Changes in Body Mass During Elementary and Middle School in a National Cohort of Kindergarteners

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KEY WORDS

BMI, childhood obesity

ABBREVIATIONS

ECLS-K—Early Childhood Longitudinal Study-Kindergarten Class

CDC—Centers for Disease Control and Prevention

CI—confidence interval

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WHAT'S KNOWN ON THIS SUBJECT: National Health and Nutrition Examination Study data suggest that the elementary school years might be a critical period for increases in obesity prevalence. However, that study is not ideal for identifying critical periods of disproportionate increases in BMI.

WHAT THIS STUDY ADDS: Changes in BMI percentiles were examined over 9 years in a nationally representative cohort of kindergarten students. The largest BMI percentile gains were observed before 3rd grade, even among children with normal BMI values in kindergarten.

abstract

OBJECTIVE: To analyze changes in BMI, according to gender and race/ethnicity, in a nationally representative cohort of children in the United States during their elementary and middle school years to identify critical periods of excess BMI gains.

METHODS: The Early Childhood Longitudinal Study-Kindergarten Class monitored a nationally representative cohort of kindergarten students over 9 years (1998–2007). Height and weight measurements were available for 4240 white, 640 black, and 1070 Hispanic children in kindergarten and 1st, 3rd, 5th, and 8th grades. In each wave, we estimated the proportions of children with BMI values in each quartile of the Centers for Disease Control and Prevention reference-population distribution according to gender and race/ethnicity. We conducted non-parametric tests of differences in BMI distributions over time within racial/ethnic groups and across racial/ethnic groups in each wave. Piecewise linear growth models were estimated to test for specific time periods during which the largest gains in BMI percentiles occurred.

RESULTS: Overall, nearly 40% of children started kindergarten with a BMI in the top quartile of the growth charts (BMI > 75th percentile). This proportion increased significantly during the elementary school years, and the largest gains were between 1st and 3rd grades (5.8 percentage points), but there was no further increase during middle school. Increases in BMI percentiles over time were most notable among Hispanic children and black girls.

CONCLUSIONS: The early school years might be a critical time for excess BMI gains, even among children with normal BMI values at kindergarten entry. *Pediatrics* 2011;128:e1411–e1417

Childhood overweight is a serious public health concern; nearly 1 in 3 children in the United States is currently overweight or obese.¹ Being overweight in childhood significantly predicts adult obesity^{2–4} and increases the risk of cardiovascular disease, type 2 diabetes mellitus, and all-cause death both in childhood and in adulthood.^{5–9}

Efforts to address this epidemic can benefit from a better understanding of body mass changes throughout childhood and from identification of critical periods for gaining excess body weight. Trajectories might vary across race/ethnicity and gender, because of different genetic, cultural, or environmental influences. Examining these patterns is an important step toward identifying malleable factors and designing appropriate interventions.

Data from the latest National Health and Nutrition Examination Study suggest that the elementary school years might be a critical period for increases in obesity. The prevalence of childhood obesity (defined as BMI of ≥ 95 th percentile for age and gender) increases sharply from 10.4% among children 2 to 5 years of age to 19.6% among children 6 to 11 years of age and then does not increase (or might even decrease slightly) among adolescents 12 to 19 years of age.¹ Because the National Health and Nutrition Examination Study does not track the same individuals over time, it is not possible to study the timing more thoroughly. Without longitudinal data, it also is not possible to distinguish cohort effects from age-specific changes (ie, 6- to 11-year-old children today might not have the same obesity prevalence 6 years later, at 12–17 years of age, as 12- to 17-year-old adolescents do today).

In this study, we use data from the Early Childhood Longitudinal Study-Kindergarten Class (ECLS-K), which monitored a single, nationally representative cohort for 9 years, from kin-

dergarten (mean age: 5.7 years) through the end of 8th grade (mean age: 14.3 years), to document increases in BMI over time according to race/ethnicity and gender. Instead of focusing on a single cutoff point, we examine changes in the entire BMI distribution during this period. The conventional definition of obesity uses a cutoff point of the 95th percentile on growth charts, which provides limited insights regarding BMI changes in the population. Tracking changes across the BMI distribution allows us to examine whether excess BMI gains are concentrated in the upper quartile of the BMI distribution or are present in other quartiles as well and whether there are critical periods between kindergarten and 8th grade when there are larger gains in BMI percentile values.

METHODS

Sample

We analyzed data from the ECLS-K. The study, which was sponsored by the National Center for Education Statistics, collected information on young children's cognitive, health, and developmental outcomes in the early school years.¹⁰ The ECLS-K surveyed a nationally representative cohort of kindergarten students from >1000 schools in the United States during the 1998–1999 school year and monitored the baseline sample over time; data were collected in the fall and spring of kindergarten and in the spring of grades 1, 3, 5, and 8. The sample remaining in the 8th grade wave represented $\sim 80\%$ of all US students in 8th grade in the 2006–2007 school year.

Our balanced sample consisted of 5940 children with complete height and weight measurements in each wave. All sample sizes reported here were rounded to the nearest 10, according to the restricted-use data agreement with the National Center

for Education Statistics. The sample included 4240 white children (2110 girls and 2130 boys), 640 black children (330 girls and 310 boys), and 1070 Hispanic children (530 girls and 540 boys). The mean age of the sample increased from 68 months (autumn, kindergarten) to 171 months (spring, 8th grade).

This sample represents $\sim 41\%$ of the kindergarten sample. The primary source of attrition was children who changed schools from one wave to the next and were not selected for follow-up monitoring. The attrition bias was minimized because the ECLS-K monitored a random subsample of one-half of the movers in each wave before 5th grade and all of the movers between grade 5 and grade 8. Use of longitudinal sampling weights calculated for the data allowed adjustment for partial follow-up monitoring of movers. The response rates were much higher than 41% of the baseline sample because of the follow-up design; 75% of the baseline sample subjects who were eligible for follow-up monitoring in 8th grade completed the child assessment. Children with incomplete BMI data for kindergarten through 8th grade were more likely to be black or Hispanic and of lower socioeconomic status, relative to those with complete data, but there were no statistically significant differences in mean BMI, obesity prevalence, proportion male, and age at kindergarten.

Measures

Child's Race/Ethnicity

Parents' responses to separate questions about the children's race and ethnicity were used to construct a race/ethnicity measure. We included only non-Hispanic white, non-Hispanic black, and Hispanic, because of insufficient sample sizes for the Asian and "other" categories.

BMI

Trained ECLS-K staff members measured children's height and weight at each data collection point by using a Shorr board (accuracy: 0.01 cm) and a Seca digital bathroom scale (model 840 [Seca, Hanover, MD]; accuracy: 0.1 kg), respectively. Children were asked to remove their shoes and other heavy clothing before the measurements. Height and weight were each measured twice, to minimize errors. Composite height and weight measurements were computed by the ECLS-K staff members from the 2 readings on the basis of the following rule: the average of the 2 readings was used when the discrepancy between them was less than a specific value (5.1 cm for height and 2.27 kg for weight); otherwise, the value closer to the grade-level median (for 1st, 3rd, 5th, and 8th grades) or the average (for kindergarten) was used. In fact, the 2 height readings were <2.5 cm apart and the 2 weight readings were <0.91 kg apart in 98% of the cases. Therefore, the average of the 2 readings was used as the composite height or weight measure in most cases. A composite BMI was computed for each child by using the composite height and weight measurements. We calculated each child's BMI percentile by using the 2000 Centers for Disease Control and Prevention (CDC) gender- and age-specific growth charts.¹¹ Obesity and overweight were defined as >95th percentile and between the 85th and 95th percentiles, respectively.

Statistical Analyses

To examine changes in the BMI distribution over time, we estimated the proportions of the ECLS-K sample with BMI values within each quartile of the growth charts, according to wave. If the BMI distribution in the ECLS-K cohort was similar to that of the growth charts, then we would see ~25% of the

ECLS-K sample in each quartile of the reference-population distribution (0–25th, 25th–50th, 50th–75th, and 75th–100th percentiles). We used these descriptive statistics to examine changes in the BMI distributions for the full sample and according to race/ethnicity for boys and girls separately. The estimates reported were calculated by using sampling weights.

We also used several nonparametric tests (Kruskal-Wallis rank test for multisample comparisons and Wilcoxon rank-sum test for pairwise comparisons) to examine changes in the BMI distributions over time within each racial/ethnic group and to compare the BMI distributions across racial/ethnic groups within each wave. These tests of distributions are available only for unweighted samples.

We divided the period between kindergarten and 8th grade into 4 time periods, that is, kindergarten to 1st grade, 1st grade to 3rd grade, 3rd grade to 5th grade, and 5th grade to 8th grade, and estimated within-child, piecewise, linear growth models to determine the time period during which children experienced the largest gains in BMI percentiles. Specifically, we estimated 2 types of models. The first model tested whether the change in a child's BMI percentile during a particular period

was statistically significantly larger than the same child's change during a different period. The second model allowed us to test which time period exhibited the largest change in the proportion of children in the top quartile of the reference-population distribution. Each of these analyses was conducted separately for the full sample and for boys and girls of different racial/ethnic groups.

Unless otherwise indicated, all analyses used the 5% level of significance to establish statistically significant differences across groups. The use of sampling weights accounted for different nonresponse rates and oversampling of certain groups and made the results nationally representative for this cohort. SEs were estimated by using Taylor series linearization. All statistical analyses were conducted by using Stata 10.1 (Stata Corp, College Station, TX). Finally, the study was approved by the RAND institutional review board.

RESULTS

BMI Distribution in ECLS-K Cohort

Figure 1 shows the proportions of children with BMI values within each quartile (0–25th, 25th–50th, 50th–75th, and 75th–100th percentiles) of the

FIGURE 1

Proportions of the ECLS-K sample in each quartile of the reference-population BMI distribution, according to wave. FK indicates fall, kindergarten; SK, spring, kindergarten; G1, grade 1; G3, grade 3; G5, grade 5; G8, grade 8.

reference-population distribution, according to wave (detailed estimates are provided in Supplemental Table 1. At kindergarten entry, the BMI distribution for the ECLS-K cohort differed significantly from that of the historical growth charts. Nearly 40% (39.8% [95% confidence interval (CI): 37.6%–42.0%]) of the children had BMI values in the top quartile, whereas only 14.1% (95% CI: 12.6%–15.7%) had BMI values in the bottom quartile.

The distribution changed significantly after 1st grade. There was a 5.8-percentage point (95% CI: 4.0–7.6) increase in the proportion of children in the top quartile between the end of 1st and 3rd grades, followed by a marginal, statistically insignificant increase (3.0 percentage points) between 3rd and 5th grades. A large part of the increase in the top quartile during elementary school was driven by increases in obesity. Obesity prevalence increased by almost 50% in the first 4 years, from 11.9% in the autumn of kindergarten to 17.6% in 3rd grade, and remained stable thereafter. Most of the increase in the top quartile during elementary school was facilitated by an approximately equal decrease in the proportion in the third quartile; there were minor reductions in the second quartile. In the middle school years (5th grade to 8th grade), there was no significant change in either the top quartile or the bottom 2 quartiles. Nonparametric tests for distributional changes over time suggested that there was a statistically significant difference in the underlying distributions of BMI percentile across all waves.

Finally, testing for critical periods of excess gains in BMI percentiles indicated that the period between 1st grade and 3rd grade was the time of greatest gains. The increase in the mean BMI percentile between 1st grade and 3rd grade (3.3 percentile points) was significantly larger than

those between 3rd grade and 5th grade (1.2 percentile points) and between 5th grade and 8th grade (0.7 percentile points). Moreover, the increase in the proportion of children in the top quartile was significantly greater (5.8 percentage points) between 1st grade and 3rd grade, compared with other periods (3.0-percentage point increase between 3rd grade and 5th grade and 1.9-percentage point decrease between 5th grade and 8th grade).

BMI Distributions in ECLS-K Cohort Across Racial/Ethnic Groups

Boys

Figure 2 shows the corresponding results for boys, according to race/ethnicity (detailed estimates are provided in Supplemental Tables 2–4). One-half of the Hispanic boys in kindergarten (49.0% [95% CI: 43.1%–54.9%]) were in the top quartile of the growth chart (double the rate in the growth charts), relative to 38.6% of white boys ($P < .05$).

The proportions of boys in the top quartile increased by 9.7, 9.4, and 5.7 percentage points among Hispanic, white, and black boys, respectively, during the elementary school years, but the increase was statistically significant only for white boys. In the middle school years, the changes were much smaller and statistically insignificant.

Nonparametric tests suggested that, for boys as a whole, there were significant differences in BMI distributions across waves. During the elementary school years (kindergarten to 5th grade), there were significant changes in the BMI distributions for boys of all racial/ethnic groups. In the middle school years, however, the distributions changed significantly for white and Hispanic boys but not black boys. We also found that the BMI distribution differed significantly for boys of differ-

ent racial/ethnic groups in each wave. In particular, the BMI distributions for black and Hispanic boys were significantly different from those for white boys in each wave.

The period between 1st grade and 3rd grade exhibited the largest gains in BMI percentiles among Hispanic boys but not so much in other groups. Increases in the mean BMI percentile (6.3 points) and in the proportion in the top quartile (10.5 percentage points) were largest in this period for Hispanic boys, relative to other periods ($P < .05$).

Girls

Figure 3 shows the corresponding results for girls (detailed estimates are provided in Supplemental Tables 5–7). At kindergarten entry, black girls had the largest proportion in the top quartile (45.5% [95% CI: 36.2%–54.8%]), followed by Hispanic girls (43.4% [95% CI: 36.9%–49.8%]). The proportion among white girls was nearly 10 percentage points smaller ($P < .05$).

During elementary school, there were 11.8-, 4.5-, and 12.3-percentage point increases in the proportions in the top quartile among black, white, and Hispanic girls, respectively, although none was statistically significant. Changes in the middle school years were much smaller and were statistically insignificant for all racial/ethnic groups. However, there seemed to have been increases in the proportions of girls in the third quartile, which were statistically significant among white girls but not black or Hispanic girls.

Nonparametric tests suggested that, as found for boys, there were significant differences in the BMI distributions across waves for girls. During the elementary school years, we found significant changes in the BMI distributions for black and Hispanic girls but not white girls. In the middle school years, the distributions changed sig-

FIGURE 2

Proportions of ECLS-K boys in each quartile of the reference-population BMI distribution. A, White boys; B, black boys; C, Hispanic boys. FK indicates fall, kindergarten; SK, spring, kindergarten; G1, grade 1; G3, grade 3; G5, grade 5; G8, grade 8.

nificantly for white and black girls but not Hispanic girls. We also found evidence of racial/ethnic disparities in each wave among girls. The BMI distributions for black and Hispanic girls were significantly different from those for white girls in each wave with 1 exception;

black and white distributions were not significantly different in kindergarten.

Finally, similar to findings for boys, the period between 1st grade and 3rd grade seemed to be a critical time for excess gains in BMI percentiles for His-

panic girls but not so much for other girls. The increases in the mean BMI percentile (6.9 points) and the proportion in the top quartile (12.9 percentage points) among Hispanic girls were significantly larger between 1st grade and 3rd grade, relative to other periods.

DISCUSSION

Our study used longitudinal data for a single, nationally representative cohort of children in the United States, over a period of 9 years, to examine changes in BMI distributions during the elementary and middle school years. We described the proportions of the ECLS-K sample with BMI values in each quartile of the CDC growth charts and how those proportions changed during the elementary and middle school years. We used the CDC growth charts to define the quartiles instead of constructing quartiles on the basis of the ECLS-K sample because this allowed us to compare the BMI distribution for a current (nationally representative) cohort with that for a reference population before the obesity epidemic, to describe how the current distribution differs from that for the reference population. Moreover, given that comparison with the growth charts is the conventional approach in the literature, this approach allows comparisons with other studies.

We found that the BMI distribution of the ECLS-K cohort was markedly different from that of the historical growth charts; as many as 40% of the children were in the top quartile, whereas only 14% were in the bottom quartile of the reference-population distribution. During the elementary school years, we saw large increases in the proportions of children with BMI values above the 75th percentile (the top quartile) of the growth charts, which suggests that excess BMI gains during this period occurred not only among children

FIGURE 3 Proportions of ECLS-K girls in each quartile of the reference-population BMI distribution. A, White girls; B, black girls; C, Hispanic girls. FK indicates fall, kindergarten; SK, spring, kindergarten; G1, grade 1; G3, grade 3; G5, grade 5; G8, grade 8.

who were already obese or overweight but also among normal-weight children. Moreover, a large part of this gain occurred in the early school years (typically between 1st and 3rd grades). In contrast, the BMI distribution re-

mained relatively stable during the middle school years, and there was no significant increase in the proportion in the top quartile. Similar patterns were found in other cohort studies with children¹² and adolescents.^{13,14}

These results suggest that the first few years in elementary school might be a critical time period for interventions. Interventions aimed at preventing excess weight gain among adolescents might be too late, because much of the excess weight gain (relative to growth charts) seems to have occurred by that time. Even within elementary school, it seems that the time before 3rd grade is more critical than the period from 3rd grade to 5th grade. There is increasing evidence indicating that decreases in children's physical activity levels occur well before adolescence,^{15–18} which might contribute to excess BMI gains in the early school years. There also might be alternative explanations. The evidence published to date suggests that obesity might be causally related to earlier puberty in girls.¹⁹ To the extent that excess weight at a young age leads to earlier puberty, which in turn is linked to changes in body fat and fat distribution,²⁰ girls might experience faster increases in BMI in the early school years but smaller-than-expected BMI gains in middle school (because they have matured earlier). Our results also seem to apply to boys, however, and few studies have found a link between body fat and earlier puberty among boys (which also would accelerate BMI gains).¹⁹

We have limited statistical power and precision to comment on differences in changes over time across racial/ethnic and gender groups. However, a few results stand out. The largest gains in BMI percentiles were among Hispanic children (both boys and girls) and black girls. There also might be differences in the timing of these gains across groups, in that the largest gains in BMI percentiles occurred before 3rd grade among Hispanic boys and girls and white boys but there were no discrete periods of large

gains in BMI percentiles among black children or white girls.

Although our study is the first to describe BMI changes in a national cohort of young children, there are several caveats. The study is descriptive and does not assess the relative contributions of energy intake versus expenditure and of physical maturation in explaining the patterns observed, because of the absence of such information in the ECLS-K data. We also were unable to test whether racial/ethnic disparities in BMI distributions increased or decreased over time, because of insufficient statistical power. Furthermore, we were unable to examine whether the excess gains in BMI percentiles seen in the early school

years were initiated before kindergarten entry and whether they were related to the timing of adiposity rebound. Finally, although BMI is conventionally used to describe obesity prevalence, it does not measure adiposity directly. If the current cohort of children matures earlier than the cohorts used to develop the growth charts, then excess BMI percentile gains observed during the early school years for the ECLS-K cohort might not reflect excess gains in adiposity, which might have different implications for policy efforts.

CONCLUSIONS

Our findings suggest that the elementary school years are marked by excess BMI gains not only among chil-

dren who are already overweight or obese but also among normal-weight boys and girls. Moreover, the early school years, particularly between 1st grade and 3rd grade, are a potentially critical time for excess BMI gains. These findings add to the rationale for population-based prevention efforts beginning early in childhood. Future research should examine whether efforts addressing childhood obesity that are focused on the early school years alter the BMI trajectory.

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