Obesity Disparities Among Elementary-Aged Children: Data From School-Based BMI Surveillance

WHAT’S KNOWN ON THIS SUBJECT: Nationally representative surveys provide insight into overall childhood obesity trends and disparities but do not identify patterns specific to individual states. School-based surveillance is recommended, but it is unclear whether surveillance is helping to identify children at greatest risk.

WHAT THIS STUDY ADDS: This study includes 3 consecutive years of surveillance findings to describe within-state spatial and socioeconomic disparities in obesity among elementary-aged children. Implications for states using and considering school-based surveillance to plan preventive interventions are considered.

abstract

OBJECTIVES: To examine 3-year trends and spatial clustering in the prevalence of obesity among elementary-aged children in Pennsylvania.

METHODS: Height and weight were measured for ~980,000 children between ages 5 and 12 years, corresponding to kindergarten through grade 6 in 3 consecutive school years (2006–2007, 2007–2008, 2008–2009). These data were obtained at the school district level and reported to the Pennsylvania Department of Health in response to a state mandate requiring public schools to conduct annual surveillance of student growth. Analyses at the school district level (n = 501) regarding obesity prevalence (BMI $\geq$ 95th percentile) according to age and gender were conducted to examine associations over time and in relation to population density, geographic boundaries, and a calculated family distress index.

RESULTS: The mean prevalence of obesity remained stable over 3 years at ~17.6% of elementary-aged children. However, within the state, significant differences in the prevalence of obesity were identified. Schools in the most rural areas had adjusted obesity prevalence over 2 percentage points higher than urban schools. Consistent with secular findings for the nation in general, students with families living in socioeconomic distress exhibited upward trends in obesity risk.

CONCLUSIONS: School-based surveillance elucidates the disparate risk of obesity for younger students living in the most rural areas, a key finding for primarily rural states. Preventive interventions are needed to reach the most rural children with an emphasis on families where parents are single, are unemployed, have a lower income, and lower educational attainment. Pediatrics 2012;130:1102–1109

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KEY WORDS: childhood obesity, geography, growth monitoring, policies, rural health

Ms Bailey-Davis and Dr Horst contributed equally to the development of this manuscript; Dr Hillemeier made substantial contributions to the analysis and interpretation of the data, critical reviews, and revisions; and Ms Lauter made significant contributions to the data analysis and revisions.

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Childhood obesity has reached epidemic proportions in the United States where more than one-third of children are overweight or obese. The prevalence of childhood obesity, defined as a BMI ≥ 95th percentile for age and gender, has more than tripled to 19.6% in the past 3 decades among elementary-aged children (6–11 years). Disparities in childhood obesity among different race/ethnic groups have received considerable research and policy attention; however, there is a need to consider additional interrelated dimensions of disparity that may affect a child's risk for obesity.

Regional disparities in the prevalence of obesity have been identified among children and adults living in less densely populated states and nonmetropolitan areas, yet explanations for these patterns remain unclear. The paucity of findings may be due in part to the limited nature of the data, because national findings have not been able to account for the geographical heterogeneity within a state or describe how sociocultural and environmental factors at the local or state levels explain obesity risk. Income disparities related to obesity risk are widely recognized across the life course but are complex, because associations between socioeconomic status and obesity vary by race/ethnicity and may be mediated by sociocultural and environmental factors. Multiple sociocultural factors have been found to be associated with childhood obesity risk including parent education attainment, single parenthood, unemployment, and prevalence of low-income households in a community. These sociocultural factors have been studied separately and in combination with population density to understand the disparities in access to healthy food but not obesity prevalence.

State surveillance data sets may be useful for identifying geographic disparities within states. The nationally recommended practice of school-based BMI screening and surveillance programs offer a wealth of data, yet little is known about how these data can be useful to states, communities, schools, health care providers, and families in understanding and reducing the risk of childhood obesity. Pennsylvania was one of the first states to implement school-based BMI screening and surveillance program with policy support. Today, 9 states implement screening to improve parent awareness of weight-related health concerns and to prompt action, when indicated, with health care providers. Fourteen states implement a surveillance component to measure progress toward preventing and reducing childhood obesity. Although the merits of the screening component are contested, surveillance is widely accepted, yet little is known about the surveillance findings. The purpose of this article is to identify disparities in the prevalence of obesity among elementary-aged students by using school-based BMI surveillance data from Pennsylvania.

METHODS

The Pennsylvania Department of Health provided data for this study from the 501 school districts in Pennsylvania. These data represented 2.97 million screenings of kindergarten through 6th grade students at public schools during the 2006–2007, 2007–2008, and 2008–2009 school years. Data were collected by school nurses that were trained on standard anthropometric methods. Nurses used calibrated equipment to annually assess individual student growth. School nurses assessed height and weight for each student and calculated their gender-specific BMI-for-age percentile. Data were reported in aggregate for each school district by numbers of total screenings and screenings falling in the <fifth percentile, fifth to 85th percentile, ≥85th to <95th percentile, and ≥95th percentile. This study focuses on obesity (≥95th percentile) because the proportion of obese children in a rural population has grown disproportionately in comparison with secular trends in growth, and Pennsylvania has a substantial (27%) and increasing rural population. The obesity focus is consistent with the recommendation to screen for obesity in children ages 6 and older to prevent weight-related health concerns.

We calculated the annual obesity prevalence for each district by dividing the number with BMI ≥95th percentile by the total number of students screened for each district. School district obesity prevalence for a school year was excluded if the change between years exceeded ±3 SD. A mean obesity rate was calculated by using 3 years of data to provide stable and robust estimates of school district obesity rates, to compensate for trimmed data due to data collection and entry errors, and to compensate for missing data for a school district in a particular school year.

To calculate a distress index for each district, we used methods outlined by Larsen and Gililand with z scores based on the overall state rates by school district for poverty, single-parent households, unemployment, and individuals with less than a high school education. After the z scores are calculated for each individual factor, they are summed and divided into quartiles with the first quartile labeled as the schools with the lowest distress and the fourth quartile labeled as the schools with the highest distress. The distress index helps to overcome colinearity issues with socioeconomic variables and provides a concise measure of multiple distress indicators for each school.
Data for the distress index and other school district demographics, including poverty rate, rate of children living in single-parent households, unemployment rate, rate of individuals with less than a high school education, population, and race/ethnicity, were extracted from the American Community Survey 2005–2009 estimates and merged with each school district.\textsuperscript{19} School district academic achievement or proficiency data were extracted from the Pennsylvania Department of Education.\textsuperscript{20} Academic achievement is overall standardized test score results for the school year ending in 2010 for each school district.

Population density, distress index, academic achievement, and the percentage of nonwhite population were divided into quartiles or by median to provide meaningful categories for analysis as well as compensate for highly skewed distributions. Data were referenced to Pennsylvania Department of Transportation 2009 school district geography shape files for Geographic Information System mapping.\textsuperscript{21} Population density was calculated by using the square mileage for each school district from the Pennsylvania Department of Transportation shape file and population from the American Community Survey data. We classified them into urban (≥1000 population per square mile), suburban (999–300 population per square mile); rural (299–100 population per square mile); and ultrarural (<100 population per square mile). Urban classification was based on the definition from the US Census Bureau 2000 census,\textsuperscript{22} and the rural classification was based on the Center for Rural Pennsylvania definitions.\textsuperscript{23} We added an ultrarural classification that coincided with the first quartile of population density to illustrate associations with childhood obesity prevalence.

Analysis
We assessed the bivariate associations of population density, distress index, percentage of nonwhite population, and academic achievement with the 3-year mean school district obesity prevalence by using $t$ tests or analyses of variance as appropriate. We constructed a linear model with the use of the covariates of population density quartile, distress index quartile, percentage of nonwhite population above/below median, and academic achievement quartiles to assess the multivariate associations with mean obesity prevalence and conducted residual analyses to assess fit. Referent categories for each covariate were selected based on the most meaningful interpretation and discussion. We changed the referent category in the population density, distress index, and academic achievement quartiles to allow for comparisons between quartile values within each covariate and report pairwise comparisons. To further investigate the interaction of population density on the association of distress index and mean obesity prevalence, we constructed a set of interaction terms for the population density and distress index categories and found that there were significant interaction terms. Afterward, we constructed a stratified model by population density class. Secondary analyses were conducted to assess factors in our data that may impact the final model. We compared variability by using the F test and model coefficients for the 2006–2007, 2007–2008, and 2008–2009 school year obesity data to determine if bias was introduced in using 3-year versus 1-year obesity data. To see if there were trends in covariate subgroups that would be masked in 3-year means, we constructed covariate stratified linear models with school year as a predictor. Predictor variables were assessed for colinearity by calculating correlation coefficients, variance inflation factors, and selective omission from the final model to determine impacts on coefficients. Our $\alpha$ for statistical significance was set a 0.05. We used Minitab version 16 (Minitab, Inc., State College, PA) and Stata version 12 (Stata Corp, College Station, TX) for statistical analyses and ArcView 10 (ESRI, Redlands, CA) for Geographic Information System mapping and analysis. This study was reviewed and granted an exemption by the Lancaster General Hospital Institutional Review Board.

RESULTS
The school districts included in the study had a range from 100 to 88,324 and a median (interquartile range) of 1270 (742–2250) annual screenings. After trimming individual school year obesity measures if the year-to-year change exceeded $\pm 3$ SDs, we calculated the mean obesity prevalence across the 3 school years included in the study. One school district was omitted because there were no data; 17 (3.4%) school districts had 2 years of data, and 483 (96.4%) school districts had 3 years of data on which to base the mean obesity prevalence calculation. Obesity prevalence was relatively stable across the 3 school years (Fig 1) with means of 17.6%, 17.8%, and 17.7% across the 2006–2007, 2007–2008, and 2008–2009 school years, respectively. Approximately 25% of school districts fall in the ultrarural category (Fig 2A), and the spatial distribution roughly corresponds with the mean rate of childhood obesity (Fig 2B).

Results of Bivariate Analyses
For each covariate category, there was a significant association with the school district mean obesity prevalence (Table 1, see the bivariate columns). Mean obesity prevalence ranged from a mean (95% confidence interval) of 15.7% (15.1–16.4) to 20.5% (19.9–21.0) in the suburban to ultrarural school districts, respectively. There was increasing obesity prevalence across the distress index quartiles starting at
a mean of 13.4% (12.9–14.0) to 20.3% (19.8–20.9) in the lowest and highest distress index quartile, respectively. School districts with above median rates of nonwhite population had lower 3-year mean obesity prevalence of 16.3% (15.8–16.9) than those with below median rates of nonwhite population of 18.9% (18.5–19.3). There was an inverse relationship between school district academic achievement scores and mean obesity prevalence with the school districts in the lowest quartile having a mean obesity prevalence of 19.9% (19.3–20.5) and school districts in the highest quartile having mean obesity prevalence of 14.6% (13.8–15.4).

**Results of Multivariate Analyses**

Ultrarural school districts, adjusted for the other covariates, had statistically higher mean obesity prevalence than the urban, suburban, and rural classifications (Table 1, see the multivariate coefficients and the adjusted pairwise comparisons columns). Rural districts,
TABLE 1 Bivariate Comparisons and Multivariate Coefficients for School Districts and 3-Year Mean Obesity Prevalence for Kindergarten to 6th Grade

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>3-Year Mean (SD) Obesity Prevalence (%)</th>
<th>3-Year Mean (SD) Obesity Prevalence (%)</th>
<th>Bivariate Coefficient</th>
<th>SE Coefficient</th>
<th>P&lt;</th>
<th>Adjusted Pairwise Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population density</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>128</td>
<td>16.2 (4.5)</td>
<td>&lt;0.001</td>
<td>Referent</td>
<td>—</td>
<td></td>
<td>Ultrarural</td>
</tr>
<tr>
<td>Suburban</td>
<td>126</td>
<td>15.7 (3.7)</td>
<td>&lt;0.001</td>
<td>—</td>
<td>0.25</td>
<td>0.46</td>
<td>Rural; ultrarural</td>
</tr>
<tr>
<td>Rural</td>
<td>121</td>
<td>18.2 (3.1)</td>
<td>&lt;0.001</td>
<td>0.55</td>
<td>0.39</td>
<td>0.206</td>
<td>Suburban; ultrarural</td>
</tr>
<tr>
<td>Ultra Rural</td>
<td>125</td>
<td>20.5 (3.0)</td>
<td>&lt;0.001</td>
<td>2.14</td>
<td>0.44</td>
<td>0.001</td>
<td>Urban; suburban; rural</td>
</tr>
<tr>
<td>Distress index</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest Quartile 1</td>
<td>124</td>
<td>13.4 (3.4)</td>
<td>&lt;0.001</td>
<td>Referent</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartile 2</td>
<td>125</td>
<td>17.8 (3.0)</td>
<td>&lt;0.001</td>
<td>2.87</td>
<td>0.42</td>
<td>0.001</td>
<td>Q1; Q4</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>126</td>
<td>19.0 (3.0)</td>
<td>&lt;0.001</td>
<td>3.48</td>
<td>0.45</td>
<td>0.001</td>
<td>Q1; Q4</td>
</tr>
<tr>
<td>Highest Quartile 4</td>
<td>125</td>
<td>20.3 (3.2)</td>
<td>&lt;0.001</td>
<td>4.88</td>
<td>0.46</td>
<td>0.001</td>
<td>Q1; Q2; Q3</td>
</tr>
<tr>
<td>Percentage nonwhite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below median</td>
<td>255</td>
<td>18.9 (3.5)</td>
<td>&lt;0.001</td>
<td>Referent</td>
<td>—</td>
<td></td>
<td>Above median</td>
</tr>
<tr>
<td>Above median</td>
<td>245</td>
<td>16.4 (4.2)</td>
<td>&lt;0.001</td>
<td>—</td>
<td>0.90</td>
<td>0.33</td>
<td>0.007 Below median</td>
</tr>
<tr>
<td>Academic achievement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest Quartile 1</td>
<td>123</td>
<td>19.9 (3.3)</td>
<td>&lt;0.001</td>
<td>2.12</td>
<td>0.45</td>
<td>0.001</td>
<td>Q2; Q3; Q4</td>
</tr>
<tr>
<td>Quartile 2</td>
<td>124</td>
<td>18.8 (3.1)</td>
<td>&lt;0.001</td>
<td>1.30</td>
<td>0.42</td>
<td>0.002</td>
<td>Q1; Q4</td>
</tr>
<tr>
<td>Quartile 3</td>
<td>127</td>
<td>17.4 (3.3)</td>
<td>&lt;0.001</td>
<td>1.08</td>
<td>0.40</td>
<td>0.007</td>
<td>Q1; Q4</td>
</tr>
<tr>
<td>Highest Quartile 4</td>
<td>124</td>
<td>14.6 (4.4)</td>
<td>&lt;0.001</td>
<td>Referent</td>
<td>—</td>
<td></td>
<td>Q1; Q2; Q3</td>
</tr>
<tr>
<td>Constant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.56</td>
<td>0.46</td>
<td></td>
</tr>
</tbody>
</table>

ANOVA, analysis of variance; —, indicates the multivariate model results where the SE coefficient and P values are not calculated because variable cases are set as the referent value.

a The multivariate column contains the adjusted coefficients from the model containing all covariates in the table.

b Bivariate P values are the ANOVA results.

c Multivariate: ANOVA P value < 0.001; Adjusted $R^2 = 48.9\%$. Multivariate P values are the results from the linear model comparing the appropriate quartile with the referent quartile as noted for each covariate.

d Adjusted pairwise comparisons lists all categories where there is a significant difference. Q1 corresponds to lowest quartile, Q2 corresponds to quartile 2, Q3 corresponds to quartile 3, and Q4 corresponds to highest quartile.

e The constant is the mean obesity prevalence in school districts where all covariates are set to the referent value and from which coefficients can be added/subtracted to calculate obesity prevalence in school districts with other covariate characteristics.

Adjusted for the other covariates, also had statistically higher obesity prevalence than suburban districts. For the distress index, the first and fourth quartiles are statistically different, adjusted for the other covariates, from all other quartiles, but the second and third quartiles are not statistically different. School districts with above median nonwhite rates have statistically lower mean 3-year obesity prevalence adjusted for the other covariates. For academic achievement, adjusted for the other covariates, the first and fourth quartiles are statistically different from all other quartiles, but the second and third quartiles are not statistically different. There was a significant interaction effect (Fig 3) such that in the ultrarural areas there was no difference in the mean prevalence of obesity across any of the distress index quartiles. In contrast, in rural, suburban, and urban areas there was a statistical association between higher distress index quartiles (higher rates of poverty, unemployment, single-parent households, and population with less than a high school education) and a higher mean prevalence of obesity.

There were no temporal trends across the 3 school years in the prevalence of obesity within population density categories, distress index quartiles, percentage of nonwhite population, and academic achievement quartiles. The largest correlation between covariates was distress index and academic achievement ($r = -0.57; P < .001$) with no other statistically significant covariate associations exceeding $r = \pm 0.30$

After removing academic achievement from our final model, none of the coefficients changed by >25%, and none of the calculated variance inflation factors exceeded 3 with academic achievement in and out of the model, therefore suggesting a limited impact of the collinearity.

**DISCUSSION**

In this study, we document geographic disparities within a state, drawing attention to the children living in the most rural areas in comparison with their urban counterparts. Children living in the least densely populated areas demonstrated a significantly higher prevalence of childhood obesity than children living in the urban, metropolitan centers of Pennsylvania. These disparities persisted over time and were associated with adverse sociocultural conditions including low parent educational attainment, single-parenthood households, unemployment, and high poverty in communities.

The major finding of geographical disparities in obesity prevalence among children living in the most rural areas is consistent with the high prevalence of obesity and chronic disease among adults living in the rural Appalachian region, which constitutes two-thirds of Pennsylvania and 13 states.24 Children living in rural areas have been found to
have nearly double the odds of obesity in comparison with their metropolitan counterparts.\(^4\)\(^{25}\) Our findings suggest that children who live in the most rural areas experience obesity risks at least as great as other groups such as children living in urban areas. Furthermore, our findings suggest that rural disparities in obesity risk among children are quite severe even after taking sociocultural distress into account. This finding should be tempered because inferences related to spatial boundaries are complicated by a heterogeneous mix of population density and sociocultural factors within an area. Nonetheless, the protective effect of living in a more densely populated area is weakened as sociocultural distress increases, eventually approximating the risk of obesity in the most rural areas. To strengthen an understanding of the persistence of the effect of geographical disparities, studies are needed that examine whether the effect of rural residency persists when a child migrates with their family to a more densely populated area. A recent review of research in low- and middle-income countries found that levels of cardiovascular risk factors were higher among rural-to-urban migrants than among rural residents.\(^{26}\)

The high prevalence of childhood obesity among children living in less densely populated areas has been a concern attributed to a lack of access to a healthy, affordable food supply, community socioeconomic deprivation, a limited diversity of physical activity facilities, and safe access to parks\(^{27}\)\(^{–}\)\(^{31}\) This study adds to these concerns with multiyear data. The secondary analyses comparing results by using school district data from single years versus 3-year averages confirm that variability of the estimates was similar in all cases, and therefore bias was not introduced by presenting results based on 3-year averages. Additional studies are needed to confirm relationships between childhood obesity, environmental factors, and social determinants of health. Schools have frequently been implicated in childhood obesity, yet little variation exists in school wellness policies for nutrition and physical activity in Pennsylvania.\(^{32}\) Future research may examine the variations in school wellness policy implementation, active transportation initiatives, and access to healthy, affordable food on the reduction of childhood obesity prevalence, particularly in the most rural areas.\(^{28}\)\(^{33}\)\(^{–}\)\(^{35}\) Academic achievement and childhood obesity is an emerging area of interest, and one of the quintessential issues in which cause and effect are complicated by sociocultural distress.\(^{35}\) This study found a significantly strong inverse relationship between academic achievement at the school level and the persistent prevalence of obesity at a young age. This finding is consistent with previous findings where overweight children had significantly lower math and reading scores.\(^{36}\) Sociocultural factors may be among the most challenging to address to reduce childhood obesity in the most rural areas. Rural parents view school-based BMI screening favorably,\(^{37}\)\(^{38}\) but only half of parents agree that schools should recommend treatment.\(^{37}\) Research is needed to understand what preventive actions parents take in response to concerns raised by school-based BMI screening. Preventive health care and clinical intervention for pediatric obesity may be challenged by rural perceptions of health, often a low priority in the context of negotiating time off work or long travel times to obtain care.\(^{39}\) Furthermore, there is a linear trend of decreasing numbers of primary care providers across population density categories in Pennsylvania.\(^{40}\) Beyond office visits, current recommendations call for clinician advocacy with schools and communities.\(^{41}\) Further research is needed to understand the efficacy of these recommendations on childhood obesity in the most rural areas.\(^{42}\)\(^{43}\)

These findings provide useful insight into geographic disparities and the interaction with sociocultural factors. However, these findings are limited by the nature of the surveillance data set. Specifically, the quality of the measured data cannot be definitively confirmed. School nurses collected these measurements by using a standardized protocol, but there is great variability in the equipment used. Furthermore, these data represent school districts,
which may not be homogenous in composition and may, in some cases, encompass several school buildings, census tracks, zip codes, and multiple counties; each with varying levels of population density, socioeconomic distress, and other factors. For example, in urban, suburban, rural, and ultrarural school districts, the median percentage of census tract centroids within the school district matching the district classification were 100%, 33%, 50%, and 100%, respectively. Thus, suburban and rural population density classifications of school districts may be less homogeneous than the urban and ultrarural school districts. In addition, these surveillance data are not gender-specific. National data suggest that female gender disparities in obesity prevalence have emerged, but within the Appalachian region boys appear to have had greater increases in obesity.4 The surveillance data do not permit identification of differences in obesity prevalence among race/ethnic subgroups, which is an additional limitation. Future research should investigate gender and ethnic disparities and how these relate to geography, population density, and distress indices. Opportunities to make this distinction in school-based BMI surveillance may be a feasible strategy for collecting these data and making analyses more useful toward the goal of reducing disparities.

CONCLUSIONS

This study underscores the need to address the complex socioenvironmental milieu that puts children living in the most rural areas at higher risk of obesity. The need to address this issue early in life is paramount, because obesity established by adolescence is likely to persist into adulthood and negatively impact physical and psychosocial health and educational attainment.44–46 School-based surveillance can be useful in identifying within-state disparities to direct resources to children, families, and communities most at risk for childhood obesity.

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