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Prevalence of and Risk Factors for Adolescent Obesity in Tennessee Using the 2010 Youth Risk Behavior Survey (YRBS) Data: An Analysis Using Weighted Hierarchical Logistic Regression

Research Article

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Abstract

Background: The rate of adolescent overweight and obesity has more than quadrupled over the past few decades, and has become a major public health problem [1]. In 2011, 55% of 12-19 year olds in the United States (U.S.) were overweight or obese [2]. Adolescence is a pivotal time in which many health risk behaviors such as tobacco, alcohol, and drug use are initiated. Such health risk behaviors have been significantly associated with overweight and obesity among adolescents.

Objective: The purpose of this study is to evaluate the relationship between obesity and the health risk behaviors most commonly associated with premature morbidity and mortality among adolescents with a novel micro area estimate approach that uses weighted hierarchical logistic regression to nest individuals in classes, classes in schools, and schools in districts.

Methods: This study is a secondary analysis of a state-wide representative sample of middle school students that participated in the 2010 Tennessee Middle School Youth Risk Behavior Survey (YRBS). Data was collected from 119 (85.6%) of Tennessee's local education agencies (LEAs), 456 (95.2%) schools, and 64,790 of 78,441 (82.6%) students. The outcome variable was adolescent obesity (≥ 95th BMI percentile). Explanatory variables were divided into four levels [1] district level: use seatbelt/helmet, asked to show ID for tobacco purchase; [2] school level: ever tried smoking, received HIV education in school; [3] class level: average number of days smoked, having ever exercised to lose weight; [4] individual level: having ever been in fight, early onset of substance use, physical activity, and thought about, planed, or attempted suicide. Weighted hierarchical logistic regression analysis was performed to assess the association between risk factors or protective factors and obesity using effect size (ES) and odds ratio (OR) estimates.

Results: The study sample included 64,790 middle school students in the state of Tennessee with a mean age of 12.8 years, of which (49.42%) were females and (50.58%) were males. Nearly one-fourth of the students had a BMI at or above the 95th percentile (22.30%). Weighted hierarchical logistic regression analysis shows that seatbelt and helmet use [ES: -2.161 OR: 0.020, 95% CI: (0.006, 0.070)], and weight misperception [ES: 1.256 OR: 9.720, 95% CI: (9.216, 10.251)], having ever exercised to lose weight [ES: -0.340 OR: 0.540, 95% CI: (0.446, 0.654)], having ever tried smoking [ES: 0.705 OR: 3.581, 95% CI: (2.637, 4.863)] and gender (male vs female) [ES: 0.327 OR: 1.810, 95% CI: (1.740, 1.880)] were strongly associated with adolescent obesity. Results from this study also showed that Black, Hispanic or Latino adolescents were more likely to be obese than Whites, Indian, and Asian adolescent [ES: 0.129 OR: 1.260, 95% CI: (1.200, 1.330)], students with grades of mostly C, D and F were more likely to be obese than those with grades of mostly A and B [ES: 0.189 OR: 1.409, 95% CI: (1.303, 1.523)], and that students having an eating disorder [ES: 0.251 OR: 1.576, 95% CI: (1.508, 1.648)] and/or engagement in sports teams [ES: -0.197 OR: 0.700, 95% CI: (0.674, 0.728)] had small or medium ES association with adolescent obesity.

Conclusion: This study uses small area estimates in weighted hierarchical logistic regression models to describe the prevalence and distribution of health risk behaviors associated with adolescent obesity among middle school student subpopulations in Tennessee. The value of small area estimates has been demonstrated previously in a variety of other contexts, and again here offers important insights for intervention design and resource allocation at different micro-levels within small and large areas (i.e., district, school, and class). This work adds to the growing body of research that supports community-driven school-based lifestyle interventions targeting early-onset chronic disease and, more specifically, enhances the geographic resolution with which adolescent obesity can be addressed in middle school populations across Tennessee.

Abbreviations: CI: Confidence Interval; DF: Degrees of Freedom; SE: Standard Error; YRBS: Youth Risk Behavior Survey; BMI: Body Mass Index; PE: Physical Education; LEAs: Local Education Agencies

Introduction

The rate of adolescent overweight and obesity has more than quadrupled over the past few decades, and has become a major public health problem [1]. In 2011 55% of 12-19 year olds in the United States (U.S.) were overweight or obese [2]. In adolescents, obesity is defined as having a body mass index (BMI) at or above the gender and age specific 95th percentile [1]. Well established demographic risk factors for adolescent obesity include age, gender, and ethnicity differences [1-3]. Personal factors such as poor nutritional habits along with a sedentary lifestyle have also been identified as major risk factors for adolescent obesity. In 2011, 11% of U.S. high school students reported drinking three or more servings of soda per day, and 69% did not attend a daily physical education (PE) class [4]. Not only are obese adolescents at risk for physical health problems such as hypertension and type 2 diabetes [5,6], but they experience poorer mental health and have significantly decreased academic performance [7]. Adolescence is a pivotal time in which many health risk behaviors such as tobacco, alcohol and other drug use are initiated [8]. Health risk behaviors such as tobacco and alcohol use have been significantly associated with overweight and obesity among adolescents [9]. Peer attitudes and behaviors have been identified as the most consistent social influence on weight gain in adolescence [10], and it has been hypothesized that obese adolescent engagement in health risk behaviors may be the result of coping with social stigmatization of their weight [9].

The majority of our understanding of adolescent obesity results from large national surveys such as NHANES, YRBS or YRBSS, and NSCH. The sampling frames used in such surveys produce demographically representative samples but lack accurate geographic representation [11]. The importance of having a geographically representative sample is apparent from identified regional disparities of adolescent obesity [12]. However, there is a gap in the understanding of how the variations of social and environmental factors at the district, school and class levels influence adolescent obesity. Many studies in the literature support the use of a multilevel model looking at the prevalence of disease in small area estimates at the level of census tracts [11,13,14]. To our knowledge, there are no reports of applying a multilevel method at the micro level of school districts, schools, and classes. The use of a weighted hierarchical model allows for the assessment of variations in obesity among adolescents across district, school and class levels while controlling for individual factors. Additionally, a multilevel approach can help identify clusters of adolescent obesity and allow public health professionals to target specific health risk behaviors and protective factors that uniquely contribute to such micro area health disparities.

The purpose of this study is to expand upon what little is known about the relationship between obesity and the health risk behaviors most commonly associated with premature morbidity and mortality among adolescents with a novel micro area estimate approach that uses weighted hierarchical logistic regression to nest individuals in classes, classes in schools, and schools in districts.

Methods

Study design

This study is a secondary analysis of the 2010 Tennessee Middle School Youth Risk Behavior Survey (YRBS) data. During alternating years, the Centers for Disease Control and Prevention (CDC) administered the YRBS to a nationally representative sample of U.S. students in grades 6th-8th. The YRBS was developed as a surveillance measure to monitor priority health risk behaviors such as unhealthy dietary behaviors, physical inactivity, and drug use associated with premature morbidity and mortality among youth [15]. During January through May of 2010, Tennessee Coordinated School Health (TNCSH) administered a modified version of the YRBS to a state wide representative sample of middle school students. Students in selected schools voluntarily completed an anonymous 46-item modified version of the YRBS questionnaire. Prior to administration of the questionnaire, passive parental consent and child assent were obtained from all participants.

Study sample

The data for this study was collected from 119 of Tennessee's 139 (85.6%) local education agencies (LEAs). Of the 119 participating LEAs, 456 of the 479 (95.2%) schools and 64,790 of the 78,441 (82.6%) middle school students participated for an overall response rate of 79.1%. The overall response rate was computed as (number of participating schools/number of eligible schools) × (number of useable questionnaires/ number of eligible students in participating schools). All standard public schools containing the grades 6th, 7th, or 8th were included in the study sample. Sampling of classes was dependent on the school, and consisted of either selecting all classes in a required subject, or all classes meeting during a specified period of the day. Systematic equal probability sampling with a random start was used to select classes from each school that participated in the survey. A total of 64,790 useable questionnaires were available for analysis. However, for our multiple logistic analyses, there were less questionnaires (from 53,194 to 60,715) available due to missing data for the variables in each multiple logistic model.

Variables

Outcome variable – adolescent obesity: Self-reported height (inches) and weight (pounds) were used to calculate BMI and the corresponding age and gender specific BMI percentile on a CDC BMI-for-age growth chart. Approximation of age in months were calculated using the following formula (age in years times 12 months + 6 months). For each of the age ranges included on the measure, corresponding BMI percentiles were recorded. As defined by the CDC, our study identified an age and gender specific BMI in the ≥95th percentile as obese, and a BMI < 95th percentile as not obese. Students were then dichotomized into categories of non-obese (< 95th BMI percentile) and obese (≥ 95th BMI percentile). Any height or weight values that were considered implausible based on the age and gender of students were coded as missing.

Explanatory variables

District level covariates: Two variables were identified to be demonstrative of factors at the district level. The first being the proportion of students in the district reporting "always or most of the time" wearing a seat belt or helmet when riding in a car or riding a bicycle, rollerblading, or skateboarding. Both seat belt and helmet use are legislated measures [16,17] and research has shown that rates of seat belt use among adolescents increase significantly in states with primary enforcement laws [18]. In addition to seat belt and helmet use, the proportion of students that were asked to provide proof of their age (being 'carded') when purchasing tobacco was used as a district level variable. Studies have shown that the enforcement of tobacco sales laws improved merchant's compliance with proof of age requirements and had a significant impact on reducing the prevalence of youth smoking [19,20]. These two variables are well suited for analysis at the district level because of their enforcement at the local level. Additionally, the enforcement of laws requires resources and resource poor areas may lack the necessary funds to enforce such laws and these variables can be a surrogate for unmeasured SES variables impacting the district.

School level variables: Two variables were evaluated at the school level. The first was the proportion of students in the school that had "ever tried smoking, even one or two puffs". The relationship between the strength and enforcement of school smoking policy is associated with student smoking prevalence [21]. The school environment is also important for peer influences on smoking. Research has shown that smoking is significantly associated with an individual's peer network and rates of adolescent smoking in the school [22]. The second variable included was the proportion of students in that reported having received HIV/AIDS education in school. The variable of ever received HIV/AIDS education was selected because of its identification as key component of comprehensive health education in the TNCSH program [23].

Class level variables: Two variables were examined at the class level. The average number of cigarettes students in each class reported smoking in the last 30 days. Multiple studies have identified peer influence as being the most significant and consistent predictor of adolescent smoking [8,21,24,25]. It would be reasonable to conclude that one of the main peer influences in school occurs in the classroom, and the association between peers and smoking status of students makes this covariate well suited for analysis at the class level. Additionally, the proportion of students in each class reporting having "ever exercised to lose weight or to keep from gaining weight" was included as a class level covariate. Similar to smoking, exercising and the motivation behind it are important for crowd affiliation and strongly influenced by peers [26], and accordingly included at the class level.

Individual level variables: Age, gender, grade, and geographic region in the state of Tennessee (Delta, Central, or Appalachia) as designated by the Appalachian Regional Commission [27] were all included at the individual level. Due to the homogeneity of the sample, race was condensed into two categories of White, Indian, and Asian vs Non-white (Blacks/African Americans, Hispanic or Latino, and Other). Additionally, students were asked if they 'had ever ridden in a car driven by someone who had been drinking alcohol", "ever carried a weapon, such as a gun, knife, or club", "ever been in a physical fight or injured in a fight" or ever thought, planned or attempted to kill themselves. Early onset of substance use (defined as initiation of use at or before the age of 11) was evaluated for tobacco, alcohol, and marijuana. Individuals' perception of weight was evaluated by the item "how you describe your weight", with responses ranging from very underweight to very overweight. An eating disorder variable was computed by creating an index score for an affirmative answer to any of the following; having fasted, taken diet pills, or vomited to lose or to keep from gaining weight. Individual sedentary behaviors were assessed using the number of hours spent watching TV on a school day (<3 or ≥3 hours/day), the average number of physical education classes participated in during the average week (<5 or ≥5), and participation on any extracurricular sports teams.

Results

A weight has been associated with each questionnaire to account for sampling design effects to reduce bias by compensating for differing patterns of non-response. The overall weights were scaled so that the weighted estimates are representative of all students in 6^{th}-8^{th} grade attending public schools in Tennessee [28]. Statistical analyses including descriptive statistics and multilevel logistic modeling were conducted on weighted data using SAS 9.4 software [29].

Simple descriptive statistics, including means, standard deviations and proportions are presented in Table 1. The study sample included 64,790 middle school students in the state of Tennessee with a mean age of 12.79 years (SD: 1.04). Of the sample 32,053.45 (49.60%) were females and 32,566.92 (50.40%) were males. Predominantly (79.96%) the students' race/ethnicity was reported as white, Indian or Asian, and resided in the 51 counties of Tennessee in the Appalachian Region (53.24%). Nearly one-fourth of the students had a BMI at or above the 95^{th} percentile (22.30%). Nearly a quarter (24.75%) of adolescents in the Delta regions was obese as opposed to only 21.90% in the Appalachian and Central regions. Among adolescent females, 17.84% were obese, whereas 28.02% of males were obese, over 10% higher. There was also nearly a 10% higher prevalence of obesity in Blacks, Hispanics, or Latinos (25.01%) compared to White, Indian, or Asian (17.31%).

Over half (52.29%) of surveyed adolescents in the state of Tennessee reported having an inaccurate perception of their weight. Nearly three-fourths (71.1%) of students reported having ever exercised to lose weight. Of obese students 37.38% had a misperception about their weight; furthermore, 29.19% reported having an eating disorder versus 20.54% of non-obese. Even though 71.59% of students reported having at least 1 PE class per week, there was no real difference in the proportion of obese adolescents receiving 0 days of PE compared to 1 or more days of PE (22.82% and 22.14% respectively). Approximately 30% of students reported having ever tried smoking (29.56%), with a class average of almost 1 day smoked in last 30 days (mean: 0.83 days/month), and a class average of 30.87% ever having a drink of alcohol. The proportion of students engaging in early use of drugs or substances ranged from 17.52% using alcohol, 9.24% using tobacco, and 3.10% using marijuana. Only 5% of students reported wearing a seatbelt when riding in a car or helmet when riding a bicycle most of the time, fewer than 20% of students reported purchasing tobacco were asked to show proof of age when purchasing tobacco, 15.5% of students reported purchasing tobacco. Only half (50.88%) of 6^{th}-8^{th} graders reported having received HIV/AIDS education in school.

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Table 1: Descriptive Statistics for Risk Factors in Adolescent Obesity in Tennessee (N=64,790).

Variables	Freq/Mean	(%)/(Std)	Variables	Freq/Mean	(%)/(Std)
Age	12.79	(1.04)	**Eating Disorder**		
Gender			No	51,026.75	(79.25)
Female	32,053.45	(49.60)	Yes	13,360.32	(20.75)
Male	32,566.92	(50.40)	**Exercise to Lose Weight**	0.711	(0.125)
Race/Ethnicity			**Ever Tried Smoking**		
White / Indian / Asian	51,395.12	(79.96)	No	44,351.00	(70.44)
Black / Hispanic / Latino	12,879.69	(20.04)	Yes	18,608.00	(18.61)
Region			**Early~ Use Tobacco**		
Appalachia	34,493.98	(53.24)	No	56,811.80	(90.76)
Central	21,144.09	(32.63)	Yes	5,781.73	(9.24)
Delta	9,151.93	(14.13)	**Days Smoked**	0.832	(1.306)
Grades in School			**Carded for Tobacco Purchase**	0.155	(0.208)
Mostly A & B	60,109.39	(94.48)	**Ever Had Drink Alcohol**		
Mostly C, D & F	3,511.83	(5.52)	No	42,125.59	(69.13)
Obesity(≥95th percentile)			Yes	18,810.56	(30.87)
No	50,159.06	(77.70)	**Early~ Use Alcohol**		
Yes	14,395.51	(22.30)	No	49,586.45	(82.48)
Often Wear Seatbelt/Helmet	0.049	(0.030)	Yes	10,533.13	(17.52)
Ridden with Drinking Driver			**Ever Use Marijuana**		
No	36,988.80	(66.62)	No	56,202.78	(89.82)
Yes	18,536.08	(33.38)	Yes	62,571.68	(10.18)
Carried a Weapon			**Early~ Use Marijuana**		
No	39,457.15	(61.23)	No	60,593.44	(96.90)
Yes	24,981.83	(38.77)	Yes	1,940.42	(3.10)
Physical Fight			**Ever Used Cocaine**		
No	28,172.77	(44.85)	No	60,617.27	(96.61)
Yes	35,300.91	(55.15)	Yes	2,129.55	(3.39)
Injured in a Fight			**Hours Watching TV (Daily)**		
No	60,452.22	(94.17)	2 or less	40,383.69	(63.83)
Yes	3,740.83	(5.83)	3 to 5	22,886.40	(36.17)
Thought, Planed, Tried Killing Yourself			**Days Attend PE Class**		
No	50,392.86	(78.05)	0	18,091.17	(28.41)
Yes	14,168.07	(21.95)	1 to 5	45,591.47	(71.59)
Misperception of Weight			**Sports Team Participation**		
No	30,501.59	(47.71)	No	26,675.96	(42.15)
Yes	33,430.00	(52.29)	Yes	36,612.36	(57.85)
			Received HIV/AIDS Education	0.509	(0.231)

~≤ 11 years of age

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Multilevel simple logistic regression analysis

Multilevel simple logistic regression analysis was first performed to assess the association between each risk or protective factor and obesity. Table 2 contains the crude odds ratios, 95% confidence intervals, p-values, and effect sizes between these factors and obesity. For analysis, the Appalachian region and Central region were merged together because of their similarity in proportion of obesity between them and difference of proportion between the Delta regions. We computed effect size (ES) based on the odds ratios (OR). We used ES to determine the association level between obesity and each risk or protective factor, rather than p-values to assess the significance level due to the study's large sample size. A small effect size is defined as an ES = 0.20, medium ES = 0.50, and large if ES = 0.80 [29]. Males were more likely than females to be obese [ES: 0.327 OR: 1.810, 95% CI: (1.740, 1.880)], while Black, Hispanic or Latinos were more likely to be obese than Whites, Indian, and Asian [ES: 0.129 OR: 1.260, 95% CI: (1.200, 1.330)]. From Table 2, we can also see that grades (C's, D's and F's vs A's and B's) [ES: 0.189 OR: 1.409, 95% CI: (1.303, 1.523)], eating disorder [ES: 0.251 OR: 1.576, 95% CI: (1.508, 1.648)], and engagement in a sports team [ES:- 0.197 OR: 0.700, 95% CI: (0.674, 0.728)] all had small effects on adolescent obesity. Additionally, having ever exercised to lose weight [ES: -0.340 OR: 0.540, 95% CI: (0.446, 0.654)] had a medium ES and having ever tried smoking [ES: 0.705 OR: 3.581, 95% CI: (2.637, 4.863)] had a very strong association with adolescent obesity. Wearing a seatbelt or helmet and having a misperception about weight had the largest effect sizes of -2.161 and 1.256 respectively. Seatbelt and helmet use [ES: -2.161 OR: 0.020, 95% CI: (0.006, 0.070)], and weight misperception [ES: 1.256 OR: 9.720, 95% CI: (9.216, 10.251)], were both significant predictors of adolescent obesity. Having to show proof of age when purchasing tobacco, geographic region, ever having ridden with drinking driver, thought about, planned, or attempted suicide, and having ever used alcohol, marijuana, or cocaine all lacked strong association with adolescent obesity. Those students who reported attending more than one PE class a week were less likely to be obese [ES: -0.042 OR: 0.927, 95% CI: (0.881, 0.971)], while those watching three or more hours of TV a day were more likely to be obese [ES: 0.165 OR: 1.348, 95% CI: (1.296, 1.402)]. Not having received HIV/AIDS education in school was also associated with obesity [ES: -0.121 OR: 0.803, 95% CI: (0.692, 0.932)].

Multilevel multiple logistic regression analysis

We then used weighted multilevel logistic regression models to explore the independent effects of districts, schools, classes, and individual student influences on adolescent obesity (Table 3). The inclusion criteria for explanatory variables was: (a) OR ≥1.20 (or ≤0.83) of the simple logistic regression model, (b) demographic or geographic variables, (c) those interval variables at class, school or district levels. Based on this criteria, the variables of age, race, gender, region, grades in school, seatbelt/helmet use, ever carried a weapon, ever been in or injured in physical fight, drug/substance use, weight perception, time spent watching TV, ever exercised to lose weight, engagement in sports team and received HIV education in school were all included in the main model.

Variables that had a strong association with obesity in the main model were, age, gender, race, grades in school, seatbelt/helmet use, having been in a physical fight, having ever smoked, weight perception, exercising to lose weight, eating disorder, time spent watching TV, engagement in sports teams, and having received HIV/AIDS education in school (Table 3). In addition to the main effects, the model [2,30] on Table 3 includes interactions between gender and age, region and gender, age and gender, age and race, and age and gender. The interactions between gender and race, and age and gender were significant ($p < 0.05$). Additionally, the interaction between region and gender was significant at $p<0.10$. We will stratify the sample by gender, region, race, and age to conduct weighted multilevel stratified logistic regression analysis as part of a future manuscript that further explores these interactions.

Discussion

Data source

Data collection and sampling methodologies used in the 2010 YRBS aimed to achieve accurate representations of youth demographics and measurements of health behaviors in the United States. However, our study drew exclusively from the Tennessee YRBS data and found an overrepresentation of White individuals (79.96%), which was addressed in accordance with YRBSS weighting techniques and guidelines. Despite weighting the data, it remained difficult and sometimes impossible to stratify the findings by ethnicity with such a large racial/ethnic disparity. It is important to consider this overrepresentation and the assumptions that underpin YRBS weighting calculations when interpreting our results. Moreover, there were many data points missing from the original dataset. For example, only 14% of the sample used included geographic region information, which precluded some potentially useful analyses. Lastly, the dataset only included middle school students attending publicly funded schools during the survey and therefore does not necessarily represent the entire Tennessee population falling within the target age group. Nevertheless, with an overall response rate of 79.1%, the diversity of obesity prevalence measures (i.e., measurements at the levels of districts, schools, and classes) and individual behavior data contained in this single survey was uniquely robust and allowed us to evaluate small area variations in the associations between behavioral risk factors and adolescent obesity with weighted multilevel logistic regression models.

Methods

We used weighted hierarchical logistic models to estimate the effect sizes of various health determinants on obesity outcomes among middle school students in Tennessee. P-values were not used as measures of association to avoid the potential for artificially inflating statistical significance that would result from such large sample sizes. Effect size, on the other hand, is not dependent on sample size and is thus a more appropriate measure for large-scale secondary data analysis. Most importantly, using multilevel models allowed us to address intra-class correlations (ICCs) and calculate more accurate measures of association than would a simple logistic regression using the original survey data.

Table 2: Multilevel Simple Logistic Regression Analysis: Association of Obesity & Risk or Protective Factors (n= 64,790).

Parameter Effect	Obesity				
	Odds Ratio (95% CI)	Effect Size	Covariance Estimates (SE)		
			Class	School	District
Age	0.930 (0.910, 0.950)***	-0.038	0.105 (0.009)	0.030 (0.008)	0.020 (0.006)
Gender (Male vs Female)	1.810 (1.740, 1.880)***	0.327	0.107 (0.009)	0.031 (0.008)	0.020 (0.006)
Race/Ethnicity (B vs W)[d]	1.260 (1.200, 1.330)***	0.129	0.108 (0.009)	0.024 (0.008)	0.023 (0.006)
Region (Delta vs Other)	1.137 (1.027, 1.258)**	0.071	0.108 (0.009)	0.028 (0.008)	0.018 (0.006)
Grades in School (C, D and F vs A and B)	1.409 (1.303, 1.523)***	0.189	0.104 (0.009)	0.028 (0.008)	0.020 (0.006)
Seatbelt/Helmet Use (Often vs Never/Rarely)	0.020 (0.006, 0.070)***	-2.161	0.108 (0.009)	0.027 (0.008)	0.009 (0.004)
Ridden with Drinking Driver	1.061 (1.016, 1.108)***	0.033	0.117 (0.011)	0.028 (0.009)	0.020 (0.006)
Carried a Weapon	1.346 (1.295, 1.400)***	0.164	0.109 (0.009)	0.029 (0.008)	0.019 (0.006)
Physical Fight	1.247 (1.200, 1.297)***	0.122	0.111 (0.010)	0.025 (0.008)	0.020 (0.006)
Injured in a Fight	1.228 (1.137, 1.327)***	0.113	0.109 (0.009)	0.029 (0.008)	0.020 (0.006)
Thought, Planned or Tried Suicide	1.178 (1.127, 1.232)***	0.091	0.105 (0.009)	0.029 (0.008)	0.021 (0.006)
Weight Misperception	9.720 (9.216, 10.251)***	1.256	0.124 (0.011)	0.018 (0.008)	0.027 (0.007)
Eating Disorder	1.576 (1.508, 1.648)***	0.251	0.106 (0.009)	0.025 (0.008)	0.020 (0.006)
Exercised to Lose Weight	0.540 (0.446, 0.654)***	-0.34	0.106 (0.009)	0.026 (0.008)	0.020 (0.006)
Tried Smoking	3.581 (2.637, 4.863)***	0.705	0.110 (0.009)	0.014 (0.007)	0.015 (0.005)
Early Onset~ Smoking	1.224 (1.148, 1.304)***	0.112	0.109 (0.010)	0.027 (0.008)	0.029 (0.006)
Days Smoked in last 30 days	1.021 (1.004, 1.039)***	0.011	0.107 (0.009)	0.028 (0.008)	0.020 (0.006)
Carded for Tobacco	0.882 (0.670, 1.162)	-0.069	0.107 (0.009)	0.029 (0.008)	0.020 (0.006)
Tried Alcohol	1.129 (1.082, 1.178)***	0.067	0.111 (0.010)	0.029 (0.008)	0.018 (0.006)
Early Onset~ Alcohol	1.210 (1.150, 1.272)***	0.105	0.113 (0.010)	0.028 (0.008)	0.018 (0.006)
Ever Use Marijuana	1.174 (1.103, 1.249)***	0.089	0.109 (0.010)	0.061 (0.008)	0.019 (0.006)
Early Onset~ Marijuana	1.346 (1.212, 1.494)***	0.164	0.110 (0.010)	0.032 (0.008)	0.020 (0.006)
Ever Used Cocaine	1.120 (1.010, 1.243)***	0.063	0.107 (0.010)	0.031 (0.008)	0.021 (0.006)
Watching TV (≥3 hours/ Day)	1.348 (1.296, 1.402)***	0.165	0.106 (0.009)	0.027 (0.008)	0.020 (0.006)
PE Class (≥1 day/ Week)	0.927 (0.884, 0.971)***	-0.042	0.109 (0.010)	0.028 (0.008)	0.021 (0.006)
Sports Team Engagement	0.700 (0.674, 0.728)***	-0.197	0.107 (0.009)	0.027 (0.008)	0.019 (0.006)
HIV/AIDS Education	0.803 (0.692, 0.932)***	-0.121	0.107 (0.009)	0.027 (0.008)	0.020 (0.006)

[a]CI: Confidence Interval; DF: Degrees of Freedom; SE: Standard Error; ~early onset is defined as ≤ 11 years old, dB: Black; Hispanic & Latino, W: White; Indian and Asian, *p<0.10, **p<0.05, ***p<0.01.

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Table 3: Multilevel logistic regressions: District, school, class and student influences, and interactions associated with the log odds of being obese (OR and 95% CI) n=53,194.

	Odds Ratio (95% CI) Model (1)	Odds Ratio (95% CI) Model (2)
Age	0.927 (0.904, 0.951)***	0.125 (0.0027, 0.581)
Gender (Male vs Female)	1.850 (1.756, 1.949)***	1.627 (1.511, 1.752)
Race/Ethnicity (B vs W)	1.116 (1.045, 1.192)***	1.148 (1.062, 1.242)***
Region (Delta vs Other)	1.071 (0.960, 1.195)	0.951 (0.893, 1.012)
Grades in School (D and F vs A and B)	1.115 (1.009, 1.233)**	1.118 (1.011, 1.237)**
Seatbelt / Helmet Use (Often vs Never)	0.120 (0.026, 0.554)***	2.454 (1.714, 3.515)***
Carried a Weapon	1.027 (0.973, 1.085)	1.016 (0.962, 1.073)
Physical Fight	0.924 (0.876, 0.974)***	0.922 (0.874, 0.972)***
Injured in a Fight	0.953 (0.859, 1.056)	0.952 (0.859, 1.056)
Weight Misperception	9.329 (8.855, 9.962)***	9.380 (8.843, 9.949)***
Eating Disorder	1.623 (1.531, 1.720)***	1.644 (1.550, 1.743)***
Exercised to Lose Weight	0.477 (0.381, 0.598)***	0.474 (0.378, 0.594)***
Tried Smoking	2.442 (1.709, 3.490)***	0.838 (0.720, 0.976)***
Early Onset ~ Smoking	1.047 (0.956, 1.147)	1.052 (0.960, 1.153)
Early Onset ~ Alcohol	1.019 (0.951, 1.091)	1.017 (0.949, 1.089)
Early Onset~ Marijuana	1.037 (0.901, 1.195)	1.044 (0.906, 1.203)
Watching TV (≥ 3 hours/Day)	1.235 (1.177, 1.295)***	1.230 (1.172, 1.290)***
Sports Team Engagement	0.713 (0.680, 0.747)***	0.717 (0.684, 0.752)***
HIV/AIDS Education in School	0.845 (0.726 ,0.983)**	2.110 (1.683, 2.645)**
Contextual Interaction		
Gender × Race	-	0.347 (0.059)***
Region × Gender × Race	-	-0.110 (0.067)*
Region × Race	-	-0.041 (0.079)
Age × Gender	-	-0.056 (0.023)**
Age × Race	-	0.048 (0.029)
Age × Region × Race	-	-0.019 (0.035)
Random Effects		
Random Intercept		
Level 4 (district)	0.015 (0.006)	0.015 (0.006)
Level 3 (school)	0.009 (0.007)	0.011 (0.008)
Level 2 (class)	0.129 (0.012)	0.128 (0.012)

*p<0.10,**p<0.05,***p<0.01. For contextual interactions: parameter estimate (standard error). For random effects: intercept estimate (standard error).
~early onset is defined as ≤ 11-year old.

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Limitations

This study is a secondary analysis of 2010 Tennessee middle school YRBS data and thus our results comprise limitations inherent in YRBS survey methodologies. The analysis could not establish temporality between covariates and outcomes due to the cross-sectional nature of the survey. Moreover, the questionnaire was voluntary and self-administered during school hours, which subjects any resulting data analyzed to information biases including volunteer bias, self-report bias, and social desirability bias. These biases may lead to under- and over-reporting of certain variables. Perhaps most problematic, however, is that height and weight measurements used to calculate BMI and determine obesity status at the individual level were self-reported by students and not measured objectively by survey staff. As a result, it is likely that obesity prevalence measures were underreported, which may have influenced the associations found in the models. Furthermore, there are many other risk factors that have been associated with obesity in previous studies that were not included in the YRBS questionnaire, including built environment factors (e.g., access to health care, healthy food, exercise facilities, parks, and walking paths, etc.) household/domestic factors (e.g., family income and parent's marriage status, etc.), and other associated co-morbidities (e.g., mental illness, metabolic conditions, etc). Crime rates may also impact the use of such resources, yet walk-ability and other neighborhood safety measures were not addressed in the YRBS survey. Thus, residual confounding by covariates missing from the original questionnaire may be influencing the associations found in the analysis.

Our statistical model also relied on a number of assumptions that may not always accurately reflect the truth. First, it is assumed that school-level variables will influence parameter estimates analogously to district-level variables given homogeneity of schools. Second, class-level variables will influence parameter estimates analogously to school-level variables given homogeneity of classes. The homogeneity of schools and classes in the sample affect individuals.

Conclusion

This study uses small area estimates in weighted hierarchical logistic models to describe the prevalence and distribution of health risk behaviors associated with adolescent obesity among middle school student subpopulations in Tennessee. The value of small area estimates has been demonstrated previously in a variety of other contexts, and again here offers important insights for intervention design and resource allocation at different micro-levels within small and large areas (i.e., district, school, and class). This work adds to the growing body of research that supports community-driven school-based lifestyle interventions targeting early-onset chronic disease and, more specifically, enhances the geographic resolution with which adolescent obesity can be addressed in middle school populations across Tennessee. Future research should consider stratification analysis on age, gender, race, and region to further understand the interaction of health risk behaviors on their association with adolescent obesity in the state of Tennessee.

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