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Longitudinal Study of Body Weight Changes in Children: Who is Gaining and Who is Losing Weight

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Abstract

Cross-sectional studies have reported significant temporal increases in prevalence of childhood obesity in both genders and various racial groups, but recently the rise has subsided. Childhood obesity prevention trials suggest that, on average, overweight/obese children lose body weight and non-overweight children gain weight. This investigation tested the hypothesis that overweight children lose body weight/fat and non-overweight children gain body weight/fat using a longitudinal research design that did not include an obesity prevention program. The participants were 451 children in 4th to 6th grades at baseline. Height, weight, and body fat were measured at Month 0 and Month 28. Each child's body mass index (BMI) percentile score was calculated specific for their age, gender and height. Higher BMI percentile scores and percent body fat at baseline were associated with larger decreases in BMI and percent body fat after 28 months. The BMI percentile mean for African-American girls increased whereas BMI percentile means for white boys and girls and African-American boys were stable over the 28 month study period. Estimates of obesity and overweight prevalence were stable because incidence and remission were similar. These findings support the hypothesis that overweight children tend to lose body weight and non-overweight children tend to gain body weight.

Keywords

childhood obesity; longitudinal study; prevalence; incidence; remission

Introduction

Studies of temporal changes in childhood obesity in the U.S. typically use cross-sectional study designs to assess prevalence of overweight and obesity at different time points (1–3). A recent National Health and Nutrition Examination Survey (NHANES) paper (1) reported that the trend for rising prevalence of childhood overweight and obesity has diminished over the past 10 years, with one exception: a continued increase in the prevalence of very obese ($\geq 97^{th}$ BMI percentile) boys in the age range from 6 to 19 years. Two longitudinal studies of obesity prevention (4,5) concluded that over periods ranging from 24 to 28 months, mean body weight for overweight and obese children (mean ages at baseline for the two studies were 9.9 and 10.5 years) decreased, but body weight of non-overweight children increased. Analogous changes in percent body fat were also reported. A two-year childhood obesity prevention study (6) found that the incidence (transition of non-overweight status to

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overweight status) in the control arm was 14.9% which differed significantly from the 7.5% incidence for the intervention arm. It is noteworthy, that remission (transition from overweight to non-overweight status) in the two arms was −7.6% for the control arm and −10.9% for the intervention arm (non-significant effect). Thus, all three recent childhood obesity prevention studies reported a trend for decreased body weight (over time) for overweight children, but increased body weight for non-overweight children. In cross-sectional studies such as the NHANES reports, prevalence for overweight and obesity will be stable if incidence equals remission; and prevalence will increase only if incidence significantly exceeds remission. The pattern of body weight changes in different groups can only be meaningfully addressed using longitudinal studies. Cross-sectional studies do not inform about which individuals become overweight or obese over several years; nor do they inform about which individuals lose weight over time. For example, studies of obesity prevalence which compare prevalence estimates across two or more cross-sectional studies conducted at different times (1), might report no changes in prevalence, but cannot report on remission and incidence across the time points because they require following the same individuals across the time points. Unfortunately, the obesity prevention reports pertaining to this issue (4–6) used extensive outcome assessment and tested at least one intervention relative to a control arm. The use of extensive measurements and testing an obesity prevention program, could impact changes in body weight, even in control arms. Research on the reactive effects of measurement and/or introducing treatment interventions has repeatedly demonstrated that it is difficult, if not impossible, to control for these reactive effects on outcomes (7).

This pilot investigation was designed to address the limitations of the earlier longitudinal investigations by studying changes in body weight and fat across a study period of 28 months in a cohort of children who did not participate in a prevention trial and did not undergo extensive outcome assessment. The primary aim of the pilot study was to test the hypothesis that non-overweight children tend to gain body weight and that overweight/obese children tend to lose body weight.

Method

Participants

Williamson et al (8) described the recruitment of schools and participants of this cohort. The study was reviewed and approved by an Institutional Review Board. The children and parents of all child volunteers (enrolled in Grades 4 to 6 at baseline) provided written informed assent/consent to participate in the study. A total of 612 students enrolled in 10 schools located in rural communities of Louisiana participated in the 28 month study. One hundred sixty one children (26%) were unavailable at Month 28. At baseline (Month 0), 52.9% of the children were white and 56.5% were white at Month 28. Statistical analyses were based on the remaining 451 students. Excluded students (on average) were slightly older than those included (10.8 versus 10.5, $p = .01$) and a higher percentage were African American (50% versus 40%, $p = .01$). The mean age of students with complete data was 10.5 (SD = 1.1) and 12.8 years (SD = 1.1) at baseline and Month 28, respectively. Girls comprised 52.9% and 53.9% of the sample at baseline and at Month 28, respectively. Mean height and weight of students who completed the study was 42.5kg (SD = 14.6) and 145.1 cm (SD = 9.2) at baseline and 58.4kg (SD = 16.8) and 158 cm (SD = 8.9) at Month 28. Mean BMI percentile score was 69.8 (SD = 29.4) at baseline and 71.3 at Month 28 (SD = 27.5). Mean baseline percent body fat was 24.5% (SD= 11.6) and 26.3% (SD = 12.2) at Month 28. There were no differences in baseline measures of adiposity (% body fat, BMI percentile, and weight) between students who completed the study versus those who were unavailable for measurement at Month 28 (p values > 0.15).

Assessment Methods

Baseline assessments of body weight and fat were conducted in the Fall semester of 2006 and in the Spring semester of 2009, after 28 months. The order of assessment was randomly assigned for each school prior to the baseline assessment, and this schedule was followed for Month 28 assessment.

Height, Weight and Body Composition—Height and weight were measured while each child was in normal school clothing with shoes and socks removed. Height was measured using a stadiometer. Weight was measured using the Tanita Body Composition Analyzer (model TBF-310) scales which measures body weight and body impedance simultaneously by standing on the scale with bare feet. Body fat and lean body mass were automatically recorded using a laptop computer. As reported by Sung et al (9), body impedance analysis has been validated as a measure of body fat and lean body mass in children (ages 7 to 16 years). They reported that body composition estimates computed by body impedance analysis and dual energy x-ray absorptiometry were comparable and that the percent body fat estimates provided by the Tanita Body Composition Analyzer were stable over short periods of time (mean deviation = 0.06%, $p = 0.19$).

BMI and Percentile Scores—Height and weight was converted to body mass index (kg/m^2) and using the 2003 NHANES database, BMI was converted to percentile scores based on gender, height, and age. For the purpose of data analyses and presentation, BMI was expressed in terms of percentile scores when BMI data were analyzed as continuous scores (see Figure 1) and when analyzed as a categorical variable (overweight or obese versus non-overweight) was expressed in terms of International Obesity Task Force (IOTF) cut-off scores (see Table 1) for each age and gender group (10).

Results

Changes in BMI Percentile Scores

Figure 1 depicts the changes in BMI percentile scores as a function of BMI percentile, using the 2003 NHANES database, at baseline (overall and with sex and race). In this figure, change in BMI percentile scores from Month 0 to Month 28 is shown on the vertical axis and baseline BMI percentile is shown on the horizontal axis. The figure also illustrates the relationship of BMI percentile changes to the 85^{th} BMI percentile at baseline, which is the standard for defining overweight using the current US criteria (11) and the value of zero weight change (on the vertical axis) serves to indicate the intersection at which children (on average) did not gain or lose weight over the 28 month study. Each child's change score was regressed against baseline BMI percentile values and the overall relationship was statistically significant, with higher BMI at baseline associated with greater change in BMI percentile at Month 28 ($p < 0.0001$). As can be seen, children with lower BMI percentiles at baseline tended to gain weight and children with higher BMI percentiles at baseline tended to lose weight. Differences in slopes as a function of sex or race were not significant ($p = 0.99$). On average, African-American girls increased BMI percentile ($M = 4.8 \pm 1.2$; $t = 3.89$, $p = 0.0001$). Boys of both races and white girls did not change significantly from baseline (p values > 0.18).

Changes in Percent Body Fat

The age ranges in this study encompass the typical timing of the adolescent growth spurt, with girls predominating the earlier years and boys the later years. Because puberty differentially affects changes in body fat of boys and girls of this age group, body fat data were analyzed separately by gender. Statistical methods identical to those reported for BMI percentile were used. The overall relationships for boys and girls were statistically

significant, with higher BMI at baseline associated with greater change in BMI percentile at Month 28 (p values < 0.0001). White boys lost body fat ($M = -1.8 \pm 0.5$; $t = -3.79$, $p = 0.0002$), but did not differ from changes in body fat of African-American boys who did not change from baseline ($M = -0.9 \pm 0.6$; $p = 0.17$). Both white girls ($M = 4.0 \pm 0.4$; $t = 9.65$, $p < 0.0001$) and African-American girls ($M = 5.7 \pm 0.4$; $t = 12.76$, $p < 0.0001$) gained body fat and African-American girls gained more body fat in comparison to white girls ($p = 0.005$).

Prevalence, Incidence, and Remission of Overweight and Obesity Status

As noted earlier, the IOTF classification system (10) was used to define overweight and obesity status.[1] Table 1 summarizes overweight/obesity incidence and remission during the course of follow-up along with the obesity prevalence at baseline and end of study. Obesity (or overweight/obese) incidence refers to the transition from non-obese (or overweight/obese) status at Month 0 to obese (or overweight/obese) at Month 28. Remission is defined conversely, e.g. transitioning from obese (or overweight/obese) status at Month 0 to non-obese (or non-overweight/obese) status at Month 28. No differences in prevalence of overweight or obesity were observed when prevalence estimates were compared at Month 0 and Month 28, for the total sample or for boys or girls. In all cases, estimates of incidence were statistically equivalent to estimates of remission.

Discussion

The results support the hypothesis that children who are not overweight tend to gain weight whereas overweight and obese children tend to lose weight as they grow older (4,5). This conclusion is reached from the data on obesity incidence and remission in Table 1 and is further solidified by the observation in Figure 1 that the projected point of zero weight gain intersected near the criterion for overweight at baseline, i.e. BMI ~ 80th percentile. Additional analysis of these data[2] indicated that this effect could be partially attributed to “regression to the mean”, but the primary effect could be attributed to an overall pattern of weight gain in children with lower baseline BMI percentiles and weight loss in children with higher baseline BMI percentiles. This intersection was invariant for white girls and African-American boys, but for white boys the intersection for zero weight gain was approximately 65^{th} percentile and African-American girls with BMI ~ ≤ 95^{th} percentile, gained body weight. Similar findings were observed for changes in percent body fat. When these data were analyzed as cross-sectional studies of prevalence, incidence, and remission, estimates were found to be stable over the 28-month study. The differences in findings from the longitudinal and cross-sectional perspectives illustrate how the two research designs can lead to very different conclusions and reinforce the utility of longitudinal research designs.

[1]Secondary analysis tested for changes in prevalence, incidence, and remission using the Center for Disease Control (CDC) classification system (1) to define overweight (≥ 85^{th} < 95^{th} BMI percentiles), obesity (≥ 95^{th} BMI percentile), and extreme obesity (≥ 97^{th} BMI percentile) status. Seven boys in the extreme obese category at baseline lost weight and became less than extremely obese at Month 28 whereas only 1 boy in the not extremely obese group at baseline gained weight ($p = .034$). Similarly, 20 boys with BMI percentile ≥ 85^{th} at baseline underwent remission and had BMI < 85^{th} percentile at the end of study whereas 9 boys below the 85^{th} at baseline developed overweight or obesity during the study ($p = .041$). Prevalence estimates remained stable except for boys with BMI percentile ≥ 97^{th} ($p = .034$) or ≥ 85^{th} ($p = .041$). Therefore, using the CDC classification system remission estimates for boys differed slightly from those reported using the IOTF criteria. Statistical analyses of continuous body weight data utilized BMI percentile the unit of measurement because this approach allows for comparison across time (as children change in height, age, and weight). The IOTF approach does not allow this type of comparison.

[2]The mean BMI percentile for children whose BMIs at baseline were ≥ the 85^{th} percentile decreased from 95.1 to 92.5 (mean change = loss of 2.6 BMI percentile) suggesting that these children on average either lost weight or gained less relative to their peers. We estimated that a 0.5 decrease in mean BMI percentile could be attributed to regression to the mean (15); thus the net realized decrease of 2.1 (paired t-test = −4.16, $p<0.0001$) presumably was due to a propensity for actual loss in percentile rank among children who were overweight or obese at baseline. Conversely, the mean BMI percentile for children whose BMIs at baseline were < the 85^{th} percentile increased from 49.1 to 53.9 (mean change = gain of 4.8 BMI percentile). An estimated 0.2 increase in mean BMI percentile could be attributed to regression to the mean resulting in a net realized increase of 4.6 ($p < .0001$).

This study is the first longitudinal investigation that did not test the efficacy of obesity prevention strategies that has reported support for the hypothesis that overweight/obese children tend to lose weight. This report is encouraging for public health officials who are fighting the epidemic of obesity (12,13). On the other side of the picture, non-overweight children tend to gain weight, which suggests a public health strategy that also targets weight gain in borderline non-overweight children, and weight loss for African-American girls, regardless of initial BMI status. The findings of this pilot study are limited because of the non-representative sample that was studied and the relatively small sample size. Also, we caution that the interpretation of changes in BMI in growing children is difficult without investigation of changes in lean body mass and fat mass. It is noteworthy, however, that findings related to changes in percent body fat were consistent with the findings related to changes in BMI percentile scores. Nevertheless, these findings taken together with recent reports from childhood obesity prevention studies, (4–6) indicate a need for longitudinal studies of weight changes in large nationally representative samples in a variety of countries (14).

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References

1. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007–2008. JAMA 2010;303:242–9. [PubMed: 20071470]
2. Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003–2006. JAMA 2008;299:2401–5. [PubMed: 18505949]
3. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. JAMA 2002;288:1728–32. [PubMed: 12365956]
4. Williamson, DA.; Champagne, CM.; Harsha, D., et al. Efficacy of two obesity prevention programs in rural schools: The Louisiana (LA) Health Study. submitted
5. Williamson DA, Copeland AL, Anton SD, et al. Wise Mind project: a school-based environmental approach for preventing weight gain in children. Obesity (Silver Spring) 2007;15:906–17. [PubMed: 17426326]
6. Foster GD, Sherman S, Borradaile KE, et al. A policy-based school intervention to prevent overweight and obesity. Pediatrics 2008;121:e794–802. [PubMed: 18381508]
7. Cone, JD.; Foster, SL. Direct Observation in Clinical Psychology. In: Kendall, PC.; Butcher, JN., editors. Handbook of Research Methods in Clinical Psychology. New York: John Wiley & Sons; 1982. p. 311-54.
8. Williamson DA, Champagne CM, Harsha D, Han H, Martin CK, Newton R Jr, et al. Louisiana (LA) health: design and methods for a childhood obesity prevention program in rural schools. Contemp Clin Trials 2008;29:783–795. [PubMed: 18448393]
9. Sung RY, Lau P, Yu CW, Lam PK, Nelson EA. Measurement of body fat using leg to leg bioimpedance. Arch Dis Child 2000;85:263–7. [PubMed: 11517118]

10. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. Bmj 2000;320:1240–3. [PubMed: 10797032]
11. Barlow SE, Dietz WH. Obesity evaluation and treatment: Expert Committee recommendations. The Maternal and Child Health Bureau, Health Resources and Services Administration and the Department of Health and Human Services. Pediatrics 1998;102:E29. [PubMed: 9724677]
12. Finegood DT, Merth TD, Rutter H. Implications of the foresight obesity system map for solutions to childhood obesity. Obesity (Silver Spring) 2010;18 (Suppl):S13–6. [PubMed: 20107455]
13. Huang TT, Story MT. A journey just started: renewing efforts to address childhood obesity. Obesity (Silver Spring) 2010;18 (Suppl):S1–3. [PubMed: 20107453]
14. Swinburn BA, de Silva-Sanigorski AM. Where to from here for preventing childhood obesity: an international perspective. Obesity (Silver Spring) 2010;18 (Suppl):S4–7. [PubMed: 20107460]
15. Johnson WD, George VT. Effect of regression to the mean in the presence of within-subject variability. Stat Med 1991;10:1295–302. [PubMed: 1925160]

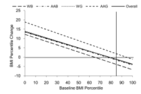

Figure 1.
Regression slopes of changes in BMI percentile as a function of baseline BMI percentile for the entire sample and for four sub-groups: white boys (WB), African-American boys (AAB), white girls (WG), and African-American girls (AAG).

Table 1

Prevalence, Incidence and Remission of Obese and Overweight/Obese at Month 28 using IOTF criteria.

	Total Sample N = 451		Boys N = 208		Girls N = 243	
Measure	**Baseline cases (%)**	**Follow-up cases (%)**	**Baseline cases (%)**	**Follow-up cases (%)**	**Baseline cases (%)**	**Follow-up cases (%)**
Obese (BMI ≥ 30)						
Prevalence	99/451 (22.0)	95/451 (21.1)	34/208 (16.3)	30/208 (14.4)	65/243 (26.7)	65/243 (26.7)
Incidence		15/352 (4.3)		2/174 (1.1)		13/178 (7.3)
Remission		19/99 (19.2)		6/34 (17.6)		13/65 (20.0)
Overweight/Obese (BMI ≥ 25)						
Prevalence	200/451 (44.3)	200/451 (44.3)	73/208 (35.1)	68/208 (32.7)	127/243 (52.3)	132/243 (54.3)
Incidence		33/251 (13.1)		12/135 (8.9)		21/116 (18.1)
Remission		33/200 (16.5)		17/73 (23.3)		16/127 (12.6)

Note: Sample sizes for prevalence included all individual with data at baseline (Month 0) and follow-up (Month 28). Sample sizes for incidence and remission were dependent on initial weight status (e.g., incidence of overweight/obese was based only on individuals who were non-obese, n = 352 for the total sample, at baseline and remission of overweight/obese was based on individuals who were obese at baseline, n = 200). No differences were observed when prevalence estimates were compared at Month 0 and Month 28, for the total sample, or for boys or girls. No differences were observed between cases of incidence and the cases of remission for the total sample, or for boys or girls.