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Accelerated Summer Weight Gain in a Low-Income, Ethnically Diverse Sample of Elementary School Children in Massachusetts

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Abstract

Background: Several studies have found that children in the United States gain weight at a faster rate in the summer than in the school year, but little is known about the prevalence of this problem, its effect on high-risk subgroups, or its determinants. This study compares school year and summer weight change in a low-income, ethnically diverse sample of school-age children in Massachusetts and explores differences by race/ethnicity, weight status, and exposure to school year physical activity (PA) programming. Diet and PA are examined as potential mediators of summer weight gain.

Methods: Children participating in a school-based PA program evaluation (in which weight change was not a primary outcome) had their height and weight measured three times between October 2015 and September 2016 to capture a school year and summer interval. Diet and PA patterns were assessed mid-school year and mid-summer in a subsample of children. Mixed linear models were used to estimate the effect of season (school year vs. summer) on change in BMI and to examine the influence of race/ethnicity, weight status, and program (walk/run, classroom activity breaks, or control) on any observed effects. Structural equation models were used to explore diet and PA as mediators of seasonal weight change in a subsample of participants.

Results: Of 769 participants, 53% were non-Caucasian, 40% were overweight or obese, and 58% were eligible for free or reduced-price school meals. BMI increased in both the school year and summer but increased more rapidly in the summer (0.046 kg/m^2 more per month, $p = 0.007$). Of the three tested interactions, statistical significance was only observed between season and program ($\chi^2 = 14.90$, $p < 0.001$); on average, children exposed to a school year walk/run program did not gain weight more rapidly during the summer, whereas children in the control group and a classroom activity breaks program did. Poorer diet and PA patterns were observed in the summer, but neither diet nor PA was statistically significant mediators of BMI change.

Conclusions: Children in this high-risk sample gained weight at a faster rate during the summer than during the school year, with no discernable demographic differences. However, this phenomenon was not observed in the subgroup exposed to a school year walk/run program. More research is needed to clarify the determinants of summer weight gain and understand how school year programming and its effects can be transferred to the summer months.

Keywords: body mass index; child obesity; out-of-school time; season; summer; weight gain

Background

Schools represent a key setting for obesity prevention, and school-based programs can have a positive effect on weight outcomes.[1] However, evidence is accumulating that many school-age children gain weight at a faster rate during the summer break than the school year[2–5] (hereafter described as accelerated summer weight gain), a phenomenon with potential to negate school year progress and disrupt efforts to

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decrease the prevalence of child obesity in the United States.

Evidence also shows that black and Hispanic[6] and overweight children[5–8] are at higher risk for accelerated summer weight gain. Just as the summer break can widen gaps in academic achievement,[9] it may promote similar gaps in child health and well-being. Strategies are needed to help prevent summer weight gain, but to develop tailored cost-effective interventions, more information is needed about the persistence of the problem, the populations that are most susceptible, and the primary determinants.

Nationally representative studies of summer weight change[4,6] have focused on the early elementary years and have observed excess weight gain during the summers from kindergarten to second grade. Studies of older children indicate that the issue may persist throughout elementary school.[5,7,8] However, this research involved children in southeast Texas,[5,7] where extreme summer heat and mild winters may uniquely affect seasonal weight change; and children on American Indian reservations,[8] where findings may not generalize to the broader US population. More research is needed to understand the extent to which older children, particularly those living in more temperate climates, gain weight over the summer break. While accelerated summer weight gain was observed in a sample of first to third graders in Massachusetts in 2004,[10] more recent data can document whether the issue remains a concern, and whether it persists in the later elementary years.

The causes of accelerated summer weight gain have not been well defined.[2,3] Speculated contributors include lack of structure,[11] increases in sedentary behavior, and decreases in physical activity (PA), dietary quality, and sleep.[2,3,11] Research examining seasonal differences from both sides of the energy balance equation—diet and PA—is limited, and to our knowledge, no published study has specifically measured diet and PA patterns as mediators of summer weight gain. Given the importance of preventing unhealthy weight gain and promoting child health during the summer months, quantitative research exploring how seasonal differences in diet and PA affect BMI change is needed. Identification of unfavorable diet and PA patterns and their impact on the rate of summer weight gain can help pinpoint targets of intervention for programs and policies.

The primary goal of this study was to compare the rate of weight change during the school year and summer in a low-income, ethnically diverse sample of school children in Massachusetts. To do this, we capitalized on the existing framework of a group-randomized controlled longitudinal trial evaluating two school-based PA programs. The 2-year study provided a unique opportunity to assess the rate of summer weight gain and to examine differences by race/ethnicity and weight status, while also exploring the effects of exposure to school year PA programming. The secondary goal of this study was to explore diet and PA patterns as mediators of summer weight gain in a subsample of participating youth.

Methods

Study Design

To allow comparison of weight change across a school year and summer interval, children's height and weight were measured at three time points between October 2015 and September 2016. Diet and PA patterns were measured once in Spring 2016 and again in Summer 2016. The human subjects protocol for this study was approved by the Tufts University Social, Behavioral, and Educational Research Institutional Review Board.

School year measurements were collected as part of the Fueling Learning through Exercise (FLEX) Study, a group-randomized controlled longitudinal trial conducted in urban, public elementary schools in Massachusetts to evaluate the impact of two school-based PA programs on children's PA engagement, cognitive performance, and academic achievement. The programs were designed to improve children's school-time PA but were not specifically designed to impact weight or BMI. The FLEX Study design and recruitment methods are described elsewhere[12]; however, it is important to note that lower income (more than 40% of students eligible for free or reduced-price lunch) and racially and ethnically diverse (more than 40% of students being non-Caucasian) schools were targeted. After enrolling, schools were randomized to one of three conditions for the duration of the 2-year study period: a walk/run program, classroom-based activity breaks, or a control.

Population and Recruitment

Recruitment for this analysis was bundled with the main FLEX Study. The original FLEX protocol involved measuring height and weight at three time points: baseline (Fall/Winter 2015), midpoint (Spring 2016), and post-intervention (Spring 2017). To allow assessment of summer weight change, we added an additional measurement in Fall 2016, and this visit was included in the FLEX recruitment materials and informed consent forms.

At least 1 week before baseline measurements, all third- and fourth-grade students in participating schools were invited to enroll in FLEX. Each child was sent home with a recruitment packet containing an informational flyer, parent consent form, child assent form, and demographic survey for a parent or guardian to complete. Packets were available in English, Spanish, Portuguese, Haitian Creole, Arabic, Vietnamese, and Mandarin, as requested by participating schools. Parent informed consent and child assent were obtained before the start of data collection. Additional details about the recruitment process can be found elsewhere.[12]

The main FLEX Study also included school year diet and PA measurements. To enable comparison of seasonal differences in diet and PA, 7 of the 18 FLEX schools granted permission for us to invite participants to complete a Summer 2016 diet and PA measurement. Informational flyers and consent forms were sent home from school with children in Spring 2016, and parents were asked to return completed forms to school.

Height and Weight Measurements

To capture weight change across a school year interval, we used height and weight measurements collected at baseline and midpoint in the FLEX Study. The majority of baseline measurements took place in September and October 2015, although four later-enrolling schools had baseline measurements between December 2015 and early February 2016. Midpoint measurements took place between late March and early June 2016. Schools with later baseline measurements were scheduled for later midpoint measurements, to maximize time between study visits. The minimum number of days between measurements was 120 in the school year and 103 in the summer.

Post-summer measurements were collected in August and September 2016. The school year interval included an average of 190 days, and the summer interval included an average of 135 days. Interval length for each season did not vary substantially across study conditions. Logistically, it was not feasible to collect measurements on the very first and very last day of the school year, so the summer interval includes some school days.

Height and weight measurements were conducted at school during school hours. Trained research assistants collected height and weight measurements in triplicate, according to standard methods.[13] Height was measured by stadiometer (Model 214; Seca Weighing and Measuring Systems, Hanover, MD) with the head in the Frankfurt plane and recorded to the nearest $\frac{1}{8}$ inch. Weight was measured using a digital electronic scale (PS-6600 ST; Befour, Inc., Saukville, WI) and recorded to the nearest $\frac{1}{4}$ pound.

For each time point, child height and weight measurements were averaged and used to calculate BMI. BMI is considered to be the appropriate metric for evaluating short-term change in child adiposity, because it is more sensitive to small changes in growth, and because it more equitably captures weight change for children who are overweight or obese.[14,15] For these reasons, we used BMI as the main outcome in this analysis. Because several key studies on summer weight gain have assessed changes in BMI z-score,[5,7,8,16,17] we also performed our analyses using BMI z-score as the outcome variable to allow for comparison across studies. We calculated BMI percentile and BMI z-score using the CDC age- and sex-specific growth charts.[18] Baseline weight status was classified according to the CDC definitions: <5th percentile as underweight, 5th to <85th percentile as normal weight, 85th to <95th percentile as overweight, and ≥95th percentile as obese.

Diet and PA Measurements

School year diet and PA measurements took place at school during school hours between April and June 2016. Summer diet and PA measurements took place in July and August 2016, either in a local elementary school or in public library.

Dietary patterns were assessed with the FLEX Dietary Questionnaire, a 39-item 7-day recall assessing five categories: beverages (such as soda, lemonade, sports drinks, 100% juice, milk, and water), fruits (excluding 100% fruit juice), vegetables (excluding fried potatoes), salty snacks (such as chips, popcorn, pretzels, and crackers), and sweets (such as baked goods, candy, and frozen desserts). The questionnaire is a composite of several dietary assessment tools that have been validated for use with children,[19–21] and with FLEX participants, showing good agreement with the validated Block Kids Food Screener.[22] At each time point, children self-administered the questionnaire with assistance from a trained research assistant as needed. Children were asked to report how many days they consumed each item in the past week and to estimate portion size on each day of consumption ("a little, some, or a lot"). Mean daily servings for each item were calculated by matching portion estimates to standard serving size equivalents: a little = 0.5 serving, some = 1 serving, and a lot = 1.5 servings. Daily servings per category were calculated by summing daily servings for all items within each category and excluding items as appropriate [*i.e.*, non-sugar-sweetened beverages (SSBs) such as milk and 100% juice that were assessed in the beverage category].

PA was assessed using waist-worn accelerometers (ActiGraph models GT3X+ and wGT3X-BT; ActiGraph, LLC, Pensacola, FL), which have been validated and calibrated for use in children.[23] Children were instructed to wear the accelerometer for 7 consecutive days during waking hours, except when bathing or swimming, since the devices are not waterproof.

Accelerometers were set to begin measurement on the first day the child was outfitted with the device. Activity counts were captured in 15-second epochs. At the end of the study period, accelerometer data were downloaded and screened using MeterPlus software (San Diego, CA). Data were classified into minutes of sedentary, light, moderate, and vigorous activity using cutoffs established for children.[24] Days with at least 10 hours of wear time were considered valid. Spans of 60 minutes or more with zero activity counts were considered nonwear time and were excluded from the analysis. Participants were included in the analysis if they had at least three valid days of wear time.

Demographics

Each child's birth date, sex, race/ethnicity, and free or reduced-price lunch eligibility was assessed on the demographic survey completed by a parent or guardian at baseline of the FLEX Study.

Seasonal Weight Change Analysis

We calculated descriptive statistics and examined the distribution of each variable to assess normality, skewness, and to identify potential outliers. Since time elapsed between height and weight measurements differed for each school, we standardized time by dividing total change in

BMI in the interval by months elapsed in the interval (days elapsed/30.42 days per month). We used this number, mean change in child BMI per month, as the outcome variable.

We used a mixed linear regression model with robust standard errors, which accounted for clustering at the school and child levels, to model the relationship between season (school year or summer) and per month change in BMI. We examined an unadjusted model and a model adjusted for sex, baseline age, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, Asian, multi-ethnic, and other/no response), baseline weight status (healthy weight, overweight, and obese), free or reduced-price lunch eligibility (eligible—at or below 185% of the poverty line—or not eligible), and study condition (walk/run program, classroom activity breaks, or control). We also explored interactions between season and race/ethnicity, baseline weight status, and study condition. We followed these same procedures using per month change in BMI z-score as the outcome variable.

Diet and PA Analysis

We used structural equation modeling (SEM) to explore whether diet and PA patterns mediated the relationship between season and BMI change. For PA, separate models were constructed to assess the mean daily minutes of

Table 1. Demographic Characteristics of Fueling Learning through Exercise Study Participants, Reported during the 2015–2016 School Year

Variable	Category	All participants ($n = 769$) n (%)	Classroom activity breaks group ($n = 249$) n (%)[a]	Walk/run group ($n = 261$) n (%)[a]	Control group ($n = 259$) n (%)[a]
Sex	Male	336 (44)	114 (46)	106 (41)	116 (45)
	Female	433 (56)	135 (54)	155 (59)	143 (55)
Grade	Third	356 (46)	123 (49)	119 (46)	114 (44)
	Fourth	413 (54)	126 (51)	142 (54)	145 (56)
Study condition	Classroom activity breaks	249 (32)			
	Walk/run program	261 (34)			
	Control	259 (34)			
Race/ethnicity	White	283 (37)	74 (30)	100 (38)	109 (42)
	Hispanic	275 (36)	110 (44)	66 (25)	99 (38)
	Black	55 (7)	13 (5)	24 (9)	18 (7)
	Asian	33 (4)	9 (4)	22 (8)	2 (1)
	Multi-ethnic	43 (6)	14 (6)	18 (7)	11 (4)
	Other/no response	80 (10)	29 (12)	31 (12)	20 (8)
Baseline weight status	Healthy weight	461 (60)	153 (61)	150 (57)	158 (61)
	Overweight	152 (20)	47 (19)	50 (19)	55 (21)
	Obese	156 (20)	49 (20)	61 (23)	46 (18)
Eligible for free or reduced-price lunch?	No	297 (39)	82 (33)	97 (37)	118 (46)
	Yes	410 (53)	150 (60)	136 (52)	124 (48)
	No response	62 (8)	17 (7)	28 (11)	17 (7)

Variable	All participants Mean (SD)	Classroom activity breaks group Mean (SD)	Walk/run group Mean (SD)	Control group Mean (SD)
Baseline age, years	9.18 (0.64)	9.17 (0.68)	9.17 (0.65)	9.21 (0.61)
Baseline BMI, kg/m^2	19.01 (3.76)	18.91 (3.71)	19.24 (3.94)	18.86 (3.63)
Baseline BMI z-score	0.709 (0.98)	0.677 (1.01)	0.767 (0.99)	0.681 (0.95)

[a] Percentages may not add up to 100 due to rounding.

sedentary time and moderate-to-vigorous physical activity (MVPA) as potential mediators. For diet, the following variables were used to construct a latent variable to represent diet quality: mean daily servings of fruits, vegetables, salty snacks, sweets, and SSBs. Fruit and vegetable servings were coded as positive values to indicate increased diet quality. Salty snacks, sweets, and SSB servings were coded as negative values to indicate reduced diet quality. All models accounted for clustering by child and were adjusted for the following covariates: child race/ethnicity, sex, baseline weight status, baseline age, free/reduced-price lunch eligibility, and study condition. All statistical analyses were conducted with Stata software (version 13; StataCorp LP, College Station, TX). A p-value of <0.05 was considered statistically significant.

Results

Participant Characteristics

Post-summer height and weight measurements were collected for 803 FLEX Study participants (90% of enrolled children in the participating schools). Children who were missing a height and weight measurement at any of the three time points ($n = 23$) were excluded from the analysis. Those considered underweight at baseline were also excluded ($n = 8$) because a higher-than-average rate of weight gain is a desirable outcome in that group. Two participants were excluded for being in fifth grade at baseline, and one additional participant was excluded due to an implausible height value recorded at midpoint. The final analytic sample for the weight change analysis included 769 children.

Demographic characteristics for this sample are presented in Table 1. Fifty-three percent of children in the sample were non-Caucasian. Forty percent were overweight or obese at baseline, and 58% were eligible for free or reduced-price lunch.

Seasonal Weight Change

In the overall sample, mean change in BMI was 0.0703 kg/m^2 per month [95% confidence interval (CI) 0.0606–0.0800] during the school year and 0.0933 kg/m^2 per month (95% CI 0.0744–0.1122) in the summer (Fig. 1). In the unadjusted model, season was significantly associated with the change in BMI, with a difference of 0.023 kg/m^2 per month in the summer compared with the school year (Table 2, $p = 0.016$). This effect was unchanged after adjusting for covariates (Table 2, Adjusted Model I, $\beta = 0.023$ kg/m^2, $p = 0.016$, Cohen's $f^2 = 0.0054$).

We detected a statistically significant interaction between season and study condition ($\chi^2 = 14.90$, $p < 0.001$). Children in the control group and children in the classroom activity breaks group gained BMI at a higher rate in the summer than in the school year, whereas children in the walk/run group did not. While school year change in BMI was similar across all three groups, summer change in BMI was significantly higher in the control and classroom activity break groups (Fig. 2). When this interaction term was added to the adjusted model, the main effect of season on BMI was amplified to a difference of 0.046 kg/m^2 per month in the summer compared with the school year, indicative of the higher rate of summer weight gain observed in the control group (Table 2, Adjusted Model II, $p = 0.007$). We did not detect a statistically significant interaction between season and race/ethnicity ($\chi^2 = 1.77$, $p = 0.880$) or baseline weight status ($\chi^2 = 2.53$, $p = 0.283$), and these two interactions were subsequently removed from the model.

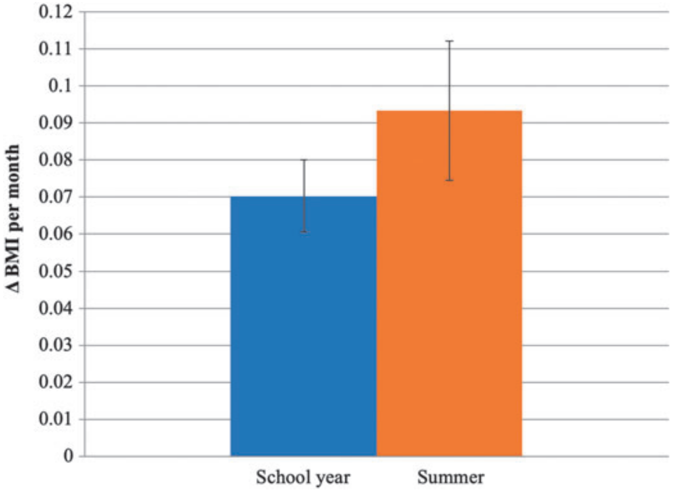

Figure 1. **Mean change in BMI by season, unadjusted and expressed on a per month basis (±95% CI, $n = 769$), the FLEX Study, 2015–2016. CI, confidence interval; FLEX, Fueling Learning through Exercise.**

The model results were similar when BMI z-score was used as the outcome variable (Supplementary Table S1 and Supplementary Figs. S1 and S2). Although there was no statistically significant relationship between season and change in BMI z-score in the unadjusted model, a significant effect indicating accelerated summer weight gain emerged after adjusting for covariates. There was also evidence of an interaction between season and study condition. No interaction between season and race/ethnicity or baseline weight status was detected.

Diet and PA

From the subsample of schools agreeing to participate in summer data collection, 144 FLEX participants enrolled. Of those, 105 completed a summer visit. Compared with the larger sample included in the weight change analysis, this sample had a slightly higher proportion of students who were Hispanic (40% vs. 36%) and a slightly lower proportion of participants who were obese (15% vs. 20%). After data reduction (due to missing data and students with <3 valid days of accelerometer wear time), the final analytic sample consisted of 89 students for the diet mediation analysis and 52 students for the PA analysis.

In this subsample, examination of the individual dietary patterns measured showed that children did consume 0.46 fewer daily servings of vegetables ($p = 0.003$) and 0.64

Table 2. Factors Associated with Mean Change in BMI (Expressed on a per Month Basis): Results of Unadjusted and Adjusted Mixed Linear Regression Models, the Fueling Learning through Exercise Study, 2015–2016 ($n=769$)

Variable	Category	Unadjusted model[a] β (95% CI)	p	Adjusted model I[b] β (95% CI)	p	Adjusted model II β (95% CI)	p
Season	School year	Referent		Referent		Referent	
	Summer	0.0230 (0.0043 to 0.0418)	0.016*	0.0230 (0.0043 to 0.0418)	0.016*	0.0458 (0.0125 to 0.0790)	0.007**
Baseline weight status	Healthy weight	Referent		Referent		Referent	
	Overweight	0.0214 (0.0031 to 0.0398)	0.022*	0.0206 (−0.0002 to 0.0415)	0.053	0.0206 (−0.0002 to 0.0415)	0.053
	Obese	0.0524 (0.0312 to 0.0736)	<0.001***	0.0523 (0.0318 to 0.0727)	<0.001***	0.0523 (0.0318 to 0.0727)	<0.001***
Race/ethnicity	White	Referent		Referent		Referent	
	Black	0.0297 (−0.0001 to 0.0595)	0.051	0.0240 (−0.0114 to 0.0593)	0.184	0.0240 (−0.0114 to 0.0594)	0.184
	Asian	−0.0414 (−0.0720 to −0.0108)	0.008**	−0.0449 (−0.0806 to −0.0092)	0.014*	−0.0449 (−0.0805 to −0.0092)	0.014*
	Hispanic	0.0201 (0.0006 to 0.0395)	0.043*	0.0118 (−0.0120 to 0.0355)	0.331	0.0118 (−0.0120 to 0.0355)	0.331
	Multi-ethnic	−0.0190 (−0.0721 to 0.0341)	0.483	−0.0204 (−0.0739 to 0.0331)	0.455	−0.0204 (−0.0739 to 0.0331)	0.455
	Other/no response	0.0067 (−0.0257 to 0.0392)	0.685	−0.0114 (−0.0534 to 0.0305)	0.593	−0.0114 (−0.0534 to 0.0305)	0.593
Sex	Male	Referent		Referent		Referent	
	Female	0.0141 (0.0027 to 0.0255)	0.015*	0.0140 (0.0020 to 0.0259)	0.022*	0.0140 (0.0020 to 0.0259)	0.022*
Baseline age	Baseline age	0.0103 (−0.0002 to 0.0207)	0.055	0.0104 (0.0002 to 0.0206)	0.045*	0.0104 (0.0002 to 0.0206)	0.045*
Free/reduced price lunch eligibility	Not eligible	Referent		Referent		Referent	
	Eligible	0.0182 (0.0010 to 0.0354)	0.038*	0.0063 (−0.0126 to 0.0252)	0.514	0.63 (−0.0126 to 0.0252)	0.515
Study condition	Control	Referent		Referent		Referent	
	Walk/run	−0.0143 (−0.0469 to 0.0183)	0.390	−0.0124 (−0.0431 to 0.0183)	0.429	0.0165 (−0.0089 to 0.0419)	0.204
	Classroom activity breaks	−0.0002 (−0.0302 to 0.0298)	0.991	−0.0009 (−0.0246 to 0.0228)	0.940	0.0039 (−0.0163 to 0.0241)	0.702
Study condition × season	Control × summer					Referent	
	Walk/run × summer					−0.0578 (−0.0976 to −0.0180)	0.004**
	Classroom activity breaks × summer					−0.0097 (−0.0458 to 0.0265)	0.600

Each mixed linear model accounted for clustering at the school and child levels.

[a] Each independent variable was modeled separately using mixed linear regression.

[b] Cohen's $f^2=0.0054$

*Statistically significant at the $p<0.05$ level.

**Statistically significant at the $p<0.01$ level.

***Statistically significant at the $p<0.001$ level.

β, regression coefficient; CI, confidence interval.

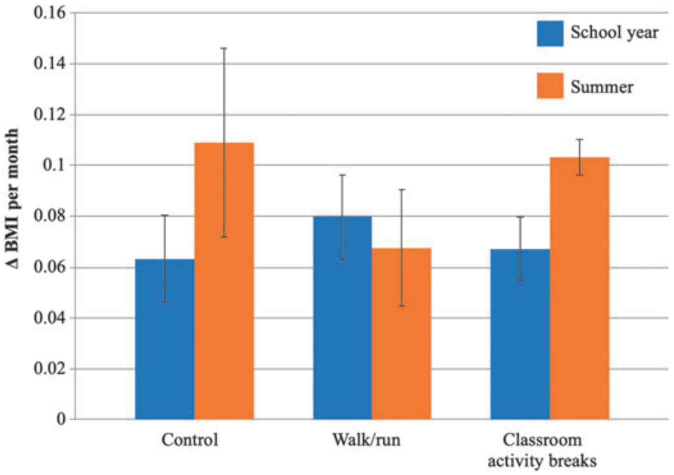

Figure 2. Mean change in BMI by season and study condition, adjusted according to Model II and expressed on a per month basis (±95% CI, $n = 769$), the FLEX Study, 2015–2016.

fewer daily servings of fruits ($p = 0.002$) in the summer compared with the school year. There were no statistically significant seasonal differences observed in consumption of salty snacks, sweets, or SSBs. Overall diet quality, as measured by the latent variable, did not significantly mediate the relationship between season and mean monthly BMI change ($\beta = -0.0051$, $p = 0.089$, 95% CI −0.011 to 0.001). Unadjusted seasonal differences in dietary patterns are illustrated in Figure 3.

The SEM analysis did show statistically significant differences in PA engagement by season. In the subsample, children engaged in 8.4 fewer daily minutes of MVPA in the summer compared with the school year ($p = 0.004$) and 27.8 more daily minutes of sedentary time ($p = 0.003$). However, as with diet, the SEM analysis showed that neither of these differences significantly mediated the relationship between season and mean monthly BMI change ($\beta = -0.0014$, $p = 0.802$, 95% CI −0.012 to 0.009 for MVPA, and $\beta = -0.0063$, $p = 0.235$, 95% CI −0.017 to 0.004 for sedentary time). Unadjusted seasonal differences in PA patterns are illustrated in Figure 4. Structural modeling equation diagrams are depicted in Supplementary Figure S3a–c. Unadjusted seasonal differences in diet and PA patterns by study condition are presented in Supplementary Table S2.

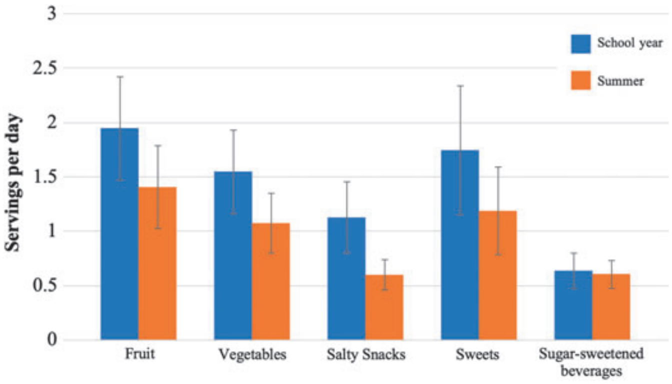

Figure 3. Seasonal differences in dietary intake in a subsample of FLEX Study participants (unadjusted ±95% CI, $n = 89$), the FLEX Study, 2015–2016.

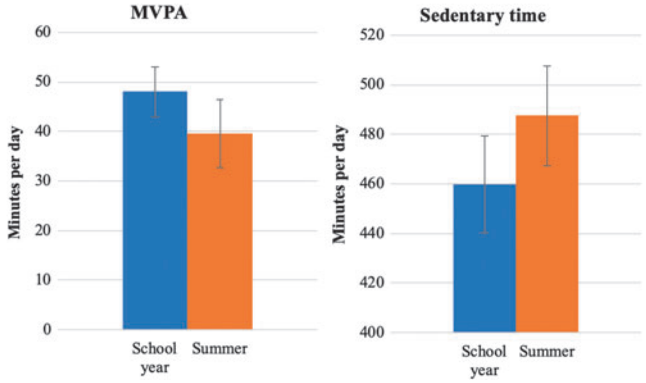

Figure 4. Seasonal differences in daily physical activity engagement in a subsample of FLEX Study participants (unadjusted, ±95% CI, $n = 52$), the FLEX Study, 2015–2016.

Discussion

In this ethnically diverse, low-income sample of third and fourth graders, children gained weight more rapidly in the summer than during the school year. These findings align with previous studies of summer weight gain in school-age children in the United States[4–8,10] and show that accelerated summer weight gain may be a concern for third- and fourth-grade students in urban lower income schools.

Because two-thirds of this sample was exposed to a school year PA program, which may have influenced energy balance and attenuated school year weight gain, it is important to examine seasonal weight change patterns in the control group. This provides a ''clean'' comparison of weight change by season, without the influence of a school year intervention. Inclusion of an interaction term to adjust for program-by-season effects showed a clear pattern of accelerated summer weight gain in the control group. The magnitude of increased summer gain observed in this group ($0.046\,kg/m^2$ per month) is nearly identical to that observed in the most recent nationally representative study of kindergarten to second graders,[4] suggesting that this issue persists beyond second grade.

We did not observe a statistically significant difference in the magnitude of seasonal weight change for children in different racial/ethnic groups or weight categories. This finding is in contrast to the first nationally representative study of summer weight gain that observed greater summertime gains among black and Hispanic youth[6] but aligns with the second nationally representative analysis[4] and the study of children in Texas.[7] The lack of difference in seasonal weight change we observed across weight status groups conflicts with evidence that overweight children are more substantially affected by summer weight gain than their healthy weight peers.[5–7] While the children in this sample, on average, gained weight more rapidly during the summer, it does not appear that any racial/ethnic subgroup or weight class was affected significantly more than any other.

To the best of our knowledge, this study is the first to explore differences in seasonal weight change for children exposed to school year PA programs. On average, children in the control group and the classroom-based breaks group gained weight more rapidly in the summer than in the school year, whereas children in the walk/run group did not. The magnitude of school year weight gain was similar across the three groups, although children in the walk/run condition had slightly higher monthly increases in BMI than children in the control and classroom-based breaks conditions. Neither of the PA programs was designed to impact changes in body weight or carry over to the summer months. It is not evident why children exposed to the walking and running program did not gain weight more rapidly in the summer and those exposed to classroom-based activity breaks did. Walking and running are activities that do not require any special equipment or instruction, so it is possible that these habits could be more easily maintained during the summer. The classroom-based activity breaks in the other program were led by a teacher or student in a more structured manner and therefore may have been less likely to translate to independent summertime activity. The number of children from the walk/run condition in our subanalysis of PA patterns ($n = 5$) was insufficient to provide insight.

The etiology of summer weight gain has not been well characterized, but differences in diet quality, PA engagement and sedentary time, screen use, and sleep are thought to play a role.[2] The present analysis indicated that children consumed fewer servings of fruits and vegetables in the summer compared with the school year and that children engaged in 8 fewer minutes of daily MVPA and almost 28 more minutes of daily sedentary time. Mediation analysis showed that neither diet nor PA appeared to be a significant driver of excess summer weight gain in this subsample of youth.

However, our findings do affirm the importance of promoting fruit and vegetable consumption and PA engagement during the summer months. Fruits and vegetables provide key nutrients, phytochemicals, and fiber known to promote health[25] and are consistently underconsumed among children in the United States.[26] Previous studies have also reported evidence of poor dietary patterns during the summer months.[27,28] Engagement in MVPA is associated with numerous health benefits, including musculoskeletal development, improved cardiometabolic health, reduced anxiety and depression, and lower risk of overweight and obesity.[29–31] Excess sedentary time is a concern because it increases children's risks for obesity, chronic disease, and poor self-esteem and academic achievement.[32,33] Larger within-subjects studies of seasonal differences are needed to identify school year and summer differences in diet and PA and clarify their role in accelerated summer weight gain.

Overall, these findings highlight the importance of changing the perception that summer brings ''time off'' from both school and healthy behaviors. Just as schools provide summer reading or math homework to help prevent academic losses, there may be value in similarly promoting healthy behaviors during the summer—such as regularly taking family walks, limiting screen time and sugary drinks, and eating a fruit or vegetable at each meal. Summertime health-promotion programs and policies may also play an important role. Health-focused summer camps for children can have a positive impact on adiposity[34] and help children achieve the recommended levels of daily PA.[35] Increasing access to free and low-cost camps that provide structure, keep children active, and provide healthy snacks and meals is a priority.

Limitations and Strengths

Our findings should be considered in the context of several limitations and strengths. Because it was not logistically feasible to measure the children's height and weight on the first and last days of the school year, we were not able to precisely capture the school year and summer intervals. As a result, some school year days were included in the summer interval. Because most studies have found the school year interval to be neutral or protective against excess weight gain,[4–7] it is likely that these misclassified days attenuated our results.

Our study was not powered to test the exploratory analyses examining seasonal weight change across demographic subgroups, and this may have precluded detecting effects. Future studies should continue to monitor whether certain groups are more susceptible to summer weight gain than others.

Although neither FLEX Study PA program was specifically designed to impact body weight, the children in the intervention groups may have gained less weight during the school year as a result of the programming. If so, this would have magnified seasonal differences. However, the control group did provide a ''clean'' comparison of seasonal weight change without the influence of a school year intervention, and summer weight gain was observed in that group.

Our exploratory analysis of diet and PA as potential mediators of accelerated summer weight gain was conducted in a small subsample of FLEX participants and therefore may not be adequately powered and provides only preliminary data regarding the importance of seasonal differences in diet and PA patterns. We hope that these data will assist other researchers and inform power calculations for more robust studies of the determinants of summer weight gain. The dietary assessment tool used in the FLEX Study did not measure total diet; therefore, we cannot gauge seasonal differences in energy intake. Future studies with more comprehensive dietary measures and a larger sample are needed to clarify the relationship between diet and summer weight gain.

Waterproof accelerometers were not available for use in this study, so aquatic activities such as swimming were not captured, potentially leading to an underestimation of summertime PA engagement. Finally, because this study was conducted in a low-income urban population, the findings may not be generalizable to higher income groups or rural settings.

Strengths of this study include its racial/ethnic diversity and focus on a low-income, high-risk population. Few studies have assessed seasonal weight gain in older elementary school children or children in the northeastern United States. Another strength is our examination of the effect of season on both BMI and BMI z-score, which allows these findings to more easily be compared with other studies. It is also the first study, to our knowledge, to explore the effects of school year PA programming on seasonal weight change and importantly measure diet and PA patterns during the summer months to explore the causes of accelerated summer weight gain.

Conclusions

Children in this diverse sample of third- and fourth-grade students in Massachusetts gained weight at a faster rate in the summer than they did during the school year. The magnitude of summer weight gain did not differ significantly by race/ethnicity or baseline weight status. Also noteworthy is the finding that, unlike children in the control and classroom-based breaks program, children exposed to a school year walk/run program did not gain weight more rapidly during the summer. Finally, poorer diet and PA patterns were observed during the summer months but did not appear to be significant drivers of accelerated weight gain in our sample. Larger studies quantifying diet and PA patterns during the summer months are needed to further inform specific targets for intervention.

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Author Disclosure Statement

No competing financial interests exist.

Supplementary Material

Supplementary Figures S1–S3
Supplementary Tables S1 and S2

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