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RESEARCH ARTICLE

Use of Data Mining to Reveal Body Mass Index (BMI): Patterns Among Pennsylvania Schoolchildren, Pre-K to Grade 12

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ABSTRACT

BACKGROUND: Health eTools for Schools was developed to assist school nurses with routine entries, including height and weight, on student health records, thus providing a readily accessible data base. Data-mining techniques were applied to this database to determine if clinically significant results could be generated.

METHODS: Body mass index (BMI) data collected and entered in eTools by school nurses from 657,068 students attending 1156 schools in 49 of 67 Pennsylvania counties during 2005-2009 were analyzed. Students in each BMI category were sorted; regression was used to model mean and percentage trends. A chi-square test of individually matched BMI percentages was computed and migration across normal, overweight, and obese states determined.

RESULTS: The highest percentage of obese students occured in middle school. The mean trends for obesity and overweight had increasing slopes of 0.189 and 0.227, respectively; with regression slope for overweight >59%. Within groups, substantial percentages of individually matched BMIs changed significantly ($p < .0001$) over 2 years, migrating between normal weight, overweight, and obese. A comparison of 2009 measured BMI for grades 9-12 from eTools with 2009 Pennsylvania Youth Risk Behavior Survey self-reported BMI yielded substantial diferences.

CONCLUSION: A pattern of increasing BMI for elementary students with a corresponding decrease among middle and high school students emerged. The means trends for both overweight and obesity were greater in 2009 than in 2005, increasing steadily to 2008 and slightly declining to 2009. The dominant overall pattern flows from overweight to obese. If continued unabated, percentage of students who are obese will dominate over time.

Keywords: obesity; overweight; BMI; school health services; student health record.

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Tripling within the last 2 decades,[1] child and adolescent obesity has dire implications for the national healthcare system.[2] Physical inactivity and unhealthy eating influenced by physical and social environments contribute to overweight and obesity.[3] Conversely, regular physical activity and adherence to recommended nutrition guidelines support healthy weight.[3]

Following reauthorization of the Child Nutrition Act, the US Department of Agriculture required that all local districts participating in the school lunch program adopt a Wellness Policy effective for 2006-2007 school year that addresses physical activity, nutritional education, provision of food on campus, and other school-based activities.[4] In concert, the Pennsylvania State Board of Education adopted physical activity and nutritional standards, asking schools to assure that all students participate in 30 minutes of daily physical activity, incorporate opportunities to be physically active, including recess and physical education, and promote Safe Routes to School.[5] Nutrition standards for competitive foods in schools were mandated.[6]

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To assist families and communities in addressing healthy weight, the Pennsylvania Department of Health (PDH) added body mass index (BMI) to student health screenings performed in schools.[7] Pennsylvania school nurses are legally required to annually report BMI findings to parents via mailed letter, which includes an explanation of age and gender factors that influence BMI and recommendations that information be shared with their child's physician.[7] School nurses are also required to annually compile and report extensive health record information to the PDH.[8]

Additionally, the Pennsylvania Department of Education (PDE) and PDH initiated collaboration with Healthy High 5, a 5-year $100 million initiative of the Highmark Foundation. Through various funding strategies, the initiative addresses physical activity, nutrition, and other critical issues such as bullying, self-esteem, and grieving.[9] A key component, ''Highmark Healthy High 5 HealtheTools for Schools'' (hereafter referred to as ''eTools''), was developed and broadly disseminated by InnerLink, a private company. eTools is a Web-based software application portal used to disseminate programming across multiple Coordinated School Health components and assist school personnel, including nurses, with routine health and fitness assessments. Examples of eTools student health data fields include height and weight, immunizations, vision and hearing screenings, acute diseases, chronic diseases, medications, and health office visits.

The eTools Health Services section was designed to expedite nurses' work. Uniquely, nurses may collect student health information via handheld personal digital assistant (PDA—Palm, iPod, iPad, or Droid) facilitating rapid data collection and streamlining the PDH reporting process. Previous evaluation found eTools to be a comprehensive, well-designed program with the potential to support school wellness policies. Web-based features provide school nurses with tools and resources for working more efficiently.[10] Owing to eTools' proven benefits and ongoing support from InnerLink, school nurses across Pennsylvania routinely collect and report expansive amounts of potentially valuable student health information that can be subjected to data-mining techniques.[9]

Derived from several disciplines, including statistics, data mining is the science of searching large data sets for important and unsuspected patterns and structures, a process called Knowledge Discovery in Databases (KDD). Data mining combines statistical methods and artificial intelligence in 2 ways—exploratory data analysis to find new associations and use of inferential statistics to rule out chance.[11] If accessed, organized, and analyzed using data-mining techniques previously applied in other medical settings,[11,12] information routinely found in eTools data files could potentially yield unique findings heretofore not available. Findings derived in this fashion from hospital[13,14] and school-based health center[15] records have been used to track factors that affect medical care and make data-driven utilization decisions.[16,17] The purpose of this study was to mine eTools data files to determine if clinically significant results could be generated for eventual use by practitioners who influence school and public health policies and practices.

As obesity is a critical issue monitored for large populations by tracking BMI rates,[3] initial efforts were devoted to mining of demographic and BMI-related data (ie, measured height and weight) in eTools files. BMI based on self-reported height and weight, while often the only means available for collecting such data, is likely to understate rates of overweight and obesity; some students completing Centers for Disease Control and Prevention's (CDC's) Youth Risk Behavior Survey (YRBS) are known to either underreport weight and overreport height.[18] eTools files contain repeated measures of actual heights and weights and, therefore, are likely to yield a more accurate finding. Furthermore, having the ability to track BMI for large numbers of students across several years could possibly provide more detailed information for use by school and public officials responsible for intervention and prevention programming.

METHODS

Instrument

This study involved secondary analysis of existing, de-identified student health record information from 2005 to 2009 collected via eTools in a non-coercive environment through routine screenings, parent completion of standard forms, and nurse visits. A common contract with InnerLink holds school districts responsible for maintaining the privacy, confidentiality and integrity of all data, systems and intellectual property related to eTools. Records protection required by the Family Educational Rights and Privacy Act of 1974 is affirmed.

Participants

The target population was all students in 1156 Pre-K to grade 12 schools, both public and private, located in 49 of 67 Pennsylvania counties. Student demographics included gender, grade, race/ethnicity, and a unique file identifier, assigned by InnerLink staff, that links individual participant data across files, allowing data tracking (eg, BMI measures) within the same file over multiple years. This study addresses 2 research questions: (1) On the basis of BMI calculated from height and weight measurements found in matched data files, what are the prevalence, distribution, trends, and patterns in underweight, normal weight, overweight, and obesity over time among Pennsylvania students? (2) How do high school students' rates of overweight and obesity in 2009, based on BMI calculated from eTools data, compare with those based on 2009 Pennsylvania YRBS data?

Data Analysis

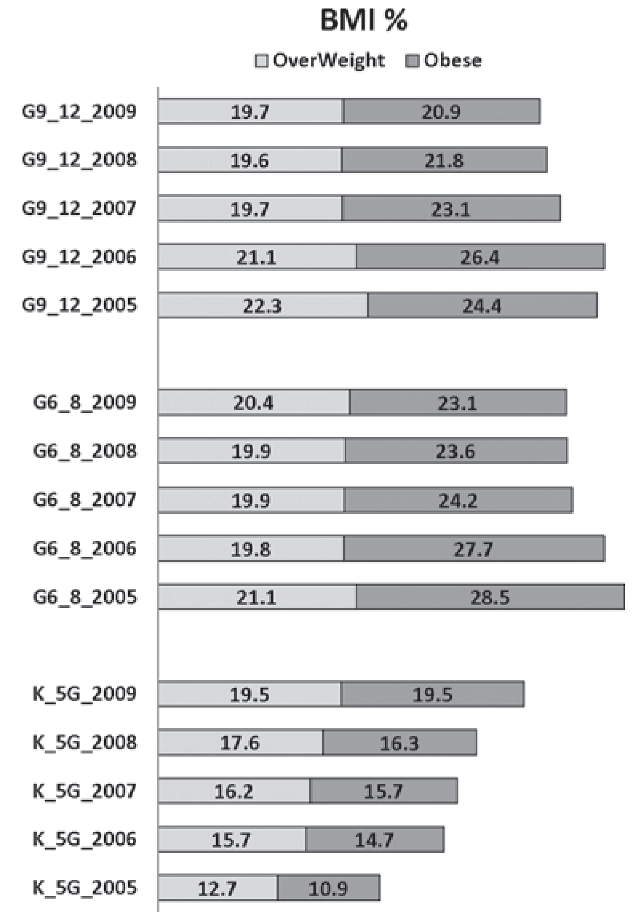
Access was provided via a password-protected Internet link to student data maintained on an InnerLInk server. Multiple discrete files contained demographics, health information, and physical fitness assessments. Through data processing techniques, files were restructured and combined into a relational database suitable for generating queries for statistical analysis[19] and were summarized and aggregated in 5 categories: age, sex, race, school type (ie, elementary, middle, high, and mixed-grades schools), and school location (eg, urban, suburban, and rural). Missing data were replaced whenever possible to conserve cases. For example, when school grade for a specific year was missing composite keys consisting of student identifier, gender, and birth date were used to link multiple files and recover data. The volume of missing data for any single attribute was <10%.

Student height and weight were uniformly measured using a standard protocol provided by the CDC,[20] and BMI was calculated for each individual based on a SAS program designed by CDC for use with children and adolescents.[21] The growth reference year for calculation of percentiles and z-score was 2000. Data validation was conducted to eliminate inconsistencies and outliers for BMI with values beyond 0.003 eliminated. Outliers constituted 2975 cases, <1% (0.75%).

Within the target population, 657,068 student health records were captured at least once between 2005 and 2009. The number of students involved was infuenced by 2 factors that caused fluctuation in the number of schools using eTools: an ever increasing number of schools initiated eTools use during the 3 earliest years, and some attrition of schools occurred each year. Thus, the number of individual student data strings varied from year to year with 7064 available for 2005, 19,517 for 2006, 71,792 for 2007, 186,932 for 2008, and 133,994 for 2009 yielding a total of 419,299 viable cases across the 5 measurement periods. Data from 2005 and 2006 were not included in some analyses because the sample size was comparatively low. Additionally, nurses measuring height and weight would be more experienced and eTools more reliable in latter years. Overall, the number of available data strings was robust enough to allow execution of appropriate analyses.[22]

BMI trends were analyzed using the least squares method.[22] To identify significant trends in overweight and obesity, linear relationships by year were fitted and tested. A simple linear regression formula,[22] $BMI_{mean} = a_0 + a_1 \times Year$, was used to ascertain trends in annual BMI mean and BMI percentage for both overweight and obese across 5 years for all students in eTools schools, yielding 4 separate equations. Correlations between the dependent variable (either overweight or obesity) and independent variable (year) were checked before constructing the regression models. Because this analysis involved only 1 independent variable, colinearity was not a concern. Conditional probabilities based on Bayesian statistics were calculated to reveal BMI category transitions from 2007 to 2009 with significance levels verified through application of chi-square test.[22] Only students who had matched ID numbers for 2007, 2008, and 2009 were included in the transition analysis.

Figure 1. **Percentage of Students Who Were Overweight or Obese by School Level, 2005-2009**



RESULTS

Percentages of students in overweight and obese categories are provided by school level (Figure 1) and by sex (Table 1) for 2005-2009. The highest percentage of obese students occured in middle school (Figure 1) and the mean BMI for girls was slightly higher than for boys ($p < .001$). BMI categories were compared across years using averages and standard

Table 1. **BMI—Underweight, Normal Weight, Overweight, and Obesity by Sex**

	N	BMI %	Lower CL Mean	BMI Mean	Upper CL Mean	SD	SE
BMI							
Under	4831	Total: 1.20 F: 46.33; M: 53.67	14.514	14.56	14.599	1.506	0.022
Normal	249,000	Total: 59.4 F: 50.17; M: 49.83	18.543	18.55	18.563	2.629	0.005
Over	79,172	Total: 18.9 F: 49.76; M: 50.24	22.66	22.68	22.704	3.169	0.011
Obese	86,532	Total: 20.6 F: 45.3; M: 54.7	29.186	29.23	29.265	5.871	0.02

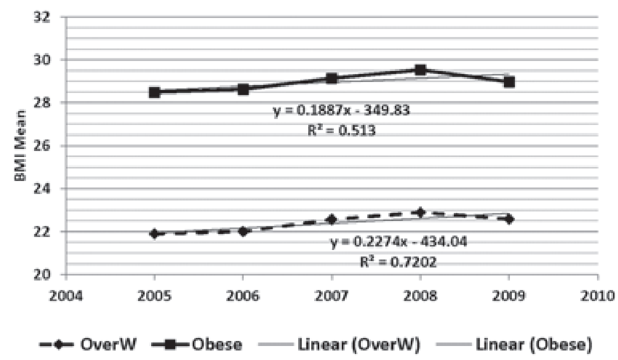
	N	N%	Lower CL Mean	BMI Mean	Upper CL Mean	SD	SE
Gender							
Female	205,000	48.90	21.509	21.53	21.558	5.666	0.013
Male	214,000	51.10	21.422	21.45	21.469	5.547	0.012

deviations (Table 1). Chi-square and nonparametric statistics Wilcoxon were used to test significance differences ($p < .05$).[22] On the basis of BMI, the percentage of students who were obese was found to be greater than for overweight (Table 1). The mean score for obesity was also greater than for overweight (Table 1). Comparisions between any 2 of the 4 BMI category pairs (Table 1), underweight, normal weight, overweight, or obese, were found to be statistically significant ($p < .001$).

Specific regression formulas were: $\text{Obesity}_{\text{mean}} = 0.1887 \times \text{Year} - 349.83$; $\text{Overweight}_{\text{mean}} = 0.2274 \times \text{Year} - 434.04$; $\text{Obesity\%} = 0.525 \times \text{Year} - 1033.9$; and $\text{Overweight\%} = 0.76 \times \text{Year} - 1507.1$. The mean trends for obesity ($R^2 = .513$) and overweight ($R^2 = .72$) had increasing slopes of 0.189 and 0.227, respectively; the rate of increase for overweight was greater than for obesity (Figure 2). Distinct formulas were used for determining obesity percentage ($R^2 = .75$) and overweight percentage ($R^2 = .95$). The regression slope for overweight percentage from 2007 to 2009 was >75%, indicating a steep rate of ascent.[22]

Figure 3 depicts changes in student BMI status from 2007 to 2009. Results are shown for all students in grades Pre-K through grade 12 as well as separately for elementary, middle, and high school students. All students included in the percentages shown had their BMI calculated in both 2007 and 2009 and, for this analysis, linked by unique member identifiers. (Data from the low number of underweight students in the sample were excluded to assure more accurate chi-square results.) Just over 80% of students who were normal weight or obese did not change category over this time span, while almost half of all students initially in the overweigh category moved one way or the other; rates at which students remained within their initial category varied by school level. Table 2 provides BMI category transition statistics, including conditional probabilities and BMI mean differences.

Figure 2. **Trend in Mean Rates of Overweight and Obesity, 2005-2009**



Simple linear Regression Results

Year	2005	2006	2007	2008	2009
Over Weight Mean	21.923	22.137	22.352	22.566	22.781
Obesity Mean	28.720	28.869	29.019	29.169	29.319

Formula: Obesity mean = 0.1887 Year -349.83; R2 =0.513 (p<.05)
Over Weight mean= 0.2274 Year -434.04; R2 =0.720 (p<.05)

Additionally, several student BMI transition patterns are evident. Loop 1 presents the BMI pattern for normal weight and overweight. For all students, movement from overweight back to normal weight was 30% higher than for the opposite movement from normal weight to overweight (Loop 1), a pattern that was much more pronounced for middle and high school students than for elementary students. Loop 2 presents BMI pattern for overweight and obese. The percentage of all students who moved from overweight to obese is 2.5 times greater than the percentage of students who moved from obese back to overweight (Loop 2). This pattern is especially profound for elementary

Figure 3. **Pattern of Student BMI Transitions, 2007-2009***

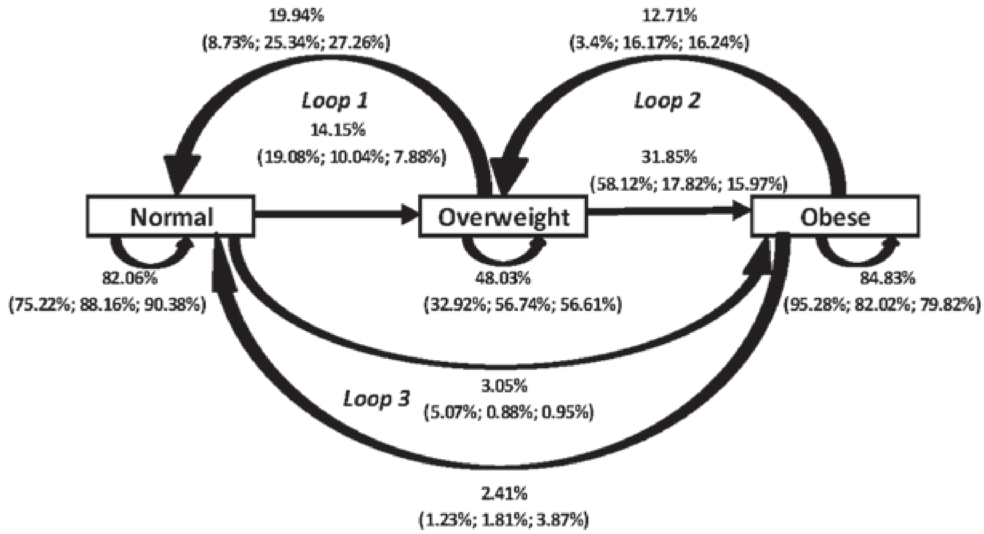


Figure 3 presents a number of percentages enclosed in parentheses. In all instances, the first percentage pertains to elementary grades PK-G5, the second percentage pertains to middle school grades 6-8, and the third percentage pertains to high school grades 9-12 (grand total N = 21,928; PK_G5 N = 9863; G6_G8 N = 5658; G9_G12 N = 6404; Missing N = 11). *Based on chi-square test, all observed values, displayed by percentages, are significantly different from the expected values ($p < .0001$). All percentages were computed using Bayesian statistics

Table 2. **Means BMI Transition Statistics, 2007-2009**

BMI Transition* (2007-2009)	Conditional Transition† % (2007-2009)	n	BMI Mean Difference (2007-2009)	Mean Difference Lower 95% CI	Mean Difference Upper 95% CI	SD of Mean Difference
Normal→Nomal=P(Normal09 | Nomal07)	82.1	11,631	.865	.865	.913	1.158
Normal→OverW=P(Normal09 | OverW07)	14.2	2005	2.798	2.728	2.869	1.379
Normal→Obese=P(Normal09 | Obese07)	3.1	433	5.56	5.192	5.921	3.252
OverW→Normal=P(OverW09 | Normal07)	19.9	715	−1.096	−1.237	−.955	1.673
OverW→OverW=P(OverW09 | OverW07)	48.0	1722	1.210	1.144	1.277	1.226
OverW→Obese=P(OverW09 | Obese07)	31.9	1142	3.685	3.558	3.812	1.895
Obese→Normal=P(Obese09 | Normal07)	2.4	93	−6.243	−7.288	−5.198	4.140
Obese→OverW=P(Obese09 | OverW07)	12.7	491	−1.690	−1.918	−1.462	2.242
Obese→Obese=P(Obese09 | Obese07)	84.8	3278	2.146	2.044	2.249	2.621

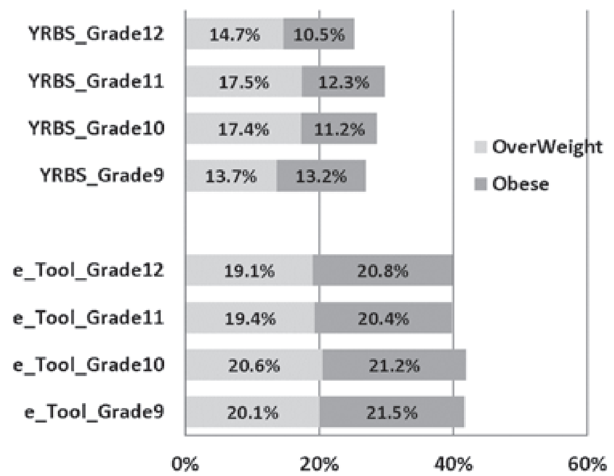
*Formulas mean the conditional probability that a student's BMI stayed the same or changed in 2009 given his/her BMI status in 2007.
†Chi-square value = 78,172.97; df = 9; $p < .0001$

school students where the percentage that moved from overweight to obese was 17 times greater than for those who moved from obese back to overweight.

For all students, the percentage that moved from overweight to obese (Loop 2) is substantially greater than the percentage that moved from overweight to normal weight (Loop 1); however, this pattern is influenced most by elementary students. The percentage of middle school and high school students who moved from overweight to obese is about equal to that which moved from obese back to overweight (Loop 2). A small percentage of students moved either directly from normal weight to obese or obese to normal weight (Loop 3). Considering this entire mechanism involving over 21,000 students for approximately 24 months, the dominant pattern flows from overweight to obese (Loop 2).

For many years, the CDC has funded state education departments, including Pennsylvania's, to collect YRBS data on a biennial basis related to 6 priority health behaviors including nutrition and physical activity.[18] To calculate BMI for each state, the survey asks students to report their height and weight.[23] A stratified random sample of 9th- to 12th-grade schools within states is chosen through use of well-established software. After schools agree to participate, a sample of students is chosen from each grade within the school. Data that are considered to be weighted (ie, data were collected in at least 60% of randomly selected schools) within each state for any 1 year are provided on a CDC Web site;[23] only Pennsylvania data 2009 appears.[24] Figure 4 provides a comparison of the percentage of overweight and obese high school students based on Pennsylvania YRBS survey results and data from

Figure 4. **Comparison of YRBS* and eTools Overweight and Obesity Findings for Pennsylvania High School Students, 2009**



Total N: YRBS = 1935; eTools = 41,262.
*Pennsylvania-specific, weighted data from CDC Web site.[25]

eTools. For every grade, the percentages of students who were overweight and the percentage that were obese were greater for eTools data.

DISCUSSION

Not surprisingly, analyses revealed substantial percentages of K-12 students in Pennsylvania to be overweight and obese. Although the number of cases for 2005 and 2006 were many fewer, the results indicate a pattern of increasing BMI for elementary students across the 5 measurement periods with a corresponding decrease among middle and high school students during the final 3 so that combined percentages of overweight and obese students in 2009 approached parity across all 3 school levels. For all students, the means trend for both overweight and obesity was greater in 2009 than in 2005 having increased steadily to 2008 and then beginning a slight decline to 2009. Whether expressed as a means trend or regression slope, the pre-K through grade 12 rate of overweight and obesity steeply increased over the 4 years. Gender differences were only apparent for obese students with a significantly greater percentage of males than females in this category. Whether the slight decline in the means for 2009 is the beginning of an overall trend remains to be seen and can only be determined by analysis of data from additional years as they become available.

The most informative findings were generated by the mechanism displayed in Figure 3. These results contribute to our understanding of the child and adolescent obesity epidemic by demonstrating that BMI status is not static but rather, changes dynamically over time. Several positive features are apparent; the vast majority of students across all grades K-12 and by school level who were normal weight remained in that category and some students, primarily in middle and high school grades, moved back in the desired direction from obese or overweight toward normal weight. Additionally, a few students even moved from obese back to normal weight. At the least, this pattern demonstrates that BMI does not uniformly move in the undesirable direction for many students and, that for some, it moves in the desired direction. The results cannot provide specific explanations for BMI changes that flow from obese back to overweight and from overweight back to normal weight. Nevertheless, several possible explanations have been identified in previous research. Results could possibly be explained by the fact that a portion of the study population was in the 12- to 14-year age group, ages at which BMI is especially complex and variable;[26] by improved physical fitness related to increased physical activity;[27] and by changes in adiposity.[28]

Several negative features also emerged in Figure 3; higher percentages of overweight students moved to obese than from obese to overweight or from overweight to normal, a pattern that was extremely pronounced for elementary school students. Specific reasons for this pattern are unknown other than some environmental factors may have changed[3] in a relatively short period of time, especially for elementary students, to generate BMI increases. Despite the positive findings, the fact remains that the dominant overall patter flows from overweight to obese. If this pattern continues unabated, the percentage of students whose BMI migrates toward obese will increase over time.

While the best option available in the absence of actual height and weight measurement, comparisons with BMI calculated from actual height and weight measures in this study indicate that those based on self-reports are likely to understate the magnitude of this problem. When assessed for reliability, CDC investigators found that students completing the YRBS tended to overreport height and underreport weight.[18] This threat to reliability was confirmed because BMI calculated from eTools measurements found both overweight and obesity at substantially higher levels for all high school grades. Markedly, the obesity rates for 10th and 12th graders, at over 20% per grade, were almost double those reported from YRBS.

In summary, the use of data-mining techniques facilitated analysis of large amounts of available health services data collected by school nurses and yielded unique and meaningful results. Further, use of data collected from the same individuals over several measurement periods allowed for identification of transition patterns across BMI categories and school types, yielding clinically significant results that can be used for programmatic decision making. Finally, since the results of this study are derived from accurate measures of BMI by qualified health professionals, they are arguably more dependable than BMI based on self-reports.

IMPLICATIONS FOR SCHOOL HEALTH

The most important implication involves wellness policy implementation.[4-6] Whereas no student category should be overlooked, the results indicate special attention must immediately be paid to overweight elementary students to prevent them from moving to obesity because they showed the greatest propensity to move in that direction. Application of simulation software[29] demonstrates that under current conditions, the percentage of students that is obese will be greater than the percentage that is normal weight by the year 2016. If half of overweight elementary students can be prevented from becoming obese, then domination of normal weight by obese will be delayed until 2021.

A second implication involves eTools as a de facto surveillance system. Intended to help school nurses be more efficient[10] and designed to produce routine utilization reports,[8] when employed on a large scale eTools compiles accurate mineable data that can generate actionable results using few additional resources.[30] The current study demonstrated the efficacy of this eTools function, which could conceivably be expanded to investigate many other health issues including diabetes, asthma, allergies, immunizations, screening results, and injuries. Such data can assist policy makers, public health officials, school officials, health care providers, and others with making better-informed decisions that can focus placement of high-return policy and program interventions.[25]

Any intervention must be aimed at assuring that the mandated school wellness policy is robust, fully implemented and evaluated[31] with parents as full partners along with physicians who care for children.[32] The state recommendation that parents inform their child's physician of BMI results[7] is a clear indication of this shared responsibility, leading to a final implication. Currently, eTools is an electronic health record (based on federal content standards) that can allow interoperability with health information exchange (HIE) systems. Connection in real time of the school-based eTools student health record with the medical practice-based electronic health record, given appropriate confidentiality safeguards, would allow physicians to more closely monitor patient's BMI and facilitate collaboration with school nurses, faculty members, and parents aimed at maintaining healthy weight.[32]

Limitations

This study has several limitations. The number of schools using eTools during the first 2 years of implementation was relatively low, and therefore, student data from those years were not included in some of the analyses. The number of schools using eTools changed each year with some schools dropping off and others joining, causing fluctuations in the total number of available student data strings. Additionally, each year some students were lost to high school graduation and to leaving their school or school district. Furthermore, some students' height and weight (eg, incoming Pre-K and kindergarten students and students moving into a new community) could only have been measured once or twice and could not be included in analyses involving 3 measurements. Nevertheless, 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.

CONCLUSION

The analyses executed for this study involved just a fraction of the information available in the eTools data base. Future research can engage data found in other health record fields to, for example, identify connections between BMI and conditions such as diabetes, asthma, allergies, orthopedic problems, and cardiovascular disease. Should wellness programming data become available from participating schools, student health record data from eTools can be used to assess effectiveness as well as to inform needed modifications. Additionally, eTools data could be used to investigate relationships between health conditions and environmental factors such as those between asthma and air quality.[33] These and numerous other studies involving mining of eTools data could yield results that may prove useful to a broad spectrum of child and adolescent health stakeholders, including school nurses, school administrators, and public health officials.

Human Subjects Approval Statement

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

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