Trends in Body Mass Index and Prevalence of Extreme High Obesity Among Pennsylvania Children and Adolescents, 2007–2011: Promising but Cautionary

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Objectives. We determined current trends and patterns in overweight, obesity, and extreme high obesity among Pennsylvania pre-kindergarten (pre-K) to 12th grade students and simulated future trends.

Methods. We analyzed body mass index (BMI) of pre-K to 12th grade students from 43 of 67 Pennsylvania counties in 2007 to 2011 to determine trends and to discern transition patterns among BMI status categories for 2009 to 2011. Vinsem simulation, confirmed by Markov chain modeling, generated future prevalence trends.

Results. Combined rates of overweight, obesity, and extreme high obesity decreased among secondary school students across the 5 years, and among elementary students, first increased and then markedly decreased. BMI status remained constant for approximately 80% of normal and extreme high obese students, but both decreased and increased among students who initially were overweight and obese; the increase in BMI remained significant.

Conclusions. Overall trends in child and adolescent BMI status seemed positive. BMI transition patterns indicated that although overweight and obesity prevalence leveled off, extreme high obesity, especially among elementary students, is projected to increase substantially over time. If current transition patterns continue, the prevalence of overweight, obesity, and extreme high obesity among Pennsylvania students in 2031 is projected to be 16.0%, 6.6%, and 23.2%, respectively. (*Am J Public Health*. Published online ahead of print February 13, 2014: e1–e7. doi:10.2105/AJPH.2013.301851)

The economic consequences of obesity in the United States were estimated at $147 billion annually in 2008.[1] To better understand these costs, obesity trends to the year 2030 were predicted.[2] Obesity prevalence could reach 51% by 2030, but is more likely to stay at more than 40% because of recently emerging positive developments. A subcategory, severe obesity, that is, body mass index (BMI; defined as weight in kilograms divided by the square of height in meters) of 40 or greater for adults, has increased faster than overall obesity and is projected to grow from 5% of adults in 2010 to 11% of adults by 2030.[2] This growth, with its attendant increased risks of disease, will escalate costs even if overall obesity prevalence stabilizes.[2]

Because obesity rates vary across states, the financial burden is not uniform.[3] State-specific differences, such as lower cost of less healthy foods, can affect obesity and severe obesity prevalence together with current and projected health care costs.[2] Because of the state-specific nature of Medicaid and Medicare expenditures, much of the high cost of obesity-related disease is borne by public sector health plans.

Today's children and adolescents will be the youngest adults in 2030; therefore, obesity prevention for the future requires monitoring of obesity prevalence rates among this population over time. Prevalence and trends in obesity among US children from 1999 to 2010 were determined based on National Health and Nutrition Examination Survey data.[4] Prevalence of high BMI in US children and adolescents has also been studied.[5] By 2010, fewer than 12% of those aged 2 to 19 years nationwide were at or above the 97th percentile (extreme high obese [ExHi obese]); 17% were above the 95th percentile (obese), and 32% were above the 85th percentile (overweight). A statistically significant increase among 6- to 19-year-old males with a BMI at or above the 97th percentile was found between 1999 and 2008.[4]

To inform prevention efforts, state governments have a vested interest in monitoring obesity prevalence among all age groups, and especially among children and adolescents. Pennsylvania, for example, mandates annual height and weight screening with BMI calculation for all public school students statewide.[6] One recent study assessed child and adolescent BMI trends in Pennsylvania, excluding Philadelphia and surrounding counties, for 2005 to 2009[7] and found combined overweight and obese rates decreased from 28.5% to 23.1% at the middle school level and from 24.6% to 20.9% at high school levels, but increased from 10.9% to 20% at the elementary level. The largest shift in BMI over the subset of years from 2007 to 2009 was among overweight elementary students; 58% of those who were overweight in 2007 were obese in 2009. Overweight and obese increased for the study population as a whole because of this sharp increase among elementary students. In a second, separate study,[8] trends in obese (BMI ≥ 95th percentile) and ExHi obese (defined[8] as BMI ≥ 35 kg/m^2) among 5- to 18-year-old students attending Philadelphia schools in 2006 to 2010 were determined; obesity across all ages decreased from 21.5% to 20.5% and ExHi obese from 8.5% to 7.9%. Obese and ExHi obese were most prevalent among middle school students, Hispanic boys, and Black girls.[8]

The purpose of our study was to determine prevalence, trends, and patterns in overweight, obese, and ExHi obese among Pennsylvania school children. Specific research questions were:

1. What were the prevalence and trends in overweight, obese, and ExHi obese from 2007 to 2011 among elementary, middle, and high school students?
2. What movement patterns, if any, occurred in normal weight, overweight, obese, and ExHi obese among Pennsylvania elementary, middle, and high school students from 2009 to 2011?
3. If current patterns continue, what percentage of children and adolescents would be overweight, obese, and ExHi obese in 2030?

METHODS

Nurses in more than 1157 pre-kindergarten (pre-K) to 12th grade public and private schools located in 43 of 67 Pennsylvania counties, excluding Philadelphia and surrounding counties, used an electronic health record included in a web-based school health portal called "Health eTools for Schools" to record and report student medical data,[7,9] including the annual height and weight for all enrolled students measured by established protocols.[10] Along with unique identifiers, gender, and date of birth, medical data were compiled in a data repository maintained by InnerLInk (Lancaster, PA), the company that provides Health eTools at no cost to schools through funding from the Highmark Foundation.[9] All applicable federal and state safeguards of family and student rights, both medical and educational, were followed in the compilation of these data. Access was provided to deidentified data on the InnerLink server via a password-protected Internet link.

Between 2007 and 2011, a total of 685 531 viable student health records were collected. The number varied, with 71 487 for 2007, 186 585 for 2008, 107 705 for 2009, 107 699 for 2010, and 212 055 for 2011. Files were configured into a relational database by using data processing techniques, which were then summarized and aggregated into 3 categories: age, gender, and school level (i.e., elementary, middle, and high school). Because race/ethnicity was not recorded in student health records, this variable could not be addressed. The total number of data strings was sufficiently robust for analyses.

A SAS program[11] for children and adolescents developed by the US Centers for Disease Control and Prevention (CDC), with 2000 as the growth reference year for calculation of percentiles and z-score, was used to calculate individual BMI. Because of a number of factors that influence height and weight in children, growth chart percentiles were used to determine high BMI in children and adolescents[5]; the 97th percentile was adequate for segmenting ExHi BMI-for-age in children.[12] Therefore, overweight was defined for this study as at or above the 85th percentile but less than 95th percentile, obese as at or above the 95th percentile but less than 97th percentile, and ExHi obese as at or above the 97th percentile. We validated data to eliminate inconsistencies and unrealistic outliers for BMI, with values of BMI greater than 56.3 ($56.3 = 40 + 3 \times \text{SD}$, i.e., 2.25% over the upper normal mass limit $56.3/25 = 2.25$) and less than 7 eliminated. Outliers constituted 263 of 685 531 cases (0.04%).

We analyzed BMI trends using the least-squares method, a simple linear regression formula, $\text{BMI}_{\text{mean}} = a_0 + a_1 \times \text{Year}$, which was used to ascertain trends in annual BMI percentage for overweight, obese, and ExHi obese over 5 years for all students. This yielded 3 separate equations (the 1.95% of underweight students was not a focus of this study). Correlations between the dependent variable (percentage of normal weight, percentage of overweight, percentage of obese, or percentage of ExHi obese) and the independent variable (year) were checked before constructing regression models. We used the Pearson χ^2 test to determine significant differences based on gender, distributed over the 5 years (2007–2011), controlling for BMI category and school level.

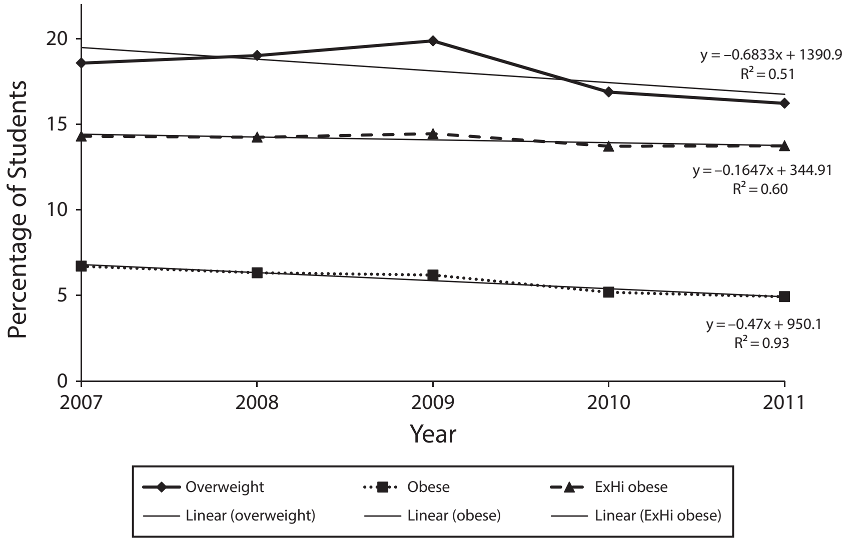
To reveal possible BMI transitions from 2009 to 2011, we calculated BMI categories via conditional probabilities, based on Bayesian statistics. We applied the χ^2 test to determine significance levels. Only students with matched identification numbers for 2009, 2010, and 2011, and only those who remained exclusively within a school level (i.e., elementary, pre-K–5; middle, 6–8; and high school, 9–12) over the 3 measurement years (2009–2011) were included in the analysis. This approach helped avoid cross-contamination for school level type, yet still yielded viable data from more than 80 000 students.

Using Vinsem[13] software, we created a simulation covering 20 years that calculated future rates of overweight, obese, and ExHi obese based on (1) the number of students within each BMI category in 2009, (2) current conditional BMI movement patterns, and (3) assumed continuation of the current BMI movement patterns. Vinsem software was previously used to simulate epidemics of both infectious[14] and chronic disease.[15] We confirmed the simulation results by Markov chain modeling.[16]

RESULTS

Regarding BMI trends, yearly percentages for overweight increased somewhat from 2007 to 2009, but the linear slope lines for all 3 categories declined from 2007 to 2011 (Figure 1).

Because food services, availability of food in school, and opportunities to be physically active, along with prevention and intervention initiatives might have varied, BMI status data were segmented by school level. School level also separated students by developmental categories—childhood (elementary school), young adolescence (middle school), and middle adolescence (high school). Therefore, percentages of students in the overweight, obese, and ExHi obese categories were provided by school level (Figure 2) for 2007 to 2011. Combined rates of overweight, obese, and ExHI obese decreased steadily from 2009 to 2011 for all school levels. The combined rates for middle and high school steadily declined across all years. After increasing from 2007 to 2009, the combined rate at elementary school peaked in 2009 and receded thereafter. With the exception of elementary students in 2008 and 2009, the combined percentage of obese and ExHi obese students was greater than the percentage overweight at all school levels for all years. Likewise, the highest percentages of combined obese and ExHi obese students were found in middle schools. For all school levels and across all years, the percentage of ExHi obese students was more than double the percentage of obese students. Based on the Pearson χ^2 test, elementary school boys were more likely than girls to be overweight ($P = .01$) or obese ($P = .04$). Both middle and high school



Note. ExHi = extreme high. The sample size was n = 685 531. The city of Philadelphia and its surrounding counties were excluded from this analysis.

FIGURE 1—Trend in overweight, obese, and extreme high obese prevalence by percentage: Pennsylvania schools, 43 of 67 counties, 2007–2011.

boys were more likely to be ExHi obese ($P = .01$).

Figure 3 depicts transitions in student BMI status from 2009 to 2011, with results provided as percentages for students in grades pre-K to 12, as well as separately for elementary, middle, and high school students as provided, respectively, in parentheses. The subset of 80 770 students included in these percentages had their BMIs calculated in 2009, 2010, and 2011, and were linked by unique member identifiers for this analysis. (Data from the very low percentage of underweight students in the sample were excluded to assure more accurate χ^2 results.) Although overweight, obese, and ExHi obese prevalence rates for this subset were somewhat lower than that for the overall study population, these differences were not statistically significant ($P = .723$).

Between 2009 and 2011, more than 80% of students who were normal or ExHi obese did not change category, whereas almost half of the students initially in the overweight category and approximately three quarters of those in the obese category decreased or increased their BMIs; rates at which students remained within their initial BMI category were relatively consistent by school level. For example, the percentage of obese students in each school level (elementary: 25.04%; middle school: 23.66%; high school: 23.06%) all clustered around the overall rate of 24.38%.

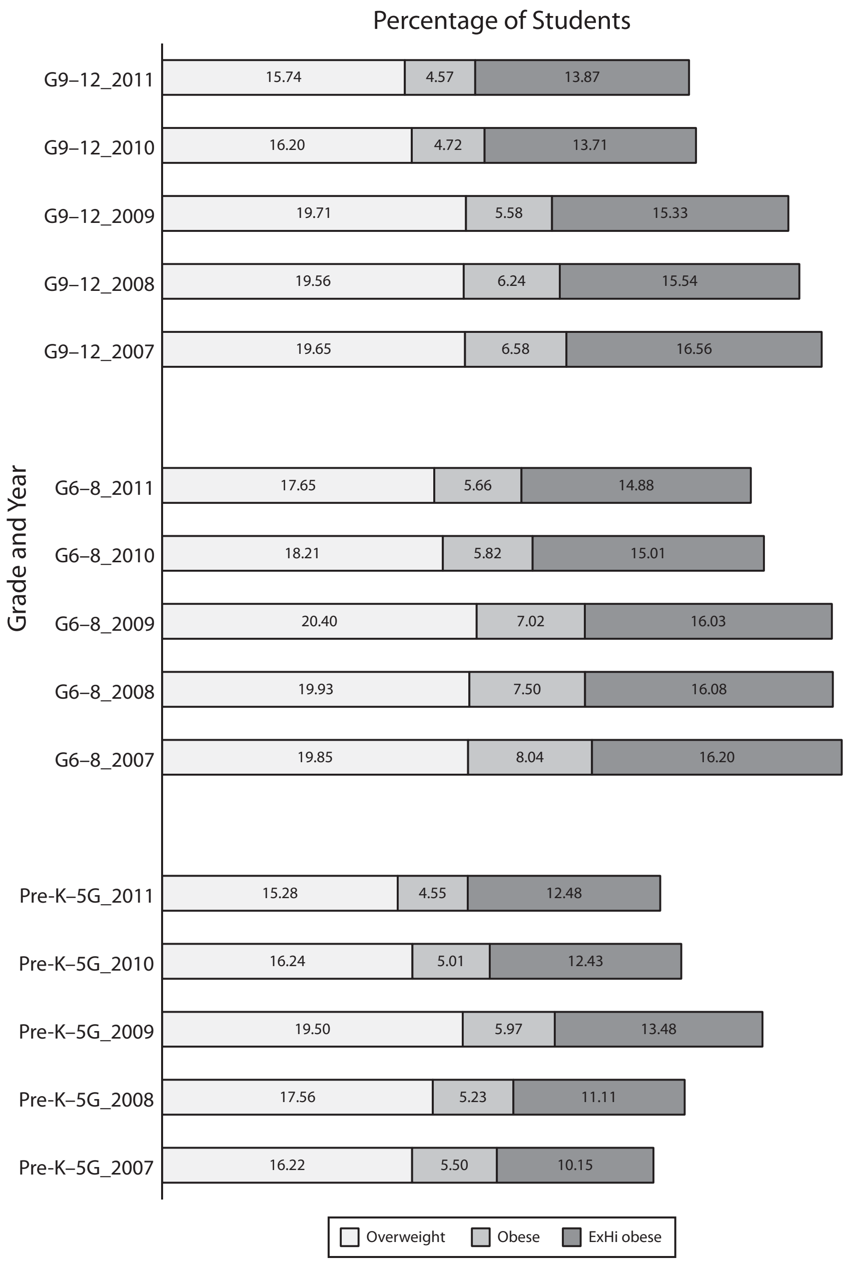
Several BMI transition patterns were evident (Figure 3). Loop 1 presents BMI patterns for normal and overweight, and loop 4 shows BMI patterns for normal and obese students. For all students, movement from overweight to normal was 19% higher than for movement from normal to overweight (loop 1), a pattern that was somewhat more pronounced for middle and high school students than for elementary students. Additionally, 7 times more students moved from obese to normal (loop 4) than moved from normal to obese; this ranged from 5.92% of elementary to 10.03% of high school students who were obese in 2009 and normal in 2011.

Loops 2, 3, and 5 present the BMI patterns for overweight, obese, and ExHi obese. The combined percentages of all students who moved from obese (loop 2) or ExHi obese (loop 5) to overweight (36.59%) were substantially higher than the combined percentages of students who moved from overweight to obese and ExHi obese (23.55%). Conversely, 4.5 times more students moved from obese to ExHi obese than moved from ExHi obese to obese (loop 3). This pattern was similar for students from all 3 school levels, with a slightly higher percentage of elementary students moving from obese to ExHi obese. In addition, a greater combined percentage of elementary (52.16%) than middle (44.01%) or high school (42.12%) students moved from obese to ExHi obese and overweight to ExHi obese, and fewer elementary (14.51%) than middle (15.57%) or high school (17.52%) students moved in the opposite direction from ExHi obese to obese and ExHi obese to overweight. Based on the simulation of BMI category transitions (Figure 4), the prevalence of overweight, obese, and ExHi obese among Pennsylvania students in 2031 was projected to be 16.0%, 6.6%, and 23.2%, respectively, with the highest prevalence of ExHi obese among elementary students (31%; middle school, 17%; high school, 13%).

DISCUSSION

The year 2009 appeared to have been a watershed for child and adolescent obesity in Pennsylvania. The rapidly escalating overweight and obesity prevalence among elementary students peaked in that year, and then decreased in 2010 and 2011 to approximately 2007 levels. Although, in retrospect, the 5-year trend began declining for all 3 conditions in 2007, this decline was not detectable before 2009. By 2010, a similar trend was identified for obese and ExHi obese students in the Philadelphia, Pennsylvania area.[8] Based on overall percentages, Pennsylvania made notable progress toward achieving the Healthy People 2020 obesity prevalence objectives for children (aged 6–11 years; 15.7%) and adolescents (aged 12–19 years; 16.1%).[17]

Despite these promising findings, the prevalence of overweight, obese, and ExHi obese among Pennsylvania children and adolescents was still more than 2% points higher in 2011 than for the United States in 2010.[4] Consistent with national findings,[5] middle school- and high school-aged boys were more likely than their female counterparts to be ExHi obese. If all individuals with BMIs at or above the 95th percentile were considered, approximately one third were classified as obese and two thirds as ExHi obese; the percentage of children and adolescents who were ExHi obese in 2011 already exceeded the 2030



Note. BMI = body mass index; ExHi = extreme high; G6–8 = middle school; G9–12 = high school; Pre-K-5G = elementary school. The sample size was n = 685 531; elementary school: n = 328 687; middle school: n = 182 851; high school: n = 173 993. Female: n = 335 111; mean BMI = 20.773 (95% confidence interval [CI] = 20.714, 20.751). Male: n = 305 420; mean BMI = 20.647 (95% CI = 20.647, 20.683). The city of Philadelphia and its surrounding counties were excluded from this analysis.

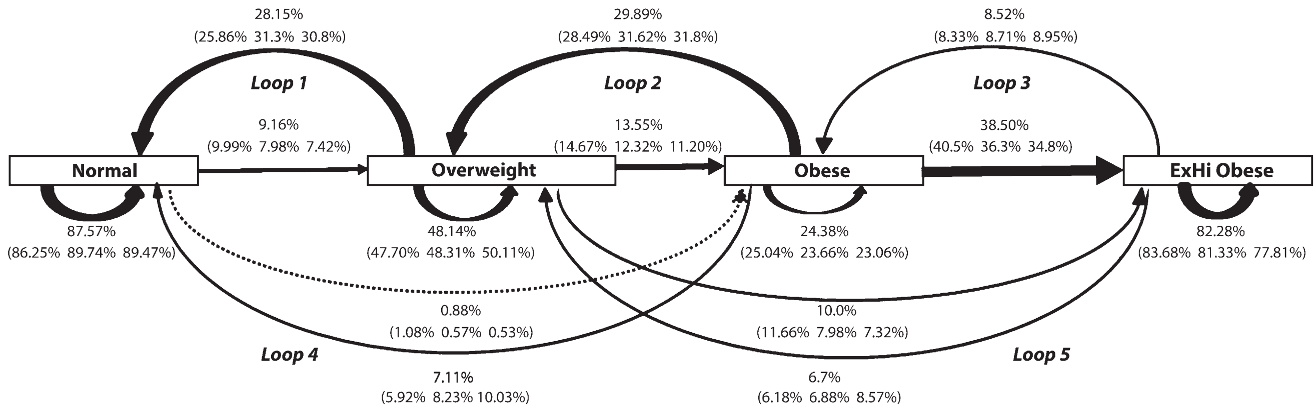
FIGURE 2—Percentages of overweight, obese, and extreme high obese students by school level: Pennsylvania schools, 43 of 67 counties, 2007–2011.

severe obese projections for US adults by more than 2 percentage points (13.7% vs the projected 11%).

Uniquely, our study and 1 previous study of the Pennsylvania school population[7] employed mathematical modeling to determine whether student BMI status remained static or changed over time. Our study confirmed the previous finding[7] that child and adolescent BMI status moved substantially in both desirable and undesirable directions, especially among overweight and obese categories, within relatively short periods of time. Results indicated that the movement of students from overweight toward obese and ExHi obese and from obese to ExHi obese, especially among elementary students, tended to overpower movement in the opposite direction. Therefore, the 20-year simulation determined that the prevalence of ExHi obese among Pennsylvania pre-K to 12th grade students could almost double by 2031, primarily driven by current transition patterns among elementary school children. The prevalence of obesity and ExHi obesity among today's children when they are adults 15 to 20 years hence cannot be predicted; however, previous research showed that children with higher levels of obesity[18] and who were obese as adolescents[19] were likely to be obese as adults.[18,19] Obesity prevalence was shown to double twice from adolescents to adults in their early 30s, with obese adolescents most likely to remain obese as adults.[20]

On the positive side, substantial percentages of students moved from ExHi obese back to either obese or overweight and from obese to overweight or normal weight in 2009 to 2011. The previous study[7] found that 56% of overweight elementary students moved to obese status between 2007 and 2009, but based on findings of our present study, that percentage then dropped by more than half (24.7%) in 2009 to 2011. These developments, if sustained, could help reduce the prevalence of ExHi obesity[20] because they clearly demonstrated that movement in the desirable direction by a considerable percentage of individuals is possible. Additionally, this type of information, when known, could be used to target intervention programming for the greatest impact.[7]

Determining the exact reasons for emerging BMI trends and movement patterns was not possible in this case because the kinds, amount, and intensity of healthy eating and physical activity programs in participating schools were not monitored and might have varied. Nonetheless, some circumstantial information about improvements in school health policy, environment, and programs nationally, and for



Note. BMI = body mass index; ExHi = extreme high; G6–8 = middle school; G9–12 = high school; pre-kindergarten–5G = elementary school. The sample size was n = 80 770; elementary school: n = 48 309; middle school: n = 24 384; high school: n = 8077. Conditional probabilities for individually matched BMI, 2009–2011. Normal→OverW = P($OverW_{11}$ $Normal_{09}$) = 9.16%. Obese→Normal = P($Normal_{11}$ $Obese_{09}$) = 7.11%. For percentages enclosed in parentheses, the first percentage pertains to elementary school, the second percentage pertains to middle school, and the third percentage pertains to high school. The city of Philadelphia and its surrounding counties were excluded from this analysis. $P < .001$ based on the χ^2 test compared with the expected values.

FIGURE 3—Pattern of student body mass index migration reported by percentage: Pennsylvania schools, 43 of 67 counties, 2009–2011.

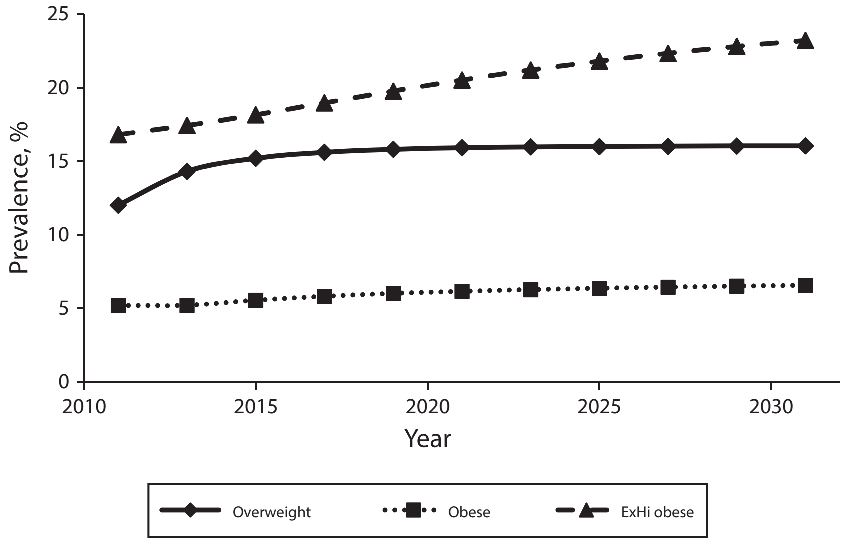
Pennsylvania, were known. As previously indicated, personnel in all Pennsylvania public schools were mandated through state policy to accurately measure every student's height and weight annually, notify all parents or guardians, in writing, of their child's BMI status, and encourage them to bring this to their child's physician's attention if the BMI was in the overweight or obese ranges.[6] Other school policies and practices were more supportive of healthy eating and increased physical activity.[21] Through its reauthorization of the school breakfast and lunch programs in 2004,[22] Congress mandated that, by 2006, all participating US schools adopt a wellness policy aimed at improving nutrition education, opportunities for physical activity, and the food environments in schools. In May 2006, the Pennsylvania State Board of Education amplified this broad federal mandate by adopting specified physical activity and nutritional standards for public schools intended to incorporate opportunities for students to be physically active, including recess and physical education, promote Safe Routes to School, and assure that all students participated in 30 minutes of daily physical activity.[6] Nutrition standards for competitive foods in schools were also mandated.[23] Again in 2006, the Pennsylvania Departments of Education and Health partnered with Highmark Foundation's Healthy High 5 program, a 5-year, $100 million initiative that supported a variety of strategies in schools designed to address physical activity, nutrition, and other critical health issues.[24] Pennsylvania is the fourth largest recipient of US Department of Agriculture Supplemental Nutrition Assistance Program Education funding nationally, and in 2010, it devoted $21 million to serving 221 227 school-aged children.[25] Previous research found that student fat, sugar, and calorie intake was reduced[26] and BMI was positively affected[27] in states with laws regulating foods sold in schools outside of the federal school meal program (i.e., competitive foods).

At the national level, the Clinton Foundation negotiated an agreement with the soft drink industry that subsequently resulted in a 90% reduction in calories distributed to schools.[28] Related positive changes were documented in Pennsylvania at the school level.[29,30] Data collected biannually from school administrators by the Pennsylvania Department of Education, and reported by the CDC, indicated that the presence of at least 1 vending machine decreased to 68% of schools in 2010, down from 77% in 2006, with content changes as well. The presence of soda pop and fruit drinks that were not 100% juice decreased from 51% of schools to 24%, and sports drinks decreased from 62% to 49%.[30] Programmatically, 77% of Pennsylvania schools instituted some type of wellness advisory board by 2010, and nearly all established expected outcomes for physical education.[29] Also by 2010, 77% of schools required students to complete 2 or more health courses, up from 65% in 2006.

Limitations

This study had several limitations. Information about race/ethnicity was not collected in student health records; therefore, no analyses based on this variable were conducted. However, some applicable demographic information was available. The racial/ethnic composition of the 43 counties containing study schools was 82.4% White, 7.9% Black, 9.7% other, 8.4% Hispanic, and 91.6% non-Hispanic.[31] Of the 19 Pennsylvania counties classified in 2010 as urban,[31] 12 (63%) were represented in this study. In these 12 counties, 17.9% of children lived in poverty compared with 12.4% in the 31 rural counties (16.0% combined).[31,32]

Furthermore, the number of student data strings available for analysis varied because the number of schools using Health eTools for Schools changed yearly, with some schools dropping off and others joining. Additionally, no comparisons could be made with students attending schools located in the 24 excluded Pennsylvania counties because health record data, including BMI, were only available from schools that used Health eTools for Schools. Because of the pattern of new children beginning school and others graduating from high school each year, some students' height and



Note. ExHi = extreme high; G6-8 = middle school; G9-12 = high school; pre-kindergarten–5G = elementary school. The sample size was = 80 770; elementary school: n = 48 309; middle school: n = 24 384; high school: n = 8077. The city of Philadelphia and its surrounding counties were excluded from this analysis.

FIGURE 4—Simulation of student overweight, obese, and extreme high obese prevalence: Pennsylvania schools, 43 of 67 counties, 2011–2031.

weight could not be measured for the 3 times required to be included in some analyses. Regardless, the total number of student data strings provided for any 1 year was sufficiently robust, as was the number of data strings available for multiyear comparisons, to generate reliable results. Because environments, medical technology, and behaviors might change, the simulation of obesity prevalence was not a prediction. Rather, simulation results suggested the prevalence rates should the child and adolescent BMI transition patterns of 2009 to 2011 remain unchanged over time. The simulation results also provided information that policymakers could use for generating better-informed decisions about obesity prevention resource allocation.

Conclusions

Overall trends in child and adolescent BMI status seem to bode well for Pennsylvania's future. BMI transition movement patterns, however, told a somewhat different story. Overweight and obesity prevalence were essentially leveling off. However, ExHi obesity, especially among elementary students, is projected to increase over time. The public health challenge most crucial to reversing the obesity epidemic is preventing the overweight and obese children and adolescents of 2011 from moving into the obese or ExHi obese categories along with accelerating movement from ExHI obese and obese back toward overweight and normal weight. To this end, evaluations should be conducted at the school level to assure compliance with mandated obesity prevention policy, environment, and program initiatives, as well as to determine which, if any, school-based initiatives are clearly associated with improved BMI trends, and therefore, might provide the greatest benefit. Given the fiscal implications, state officials should be motivated to invest the current resources required to substantially improve the obesity and severe obesity trends among the adults of tomorrow. ■

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Contributors

D. Lohrmann contributed to the interpretation of findings and writing of the article. A. YoussefAgha contributed to the data mining and analysis. W. Jayawardene contributed to data validation and review of the article.

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Human Participant Protection

This study was approved by the Indiana University Bloomington institutional review board.

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