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Circannual variation in relative weight of children 5 to 16 years of age

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Abstract

Background—Summer weight gain in children has been reported, however, this is usually based on two time points. Our objective was to investigate monthly variation in weight status.

Methods—Cross-sectional, de-identified health records including height, weight, and demographics, collected between 2007–2012 from South Central Wisconsin in 70,531 children age 5–16 years were analyzed. The monthly averages in BMI z-score were analyzed cross-sectionally followed by a paired analysis for a subset with one visit each during school and summer months.

Results—BMI z-scores during the summer months (June–August) were lower than values during the school year (September–May). Of note there was a rapid decrease in BMI z-scores from May to June, with June BMI z-score values being 0.065 units less (95% CI 0.046 – 0.085) than those in May, little change from June to August and a rapid increase between the August and September BMI z-scores.

Conclusion—The monthly pattern does not fully agree with previous two-point school based studies. Results raise concern that the use of two-time point measures of BMIs (early fall and late spring) are suboptimal for evaluation of circannual variation. We suggest that future evaluation of the effect of school based or summer interventions utilize additional measures in those periods so that a seasonal analysis can be performed.

Keywords

Obesity; children; electronic medical records; prevention; evaluation

INTRODUCTION

The National Health and Nutrition Examination Survey (NHANES) reported that 14.9% of children were overweight and 16.9% of children were obese in year 2011–2012.¹ Despite a recently reported small decline in the childhood obesity incidence in 2–5 year olds, national obesity rates remain high,² and are associated with an increased incidence of type-2 diabetes, hypertension, hyperlipidemia, cancer, psychological issues and death in young adulthood.^{3–8} Because of these issues, investigators have initiated interventions to reduce body weight and prevent excess weight gain among children often based in schools.^{9–12} To evaluate the efficacy of these interventions, repeat measures of body mass index (BMI) were performed at the start and the end of the school year; and some have demonstrated success in terms of small decreases in excess weight.^{9, 13, 14} In doing so, however, a surprising result has been that children returned to school in the following fall with an increased relative weight, and this was most pronounced in already overweight and obese children.^{9, 13–16}

The reports of relative weight gain between the end of the academic year and the start of the following fall term were quite interesting to us as they indicated there might be a need for summer interventions to prevent childhood obesity. We there began a retrospective study to better describe the time course of summer weight gain. We performed a cross-sectional analysis of data from electronic health records (EHR) for children aged 5–16 years living in South-central Wisconsin. Herein, we report the results of that study. Two data analyses were performed. The first was a tabulation of body mass index (BMI) z-score data by the month of the year based on cross-sectional EHR data. This analysis provided information on the circannual (within year) variation in BMI z-score for children that was categorized by age, sex, weight status and minority status. A second sub-group analysis was performed in children with repeated visits, one each during academic months and summer months to confirm our finding of a summer relative weight loss in the cross sectional data analysis using longitudinal data.

METHODS

Source(s) of records:

This analysis used the University of Wisconsin Public Health Information Exchange (PHINEX) dataset, which has been shown to be in general agreement with NHANES obesity status data.^{17, 18} Briefly, this PHINEX database links de-identified electronic health records (EHR) that contain demographic variables (age, sex, race/ethnicity), clinical data (e.g. laboratory tests, pharmaceutical prescriptions and other treatments) and community level data (e.g. poverty, economic hardship, built environment, fresh fruit and vegetable consumption, etc.) from other public records including census information.^{19, 20} The database used for this analysis is for all primary care visits of children from South-central Wisconsin (Counties- Dane, Sauk, Columbia, Dodge, Jefferson, Iowa, Rock, Green Marquette; also includes widely dispersed sampling of patients in Eau Claire, Augusta, Wausau, and Appleton counties) from a multicenter healthcare system (family medicine, pediatrics, and internal medicine). All PHINEX data were derived from the Epic EHR Clarity Database (EpicCare Electronic Medical Record, Epic Systems Corp., Verona WI).

This proposed data base and its use was reviewed and approved by the UW–Health Sciences Institutional Review Board.

Inclusion/exclusion of patients and missing data:

Records from 70,531 children aged 5 to 16 years, collected between 2007–2012 were considered for the analysis. Children were excluded from the analysis if: BMI data was missing, height and weight were not measured on the same visit, or BMI z- score not between –2 and +4 to remove data points more than 2.5SD below or 3.5 SD above the average, which otherwise might influence the averages of small data cells. The resulting sample size used for final analysis was 69,881 children. If a patient had more than one visit in a month, the last record was selected for analysis.

Patient data collection:

Information on patient's age, sex, parent reported race/ethnicity, height and body weight was collected during the normal medical visits. We calculated the body mass index (BMI) for all patients using the standard formula height (m)/weight² (kg). BMI z-scores were categorized based on WHO growth reference with $-2 < \text{BMI z-score} < +1 \text{ SD}$ = healthy weight, BMI z-score ≥ 2 = overweight, BMI z-score > 2 = obese.²¹ Race/ethnicity was categorized as non-Hispanic white, non-Hispanic black, Hispanics and others as reported by the parent or guardian. The economic hardship index (EHI), for which a high score indicates a lower socioeconomic status of the patients, was calculated using six social and economic conditions from census data: crowded housing (percent of occupied units with > 1 person per room), poverty (percent of households below federal poverty level), unemployment (percent of people 16 years who are unemployed), dependency (percent of population < 18 or > 64 years), education (percent of people 25 years with less than a twelfth grade education or its equivalent) and per capita income.²² Based on these conditions, these EHI scores ranged from 0 (lowest degree of hardship) to 100 (hardest degree of hardship).²² Patients were linked to census block groups using their geocoded address of residence as of 2012 and the EHI score was calculated for the block groups.

Definition of academic year/summer:

The academic year was defined as September through May and summer as June, July and August. September was chosen as the start based on the 2000 Wisconsin statute which states that schools may not start the school year before September first and that the required number of school instruction hours extends the school year through the first 10 days in June depending on grade and the number of early release days. The largest school district (Madison) in the geographic area encompassed by the health system from which we drew EHR data began the school year the first Tuesday after Labor Day and ended the school year around June 8th for the years in which EHR data was collected. It should be noted that the EHR data did not include any information of school attended or attendance of summer school and would include an unknown number of children who were home schooled or attending summer school during portions of June, July and August.

Statistical Analysis:

Summary statistics (mean and 95% CI) were calculated based on the last measurement in each year for all records and subgroups of age, sex, and race/ethnicity. To mimic school classroom data, children were grouped by age as of September 1 of each year. For the calculation each BMI z-score for the child, however, the age (years and months) was calculated from the child's birthdate and the date of the clinic visit. To assess the change in average BMI z-score between the academic months and summer months in the cross-sectional data set, a linear, mixed model was used with subject included as a random effect. The academic year was defined as Sept – May and summer was defined as June, July and August. We also performed a separate subset analysis in pediatric patients with a record both in the academic year (September-May) and in the subsequent summer (June-August). All analyses were performed using R version 3.2.3, 2015²³, and the criterion for significance was $p < 0.05$.

RESULTS

Overall analyses:

General characteristics of 69,881 children included in the analyses are described in Supplemental Table S1. The children were approximately equally divided by gender with an overall mean age of 11.3 yr. More than half of the children were classified as healthy weight (68%) with nearly a quarter classified as overweight and 8.3% classified as obese. The prevalence of obesity in our cohort was lower than that observed in NHANES for the similar year (16.9%), although this can be partially explained by the lower fraction of children being of minority status in the PHINEX cohort.¹⁸ Majority of children were classified as Non-Hispanic White (81%) followed by African American (8%). Forty-three percent of children were from a very low socio-economic background ($EH1 > 25$).

As shown in Figure 1, BMI z-score increases with age as expected. The data for males showed an increase for some of the months but not others. The results for females are more pronounced showing a difference for all months displayed.

Averaged across ages and sex, the pattern for the BMI z-scores across the year displayed a systematic variation, with progressively greater BMI z-scores during the school year (September – May), but lower values in May to June and then larger values again in Sept (Figure 1). Both males and females displayed similar differences in BMI z-scores between May and June.

When categorized by race/ethnicity, last record per subject per month data indicates that BMI z-scores were lower during June-August as compared to September - May only in Non-Hispanic Whites (Figure 2). In both Non-Hispanic Blacks and Hispanics, BMI z-scores were similar in June (beginning of summer), August (end of summer) and September (beginning of academic year). The month-to-month variation was greater in the Non-Hispanic Blacks and Hispanics than in the Non-Hispanic Whites and a circannual pattern was not observed in those two minority cohorts.

Average BMI z-scores for all categories of age, sex, ethnic groups, insurance status, and EHR between academic months and summer months are reported in Table 1. Overall, a significantly lower ($p < 0.0001$) BMI z-score was observed during the summer months when compared to preceding academic months (-0.048 units).

The BMI z-score was significantly higher during the school year compared to summer when categorized by relative weight. During the academic months and summer months BMI z-score with its 95% CI averaged 0.020 ($0.017-0.023$) and -0.030 ($-0.033- -0.027$) respectively for healthy weight children ($p < 0.0001$), 1.435 ($1.433-1.437$) and 1.425 ($1.423-1.427$) respectively for the overweight children ($p < 0.0001$) and 2.308 ($2.305-2.311$) and 2.300 ($2.297-2.303$) respectively for children with obesity ($p < 0.001$) (Supplemental Figure S1). The monthly variation in BMI z-score was more pronounced in the overweight category in both academic and summer months, but the 95% CI in the overweight group was large due to the smaller number of subjects.

To test if the summer dip in BMI z-score was due to a greater height or a lower weight, we investigated the circannual difference in these variables. Height squared displayed gradually larger values across the year with no short-term rise during the period of the BMI z-score nadir. Weight, on the other hand, displayed a lower average beginning in May and a nadir in June. It should be noted that when categorized by childhood and adolescence that height did contribute to a larger percentage of the academic vs summer difference in BMI in the 12–16 year age group consistent with the adolescent growth spurt.

Subset analysis:

We also performed a paired analysis of school year vs. summer BMI z-scores in a subset of pediatric participants ($n = 15,503$) who had at least one visit in both the academic year and during the subsequent summer. Table 1 presents data on BMI z-score of these participants by subgroup. A significant reduction in BMI z-score was observed during the summer months when compared to preceding academic months, in this paired analysis (0.043 , $0.027-0.059$, $p < 0.0001$).

DISCUSSION

This cross-sectional study identified a strong circannual variation in weight gain in children as measured by BMI z-score. The BMI z-score averages recorded across all ages during the clinic visits in September were greater compared to the averages recorded in end of May/ beginning of June. The novel finding of our analyses, however, was that there was no decrease in BMI z-score during most of the school year, but there was rather a rapid drop between BMI z-scores recorded in May and June, followed by an increase in BMI z-score in August. This cross-sectional finding was confirmed in the subset of children who had two clinic visits in which BMI was measured once during the school year and once during summer.

This circannual pattern is likely to have a major impact of how obesity interventions might be interpreted for school based interventions. Most such evaluations employ a paradigm where BMI is measured only twice, once each at the beginning and the end of school year-

e.g. mid-September and end of May. If these evaluations were done using the data from our cross-sectional study, it would appear that there was a slight decrease in BMI z-score during the school season (September to end of May) and an increase during the summer (end of May to September). This pattern might be interpreted as a successful obesity intervention during the school year followed by gain of excess weight during summer. When our cross-sectional data is viewed for all 12-months, the pattern is not consistent with an interpretation as a slow excess weight gain during summer, but rather as two unexplained, opposing short-term changes in BMI z-score at the very end of the academic year and start of the next.

The differences in BMI z-score observed between the months of June to September in our cross-sectional study are small, but not unlike those reported by others. Investigators have recorded a BMI z-score increase of 0 to 0.09 units for children aged 5 to 8 years.^{9, 13, 14, 24–28} Our data fall in the center of this range. These higher BMI z-scores observed in September compared to June are similar to above reports of summer weight gain among children from longitudinal studies.^{9, 13} However, our results suggest that the June to September difference in BMI z-score is not a gradual summer weight gain, but a sudden increase in late summer, which might not be explained as a detrimental influence of the home environment alone. Unlike our findings, previous studies could not report on the decreases we observed between May and June but this is because they lacked measures of BMI in both of those months. Indeed, most studies do not even report the dates of the measures and report rather “start and end of the school year”. We strongly suggest that dates of measures should be reported in future studies. A limitation of our data, however, is that our month by month analysis is based on cross-sectional data. A longitudinal study is required to determine if the circannual pattern we observed is also observed on a within student basis.

The circannual variations we observed are small, corresponding to 0.5–2 lbs depending on age and BMI status; but in other childhood obesity prevention studies, it has been argued that small BMI z-score changes would become biologically important should they accumulate between the age of ~5 to 9 years.^{9, 28} A limitation of our data is that they do not provide data that would explain the circannual variation. The Wisconsin climate in May, September and October, however, is very conducive to outdoor activity and this is not consistent with the differences in BMI z-score we observed in the cross-sectional data. Little or no systematic variation in relative weight was observed during those months, suggesting that ambient temperatures conducive to outside activities alone do not explain the circannual pattern we observed in our data.

A second limitation is that the fraction of children within each excessive relative weight category for the geographic area in and around Madison, WI were lower than the national values, while those classified over-weight were higher. The National Health and Nutrition Examination Survey reported that 14.9% of children were overweight and 16.9% of children were obese in year 2011–2012.¹¹ This may have influenced our findings relative to what would be observed in a more representative sample.

The major limitation to our study is that it was a cross-sectional study and therefore may not represent the changes in body weight that would be observed during a longitudinal follow-

up. For example, the number of clinic visits in June, July and August were 30–85% greater than in the other months of the year and thus not equal across the months suggesting a potential for monthly selection bias. Variance in the timing of growth and weight gain could also be expected to result in differences in BMI z-scores. Another limitation of this analysis was that the BMI measurements were performed in multiple clinics by staff with varying levels of training. This could increase the variance in the BMI z-scores, but would not explain the timing of the circannual variations. Because of the potential future use of EHR data, an effort should be made to create best practice guidelines that would standardize the measurement of height and weight in clinics. At present, there is lack of standardization of clothing for body weight measures. Our study in Wisconsin adults reported a difference of 1 lb in clothing weight without shoes or other footwear over a 55°C range in lowest to the highest outdoor temperatures.²⁹ Although the seasonal difference in clothing weight would be expected to be less than 1 lb among children because of their shorter stature, lighter clothing during summer may explain some of the difference between BMI z-scores for summer vs. school year in our dataset, but it would be important for this to be confirmed in a study similar to that which has been done in adults. We also speculate that if the dip were due to differences in clothing alone, the period of depressed BMI z-scores would probably have continued through September or early October in the Wisconsin climate before rising again due to the wearing of warmer clothing, which is not consistent with our data.

Our results indicate that the practice of basing the relative weight outcomes on just two measures per year appears insufficient. Investigators are encouraged to add additional measures during the school year. We suggest taking additional measures so that one can test whether the academic year change in BMI z-scores is unidirectional across the school year or seasonal starting in late spring as suggested by our cross-sectional data.”, however, more studies from other parts of the United States are needed to fully understand the timing and causes of variations in BMI z-score across the year. In addition, because the number minority children in our study was small, more studies are needed to determine if race, SES, or other factors influence the circannual variation in BMI z-scores.

Using EHR data, we found a nadir for BMI z-scores in June, July and August in Wisconsin. The increase between August and September was not inconsistent with previous reports of summer weight gain, but this was accompanied by a lower BMI z-score in June compared to May which has not been previously reported. If confirmed in other geographic locations, this circannual variation has major implications for the evaluation of obesity prevention efforts in schools as it requires that BMI be measured frequently and not just in September and June as it would introduce an artifact into the BMI outcomes of any intervention. A longitudinal study that includes measures of possible contributors to the differences in relative weights should be performed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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SB organized the results and prepared the first draft. LH initiated the assembly of the database and directed it use. DS conceived the study design. All authors were involved in the writing and approval of the final manuscript. Special thanks is given to John Klope, PhD who helped formulate and then performed the statistical analysis.

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Abbreviations

BMI	body mass index (kg/m ²)
CI	confidence interval
EHI	economic hardship index
EHR	electric health records

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What is known about this subject:

- Children do not grow uniformly throughout the year
- Studies have observed disproportionate increases in weight for height² between the end of one school year and the start of the next.
- The availability of electronic medical records has opened an opportunity to access large amounts of medical information on health statistics.

What this study adds

- Children average a lower weight for height² during the summer than during the school year.
- The common paradigm of measuring weight and height at the “start” and “end” of the school year misses potential fine structure in short-term changes of excess weight.

Figure 1. Monthly variations in average BMI z-score of all pediatric patients by age (5–11 years and 12–16 years) and sex (M: Male; F: Female).

BMI: body mass index. Vertical bars represent 95% Confidence intervals.

Figure 2. Monthly variations in average BMI z-score of all pediatric patients by race/ethnicity.
 BMI: body mass index. Vertical bars represent 95% Confidence intervals

Table 1.

Average academic months and summer months BMI z-score of all pediatric patients and pediatric patients with repeated visits by age, sex ethnicity health insurance and EHI

Variables	BMI z-score all pediatric patients			BMI z-score pediatric patients with repeated visits			P* value
	Academic months (September- May)	95%CI	Summer months (June- August)	Academic months (September- May)	95%CI	Summer months (June- August)	
Overall							<0.0001
Age group							
5–11 yr	0.50	0.49–0.51	0.45	0.55	0.53–0.57	0.51	0.48–0.53
12–16 yr	0.58	0.57–0.59	0.51	0.58	0.56–0.61	0.55	0.52–0.57
Sex							
Male	0.56	0.55–0.57	0.50	0.58	0.56–0.60	0.52	0.50–0.55
Female	0.51	0.50–0.52	0.46	0.55	0.53–0.58	0.53	0.50–0.55
Ethnicity							
White (NH)	0.48	0.47–0.49	0.43	0.51	0.49–0.53	0.47	0.45–0.49
African American (NH)	0.86	0.83–0.89	0.85	0.97	0.91–1.03	0.93	0.87–1.00
Hispanic	0.43	0.39–0.47	0.35	0.43	0.34–0.52	0.37	0.28–0.46
Other	0.88	0.84–0.91	0.86	0.98	0.91–1.05	0.94	0.86–1.01
Health Insurance							
Commercial	0.47	0.46–0.48	0.43	0.50	0.49–0.52	0.46	0.44–0.48
Medicare	0.92	0.36–1.48	0.72	1.06	0.34–1.77	0.95	0.22–1.67
Medicaid	0.79	0.77–0.81	0.77	0.86	0.81–0.91	0.83	0.79–0.87
No insurance	0.73	0.62–0.84	0.60	0.68	0.17–1.19	0.82	0.29–1.35
EHI[#]							
<20	0.32	0.30–0.34	0.31	0.40	0.35–0.44	0.34	0.30–0.39
20 - <25	0.46	0.45–0.47	0.40	0.50	0.47–0.52	0.45	0.42–0.47
25+	0.65	0.63–0.66	0.60	0.68	0.65–0.71	0.65	0.62–0.67

BMI: body mass index; SE: standard error and NH: non-hispanic; EHI: economic hardship index

[#] Higher the economic hardship index score, lower the socioeconomic status.

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* P value represents overall difference in average BMI z-score between academic months and summer months.