescent obesity (< 20 y) defined using the 2000 NCHS/CDC growth chart age- and sex- specific BMIs ≥ 95th percentile cut point or BMI ≥ 30. Adult obesity (≥ 20 y) defined as BMI ≥ 30. All results were weighted for national representation, and the standard errors were corrected for multiple stages of cluster sample design and unequal probability of selection.

[b] Male and female differences, $p \leq 0.05$

[c] Within-sex, white and black differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[d] Within-sex, white and Asian differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[e] Within-sex, black and Hispanic differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[f] Within-sex, black and Asian differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[g] Within-sex, Hispanic and Asian differences, $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[h] Age group differences (24–27 y vs. 28–29 y), $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[i] Age group differences (24–27 y vs. 30–33 y), $p \leq 0.05$ (F Test with Bonferroni's adjustment)

[j] Age at Baseline (Wave II)

[k] Annualized rate differences 1996 to 2001 versus 2001 to 2008, $p \leq 0.05$