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State Disparities in Time Trends of Adolescent Body Mass Index Percentile and Weight-Related Behaviors in the United States

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Abstract

Evidence is conflicting as to whether youth obesity prevalence has reached a plateau in the United States overall. Trends vary by state, and experts recommend exploring whether trends in weight-related behaviors are associated with changes in weight status trends. Thus, our objective was to estimate between-state variation in time trends of adolescent body mass index (BMI) percentile and weight-related behaviors from 2001 to 2007. A time series design combined cross-sectional Youth Risk Behavior Survey data from 272,044 adolescents in 29 states from 2001 to 2007. Self-reported height, weight, sports participation, physical education, television viewing, and daily consumption of 100% fruit juice, milk, and fruits and vegetables were collected. Linear mixed models estimated state variance in time trends of behaviors and BMI percentile. Across states, BMI percentile trends were consistent despite differences in behavioral trends. Boys experienced a modest linear increase in BMI percentile ($\beta = 0.18$, 95% CI: 0.07, 0.30); girls experienced a non-linear increase, as the rate of increase declined over time from 1.02 units in 2001–2002 (95% CI: 0.68, 1.36) to 0.23 units in 2006–2007 (95% CI: –0.09, 0.56). States in which BMI percentile decreased experienced a greater decrease in TV viewing than states where BMI percentile

increased. Otherwise, states with disparate BMI percentile trends did not differ with respect to behaviors. Future research should explore the role of other behaviors (e.g., soda consumption), measurement units (e.g., portion size), and societal trends (e.g., urban sprawl) on state and national adiposity trends.

Keywords

Adiposity; Adolescents; Weight-related behaviors; Time trends; Mixed models

Background

Obesity has physical, psychosocial, and economic consequences during childhood and across the lifespan. Effects at an early age include type 2 diabetes, hypertension, dyslipidemia, sleep apnea, negative body image, low self-esteem, and depressive symptoms [1]. Obesity during childhood also tends to track into adulthood [1] during which it is associated with cardiovascular disease, diabetes, several types of cancer, sleep disorders, and all-cause mortality [2]. As the United States (US) population ages, the long-term effects of youth obesity are likely to become a greater public health burden. Using data on adolescent obesity in 2000 and historical trends of obesity tracking into adulthood, Bibbins-Domingo et al. [3] projected that coronary heart disease prevalence in the US will increase 5–16% by 2035 as a result of obesity among today's adolescents, resulting in an increase of 100,000 prevalent cases.

The prevalence of obesity among 12–19 year-olds increased from 5% in 1976–1980 to 16% in 1999–2000 [4], but in recent years there has been conflicting evidence of whether it has reached a “plateau.” Ogden et al. [5] reported no linear trend across 2-year periods from 1999 to 2008, based on data from the National Health and Nutrition Examination Survey (NHANES). In contrast, Bethell et al. [6] and Singh et al. [7] both reported that the prevalence of obesity increased among 10–17 year-olds from 2003 to 2007, based on data from the National Survey of Children's Health (NSCH). Singh et al. [7] also reported substantial between-state variation in obesity trends, as changes in the prevalence ranged from –32.1% (Oregon) to 45.8% (Arizona). Such variation raises the question of whether that US is achieving one goal of *Healthy People 2010* (reducing obesity overall) at the expense of another (eliminating geographic disparities) [8].

The discrepancies between national obesity trends estimated in NHANES and NSCH, along with the state variation reported by Singh et al. [7], highlight the need to continue to investigate national and state trends using different data sources. In a systematic review, Rokholm et al. [9] recommended that future studies explore: (1) non-linear trends in obesity prevalence and (2) behavioral changes that may account for the stabilization. As the authors discussed, investigating the association between trends in weight-related behaviors and changes in obesity trends is an opportunity to explore causes of the obesity epidemic [9]. This opportunity is salient when examining both national obesity trends and between-state variation in trends. Many states have introduced legislation designed to reduce obesity by targeting different weight-related behaviors, but legislative activity has varied considerably by state [10]. Identifying behavioral trends that distinguish states that reversed or attenuated youth obesity trends from states that did not can provide insight as to how certain states have been successful in preventing further increases in obesity.

Behavioral differences are just one of many potential source of state variation in obesity trends. Geographic disparities in obesity are a common finding worldwide [11–18] and can result from a complex interplay of sociodemographic, behavioral, and environmental

differences. Du et al. [19] argued that many longitudinal studies ignore population shifts that occur during follow-up, and such demographic changes must be considered particularly when studying larger geographic areas such as states that are more dynamic. Singh et al. [17] identified many behavioral, demographic, and contextual sources of cross-sectional geographic disparities in youth obesity, but did not explore whether these variables were associated with state variation in obesity trends.

The objectives of this study were to build upon previous studies of obesity trends and address the gaps noted by Rokholm et al. by: (1) estimating between-state variation in adolescent time trends in body mass index (BMI) percentile and weight-related behaviors from 2001 to 2007, using Youth Risk Behavior Survey (YRBS) data, (2) testing for non-linear trends, and (3) identifying behavioral, demographic, and contextual factors that distinguish states with disparate trends.

Methods

Sample

The time-series design combined cross-sectional samples from the 2001, 2003, 2005, and 2007 YRBS, a biennial survey of 9th–12th grade students, administered on the national, state, and local level. Data used in this study came from the state-level YRBS. Participation by states was voluntary in each year and individual students were not followed over time. Students were sampled by the state using a two-stage cluster sampling design, and data were weighted according to school and student response rates to produce estimates that are representative of the state jurisdiction [20]. Data were weighted only in states that provide appropriate documentation and have an overall response rate ≥ 60%. Years in which states did not fit these criteria were excluded from analyses because their data were not considered representative. To allow estimation of non-linear trends, we limited analyses to states that provided height and weight data in 3 survey years ($n = 15$: AL, AZ, AR, DC, GA, IN, KY, MS, NH, NY, OH, TN, TX, VT, WV) or all 4 survey years ($n = 14$: DE, FL, ID, MA, ME, MI, MO, MT, NC, ND, RI, UT, WI, WY) from 2001 to 2007. A total of 272,044 students from these 29 states provided data in 2001, 2003, 2005, and 2007 combined.

Variables

Anthropometric and Behavioral Data—Data were collected using a written questionnaire administered to students in classrooms. Our outcome of interest was BMI percentile, calculated from self-reported height and weight. BMI percentile accounts for developmental differences between boys and girls of different ages by measuring each student's BMI relative to a reference population composed of children of the same age and sex in the US from 1963 to 1994 [21]. Brener et al. [22] studied the validity of self-reported height and weight data in YRBS and found that students over-reported their height by an average of 2.7 inches and underreported their weight by 3.5 lb, but the correlations between measured and self-reported BMI was 0.89.

We focused on trends in BMI percentile rather than obesity for several reasons. The 95th percentile of BMI is commonly used to define obesity among youth [23], but the ability of this cut-point to identify youth of excess fatness can vary by race/ethnicity, particularly among girls [24]. Weight gains in childhood have also been associated with cardiovascular risk factors independent of weight classification [25, 26]. Finally, Ogden et al. [5] noted changes in the BMI distribution that may not be reflected in changes in obesity prevalence (e.g., an increase in the proportion of boys with a BMI above the 97th percentile). To facilitate comparisons of our results with other studies, we also repeated analyses of time trends using obesity as the outcome.

Our analyses included all nutrition and physical activity behaviors (referred to collectively as “weight-related behaviors”) that were measured in the majority of states in each survey year from 2001 to 2007: sports played in the past 12 months, days of physical education (PE) per school week, hours of television (TV) watched per school day, and daily consumption of 100% fruit juice, fruit, salad, potatoes, carrots, other vegetables, and milk. Daily servings of fruit, salad, potatoes, carrots, and other vegetables were summed to create a measure of fruit and vegetables per day. All behaviors were hypothesized to be negatively associated with BMI percentile except TV viewing, which was hypothesized to be positively associated with BMI percentile.

Demographic Variables—The demographic variables of interest were self-reported age, gender, and a 4-category measure of race and ethnicity: non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic Other.

Contextual Variables—Singh et al. [17] found that state-level poverty rate, income equality, and violent crime rate statistically accounted for 17, 16, and 7% of the state variance in youth obesity respectively, independent of individual-level behavioral and demographic variables. We obtained data on these variables for each survey year to determine if they were similarly associated with adolescent BMI percentile trends. State-level data on household income inequality, as measured by the Gini coefficient, were obtained from the US Census, as were poverty rate and violent crime rate [27].

Multiple studies have examined the impact of cigarette prices and taxes on adult BMI trends, with two studies finding a positive association [28, 29] and one study documenting a negative association [30]. This topic has not been explored in adolescents to our knowledge. Given that youth are responsive to changes in cigarette prices [31], we examined whether state-level changes in cigarette taxes were associated with state BMI percentile trends, using data from the Tax Foundation [32].

Statistical Analyses

Overall Time Trends—All analyses accounted for the complex sample design in YRBS [20]. As a preliminary analysis, we estimated the time trend in BMI percentile and all weight-related behaviors in the sample overall. We used a linear model with a robust standard error to account for state clustering in this part of the analysis [33]. In the model of BMI percentile trends, we tested for an interaction between gender and year ($\alpha = 0.10$) and found that it was significant. Subsequently, all analyses were stratified by gender. We chose not to test for an interaction between race/ethnicity and year because the primary purpose of this study was to estimate state disparities, and several states did not have sufficient racial/ethnic diversity to accurately estimate within-state time trends by race/ethnicity. After stratifying by gender, we tested for non-linear time trends by including a quadratic term for time in both gender groups ($\alpha = 0.10$).

Associations Between BMI Percentile and Weight-Related Behaviors

Subsequently, we used a linear model with robust standard errors to estimate the associations between behavioral variables and BMI percentile. Gender-specific models adjusted for race/ethnicity, age, and all contextual variables. Juice consumption and TV viewing were modeled as continuous variables, and the following behaviors were dichotomized: sports (< 1 per 12 months), PE attendance (< 1 day per week), fruit/vegetable consumption (< 5 per day), and milk consumption (< 4 glasses per day). The cut-point for milk consumption was chosen after exploratory analyses revealed that the bivariate association between milk consumption and BMI percentile in the sample was decidedly non-linear, with an obvious change in the direction of association at 4 glasses per day.

Between-State Variance in Time Trends—Linear mixed models were used to estimate variance in the time trends of BMI percentile and weight-related behaviors across states. The notation for the mixed models was adapted from Murray [34]. BMI percentile is used as an example, but identical models were used to estimate time trends in each weight-related behavior. For this part of the analysis, all variables were modeled as continuous outcomes:

$$\text{BMI}_{i,jk} = \beta_0 + T_{(\text{lin})}t_k + S_j + S_j T_{(\text{lin})}t_k + \varepsilon_{i,jk}$$

$\text{BMI}_{i,jk}$ represents the BMI percentile of the i th individual nested within state j in year k . Mixed models account for state clustering by estimating an overall intercept, β_0 , as well as a random intercept (S_j) by state, $\sim N(0, \sigma_s^2)$. The overall intercept can be interpreted as the mean state-level BMI percentile in 2001. $T_{(\text{lin})}t_k$ represents the linear time trend, or the average change in mean BMI percentile per year across states. $S_j T_{(\text{lin})}t_k$, $\sim N(0, \sigma_{t(\text{lin})s}^2)$, represents a random slope for time by state. When trends were found to be non-linear, we added another random component ($S_j T_{(\text{quad})}t_k^2$) to estimate the variance of the quadratic component of the estimated time trend. We calculated the intraclass correlation (ICC) for the intercept and time trend (ICC_T). The ICC represents the proportion of variance in BMI percentile due to state differences in each parameter. All random parameters were allowed to covary, allowing us to determine if, for example, states with a higher mean BMI percentile in 2001 had a larger or smaller increase in BMI percentile from 2001 to 2007. Mixed model analyses were conducted with Mplus Version 5.21 to incorporate the sampling weights in the YRBS [35]. All other analyses were conducted with Stata 11 [36].

State-Level Case–Control Analysis—After estimating between-state variance, we explored differences between states in which BMI percentile increased between survey years and those in which it decreased. We created a data set in which state was the unit of analysis and each 2-year survey interval (i.e., 2001–2003, 2003–2005, 2005–2007) was a separate observation, meaning states would appear in the data set 3 times if data were collected in each survey year. Each observation was categorized according to whether the mean BMI percentile increased or decreased during that interval in that state. We used t -tests ($\alpha = 0.10$) to compare state/interval observations in which BMI percentile increased to those in which it decreased—analogueous to a case–control analysis—with respect to changes in demographic, behavioral, and contextual variables during the same interval.

Results

Descriptive Statistics

Table 1 provides the sample size, mean BMI percentile, obesity prevalence, and distribution of demographic variables overall, and descriptive statistics of state participation and within-state sample size and student response rates. BMI percentile and prevalence of obesity, as defined by the 95th percentile of BMI [23], both increased across years. Across states, the mean BMI percentile in 2001 ranged from 52.7 in Utah to 65.5 in Washington D.C. BMI percentile clustered by region, as most states in the Southeast had a mean percentile above the sample median, while all states in the Rocky Mountains had a mean percentile below the median.

Estimated Trends in BMI Percentile and Weight-Related Behaviors

Table 2 displays the estimated 2001 mean and time trends in BMI percentile and weight-related behaviors, by gender. The mean BMI percentile in 2001 was 57.67 and 63.57 among girls and boys, respectively. Among boys, the mean increased modestly over time, in a

linear fashion, by 0.18 units per year (95% confidence interval (CI): 0.07, 0.30). Trends among girls were non-linear, and the linear and quadratic coefficients for time (1.10 and -0.08 , respectively) suggested that the mean BMI percentile increased throughout the study time period but the magnitude of increase declined from 1.02 units in 2001–2002 (95% CI: 0.68, 1.36) to 0.23 units in 2006–2007 (95% CI: -0.09 , 0.56). Analyses of obesity trends (not shown) showed a linear increase over time among girls (OR for 1-year change: 1.04, 95% CI: 1.02, 1.06), but no change among boys. TV viewing, milk consumption, and 100% fruit juice consumption decreased across years in both genders, but the change per year was <0.05 units. Milk consumption, for example, decreased each year by 0.02 glasses per day among girls, or 1.7% of the 2001 mean. PE attendance, sports participation, and fruit and vegetable consumption did not change over time in either group.

Associations Between BMI Percentile and Weight-Related Behaviors

Cross-sectional associations between each behavior and mean BMI percentile on the student level are displayed in Table 3. TV viewing was the only behavior that was associated with mean BMI percentile in the hypothesized directions among both boys and girls. Playing at least one sport was negatively associated among girls, but positively associated among boys. Greater juice consumption was also associated with lower mean BMI percentile among girls. Among boys, higher mean BMI percentile was associated with drinking four or more glasses of milk per day or having at least 1 day of PE per week. Other estimates were close to the null.

Table 3 also displays the association between sociodemographic and contextual variables and BMI percentile. Mean BMI percentile was substantially higher among non-Hispanic Blacks and Hispanics, relative to non-Hispanic Whites, among both boys and girls. Poverty status was positively associated with mean BMI percentile among boys ($\beta = 0.37$, 95% CI: 0.03, 0.71), while income inequality was positively associated with mean BMI percentile among girls ($\beta = 0.50$, 95% CI: 0.01, 0.99).

Between-State Variance in Trends

Though the behavioral changes over time were small overall, Fig. 1 shows that time trends in most behaviors varied by state in magnitude and even in direction. Each line represents the time trend among girls for a different state, as estimated by the mixed model. Graphs of state trends among boys were qualitatively similar (results not shown), and the intraclass correlations for both genders are displayed in Table 4. Even though the proportion of variance attributable to state differences in time trends was low for each behavior ($ICC_T < 0.1\%$), Fig. 1 shows a heterogeneous combination of state trends in fruit and vegetable consumption, sports participation, and PE attendance. For each behavior, some states experienced an increase over time while others experienced a decrease. All states experienced a decrease in milk and fruit juice consumption among girls, but the range of decline was small (0.01–0.03 daily servings of milk; <0.01 –0.04 daily servings of juice.) State trends were negatively correlated with their 2001 mean (r_{β_0, β_T}) for each behavior, indicating that states with a lower mean in 2001 had a greater increase over time. ICC_0 estimates indicate that state differences accounted for 1–2% of the variance in sports participation, fruit and vegetable consumption, and fruit juice consumption in both genders, as well as PE attendance in boys, and 5–7% of the variance in TV viewing and milk consumption, and PE attendance in girls.

In contrast to Fig. 1, the state variance in BMI percentile time trends was very low (Fig. 2), particularly among boys ($ICC_T = 0.0008\%$). The ICC_T was higher for girls, but the shape of the trend was very similar across states. BMI percentile increased from 2001 to 2007 among girls in all states, but the rate of increase generally declined over time.

Case–Control Analysis

Table 5 displays the results of the state-level case–control analysis. TV viewing was the only variable that distinguished states in which BMI percentile increased from those in which it decreased in both boys and girls. For example, during 2-year YRBS intervals in which states experienced a decrease in BMI percentile among girls ($n = 19$), average TV viewing declined by 0.08 h per day, compared to a decline of only 0.01 h per day in intervals in which states experienced an increase in BMI percentile among girls ($n = 49$) (difference = -0.07 , 90% CI: -0.13 , -0.02). Changes in cigarette taxes, juice consumption, and the distribution of race/ethnicity also differed across categories of states among girls. During intervals when BMI percentile increased, there was a greater decrease in the proportion of non-Hispanic Whites (difference = -1.01 , 90% CI: -2.01 , 0.00); conversely, the proportion of non-Hispanic Blacks increased by 0.51 percentage points during intervals when BMI percentile increased and decreased by 0.23 percentage points during intervals when BMI percentile decreased (difference = 0.74 , 90% CI: 0.00 , 1.50).

Discussion

Among 9th–12th grade students, states experienced different trends in weight-related behaviors from 2001 to 2007, but BMI percentile changes over time were similar across states. These results are not contradictory given that both the behavioral trends and the association between the behaviors and BMI percentile were modest in size. Sports participation among girls, for example, had a relatively high association with BMI percentile, but its prevalence was stable from 2001 to 2007, and the change in prevalence did not differ between states with different BMI percentile trends. Among girls, differences in BMI percentile between states may be attributable to demographic shifts in the racial distribution more than behavioral changes. It should be noted that our estimates of behavioral trends and associations between behaviors and BMI percentile may have been attenuated by measurement error or unmeasured confounding. Overall, however, results suggest that the measured behaviors do not account for recent trends in adolescent BMI percentile, which increased from 2001 to 2007 particularly among girls.

Among the behaviors that we examined, TV viewing had the strongest evidence of being associated with BMI percentile on the student level and BMI percentile trends on the state level. The positive association on the student level, coupled with the decline in TV viewing, might seem to contradict the overall increase in BMI percentile. However, TV viewing declined primarily in states in which BMI percentile decreased. This finding suggests that the decline may partially account for the decelerating BMI percentile trend overall. TV viewing also had the highest overall ICC of any behavior, implying that it may be influenced by state-level factors. Future research could explore state-level determinants of TV viewing and determine if adolescents have replaced TV viewing with alternative pursuits that are more active or sedentary (e.g., computers, phone).

The lack of state variance in BMI percentile trends is interesting given that legislative activity to reduce childhood obesity has varied considerably across states [10]. Arkansas, for example, has taken aggressive action to remove vending machines from schools and require that students' BMI be measured and results confidentially mailed to parents. After the legislation was passed in 2003, researchers reported that obesity did not increase in Arkansas between the 2003–2004 and 2004–2005 school years [37]. Arkansas' results are encouraging, but they must be considered in light of the fact that the state had the 2nd-highest BMI percentile among states in our sample in 2001. We found that populations with a higher BMI percentile at baseline generally experienced less BMI percentile gain, and thus Arkansas' stability may simply be due to a nationwide pattern of heavier populations

reaching a plateau. States with similar BMI percentile distributions at baseline would need to be compared to support the causal effect of legislative changes.

Similar to the studies of obesity time trends conducted with NSCH data [6, 7], our analyses of YRBS data suggested an overall increase in obesity from 2001 to 2007 that was particularly strong among girls. The discrepancies in these results and those reported by Ogden et al. [5] may be due to the fact that NHANES measures height and weight directly while YRBS and NSCH rely on student and parental self-report, respectively. YRBS height and weight data are prone to measurement error [22], and we likely underestimated adolescent BMI percentile as a result. This would not create a bias toward detecting a time trend, however, unless measurement error decreased over time.

In addition to being limited to self-reported height and weight, our analyses were limited to self-reported behaviors that are also prone to measurement error [38, 39]. Non-differential error may have caused us to underestimate the association between these behaviors and BMI percentile. Even when associations were detected, we were unable to assess causality between weight-related behaviors and BMI percentile because the analyses were based on a series of cross-sectional surveys and did not measure within-student changes over time. Our analyses were also limited to the 29 states that provided representative data in enough survey years during the study period. Results cannot be generalized to other states, and we were unable to estimate state variation in time trends by race/ethnicity because of the limited sample.

BMI is also an imperfect measure of adiposity because it does not distinguish between fat mass and fat-free mass, and this limitation may explain the positive associations that we found between BMI percentile and physical activity behaviors (PE attendance, sports participation) among boys. Boys who play more sports and attend PE class more often may build up more muscle mass, resulting in a higher BMI even if their body fat distribution improves. Boys who consumed four or more glasses of milk per day were also found to have a higher mean BMI percentile than those who consume less. This finding is similarly difficult to interpret because the YRBS does not distinguish between types of milk; additional research would be needed to determine if the association was due to the quantity of consumption per se or the specific types of milk that boys consumed.

Similar to the behavioral variables, contextual variables that we examined did not account for state trends in BMI percentile even when they were associated with BMI percentile on the student level. Of all the variables that we examined, race/ethnicity had the strongest evidence of association with BMI percentile on both levels. The large differences in BMI percentile between both non-Hispanic Blacks and Hispanics, compared to non-Hispanic Whites, is not surprising given the consistent racial/ethnic disparities in obesity [40]. Many societal trends that we did not examine have been hypothesized to contribute to the contemporary “obesogenic” environment, such as increased portion sizes [41], urban sprawl [42], and growth of the processed food sector [43]. These trends may impact other behaviors such as soda consumption, which the YRBS did not measure until 2007, or measurement units that are not captured by YRBS (e.g., portion size). Future research should explore if such trends have contributed to recent increases in youth adiposity.

Our study was strengthened by using multiple years of data designed to be representative of individual states. The sampling design of YRBS and sample size of our analysis provide evidence that adolescent BMI percentile has not peaked in many states even if youth obesity prevalence is no longer increasing in the US overall [5]. Moreover, the fact that BMI percentile trends differed by gender in both slope and shape, and obesity trends differed by state in NSCH [7], indicates that national trends are complex and dynamic, and must be

carefully deconstructed in future research. National, state, and local health organizations should continue to monitor adiposity patterns to determine if subgroups with a lower BMI percentile are continuing to gain weight. The lack of increase in obesity in individual states, such as Arkansas, is encouraging. However, rigorous studies are needed to determine if legislative action caused the stability, so that states in which obesity continues to rise can apply effective methods to alleviate the trend.

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References

1. Must A, Strauss RS. Risks and consequences of childhood and adolescent obesity. *International Journal of Obesity and Related Metabolic Disorders*. 1999; 23(Suppl 2):S2–S11. [PubMed: 10340798]
2. World Health Organization. Obesity: Preventing and managing the global epidemic. World Health Organization technical report series. Geneva: World Health Organization; 2000.
3. Bibbins-Domingo K, Coxson P, Pletcher MJ, Lightwood J, Goldman L. Adolescent overweight and future adult coronary heart disease. *New England Journal of Medicine*. 2007; 357(23):2371–2379. [PubMed: 18057339]
4. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA*. 2002; 288(14):1728–1732. [PubMed: 12365956]
5. 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(3):242–249. [PubMed: 20071470]
6. Bethell C, Simpson L, Stumbo S, Carle AC, Gombojav N. National, state, and local disparities in childhood obesity. *Health Affairs*. 2010; 29(3):347–356. [PubMed: 20194972]
7. Singh GK, Kogan MD, van Dyck PC. Changes in state-specific childhood obesity and overweight prevalence in the United States from 2003 to 2007. *Archives of Pediatrics and Adolescent Medicine*. 2010; 164(7):598–607. [PubMed: 20603458]
8. US Department of Health and Human Services. Healthy people 2010. Washington, DC: Government Printing Office; 2000.
9. Rokholm B, Baker JL, Sorensen TI. The levelling off of the obesity epidemic since the year 1999—A review of evidence and perspectives. *Obesity Reviews*. 2010; 11(12):835–846. [PubMed: 20973911]
10. Boehmer TK, Brownson RC, Haire-Joshu D, Dreisinger ML. Patterns of childhood obesity prevention legislation in the United States. *Preventing Chronic Disease*. 2007; 4(3):A56. [PubMed: 17572960]
11. Ackerson LK, Kawachi I, Barbeau EM, Subramanian SV. Geography of underweight and overweight among women in India: A multilevel analysis of 3204 neighborhoods in 26 states. *Economics and Human Biology*. 2008; 6(2):264–280. [PubMed: 18602351]
12. Chaix B, Chauvin P. Tobacco and alcohol consumption, sedentary lifestyle and overweightness in France: A multilevel analysis of individual and area-level determinants. *European Journal of Epidemiology*. 2003; 18(6):531–538. [PubMed: 12908718]
13. Dollman J, Pilgrim A. Changes in body composition between 1997 and 2002 among South Australian children: Influences of socio-economic status and location of residence. *Australian and New Zealand Journal of Public Health*. 2005; 29(2):166–170. [PubMed: 15915622]
14. Ellaway A, Anderson A, Macintyre S. Does area of residence affect body size and shape? *International Journal of Obesity and Related Metabolic Disorders*. 1997; 21(4):304–308. [PubMed: 9130028]

15. Moon G, Quarendon G, Barnard S, Twigg L, Blyth B. Fat nation: Deciphering the distinctive geographies of obesity in England. *Social Science and Medicine*. 2007; 65(1):20–31. [PubMed: 17467130]
16. Rami B, Schober E, Kirchengast S, Waldhor T, Sefranek R. Prevalence of overweight, obesity in male adolescents in Austria between 1985 and 2000. A population based study. *Journal of Pediatric Endocrinology and Metabolism*. 2004; 17(1):67–72. [PubMed: 14960023]
17. Singh GK, Kogan MD, van Dyck PC. A multilevel analysis of state and regional disparities in childhood and adolescent obesity in the United States. *Journal of Community Health*. 2008; 33(2): 90–102. [PubMed: 18049885]
18. Willms JD, Tremblay MS, Katzmarzyk PT. Geographic and demographic variation in the prevalence of overweight Canadian children. *Obesity Research*. 2003; 11(5):668–673. [PubMed: 12740457]
19. Du P, Coles FB, O'Campo P, McNutt LA. Changes in population characteristics and their implication on public health research. *Epidemiologic Perspectives & Innovations*. 2007; 4(6)
20. Brener ND, Kann L, Kinchen SA, et al. Methodology of the youth risk behavior surveillance system. *Morbidity and mortality weekly report. Morbidity and Mortality Weekly Report – Recommendations and Reports*. 2004; 53(RR-12):1–13. [PubMed: 15385915]
21. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. *Advance Data*. 2000; 314:1–27. [PubMed: 11183293]
22. Brener ND, McManus T, Galuska DA, Lowry R, Wechsler H. Reliability and validity of self-reported height and weight among high school students. *Journal of Adolescent Health*. 2003; 32(4):281–287. [PubMed: 12667732]
23. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: Summary report. *Pediatrics*. 2007; 120(Suppl 4):S164–S192. [PubMed: 18055651]
24. Freedman DS, Wang J, Thornton JC, et al. Racial/ethnic differences in body fatness among children and adolescents. *Obesity (Silver Spring)*. 2008; 16(5):1105–1111. [PubMed: 18309298]
25. McGavock JM, Torrance B, McGuire KA, Wozny P, Lewanczuk RZ. The relationship between weight gain and blood pressure in children and adolescents. *American Journal of Hypertension*. 2007; 20(10):1038–1044. [PubMed: 17903685]
26. Sinaiko AR, Donahue RP, Jacobs DR Jr, Prineas RJ. Relation of weight and rate of increase in weight during childhood and adolescence to body size, blood pressure, fasting insulin, and lipids in young adults. The Minneapolis children's blood pressure study. *Circulation*. 1999; 99(11): 1471–1476. [PubMed: 10086972]
27. US Bureau of the Census. American Community Survey. Available from <http://www.census.gov/>.
28. Baum CL. The effects of cigarette costs on BMI and obesity. *Health Economics*. 2009; 18(1):3–19. [PubMed: 18241088]
29. Chou SY, Grossman M, Saffer H. An economic analysis of adult obesity: results from the behavioral risk factor surveillance system. *Journal of Health Economics*. 2004; 23(3):565–587. [PubMed: 15120471]
30. Gruber J, Frakes M. Does falling smoking lead to rising obesity? *Journal of Health Economics*. 2006; 25(2):183–197. discussion 389–193. [PubMed: 16165234]
31. Liang L, Chaloupka F, Nichter M, Clayton R. Prices, policies and youth smoking, May 2001. *Addiction*. 2003; 98(Suppl 1):105–122. [PubMed: 12752364]
32. The Tax Foundation. State sales, gasoline, cigarette, and alcohol tax rates by State, 2000–2009. 2010 Available from <http://www.taxfoundation.org/taxdata/show/245.html>.
33. Williams RL. A note on robust variance estimation for cluster-correlated data. *Biometrics*. 2000; 56(2):645–646. [PubMed: 10877330]
34. Murray, D. Design and analysis of group-randomized trials. New York: Oxford University Press; 1998.
35. Muthen, LK.; Muthen, BO. MPlus user's guide. 5th ed.. Los Angeles, CA: Muthen & Muthen; 1998–2007.
36. StataCorp. Stata statistical software: Release 11. College Station, TX: StataCorp LP; 2009.

37. Ryan KW, Card-Higginson P, McCarthy SG, Justus MB, Thompson JW. Arkansas fights fat: Translating research into policy to combat childhood and adolescent obesity. *Health Affairs*. 2006; 25(4):992–1004. [PubMed: 16838410]
38. Kipnis V, Subar AF, Midthune D, et al. Structure of dietary measurement error: Results of the OPEN biomarker study. *American Journal of Epidemiology*. 2003; 158(1):14–21. [PubMed: 12835281]
39. Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine*. 2003; 37(3):197–206. [PubMed: 12782543]
40. Wang Y, Beydoun MA. The obesity epidemic in the United States—Gender, age, socioeconomic, racial/ethnic, and geographic characteristics: A systematic review and meta-regression analysis. *Epidemiologic Reviews*. 2007; 29:6–28. [PubMed: 17510091]
41. Young LR, Nestle M. The contribution of expanding portion sizes to the US obesity epidemic. *American Journal of Public Health*. 2002; 92(2):246–249. [PubMed: 11818300]
42. Lopez R, Hynes HP. Sprawl in the 1990s: Measurement, distribution, and trends. *Urban Affairs Review*. 2003; 38(3):325–355. [PubMed: 16990927]
43. Schluter G, Lee C. Changing food consumption patterns: their effect on the US food system, 1972–1992. *Food Review*. 1999; 22:35–37.

Fig. 1. State-specific trends in weight-related behaviors among adolescent girls in the United States, state Youth Risk Behavior Survey, 2001–2007 (All variables coded as continuous outcomes)

Fig. 2.
 State-specific trends in BMI percentile among adolescent girls and boys, state Youth Risk Behavior Survey, 2001–2007

Table 1

Unweighted descriptive statistics of samples from 29 states that participated in Youth Risk Behavior Survey (YRBS) in at least 3 years, 2001–2007

	2001	2003	2005	2007
<i>Sample size (students)</i>	53,292	60,114	76,342	82,296
<i>Anthropometric variables</i>				
BMI percentile (mean)	60.3	61.1	62.5	62.6
Obesity (%)	10.6	11.4	11.9	12.5
<i>Demographic variables (%)</i>				
Gender				
Male	50.7	51.2	51.2	50.9
Female	49.3	48.8	48.8	49.1
Age				
14	10.7	11.6	12.1	11.1
15	26.6	26.8	27.1	26.5
16	27.2	26.8	27.0	27.2
17	22.2	21.9	22.2	23.3
18	13.3	12.9	11.6	11.9
Race/ethnicity				
Non-Hispanic White	67.3	63.9	62.2	61.1
Non-Hispanic Black	14.0	15.1	15.1	14.5
Hispanic	11.2	11.0	13.5	15.7
Non-Hispanic other	7.5	10.0	9.3	8.7
<i>State participation</i>				
# of states that participated	19	26	28	28
Within-state sample size (students)				
Median	2,120	1,781	2,375.5	2,398
Minimum	1,071	1,088	1,140	1,324
Maximum	7,067	9,320	9,708	13,439
Within-state student response rate ^a				
Mean	81.2	82.2	78.8	78.1
Minimum	69	64	68	69
Maximum	90	94	92	89

^aStudent response rate = (number of useable questionnaires/number of students sampled)

Table 2

Estimated 2001 mean and time trends (β_T) of BMI percentile and weight-related behaviors in the United States, by gender, Youth Risk Behavior Survey, 2001–2007

	Mean ^a	SEM	β_T	95% CI
<i>BMI percentile</i>				
Girls	57.67	0.43		
Linear			1.10	0.73, 1.47
Quadratic			−0.08	−0.14, −0.01
Boys	63.57	0.30	0.18	0.07, 0.30
<i>TV viewing</i>				
Girls	2.07	0.03	−0.01	−0.03, 0.00
Boys	2.30	0.03	−0.04	−0.05, −0.03
<i>Sports participation</i>				
Girls	0.87	0.02	0.00	−0.01, 0.01
Boys	1.18	0.01	0.00	−0.01, 0.01
<i>PE attendance</i>				
Girls	1.68	0.05	0.01	−0.01, 0.02
Boys	2.17	0.04	0.01	−0.01, 0.03
<i>Fruits and vegetables</i>				
Girls	2.28	0.03	0.00	−0.01, 0.01
Boys	2.50	0.03	0.00	−0.01, 0.01
<i>100% fruit juice</i>				
Girls	0.86	0.01	−0.02	−0.02, −0.01
Boys	1.01	0.01	−0.02	−0.03, −0.02
<i>Milk</i>				
Girls	0.91	0.01	−0.02	−0.03, −0.01
Boys	1.42	0.02	−0.03	−0.04, −0.03

^aEstimated 2001 mean, based on linear model

Table 3

Cross-sectional association of behavioral and contextual variables with BMI percentile in the United States, by gender, Youth Risk Behavior Survey, 2001–2007

	Girls		Boys	
	β	95% CI	β	95% CI
<i>Behavioral^a</i>				
TV viewing	0.81	0.63, 0.99	0.69	0.38, 1.01
Sports participation	-3.12	-3.96, -2.27	1.46	0.71, 2.21
PE attendance	-0.57	-1.65, 0.49	0.85	0.12, 1.57
Fruit and vegetables	1.00	-0.04, 2.03	0.91	-0.61, 2.42
Milk	-0.30	-2.17, 1.56	2.75	1.44, 4.06
100% fruit juice	-0.41	-0.69, -0.14	0.17	-0.27, 0.62
<i>Demographic</i>				
Age (years)	-1.71	-1.91, -1.51	-1.47	-1.93, -1.02
Race/ethnicity (%)				
Non-Hispanic White	–	–	–	–
Non-Hispanic Black	9.65	8.86, 10.44	2.94	1.42, 4.46
Hispanic	6.74	4.72, 8.76	4.28	2.99, 5.57
Non-Hispanic other	-0.56	-3.28, 2.17	-2.38	-4.36, -0.39
<i>Contextual</i>				
Poverty status (%)	0.05	-0.39, 0.48	0.37	0.03, 0.71
Income inequality ^b	0.50	0.01, 0.99	0.17	-0.38, 0.73
Violent crime rate ^c	-0.61	-1.28, 0.06	-0.16	-0.84, 0.51
Cigarette taxes (cents)	0.00	-0.02, 0.02	-0.01	-0.03, 0.01

^aModeled as follows: TV viewing and 100% fruit juice (continuous), sports participation (binary, 1 per 12 months), PE attendance (binary, 1 day per week), fruits/vegetable consumption (binary, 5 per day), and milk consumption (binary, 4 glasses per day)

^bMeasured by Gini coefficient, on a 0–100 scale

^cPer 100,000

Table 4

Proportion of variance of weight-related behaviors and BMI percentile attributable to state differences overall (ICC_0) and state differences in time trends (ICC_T), and correlation between states' 2001 mean and time trend ($r_{\beta 0, \beta T}$)

	ICC_0	ICC_T	$r_{\beta 0, \beta T}$
<i>TV viewing</i>			
Girls	0.07	0.0001	-0.63
Boys	0.05	0.0004	-0.68
<i>Sports participation</i>			
Girls	0.02	0.0001	-0.11
Boys	0.01	0.0002	-0.49
<i>PE attendance</i>			
Girls	0.05	0.0006	-0.40
Boys	0.02	0.0006	-0.02
<i>Fruits and vegetables</i>			
Girls	0.01	0.0002	-0.42
Boys	0.01	0.0003	-0.63
<i>100% fruit juice</i>			
Girls	0.01	0.0002	-0.74
Boys	0.02	0.0003	-0.75
<i>Milk</i>			
Girls	0.05	0.0001	-0.68
Boys	0.05	0.0002	-0.72

All variables coded as continuous outcomes

Table 5

Mean change per year (standard error) in behavioral, demographic, and contextual variables among states in which mean BMI percentile among adolescents increased between survey years, $\Delta X_{\text{BMI}(\uparrow)}$, and states in which BMI percentile decreased between survey years, $\Delta X_{\text{BMI}(\downarrow)}$, by gender, Youth Risk Behavior Survey, 2001–2007

	Girls		Boys	
	$\Delta X_{\text{BMI}(\uparrow)}$	$\Delta X_{\text{BMI}(\downarrow)}$	$\Delta X_{\text{BMI}(\uparrow)}$	$\Delta X_{\text{BMI}(\downarrow)}$
<i>Behavioral variables^a</i>				
TV viewing	−0.01 (0.02)	−0.08 (0.02)	−0.04 (0.02)	−0.12 (0.03)
Sports participation (%)	−0.05 (0.56)	0.04 (0.81)	0.34 (0.55)	−0.46 (0.63)
PE attendance (%)	−0.50 (0.82)	−1.68 (1.25)	−0.69 (1.08)	0.62 (0.99)
Fruit/vegetables (%)	−0.11 (0.33)	0.09 (0.55)	−0.24 (0.37)	−0.59 (0.35)
Milk (%)	−0.54 (0.20)	−0.28 (0.18)	−1.30 (0.35)	−1.48 (0.37)
100% fruit juice	−0.06 (0.01)	−0.01 (0.02)	−0.05 (0.01)	−0.04 (0.02)
<i>Demographic variables</i>				
Age (years)	−0.02 (0.02)	0.03 (0.01)	−0.03 (0.01)	0.01 (0.02)
Race/ethnicity (%)				
Non-Hispanic White	−1.68 (0.32)	−0.67 (0.49)	−1.37 (0.40)	−1.48 (0.42)
Non-Hispanic Black	0.51 (0.23)	−0.23 (0.41)	0.19 (0.23)	0.55 (0.28)
Hispanic	0.91 (0.21)	0.54 (0.48)	0.92 (0.27)	0.64 (0.30)
Non-Hispanic other	0.25 (0.19)	0.37 (0.47)	0.26 (0.31)	0.30 (0.22)
<i>Contextual variables</i>				
Poverty (%)	0.02 (0.09)	−0.18 (0.16)	0.00 (0.10)	−0.01 (0.14)
Income inequality ^b	0.59 (0.13)	0.46 (0.12)	0.50 (0.13)	0.64 (0.14)
Violent crime rate ^c	−10.69 (6.85)	−1.74 (5.15)	−8.14 (5.11)	−8.27 (10.78)
Cigarette tax (cents)	7.90 (1.88)	15.04 (4.56)	8.89 (2.25)	11.5 (3.34)

^a Changes in TV viewing and 100% fruit juice represent change in mean (hours per school day and servings per day, respectively); others represent change in prevalence on 0–100 scale (sports: 1 in past 12 months, PE attendance: 1 day per week during school year, fruits/vegetable consumption: 5 servings per day; milk consumption: 4 glasses per day)

^b Measured by Gini coefficient, on a 0–100 scale

^c Per 100,000