Longitudinal, Time-Varying Behavioral Exposures and Changes in Childhood Adiposity

Longitudinal, time-varying behavioral exposures and changes in childhood adiposity

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A Dissertation Submitted to the Faculty of

The Harvard T.H. Chan School of Public Health

in Partial Fulfillment of the Requirements

for the Degree of Doctor of Science

in the Department of Epidemiology

Harvard University

Boston, Massachusetts.

May 2016

Dissertation Advisor: Dr. Alison E. Field Melanie Lynn Kornides

Longitudinal, time-varying behavioral exposures and changes in childhood adiposity

Abstract

Problem: Our objective was to exam associations between time-varying behaviors in childhood and changes in adiposity. Our aim in Paper 1 was to assess patterns and regional trends in seasonal variation of moderate-vigorous (MVPA) and vigorous (VPA) physical activity in adolescence. In Paper 2, our aim was to determine how seasonal variations in meeting activity guidelines relate to adolescent weight change. In Paper 3, our aim was to assess the time-varying effects of television time starting in early childhood on adiposity, and the extent to which sleep and diet quality mediated its effects.

Methods and Procedures: For Paper 1, we used data from the Growing Up Today Study (GUTS) 2 to prospectively identify the prevalence of not meeting MVPA and VPA guidelines by season, climate region and other characteristics. For Paper 2, we used data from GUTS 1 and 2 to examine the relation between the number of seasons per year that adolescents met guidelines and incident overweight. In paper 3, we used data from Project Viva to categorize hours per week of television viewing, using American Academy of Pediatrics (AAP) age-based recommendations on screen time. The main outcome was incident overweight from age 3 years to 7 years. We fit generalized linear models for longitudinal binary data using generalized estimating equations to model the outcomes in aims 1, 2, and 3.

Main results: In Paper 1, we found that over three-quarters of youth did not meet MVPA or VPA recommendations for at least one season during adolescence. Regardless of U.S. climate region, gender, race/ethnicity, or age group, adolescents were less likely to meet activity recommendations in the winter than the summer. In Paper 2, the risk of becoming overweight or obese was 17% (5%, 30%) higher for girls meeting the recommendations for MVPA on less than 3 seasons when compared to girls meeting these recommendations on 3

or 4 seasons. In Paper 3, children who watched more than the AAP recommended amount of television (2 hrs/day) had an adjusted 1.36 times the odds of becoming overweight each year (OR 1.36, 95%CI 0.89, 2.08).

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Funding: This study was funded by the Breast Cancer Research Foundation and a grant (R01-DK084001) from the National Institutes of Health. Melanie L. Kornides was supported by training grant T32HD060454 in Reproductive, Perinatal, and Pediatric Epidemiology from the National Institute of Child Health and Human Development, National Institutes of Health.

Paper Three:

Funding: This study was funded by a grant (R37-HD034568) from the National Institutes of Health. Melanie L. Kornides was supported by training grant T32HD060454 in Reproductive, Perinatal, and Pediatric Epidemiology from the National Institute of Child Health and Human Development, National Institutes of Health.

Appreciation

Thank you to my advisor, Alison Field, for your invaluable help, guidance, feedback, and support throughout my time in the program. You have been inspiring.

I would also like to thank my research committee, Matthew Gillman, Bernard Rosner, and Eric Rimm for the countless hours you have invested in giving feedback and guidance.

Thank you, Sheryl Rifas-Shiman, for all of your help with Paper Three. Thank you to the Project Viva and Growing Up Today studies faculty and support staff.

Finally, thank you to my family and friends: Bryan, Yara, Priyanka, Myra, Mom, and Audrey.

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Paper One: U.S. adolescents at risk for low physical activity: the impact of climate and season

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Abstract

Importance: No prospective study has assessed the U.S. regional and seasonal prevalence of not meeting the United States national physical activity recommendations of 7 hours a week of moderate-vigorous activity (MVPA) and 3 hours a week of vigorous activity (VPA) over the course of adolescence.

Objective: To prospectively identify the prevalence of not meeting MVPA and VPA guidelines by season, climate region and other characteristics from early adolescence into young adulthood.

Design, Setting and Participants: Longitudinal study from 2004 through 2011 of 10,918 U.S. youth, age 9 to 22 years, from the Growing Up Today Study 2 cohort.

Main Outcome and Measures: We dichotomized weekly hours of MVPA and VPA into not meeting versus meeting national recommendations. We estimated MVPA and VPA using self-reported hours/week spent in 15 to 18 activities by season.

Exposures: We grouped the contiguous U.S. into 9 climatically consistent regions. We also examined effects of season, sex, race/ethnicity, weight status, and age group.

Results: 85% of adolescents did not meet MVPA and 91% did not meet VPA recommendations during one or more of the sixteen seasons over the study period. Participants were over two times more likely to not meet the MVPA recommendations during the winter compared to summer (adjusted odds ratio [OR], 2.02 [95% CI 1.96-2.08]). Compared to the Northeast, adolescents living in the South, Southeast, and Ohio Valley were significantly more likely to not meet both MVPA and VPA recommendations ($p<.001$). During the summers, adolescents living in the South compared to the Northeast were over 50% more likely to not meet MVPA recommendations (OR 1.55 [95% CI 1.36-1.76]) and about 20% more likely to not meet recommendations in the winters (OR 1.23 [95% CI 1.08-1.40]).

Conclusion and Relevance: Over three-quarters of youth did not meet MVPA or VPA recommendations for at least one or more seasons during adolescence. Regardless of U.S. climate region, gender, race/ethnicity, or age group, adolescents were more likely to not meet activity recommendations in the winter than the summer. Certain regions of the U.S. were also more likely to not meet activity recommendations.

U.S. adolescents at risk for low physical activity: the impact of climate and season

Background

The U.S. Department of Health and Human Services (DHHS) recommends that adolescents engage in $\geq$ 1 h/ day of moderate-vigorous activity (MVPA) and engage in $\geq$ 1 hour of vigorous physical activity (VPA) 3 days each week [1]. The recommendation is based a scientific advisory committee's findings suggesting a dose-response relationship between amount of physical activity and health benefits, with substantially increased health benefits, including improved bone health and improved cardiorespiratory fitness, at the recommended levels.

Estimates on the percentage of U.S. adolescents meeting national recommendations vary across studies, with up to 80% not meeting guidelines for MVPA [1]. Studies often ascertain physical activity status by directly measuring activity with accelerometers over a week and assume that this represents typical activity level throughout the year. However, season of the year, region of the country, changes in climate and seasonal sports participation may influence activity measurements [2-4]. Estimates from one point in time may not represent usual activity over an entire year [4, 5]. The extrapolation of accelerometer data to a longer time period may not adequately capture these important sources of variation and impact the estimate of U.S. adolescents who meet the recommended amounts of daily physical activity [6].

The studies published on seasonal variation in physical activity have been limited to particular geographic regions [7]. There are no longitudinal cohort studies that have captured both region of the U.S. and seasonal variations in activity, as well as how factors such as sex, weight status, and developmental stage affect variability in activity levels. Our objective was to assess the patterns and regional trends in seasonal variation of physical activity in a longitudinal cohort of U.S. adolescents. To determine subgroups of adolescents at risk for low physical activity, we sought to identify the factors associated with increased odds of not meeting MVPA and VPA recommendations, defined as weekly hours of activity less than 7 hours per week for MVPA and 3 hours per week of VPA.

Methods

Participants

We used data from the Growing Up Today Study 2 (GUTS 2) study, a longitudinal cohort of offspring of participants of the Nurses Health II study [8]. 6002 girls and 4916 boys returned baseline questionnaires and thus gave assent to participate. At baseline (2004) the participants came from 50 U.S. states and were ages 9-15 years. The study was approved by the Human Subjects Committee at Brigham and Women's Hospital. Details of the study methods are described elsewhere [9, 10].

Physical activity was assessed by season on the 2004, 2006, 2008 and 2011 surveys. Adolescents with physical activity data on at least one survey were eligible for inclusion in the analysis. Participants were excluded for a survey period for the following reasons: missing outcome (n= 3 in 2004), missing weight status (n= 649 in 2004), living in a geographical area with limited number of participants for analysis (n=191 in 2004). After these exclusions, 10,095 adolescents were eligible for the study in 2004 and 5031 were eligible in 2011 (See supplemental table 1.4 in Paper 1 Appendix for participant flow). In a sensitivity analysis, adolescents with missing data after baseline did not differ from those who remained in the study with respect to activity levels by season, region of the country, or race/ethnicity. Boys were more likely to have missing data than girls, and overweight/obese adolescents were more likely than their normal weight peers were. All analyses were conducted using SAS 9.3 (Cary, NC).

Measures

Outcome

Participants reported hours/week each season (spring, summer, fall, winter) for activities in which they participated over the past year. These 15 activities for girls and 16 for boys included baseball/softball, basketball, biking, dancing/aerobics, football (boys only), ice/field/street hockey or lacrosse, running/jogging, swimming, rollerblading/skating or ice-skating, skateboarding, soccer, tennis/other racquet sports, Stairmaster/elliptical or rowing machine, gymnastics or cheerleading, strength training, and volleyball. An earlier, non-seasonal version of the activity questionnaire had moderate validity and strong reliability but was difficult for children to complete because their activity patterns changed over the year [11, 12].The seasonal format questionnaire is easier for children to complete, with improved accuracy [13]. For each survey year that an adolescent reported activity, he or she contributed four person-seasons. There were a maximum of 16 person-seasons of activity for each participant.

We combined hours per week in the all reported sports/activities to create total weekly MVPA and VPA each season. We used METs, or metabolic equivalent of task, to classify the intensity of each activity as moderate-vigorous or vigorous. MET values are defined as the ratio of the work metabolic rate to a standard resting metabolic rate (RMR) of 1.0 kcal*kg^{-1}*h^{-1}[14]. METS can be used to distinguish between light-intensity (< 3 METs), moderate-intensity (3-6 METs), and vigorous-intensity (>6 METs) activities. As adolescents did not report intensity for each activity, we assigned the "general" MET level for each sport based on the 2011 Compendium of Physical activities [14]. For example, METs for running can vary from 4.5 to 23.0 depending on intensity, but we assigned all running a MET level of 7.0 for "general" jogging.

To estimate VPA each season, we summed the hours spent each week in activities with MET levels > 6. These included basketball, hockey/lacrosse, running, skating, soccer, tennis, and use of aerobic exercise machines. We did not include swimming in the VPA category due to the large variation in MET values depending on the type of stroke and intensity of effort (range 3.5 to 10). Swimming was most popular at younger ages (ages 9-10) and during the summer months, suggesting recreational rather than competitive swimming. We assumed a MET level of 5.8, i.e. swimming laps, freestyle, front crawl, slow, light, or moderate effort. For the same reason, we included biking in the MVPA but not VPA category.

Correlates

We examined whether activity levels were related to season of the year, climate region of the country, sex, age, race/ethnic group, weight status, and self-reported hours per week of television viewing. Region of the country was updated at each survey period and was available at the U.S. state level. We categorized the adolescents' home states into nine climate regions in the continental U.S. (see figure 1.2). The regions consisted of groupings of states with consistently similar climates as identified by the National Climatic Data Center (www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php; last accessed 8/12/15).). We excluded participants who resided outside the U.S. (n=131); due to small sample sizes we also excluded those in Alaska (n=8), Hawaii (n=10), and the Northern Rockies and Plains region (n=42).

Race/ethnicity was self-reported at baseline as white, black, Hispanic, or other. We used the American Academy of Pediatrics classification for age groups to divide adolescence into four age/developmental stages: pre-adolescence (ages 9-10), early adolescence (ages 11-14), middle adolescence (15-17), and late adolescence (ages 18-21)[15]. We used self-reported height and weight to calculate body mass index (BMI) [kg/m^2]. Self-reported height and weight correlate strongly with objectively measured anthropometrics in adolescents[16]. We used the International Obesity Task Force BMI cut-offs for children and adolescents to classify participants as overweight/obese vs. healthy or low weight [17].

Data Analysis

We dichotomized weekly hours of activity to indicate meeting versus not meeting recommendations for MVPA and VPA. To assess the odds of not meeting MVPA and VPA recommendations we fit binary logistic regression models using generalized estimating equations (GEE) with an independent correlation working structure to account for the correlations between siblings and between the repeated measures for each individual subject. An increased odds ratio (OR > 1) represents the odds of not meeting MVPA or VPA recommendations as compared to meeting them.

We selected the reference groups for the correlates *a priori* as those groups we hypothesized to have the highest levels of physical activity based on prior literature. By using the group with the highest activity level as the referent, we were able to identify subgroups at risk for not meeting MVPA and VPA recommendations.

To assess for group differences within individual seasons (effect modification by season), we stratified the described models by season. We had inadequate power to assess pre-adolescent activity separately. Because pre-adolescents followed similar activity patterns to those in the early adolescent stage, we compared models excluding pre-adolescents to those combining the pre and early adolescent age groups. As there were not substantial differences, we combined the pre and early adolescent age groups in the final models. We excluded television time from the final models as it was not significantly associated with activity, nor did it substantially alter the associations between activity and the other variables.

As a sensitivity analysis, we fit the same models using generalized linear mixed effects models (GLMM) for binary outcomes; we obtained very similar estimates (results not shown). We also modeled continuous physical activity (hours/week) using longitudinal linear mixed effects models. To reduce the influence of implausible values of activity, we set all adolescents reporting > 40 hours a week to 40 hours. Due to the right skew of both the MVPA and VPA hours, we included the linear models as supplemental material.

Table 1.1 Characteristics of the Growing Up Today Study 2 Cohort at baseline

Year		2004	
Gender		Female	Male
Total Cohort N =10918		6002	4916
Baseline sample size after exclusion criteria[a] n=10095		5521	4574
Adolescent Stage (%)	Pre-Adolescent (9-10 years)	544 (9.9%)	505 (11.0%)
	Early (11 -14 years)	3373 (61.1%)	2930 (64.1%)
	Middle (15-17 years)	1604 (29.1%)	1139 (24.9%)
	Late (18+)	--	--
Region (%)	South	304 (5.5%)	262 (5.7%)
	Southeast	398 (7.2%)	337 (7.4%)
	Southwest	59 (1.1%)	56 (1.2%)
	West	718 (13.0%)	605 (13.2%)
	Northwest	56 (1.0%)	44 (1.0%)
	Midwest	855 (15.5%)	704 (15.4%)
	Ohio Valley	1296 (23.5%)	1037 (22.7%)
	Northeast	1835 (33.2%)	1529 (33.4%)
Race/Ethnicity (%)	White (Non-Hispanic)	5114 (92.6%)	4307 (94.2%)
	Other[b]	407 (7.4%)	266 (5.8%)
TV mean hours/week (SD)		11.1 (8.8)	12.3 (9.3)
Overweight /Obese[c] (%)		1039 (18.8%)	1155 (25.3%)
Low moderate-vigorous physical activity[d] (%)		3984 (72.2%)	3049 (66.7%)
Low vigorous physical activity[e] (%)		4530 (82.1%)	3341 (73.0%)

[a]Adolescents living in the Northern Rockies/Plains, Alaska, or Hawaii, or outside the U.S. excluded from study due to small sample size (n=191). Also excluded those with missing activity status (n=3) or weight status (n=649). All were eligible to re-enter the study if they no longer met exclusion criteria during follow-up.
[b]Other includes Black, Hispanic, Asian, Pacific Islander, Native American, and unreported
[c] Overweight/obese defined by International Obesity Task Force BMI cut-points for adolescents
[d]Low MVPA: n (%) reporting < 7 hours per week of moderate-vigorous physical activity for 1+seasons
[e]Low VPA: n (%) reporting < 3 hours per week of moderate-vigorous physical activity for 1+seasons

Results

Among the 10095 adolescents in the study at baseline, the majority of participants were in early adolescence (62% were ages 11-14 years) and 55% were female (table 1.1). The cohort was primarily white (93%). Similar to the population distribution in the U.S., most participants lived in the Northeast (33%), Ohio Valley (23%), Midwest (15%) and West (13%) climate regions. The gender, race/ethnicity, and residential distributions in the cohort remained stable over the study period. 85% (n=8579) of adolescents in the study did not meet MVPA recommendations and 91% (n=9231) did not meet VPA recommendations during one or more of the sixteen study seasons.

Table 1.2 Odds ratios of low physical activity

		< 7 hours Moderate-Vigorous hours/week		< 3 hours Vigorous hours/week	
N=10918		OR	95% CI	OR	95% CI
Survey Year (time)		1.02	(1.01, 1.03)[b]	1.00	(0.99, 1.02)
Season	Spring	1.27	(1.24, 1.31)[b]	0.90	(0.88, 0.92)[b]
	Summer	Reference		Reference	
	Fall	1.36	(1.33, 1.40)[b]	0.93	(0.91, 0.95)[b]
	Winter	2.02	(1.96, 2.08)[b]	1.22	(1.18, 1.25)[b]
Adolescent Age Group					
	Pre (9-10) and Early (11 -14)	1.22	(1.17, 1.27)[b]	1.05	(1.00, 1.10)
	Middle (15-17)	Reference		Reference	
	Late(18+yrs)	1.50	(1.42, 1.58)[b]	1.08	(1.02, 1.14)
Weight Status	Normal	Reference			
	Overweight /Obese	1.22	(1.16, 1.28)[b]	1.32	(1.25, 1.39)[b]
Climate Region	Northeast	Reference		Reference	
	South	1.35	(1.21, 1.51)[b]	1.38	(1.23, 1.55)[b]
	Southeast	1.30	(1.18, 1.44)[b]	1.25	(1.13, 1.39)[b]
	Southwest	1.10	(0.89, 1.37)	1.38	(1.09, 1.74)
	West	1.14	(1.05, 1.23)	1.42	(1.31, 1.55)[b]
	Northwest	0.96	(0.77, 1.20)	1.29	(1.02, 1.63)
	Midwest	1.06	(0.98, 1.14)	1.09	(1.01, 1.17)
	Ohio Valley	1.12	(1.05, 1.20)	1.19	(1.11, 1.28)[b]
Race/Ethnicity	White	Reference		Reference	
	Black, Hispanic, Asian, or other	1.12	(1.01, 1.24)	1.03	(0.94, 1.15)
Gender	Female	1.40	(1.33, 1.47)[b]	1.47	(1.39, 1.54)[b]
	Male	Reference		Reference	

[a] U.S. Department of Health and Human Services recommends adolescents get 7 hours of moderate-vigorous physical activity (MVPA) each week, including 3 hours of vigorous activity (VPA) each week;
[b] P<=.0001

We observed substantial variability in the percentage of adolescents not meeting activity recommendations across gender, weight status, age, season of the year, and region of the country. 87% of girls (n=4834) and 82% of boys (n=3745) did not meet MVPA for one or more seasons. 93% of girls (n=5155) and 89% of boys (n=4076) did not meet VPA recommendations for one or more seasons. After adjusting for age, race/ethnicity, weight status, region of the country, girls were at 40% higher odds of low MVPA (OR=1.40, 95% CI 1.33-1.47) and 46% higher odds of low VPA (OR=1.46, 95% CI 1.39-1.54) compared to boys (table 1.2). Overweight or obese youth had 22% increased odds of low MVPA compared to their normal weight peers (OR 1.22, 95% CI 1.16, 1.28).

Among the pre, early and middle adolescent age groups there was considerable variation in the percent of the cohort not meeting MVPA recommendations by season (figure 1.1). Pre and early (ages 9-14) adolescents had 0.89 times the odds of low MVPA in the summer compared to those ages 15-17 (table 1.3, OR=.89, 95% CI .84-.94). During the winter, pre and early adolescents had 1.62 times the odds of low MVPA compared to middle adolescents (OR=1.62, 95% CI 1.53-1.72). Older adolescents (ages 18+) had consistently higher odds of not meeting MVPA recommendations each season compared to the middle adolescence age group.

Adolescents reported lower activity levels during the winter, regardless of gender, age group, weight status, race/ethnicity, calendar year or climate regions. Seasonally, 60% of the cohort (n=6050) reported low MVPA for one or more summers over the course of the study, while 78% (n=7913) reported low MVPA for one or more winters. After adjusting for age, race/ethnicity, weight status, region of the country and gender, participants had 2.02 times the odds of not meeting MVPA recommendations in the winter than the summer (table 1.2, OR=2.02, 95% CI 1.96-2.07).

Regional differences in the percentage of adolescents who did not meet MVPA recommendations were more pronounced during the summer (figure 1.2). 39% of those living in the South (n=223) and 40% in the Southeast (n=293) reported low summer MVPA in 2004 compared to 27% living in the Northeast (n=923). During the winter of 2004, the percentages of adolescents not meeting MVPA recommendations were similar amongst the various regions with most over 60%. When examined within season (table 1.3), those living in the South, Southeast, and West compared to the Northeast had higher odds ratios of not meeting MVPA recommendations during the summer than the winter. There were not significant differences in odds for low MVPA between the Northeast and the Southwest or Northwest regardless of season.

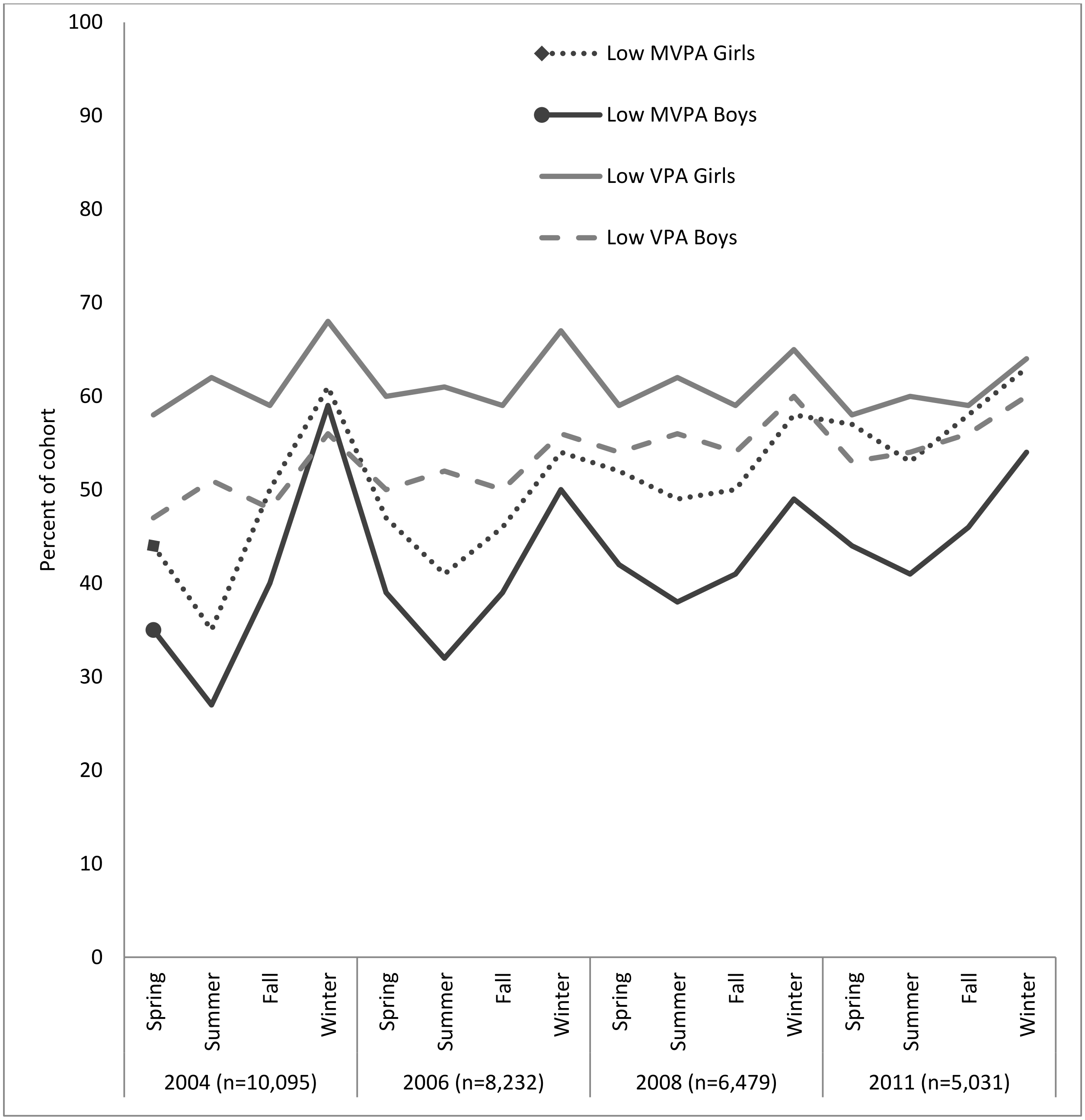

Figure 1.1 Percent of cohort reporting low physical activity by gender, season and year

Table 1.3 Season-specific odds ratios for low MVPA

	Spring		Summer		Fall		Winter	
N=10,918	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Gender								
Girls	1.50	(1.41, 1.59) [b]	1.50	(1.41, 1.59)[b]	1.49	(1.40, 1.58)[b]	1.26	(1.19, 1.33)[b]
Boys	Reference group							
Stage								
Pre and Early	1.22	(1.15, 1.30)[b]	0.89	(0.84, 0.94)	1.34	(1.27, 1.42)[b]	1.63	(1.53, 1.72)[b]
Middle	Reference Group							
Late	1.40	(1.31, 1.50)[b]	1.52	(1.42, 1.62)[b]	1.57	(1.47, 1.68)[b]	1.46	(1.36, 1.56)[b]
Climate Region								
South	1.36	(1.19, 1.55)[b]	1.55	(1.36, 1.76)[b]	1.27	(1.12, 1.45)	1.23	(1.08, 1.40)
Southeast	1.26	(1.12, 1.42) [b]	1.43	(1.27, 1.61)[b]	1.25	(1.11, 1.41)[b]	1.21	(1.08, 1.37)
Southwest	1.07	(.82, 1.40)	1.27	(.98, 1.65)	1.09	(.83, 1.42)	0.90	(0.70, 1.16)
West	1.16	(1.05, 1.27)	1.36	(1.23, 1.50)[b]	1.16	(1.06, 1.28)	0.91	(0.83, 1.00)
Northwest	0.91	(0.68, 1.21)	1.03	(0.79, 1.35)	1.01	(.77, 1.33)	0.88	(0.68, 1.13)
Midwest	1.15	(1.05, 1.26)	1.03	(0.94, 1.13)	1.06	(.97, 1.16)	1.06	(0.97, 1.16)
Ohio Valley	1.24	(1.14, 1.34)[b]	1.04	(.96, 1.13)	1.15	(1.06, 1.24)	1.15	(1.06, 1.25)
Northeast	Reference Group							

[a] Adjusted for study year, race/ethnicity, and weight status
[b] P<=.0001
[c] Low MVPA: engaging in < 7 hours a week of moderate-vigorous activity

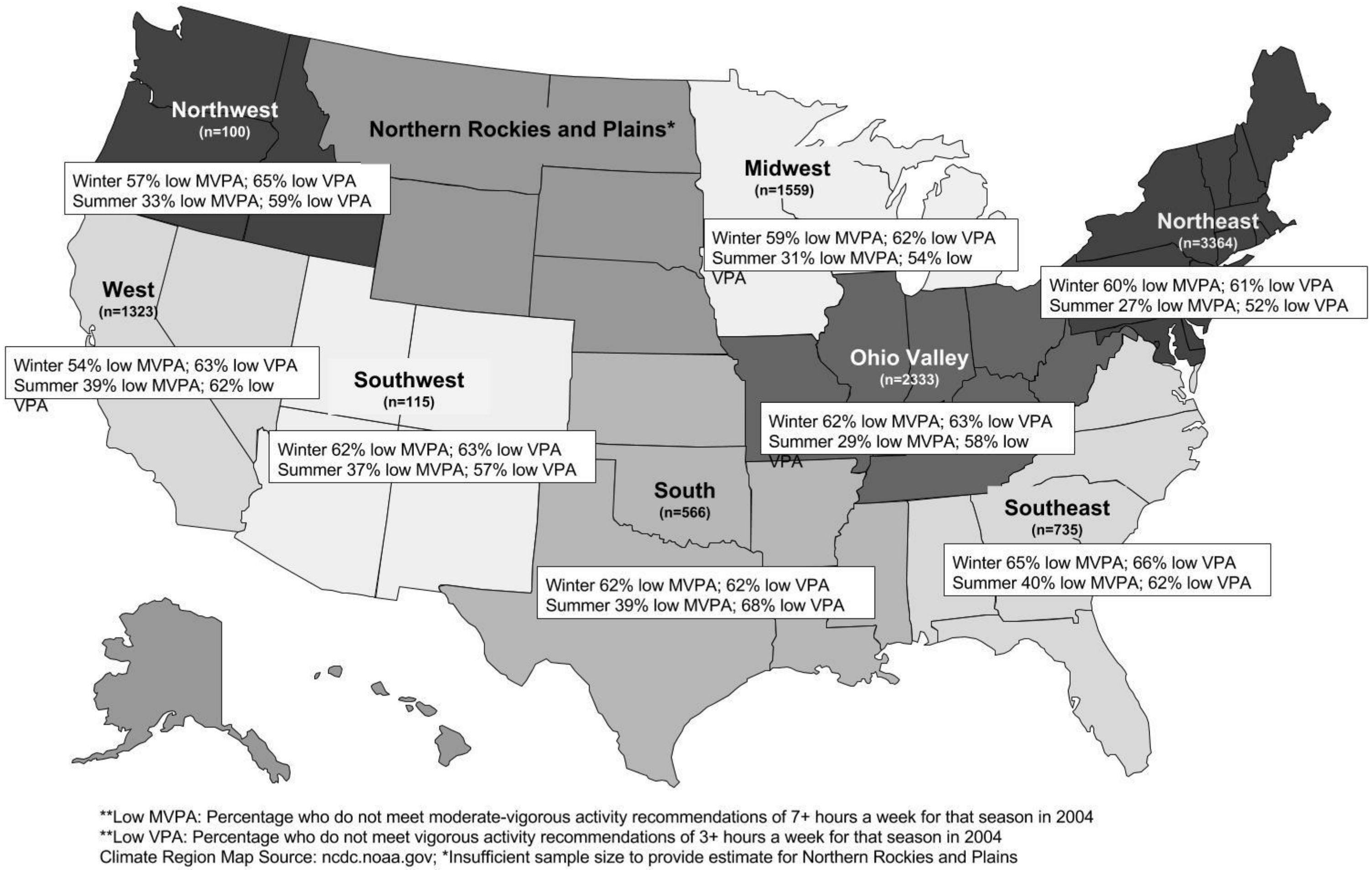

Figure 1.2 Percentage of adolescents by climate region with low weekly physical activity levels during the 2004 winter and summer seasons

Discussion

In this prospective cohort, we found that 85% of adolescents did not meet MVPA recommendations and 91% did not meet VPA recommendations. Adolescents were less likely to meet physical activity recommendations during the winter, regardless of climate region. Adolescents living in the South and Southeast were less likely to meet recommendations than adolescents in Northeast were, especially during the summer. Girls were less likely to meet recommendations than boys were, as were overweight compared to normal weight adolescents. These findings are in agreement with previous studies documenting seasonal variation in children and adolescents' physical activity levels [18-22] and provide new data on how this seasonal variation may vary across age, gender, weight status, and geographical region among US adolescents.

It has been proposed that the lack of seasonal variability in activity found in some single region cross-sectional studies are related to more temperate climate regions with milder winters [6, 7]. In a study looking at seasonal variation between two regions in Europe, girls living in the darker and colder Central-North showed more seasonal variability in physical activity and sedentary time than girls living in more moderate South [23]. The adolescents in our study reported remarkably similar patterns of higher activity in the summer and lower activity levels in the winter across U.S. climate regions, even after adjusting for age, weight status, and gender, suggesting less impact of mild climate in the U.S on winter activity levels.

We observed more climate region variation in not meeting MVPA recommendations during the summer. Adolescents who lived in the South, Southeast, and West were more likely to report low MVPA during the summer season compared to those living in the Northeast. In contrast, adolescents living in the Northwest did not differ significantly from the Northeast in their activity levels or risk of low activity across season. Although we were limited in our ability to assess climate differences beyond the state level, our findings suggest regional climate plays a role in the activity levels among American youth.

Few studies of seasonal variation in adolescent physical activity have compared age subgroups. Overall, adolescents' activity levels decline with age [24, 25]. Consistent with this trend, activity levels declined over our study period. However, we found middle adolescents (ages 15-17 years) to be the more active compared to the pre, early and late age groups after adjusting for season and other factors. We also observed larger seasonal variations in physical activity among the younger age groups, and less seasonal variation in activity levels for older adolescents and young adults, indicating that time of the year should be accounted for when measuring activity in younger adolescents.

The impact of gender on seasonal physical activity levels is not well known [26, 27]. Data from the 2003-2004 and 2005-2006 NHANES have shown that boys are more active than girls in general [25]. Adjusting for season and age group, the girls in our study were much more likely to not meet MVPA or VPA recommendations than the boys. The gender difference for engaging in low MVPA was less in the winter months as compared to the other seasons, which likely reflects that activity levels were lower in the winter across gender, region, and age groups. During the spring, summer, and fall, girls were consistently between 40 and 50% more likely than boys to not meet VPA recommendations.

One possible limitation to our study was self-report of physical activity rather than an objective measure. Using accelerometer to assess seasonal activity throughout the year for multiple years represents a heavy participant burden, does not accurately capture certain activities, such as swimming and biking, and would be costly given the size of our cohort. Self-reported activity strongly correlate with activity measured through accelerometer, indicating it is an acceptable substitute for large longitudinal studies [28]. A second limitation is that adolescents did not report how intensely they performed each activity. We based our measure of MVPA on the assumption that the activities were most often performed using moderate-vigorous energy expenditure. We also assumed that the adolescents performed each activity continuously throughout the entire reported time. As a result, we may have over-estimated the time spent in moderate-vigorous activity. Our over-estimate of MVPA may be more likely in certain activities that can be either recreational or competitive, such as swimming, or are characterized by long periods of inactivity interspersed with brief periods of moderate activity, such as baseball or wrestling. To minimize possible overestimation, we excluded walking from our MVPA estimates and swimming and biking from our VPA estimates.

Our study is strengthened by the longitudinal, repeated measures design spanning different adolescent age groups and developmental stages. We have detailed information collected on activities each season providing a better picture of activities by gender, age group, and season of the year. The large number of participants in the study covers most of the U.S. climate regions and has a similar geographic population density distribution to the U.S. population.

In conclusion, most adolescents in our study did not meet MVPA or VPA recommendations. Adolescents were more at-risk for low activity in the winter than summer regardless of U.S. climate region, gender, race/ethnicity, or age group. Certain regions of the U.S. were also more likely to not meet activity recommendations.

Appendix: Supplemental Materials

Table 1.4 Participant flow from 2004 to 2011

Year	2004		2006		2008		2011	
Gender	Female	Male	Female	Male	Female	Male	Female	Male
1. Total N	6002	4916	4779	3861	4098	3014	3899	2760
% Loss to follow-up			20%	21%	14%	22%	5%	8%
2. (n) after exclusions[a]	5521	4574	4522	3710	3747	2732	3043	1988
Combined girls and boys Sample N (% of 10918 in original 2004 cohort)	10095(92%)		8232 (75%)		6479 (59%)		5031 (46%)	

[a]Exclusions: missing activity variable for that year; missing weight status for that year; lives outside U.S., lives in Hawaii, Alaska, or Northern Plains (MT, NE, ND, SD, WY) during that survey period

Table 1.5 Season-specific odds ratios for low VPA

	Spring		Summer		Fall		Winter	
N=10,918	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Gender								
Girls	1.43	(1.35, 1.52)[b]	1.49	(1.40, 1.58)[b]	1.42	(1.33, 1.50)[b]	1.46	(1.37, 1.55)[b]
Boys				Reference group				
Stage								
Pre and Early	1.05	(1.00, 1.12)	1.12	(1.06, 1.19)[b]	1.03	(.97, 1.09)	1.04	(.98, 1.10)
Middle				Reference Group				
Late	1.13	(1.06, 1.21)	1.11	(1.04, 1.19)	1.05	(.98, 1.13)	1.02	(.95, 1.09)
Climate Region								
South	1.33	(1.17, 1.52)[b]	1.60	(1.40, 1.82)[b]	1.36	(1.20, 1.55)[b]	1.18	(1.03, 1.35)
Southeast	1.18	(1.05, 1.32)	1.35	(1.20, 1.52)[b]	1.25	(1.11, 1.40)	1.17	(1.03, 1.32)
Southwest	1.37	(1.04, 1.79)	1.31	(1.01, 1.70)	1.51	(1.16, 1.98)	1.37	(1.0, 1.81)
West	1.61	(1.46, 1.77)[b]	1.57	(1.43, 1.73)[b]	1.37	(1.24, 1.50)[b]	1.19	(1.07, 1.31)
Northwest	1.16	(0.88, 1.53)	1.48	(1.11, 1.99)	1.29	(0.99, 1.69)	1.28	(.94, 1.73)
Midwest	1.07	(0.98, 1.17)	1.07	(0.98, 1.17)	1.13	(1.03, 1.24)	1.09	(.99, 1.19)
Ohio Valley	1.23	(1.14, 1.34)[b]	1.16	(1.07, 1.26)	1.24	(1.15, 1.35)[b]	1.16	(1.06, 1.26)
Northeast				Reference Group				

[a]Odds ratios adjusted for study year, race/ethnicity, and weight status
[b]P<=.0001
[c]Low VPA: engaging in < 3 hours a week of vigorous activity

Table 1.6 Predictors of hours of moderate to vigorous physical activity per week (Longitudinal Linear Mixed Effects Model)

		Moderate-Vigorous Activity hours/week		Vigorous Activity hours/week	
N=10918		B[a]	95% CI	B*	95% CI
Survey Year (time)		-.08	(-.13, -.03)[b]	-.01	(-0.43 .02)
Season	Spring	-1.66	(-1.74, -1.58)[b]	0.28	(0.23, 0.33)[b]
	Summer		Reference group		
	Fall	-2.11	(-2.20, -2.03)[b]	0.28	(0.23, 0.33)[b]
	Winter	-3.78	(-3.88, -3.68)[b]	-0.50	(-0.56, -0.45)[b]
Adolescent Age Group					
	Early (11 -14)	-.93	(-1.10, -.69)[b]	-.42	(-0.55, -0.30)[b]
	Middle (15-17)		Reference group		
	Late(18+yrs)	-1.89	(-2.12, -1.66)[b]	-0.89	(-1.02, -0.75)[b]
Weight Status	Normal		Reference Group		
	Overweight /Obese	-.54	(-0.81, -0.33)[b]	-0.60	(-0.74, -0.46)[b]
Resident region of country	Northeast		Reference Group		
	South	-1.24	(-1.83, -.067)[b]	-1.09	(-1.41, -0.76)[b]
	Southeast	-1.09	(-1.60, -0.58)[b]	-0.79	(-1.11, -0.47)[b]
	Southwest	-1.04	(-2.43, 0.34)	-1.11	(-2.00, -0.23)
	West	-0.94	(-1.36, -0.52)[b]	-1.16	(-1.40, -0.93)[b]
	Northwest	-0.50	(-1.42, 0.33)	-1.21	(-1.76, -0.67)[b]
	Midwest	-0.37	(-0.75, 0.01)	-0.27	(-0.51, -0.03)
	Ohio Valley	-0.50	(-0.86, -0.14)	-0.51	(-0.72, -0.30)[b]
Race/Ethnicity	White		Reference Group		
	Black, Hispanic, Asian, or other	-0.35	(-.80, 0.11)	0.06	(-0.23, 0.34)
Gender	Female	-2.08	(-2.32, -1.84)[b]	-1.03	(-1.17, -0.88)[b]
	Male		Reference Group		

[a]Beta=Difference in weekly hours of physical activity for the comparison group from the mean hours of weekly activity of reference group. For example, Females had 2.08 (95% CI, -2.31, -1.84) fewer mean weekly hours of MVPA compared to males, adjusting for the other predictors.
[b]P<=.0001

Paper Two: Seasonal Variations in Meeting Physical Activity Guidelines and Development of Overweight during Adolescence

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Abstract

Objective

To evaluate whether seasonal variation in physical activity is related to incident overweight or obesity.

Methods

Season-specific physical activity was assessed among 12,949 adolescents in participating in the Growing Up Today Study (GUTS) and 10,920 adolescents participating in GUTS 2. We examined the relation between the number of seasons per year that adolescents met moderate-to-vigorous (MVPA) and vigorous (VPA) physical activity recommendations and incident overweight or obesity at the next survey period using generalized estimating equations for binary data. Analyses were sex-specific, and controlled for survey year, cohort, age, race, sexual development, television watching, region of the country and intakes of sugar-sweetened beverages and fried foods away from home.

Results

Thirty-four percent (34%) of the adolescents met MVPA recommendations for all four seasons while 20% met for 3, 15% for 2, 15% for 1, and 16% for 0 seasons. The risk of becoming overweight or obese was 17% (5%, 30%) higher for girls meeting the recommendations for MVPA on less than 3 seasons when compared to girls meeting these recommendations on 3 or 4 seasons. The corresponding elevated risk for failing to meet VPA recommendations was 12% (0%, 25%). The number of seasons meeting MVPA or VPA recommendations was unrelated to overweight or obesity among boys.

Conclusions

Meeting MVPA recommendations on less than three seasons is related to higher risk of overweight or obesity among girls but not boys.

Seasonal Variations in Meeting Physical Activity Guidelines and Development of Overweight during Adolescence

Background

The U.S. Department of Health and Human Services (DHHS) recommends that children and adolescents exercise for at least 60 minutes a day to benefit health and promote a healthy body weight [29]. Estimates on the percentage of adolescents meeting DHHS recommendations vary, with up to 80% not meeting guidelines for moderate-vigorous activity [1]. One difficulty in obtaining accurate estimates is that studies often ascertain physical activity status by directly measuring activity in a relatively small sample over a brief period or relying on self-reports assessing a brief period (such as yesterday or past week) and assuming the estimate represents a much longer time frame. By measuring smaller time intervals during only one season, these studies may miss important seasonal variations in meeting activity patterns. Nevertheless, multiple activities in which youth engage often vary seasonally [2-4]. Thus, activity estimates from one point in time may be biased [4, 5]. For example, an adolescent who participates in basketball during the fall and winter, but has low levels of physical activity during the spring and summer might appear to meet national recommendations if sampled during fall or winter, but not otherwise.

Cross-sectional and longitudinal studies have examined the association between average physical activity over a year and BMI and some have examined the effects of seasonal physical activity patterns in adults on weight change [30, 31]. However, data on the effects of seasonal variations in physical activity patterns on the development of overweight in U.S. adolescents is lacking. Children and young adults gain BMI faster during the summer as compared to the school year, suggesting that seasonal variability in activity is related to weight gain [32-34]. However, summer weight-gain trends are not consistent in all studies [35].The objective of this study was to determine prospectively how seasonal variations in meeting physical activity guidelines are related to adolescent weight change.

Methods

We used data from the Growing Up Today Study cohorts (GUTS I and GUTS 2). Both longitudinal cohorts were recruited from the offspring of women participating in the Nurses' Health Study II (NHS II) [8]. In 1996, 9039 girls and 7843 boys, aged 9-15 years were enrolled in the GUTS I study. GUTS 2 enrolled 6002 girls and 4917 boys, aged 9-15 years, in 2004. The studies were approved by the Human Subjects Committee at Brigham and Women's

Hospital. Details of the study are described elsewhere [9, 10]. Adolescents with complete data on physical activity on one survey and BMI on the same and the sequential following survey period were eligible for the current study. We excluded participants who were overweight at baseline (1997 for GUTS 1 and 2004 for GUTS 2; n=4743), missing weight status at baseline (n=4700), missing weight status at first follow-up (n=2688), or missing covariate information (n=980). We also excluded those with biologically implausible BMI (n=186) and those living outside the U.S. or in Hawaii, Alaska or Northern Rockies (n=14). After these exclusions, 14490 adolescents were eligible for the study at baseline (8721 from GUTS 1 and 5769 from GUTS 2). Adolescents with missing data after baseline did not differ from those remaining in the study with respect to level of meeting activity recommendations at baseline, nor was one cohort more likely to have missing information than the other post-baseline. Adolescents who were older, watched more television, and those who were postmenarche or later tanner stage at baseline were more likely to have missing information after baseline (p<0.05).

Physical activity was assessed in 1997, 1998, 1999, and 2001 in GUTS and in 2004, 2006, and 2008 GUTS2. The PA questionnaire asked participants to report the hours per week in each season the adolescents engaged in specific activities. The activities listed in the questionnaire administered in both cohorts were basketball, baseball/softball, biking, dancing and aerobics, hockey/lacrosse, running/jogging, swimming, skateboarding, rollerblading/roller-skating or ice-skating, soccer, tennis, cheerleading, strength training, volleyball, walking, and football (boys only). The GUTS questionnaire also included outdoor chores, martial arts/karate, and wrestling while the GUTS2 questionnaire also included Stairmaster, elliptical, rowing machine, and gymnastics. The seasonal format questionnaire was found to provide improved accuracy in reporting of physical activity over annual questionnaires [13]. Metabolic equivalent of task (METs) were used to classify the intensity of each activity as moderate (3-6 METs) or vigorous (>6 METs) [14]. We summed the time spent in moderate to vigorous physical activity each week for each season across all activities in the questionnaire. We then identified participants meeting the DHHS recommended guidelines of 60 minutes or more a day (7+h/week) of physical activity for children and adolescents[29] after excluding outliers in physical activity detected by the generalized extreme Studentized deviate many-outlier procedure[36] and reassigning any remaining activity hours > 40 hours a week to 40. The same procedure was used to identify individuals meeting recommendations for time spent on vigorous physical activity (>3h/week).

The main outcome was the development of overweight/obesity during the 1-3 years of follow-up between surveys. Adolescent BMI were calculated using self-reported height and weight. International Obesity Task Force cutoffs were used to classify children as normal weight vs. overweight or obese [17]. At age 18 and older, we used a BMI cut-point of >=25 to define overweight. Continuous changes in BMI between each survey period were also examined. We excluded participants with outlying values for BMI, height or change in height between survey periods detected through the generalized extreme Studentized deviate many-outlier procedure.

Race/ethnicity was self-reported at baseline. Menarcheal status was assessed on each survey among girls and was used to classify girls as either pre- or post-menarche. Self-reported validated Tanner stage ratings for pubic hair development for each survey period were used to estimate boys' sexual maturation status [37]. Intake of sugar-sweetened beverages and fried foods away from home was assessed using a previously validated food frequency questionnaire (FFQ) designed for children and adolescents [38, 39]. Television viewing was reported at each survey period as total hours spent watching TV (including DVD, video and pre-recorded content) on weekdays and weekends. These were combined and averaged over the week to create total daily hours of television viewing. Participants' home states were categorized into nine climate regions in the continental U.S. as identified by the National Climatic Data Center (www.ncdc.noaa.gov/monitoring-references/maps/us-climate-regions.php; last accessed 8/12/15. Due to small number of adolescents living within certain regions, we combined the South and South West climate regions as well as the West and North West regions. We excluded participants who resided outside the U.S. Due to small sample sizes we also excluded those in Alaska, Hawaii, and the Northern Rockies region.

We fit generalized linear models for binary data using generalized estimating equations [40] to estimate among normal weight subjects the association of not meeting physical activity recommendations with risk of becoming overweight or obese using pooled data from the cohorts. Models were fit with different seasonal patterns of meeting physical activity recommendations for each year. All analyses were conducted separately by sex. We compared adolescents who met MPVA or VPA recommendations for all 4 seasons in a survey period to those who met for fewer seasons. We also compared meeting recommendations for 3-4 seasons to meeting them for two or fewer (binary). Other covariates allowed to vary over time include age, sexual maturity, fried food and SSB intake, television and region of the country. All analyses were completed using SAS 9.4.

Results

Table 2.1 Baseline characteristics of the GUTS 1 (year=1997) and GUTS 2 (2004) Cohorts

		GUTS 1		GUTS 2	
		Female	Male	Female	Male
Original N		9039	7843	6002	4917
Sample N[a]		5128	3593	3286	2483
Age in years mean (SD)		12.6 (1.6)	12.4 (1.6)	13.1 (1.8)	12.9 (1.9)
Race/Ethnicity (%)	White	93%	93%	92%	93%
	Other	7%	7%	8%	7%
Region of the Country	Southeast	6%	6%	7%	7%
	South and Southwest	8%	7%	6%	7%
	West and Northwest	14%	15%	15%	15%
	Upper Midwest	14%	14%	17%	15%
	Central Midwest	23%	23%	22%	22%
	Northeast	35%	36%	33%	34%
Hours of television/day (SD)		2.1 (1.4)	2.4 (1.6)	2.3 (1.5)	2.4 (1.6)
Sugar sweetened beverage intake/day (SD)		0.9 (0.9)	1.04 (1.0)	0.9 (0.9)	1.2 (1.1)
Fried food away from home svgs/week (SD)		1.2 (1.3)	1.5 (1.3)	1.1 (1.3)	1.3 (1.2)
Meets MVPA Recommendation %	All 4 seasons	31%	42%	29%	35%
	3 seasons	19%	22%	17%	21%
	2 seasons	16%	14%	15%	15%
	1 season	18%	12%	17%	12%
	0 seasons	16%	10%	22%	17%
Meets VPA Recommendations %	All 4 seasons	18%	34%	19%	29%
	3 seasons	15%	18%	14%	17%
	2 seasons	15%	14%	14%	15%
	1 season	16%	13%	15%	13%
	0 seasons	35%	21%	39%	26%

[a]Sample size restricted to normal weight at baseline and non-missing on study variables

In both GUTS and GUTS 2 the majority of the participants were in early adolescence (11-14 years) at baseline, although the GUTS 2 cohort skewed slightly older than the GUTS I cohort (table 2.1). Both cohorts had similar distributions of baseline region of residence, television hours per day and fried foods away from home intake. TV, SSB, and fried foods away from home were all weakly correlated with weekly hours of MVPA at baseline (supplemental table 2.5 in appendix for Paper Two).

Both cohorts and genders reported higher median levels of physical activity at baseline with a slight decline over the course of each study (figure 2.1). Overall, the median weekly activity was slightly higher in GUTS I adolescents than GUTS 2 adolescents. Boys reported higher levels of MVPA and VPA each season than girls. There was considerable seasonal variation in median weekly hours among all the youth. Most adolescents reported higher weekly hours of activity in the fall and spring, with peak hours in the summer. Adolescents consistently reported much less activity in the winter compared to the other seasons.

Table 2.2 Percent of Cohorts Meeting Activity Recommendations at Baseline

	Total	GUTS I	GUTS 2
N	14490	8721	5769
Meets MVPA Recommendations on average over the year	63%	67%	59%
Meets MVPA Recommendations (%) by Season			
All 4 seasons	34%	35%	32%
3 seasons	20%	20%	19%
2 seasons	15%	15%	15%
1 season	15%	15%	15%
0 seasons	16%	14%	20%
Meets VPA Recommendations on average over the year	39%	41%	37%
Meets VPA Recommendations (%) by Season			
All 4 seasons	24%	25%	23%
3 seasons	16%	16%	15%
2 seasons	15%	14%	15%
1 season	15%	15%	14%
0 seasons	31%	29%	33%

Baseline year: GUTS 1 (year=1997) and GUTS 2 (2004) Cohorts

When activity was averaged over the year, 63% (n=9199) of the combined cohorts (n=14490) met MVPA recommendations at baseline (table 2.2). However, only 34% of the adolescents met MVPA recommendations all four seasons that year. 39% of the youth met VPA recommendations on average over the baseline year, while 24% met the VPA recommendations for all four seasons. When compared to girls who met recommendations for 3 or 4 seasons, those who met for 2 or 3 seasons had 17% increase in odds of overweight (table 2.3: OR 1.17, 95% CI 1.05, 1.30). Boys who meet MVPA recommendations for 2 or fewer seasons in a year compared to 3 or 4 had slightly lower odds of becoming overweight (table 2.3: OR 0.87, 95% CI 0.78, 0.98). There was a suggestion that girls and boys who met VPA recommendations for 2 or fewer seasons in a year compared to 3 or 4 seasons had an increase in likelihood of becoming overweight (Girls OR 1.12, 95% CI 1.00, 1.25; boys OR 1.10, 0.98, 1.23).

Table 2.3 Odds ratios for becoming overweight each year among adolescents who do not meet physical activity recommendations for 0, 1 or 2 seasons

	Moderate-Vigorous[a]	Vigorous Activity[b]
Girls	OR[c] (95% CI)	OR[c] (95% CI)
Model for physical activity by season		
Meets recommendations for 3 or 4 Seasons (reference)		
Meets for 0, 1 or 2 seasons	1.17 (1.05, 1.30)	1.12 (1.00, 1.25)
Boys		
Model for physical activity by season		
Meets recommendations for 3 or 4 Seasons (reference)		
Meets for 0, 1 or 2 seasons	0.87 (0.78, 0.98)	1.10 (0.98, 1.23)

[a]Moderate-Vigorous Recommendations: 7 hours a week or more of moderate to vigorous level physical activity
[b]Vigorous Activity Recommendations: 3 hours a week or more of vigorous level activity
[c]Adjusted for Follow-up time between surveys, Cohort, age, race, menstrual status (girls), tanner stage (boys), and climate region of country,TV (h/d), SSB (servings/day), Fried foods eaten away from home (servings/week)

Compared to girls who met MVPA recommendations for all four seasons, girls who only met the recommendations for 2 seasons were 23% more likely to become overweight or obese from one survey period to the next (table 2.4: OR 1.23, 95% CI 1.05, 1.45). Similar associations were seen among girls who only met MVPA recommendations for 1 seasons (Girls OR 1.23, 95% CI 1.05, 1.44).

Table 2.4 Odds ratios for becoming overweight each year among adolescents who do not meet physical activity recommendations for all 4 seasons

	Moderate-Vigorous	Vigorous Activity
Girls	OR[a] (95% CI)	OR[a] (95% CI)
Model for physical activity by season		
Meets recommendations for 4 Seasons (reference)		
Meets for 3 out of 4 seasons	1.04 (0.88, 1.23)	1.02 (0.85, 1.24)
Meets for 2 out of 4 seasons	1.23 (1.05, 1.45)	1.08 (0.89, 1.30)
Meets for 1 out of 4 seasons	1.23 (1.05, 1.44)	1.18 (0.98, 1.42)
Meets for 0 seasons in a year	1.13 (0.97, 1.31)	1.13 (0.97, 1.31)
Boys		
Model for physical activity by season		
Meets recommendations for 4 Seasons (reference)		
Meets for 3 out of 4 seasons	0.98 (0.84, 1.14)	1.10 (0.92, 1.30)
Meets for 2 out of 4 seasons	0.83 (0.70, 0.99)	1.18 (0.99, 1.41)
Meets for 1 out of 4 seasons	0.85 (0.70, 1.02)	1.13 (0.93, 1.36)
Meets for 0 seasons in a year	0.91 (0.77, 1.08)	1.11 (0.96, 1.29)

[a] Adjusted for Follow-up time between surveys, Cohort, age, race, menstrual status (girls), tanner stage (boys), climate region of country, TV (h/d), SSB (servings/day), Fried foods eaten away from home (servings/week)

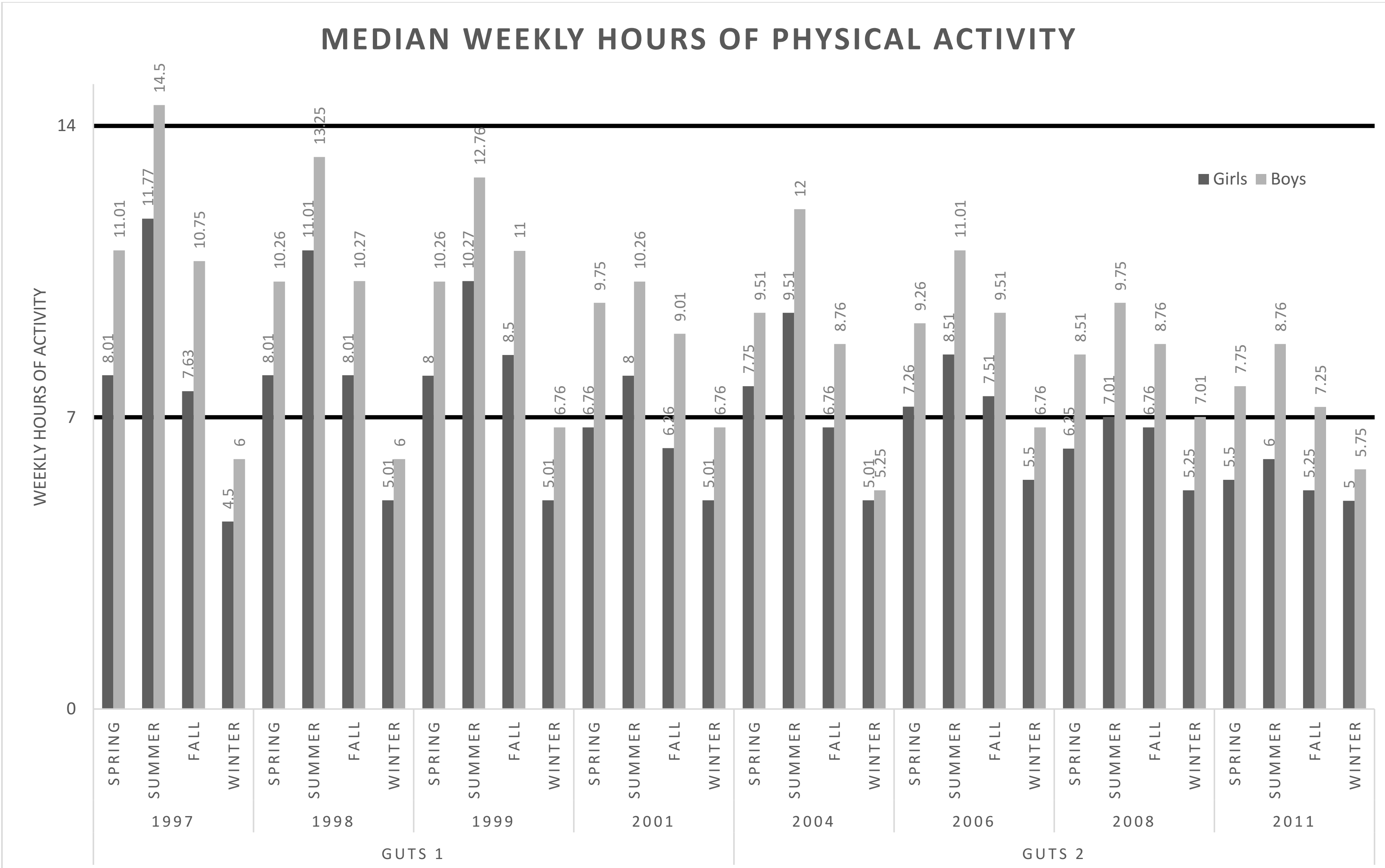

Figure 2.1 Median weekly hours of self-reported moderate-vigorous physical activity by gender, season, and year

Discussion

The majority of adolescents in these two, nationally based U.S. longitudinal cohorts did not meet MVPA or VPA recommendations for all four seasons each year. We found an increase in odds of incident overweight among adolescent girls who met MVPA recommendations for fewer than four seasons in a year. Both girls and boys who did not meet VPA recommendations for at least 3 or 4 seasons also appeared to be at increased odds. Adolescent boys who did not meet MVPA guidelines for 3 or 4 seasons in a year had slightly lower likelihood of becoming overweight. Our findings suggest that the threshold effects of getting at least 7 hours a week of MVPA on weight gain differs by sex. Although the majority of adolescents in the cohorts did not meet activity recommendations for all four seasons, when weekly activity levels from each season were averaged over the entire year, 65% of the combined cohorts met recommendations because of high levels of activity for at least a few seasons a year. Combined with our finding that consistency in getting at least 1 hour a day of MVPA and 3 hours a week of VPA across all 4 seasons in a year is important for preventing excess weight gain in adolescent girls, this suggests that meeting the activity recommendations on average through high levels of activity for 1 or 2 seasons and low levels the other seasons does not have equivalent benefits to meeting recommendations for all four season.

We observed a pattern of lower activity in the winter months, and highest activity during the summer months in both cohorts. The pattern does not support the hypothesis of increased weight gain during the summer months due to low levels of activity during school breaks, but rather suggests that adolescents may be more at risk for weight gain during the winter or that other factors such as excess energy intake plays a larger role than low summer activity. A previous analysis of the GUTS I cohort on physical activity and BMI changes from 1997 to 1998 found that BMI decreased in overweight girls who increased winter activity levels from one year to the next [5]. A trend towards lower BMI during summer months as compared to winter has been seen in a large study of adults aged 20-59 years old in the Netherlands that examined trends in BMI and waist circumference changes across seasons over a four-year period [35]. Mean BMI and waist circumference were lower in each summer season as compared to the previous winter season. Lower activity levels during the winter months as compared to other seasons have been seen in some recent studies [7, 22, 41-43]. Preschool children in Northern Ireland were found to have decreased activity during the winter as compared to the spring, as measured by pedometers. Lower activity levels in the winter compared to the other seasons were seen in parental reports of physical activity among Canadian preschoolers [42], and in UK 11- and 12-year-olds as measured by accelerometers [22]. A study of U.S. adults in Massachusetts found increased activity during the summer in comparison to the winter [43]. In contrast, a nationally-representative, longitudinal study of U.S. adolescents found lower participation rates in summer sports and increased risk for obesity in youth who did not participate in organized summer sports compared to those who did [44].

When the low levels of winter activity are considered in addition to the importance of meeting recommendations each season to prevent excess weight gain, there are national policy implications for schools. There is no federal law requiring physical education in U.S. schools, and policies for physical education and extra-curricular physical activity opportunities vary by individual states and districts [45]. Promoting adequate levels of MVPA and VPA during the winter, fall, and spring, when school is in session and activity tends to be lower for both girls and boys will help ensure that they meet MVPA and VPA recommendations during these seasons. Middle and high school physical education courses and after-school sports programs that include vigorous physical activity may play an important role in preventing overweight in adolescent girls and possibly adolescent boys. Evidence suggests that physical education programs in school affect adolescent activity levels [46-48]. A recent study from the National Longitudinal Study of Adolescent to Adult Health found the number of physical education classes an adolescent participated in each week during high school to be associated with increased MVPA levels during high school [47]. A review of over 300 studies found that school-based policies including mandatory physical education, classroom activity breaks, and active commuting to school all had larger effects on adolescent MVPA levels than built environment changes [48]. A 2013 Cochran review of randomized controlled trials for school-based activity programs found that school-based interventions had positive effects on increasing the proportion of children and adolescents who engaged in MVPA as well as on increasing duration of physical activity [46].

There is also evidence that physical activity patterns established in high school and maintained into adulthood impact long term weight gain, especially among women, with high levels of activity being beneficial [49, 50]. Young adults who were in the highest sex-specific tertile of moderate-vigorous activity at baseline in the Coronary Artery Risk Development in Young Adults (CARDIA) study gained less weight and had smaller increases in BMI and waist circumference over the 20 year follow-up [49]. In the National Longitudinal Study of Adolescent Health, for adolescents participating in extracurricular and in-school physical education physical activity, each additional day of participation each week decreased the odds of being overweight five years later as an adult by 5%, mainly through maintenance of normal weight [50]. Participation in physical education 5 days a week reduced odds of overweight by 28%.

Cross-sectional research has shown an association between weight and meeting national activity recommendations, with adolescents who are overweight being less likely to meet recommendations [51-54]. A cross-sectional study across 12 countries, including the United States, of children ages 9-11 found that those with higher levels of MVPA and VPA, respectively, had lower odds of obesity in both girls and boys [55]. They also found that children who attained at least 55 min/day of MVPA (approximately meeting recommendations) were at lower odds of being obese. Similarly, in the cross-sectional HELENA study of European adolescents, those overweight and obese boys and girls were less likely to meet MVPA recommendations [56]. Both studies relied on activity measurements taken over several days within a single season. Our longitudinal results on incident overweight support these conclusions for MVPA in girls, and VPA in both genders, but we did not see a similar association for MVPA preventing overweight in boys. This finding may be due in part to our use of BMI cut-points to define overweight. Highly active adolescent athletes are more likely to be misclassified as overweight or obese [57, 58]. A study looking at classification of obesity using body fat percentage measured by skin-fold thickness compared to

BMI cut-points in adolescent athletes found athletes were more likely to be classified as obese by BMI than by body fat percentage [57]. The type of sport that boys participate in may also play a role, as certain sports may be associated with higher BMI due to increased muscle mass [58].

It is important to acknowledge that there are some limitations to the current study. First, the sample was largely white and the participants are children of nurses, thus it is unclear whether the results are generalizable to non-white youth or youth from a low socioeconomic status. Although the participants live throughout the United States, neither GUTS nor GUTS 2 is a representative sample, so prevalence of US youth meeting recommendations cannot be inferred from our study. In addition, the physical activity levels, as well as weight and height, were based on self-reports on an annual survey, and could be impacted by measurement error. When compared to physical activity measured by accelerometer in adolescents, self-report of physical activity tends to be overestimated [59]. Finally, we used BMI cut-points to classify the outcome, which could contribute to misclassification of the overweight status in adolescent athletes [58]. However, the longitudinal design, large sample size, seasonal, activity specific exposure measurements, and repeated measures are all strengths of the study.

Conclusion

Physical activity among adolescents varies by season. Averaging physical activity over the year may miss these variations. Girls who do not meet moderate to vigorous activity guidelines consistently for at least three to four seasons a year may be at increased risk of weight gain during adolescence. Boys and girls who do not meet vigorous-activity recommendations for at least three or four seasons may also be at increased risk of overweight, but further study is needed.

Appendix: Supplemental Materials

Table 2.5 Baseline Spearman Correlations between SSB, TV, Fried Foods away from home and weekly MVPA

	SSB	TV	Fried Food	Activity
SSB (svgs/day)	1.00	0.24	0.24	0.14
TV (hours/day)	0.24	1.00	0.22	0.06
Fried Foods (svgs/wk)	0.24	0.22	1.00	0.09
Activity (hours/week	0.14	0.06	0.09	1.00

(p<.0001 for all correlations)

Table 2.6 Odds ratios for becoming overweight each year among adolescents who do not meet physical activity recommendations averaged over the year

	Moderate-Vigorous Activity	Vigorous Activity
Girls	OR (95% CI)	OR (95% CI)
Model for physical activity		
Meets recommendations on average (reference)		
Does not meet on average over year	1.07 (0.96, 1.19)	1.13 (1.01, 1.27)
Boys		
Model for physical activity		
Meets recommendations on average (reference)		
Does not meet on average over year	0.88 (0.78, 1.00)	1.09 (0.97, 1.22)

*Moderate-Vigorous Recommendations: 7 hours a week or more of moderate to vigorous level physical activity
Vigorous Activity Recommendations: 3 hours a week or more of vigorous level activity
**Adjusted for Follow-up time between surveys, Cohort, age, race, menstrual status (girls), tanner stage (boys), and climate region of country,
TV (h/d), SSB (servings/day), Fried foods eaten away from home (servings/week)

Table 2.7 Odds ratios for becoming overweight each year among adolescents who do not meet physical activity recommendations for all 4 seasons

	Moderate-Vigorous Activity[a]	Vigorous Activity[a]
Girls	OR[c] (95% CI)	OR[c] (95% CI)
<u>Model for physical activity</u>		
Meets recommendations on average (reference)		
Does not meet on average over year	0.87 (0.73, 1.03)	1.11 (.90, 1.38)
Meets recommendations for 3 or 4 Seasons (reference)		
Meets for 0, 1 or 2 seasons	1.31 (1.11, 1.55)	1.02 (.83, 1.25)
Boys		
<u>Model for physical activity</u>		
Meets recommendations on average (reference)		
Does not meet on average over year	0.97 0.79, 1.19)	1.04 (0.88, 1.23)
Meets recommendations for 3 or 4 Seasons (reference)		
Meets for 0, 1 or 2 seasons	0.89 (0.74, 1.08)	1.06 (.90, 1.25)

[a]Moderate-Vigorous Recommendations: 7 hours a week or more of moderate to vigorous level physical activity
[b]Vigorous Activity Recommendations: 3 hours a week or more of vigorous level activity
[c]Adjusted for Follow-up time between surveys, Cohort, age, race, menstrual status (girls), tanner stage (boys), climate region of country, TV (h/d), SSB (servings/day), Fried foods eaten away from home (servings/week)

Paper Three: A prospective study of television watching and weight gain among preschoolers and young children – are changes in diet and sleep to blame?

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Abstract
Background: There is a well-established association between hours spent watching television and increased risk of childhood overweight. Television viewing among preschool age children is associated with increased risk for poor diet quality and shorter sleep duration. However, it is unclear how television impacts sleep and diet quality to effect changes in early childhood adiposity. Our purpose was to assess the time-varying relationship between television viewing starting in early childhood on childhood adiposity, and the extent to which sleep and diet quality mediate this association.

Methods: Project Viva is an ongoing pre-birth cohort in Eastern Massachusetts with data collection completed through mid-childhood (7-10 years). We conducted in-person visits or mailed surveys prenatally, at birth, and 6 months, and then yearly beginning at age 1 year, to obtain information on television watching. We obtained children's heights and weights from in-person visits and medical records.

We categorized the main exposure, hours per week of television viewing, using American Academy of Pediatrics (AAP) age-based recommendations on screen time. The main outcome was incident overweight/obesity (BMI $\geq$ 85th percentile for age and sex) from early (age 3 years) to mid-childhood (age 7 years). We assessed four time intervals, with television measured at the start of each interval, and BMI z-score assessed at the end: 3 -4 years old, 4-5 years, 5-6 years, and 7-8 years. We fit generalized linear models for longitudinal binary data using generalized estimating equations (GEE) to model incident overweight/obesity. All models were adjusted for time period (categorially), maternal pre-pregnancy BMI and education, and child sex and race/ethnicity.

Results: Of the 540 eligible participants for the incident overweight analysis, 51% watched >= 2 hours/day of television at age 3 years. Children who watched more than the American Academy of Pediatrics recommended amount of television (2 hrs /day) had an adjusted 1.36 times the odds of becoming overweight each year (OR 1.36, 95% CI 0.89, 2.08) compared to those who watched < 2 hours/day. Additionally adjusting for sleep duration, intake of sugar-sweetened beverages (SSB), and fast food did not attenuate the odds ratio (OR 1.40, 95% CI 0.90, 2.16).

Conclusion: In conclusion, watching two or more hours a day from 3- to 7-years of age was associated with a suggested increase in risk of overweight. Sleep duration and intake of SSBs and fast food did not appear to mediate the association between television exposure and overweight in mid-childhood.

Keywords: television, childhood obesity, sleep, SSB, fast food

Background

Over one third of U.S. children are overweight or obese [60]. Studies have linked being overweight in infancy, childhood, and adolescence with a variety of negative health outcomes in both childhood and adulthood. Starting at age 2 years, obese children and adolescents (BMI > 95^{th} percentile for age and height) are more likely to have inflammatory changes at the cellular level, hyperlipidemia, hypertension, impaired glucose tolerance, type 2 diabetes, and sleep apnea [61-66]. In addition, obese children are at risk for lowered self-esteem, and associated increased rates of sadness, loneliness, and nervousness, and increased likelihood of engaging in high-risk health behaviors such as smoking and drinking alcohol [67].

Childhood obesity is also associated with increased risk for various diseases in adulthood. Starting in infancy and continuing throughout adolescence, overweight and obesity increase the risk for adult obesity [68-70]. In a cohort of children in East Boston, overweight in childhood and early adolescence was associated with 5.1 times the odds of developing hypertension in young adulthood [71], and in a study of Finnish children, with 2.9 times the odds of developing metabolic syndrome in adulthood [72]. Increased BMI in late childhood and early adolescence increases the risk for cardiovascular disease and both fatal and nonfatal acute myocardial infarction in adulthood [73, 74].

Although there is a well-established association between hours spent watching television and increased risk of childhood overweight and obesity, there are still unanswered questions regarding the time-varying effect of television time beginning in early childhood on adiposity changes from early to mid-childhood and how known obesity risk factors, such as sleep and diet, mediate the effect. Longitudinal studies have demonstrated a dose-response increase in childhood adiposity with hours spent viewing television across different ages and populations [11, 75, 76]. However, these studies often focus on the correlation over short time-periods.

Television viewing among preschool age children is associated with increased risk for poor diet quality [77, 78]. It is also associated with shorter sleep duration from infancy through mid-childhood in the Viva cohort [79]. While sleep and dietary intake are both associated with childhood adiposity, [80-83] it is unclear the extent to which they mediate the relationship between television screen time and adiposity. Our objectives were to examine the association of longitudinal, time-varying television exposure starting in preschool on changes in adiposity through mid-childhood, and assess the mediation of dietary intake and sleep duration on the association of television exposure and adiposity.

Methods

Study Design and population

Project Viva is an ongoing pre- birth cohort study focused on maternal and child health and development [84]. We recruited pregnant women from eight obstetric offices of Atrius Harvard Vanguard Medical Associates (HVMA), a large multi-specialty urban/suburban group practice in Eastern Massachusetts between 1999 and 2002. The human subjects committees of Harvard Pilgrim Health Care, Brigham and Women's Hospital, and Beth Israel Deaconess Medical Center approved the study protocols. Women were eligible for the study if they were fluent in English, gave informed consent, had a gestational age less than 22 weeks at the first prenatal visit, received prenatal care at one of the selected HVMA practices, and planned to deliver at Brigham and Women's Hospital (BWH) or Beth Israel Deaconess Medical Center. We excluded women if they planned to terminate the pregnancy, planned to move from the local Eastern Massachusetts area before the end of the initial follow-up period of six-months after delivery, or had multiple gestation (i.e. twins, triplets etc).

We enrolled 2670 women during pregnancy in the late first trimester (median 9.9 weeks of gestation).Subsequent in-person study visits occurred at mid-pregnancy (median 27.9 weeks of gestation), delivery, infancy (median 6.3 months), early childhood (median 3.2 years) and mid-childhood (median 7.7 years). Participants living too far away and those unable to meet with research investigators in person had the option of completing a self-administered questionnaire with an additional research assistant administered interview by telephone. We administered mailed questionnaires at child ages 1, 2, 4, 5 and 6 years. For those participants who provided written informed consent for medical record review, we obtained clinical measurements of lengths, heights and weights from birth onwards. Of the initial 2670 women we enrolled, 2128 had live births and were eligible for enrollment in the study. Of these, 1449 children completed the early childhood visit (which ranged in age from 2.8 to 6.3 years). All children participating in Project Viva with anthropometric measurements for at least two sequential years between early childhood (ages 33 months) and mid-childhood (93 months) were eligible for study inclusion. Among the 1214 children who had baseline (ages 33 to <45 months) data on television, we excluded those with missing baseline BMI-Z (n=195), those who were overweight at baseline (n=269), and those with missing BMI-Z at the first follow-up (n=312). After these exclusions, 438 children were eligible for the present analysis at the start of the 3-4 year old interval (see table 3.1). 540 children contributed data to at least one time interval for the incident overweight analysis over the course of the study. Excluded children had similar baseline characteristics to children eligible for the incident overweight analysis. Among the 1588 excluded participants, we found similar proportions of sex, race/ethnicity, and similar mean in maternal pre-pregnancy BMI. Excluded children were more likely to have mothers without a college degree (72% among eligible participants vs 62% among excluded).

Table 3.1 Study Flow

Time Period: Ages 3 to 4 years	
N=1214	TV start
1019	BMI-z start not missing
750	BMI-z <85th %tile start
438	BMI-z end not missing
4 to 5 years	
N=1238	TV start
626	BMI-z start not missing
433	BMI-z <85th %tile start
308	BMI-z end not missing
5 to 6 years	
862	TV start
344	BMI-z start not missing
260	BMI-z <85th %tile start
213	BMI-z end not missing
6 to 7 years	
N=940	TV start
341	BMI-z start not missing
255	BMI-z <85th %tile start
208	BMI-z end not missing

Measures

Main Exposure: TV Viewing

The main exposure was early to mid-childhood television. We measured time spent watching or exposed to television on the 3, 4, 5, 6 year old questionnaires. We asked mothers, “In the past month, on average, how many hours a day does your child spend sitting still watching TV/videos?” Mothers selected separate responses for weekday and one weekend day. We assigned the middle numeric value for each response category and averaged the weekend and weekday hours to create a daily average. At age 3 years, response categories and the hours we assigned were none (assigned 0 hours), < 1 hour a day (assigned 0.5 hours), 1 to 3 hours a day (assigned 2 hours), 4 to 6 hours a day (assigned 5 hours), 7-9 hours a day (assigned 8 hours), and 10 or more hours a day (assigned 10 hours). For ages 4 through 6 years, response categories and hours we assigned were none (0 hours), < 1 hour a day (0.5 hours), at least 1 but less than 2 hours a day (assigned 1.5), 2-3 hours a day (assigned 2.5 hours), 4-6 hours a day (assigned 5 hours), and 7 or more hours a day (assigned 7 hours). We adapted this measure of television time from the National Longitudinal Survey of Youth Child Study [85]. Maternal estimates of child’s weekly television viewing time in 5-year-olds correlates well with maternal daily diaries of child television viewing (r=.60), though it may overestimate television viewing compared to diaries and direct observation [86].

To ensure that we did not assess the outcome before the exposure, we limited the age ranges for television exposure to between -3 and <+9 months of the target age each year, using the child’s age when the mother returned the survey (table 3.2). For example, a three-year old’s (target age 36 months) television exposure could be measured anywhere between age 33 months and <45 months. We similarly limited our outcome measurements to specific age ranges (see below). We based our classification of television viewing on the recommendation of the American Academy of Pediatrics that children’s total media time be limited to less than 2 hours per day over age 2 years [87]. We evaluated television as a dichotomous variable with >= 2 hour per day defined as above the AAP recommended amount of television viewing time.

Table 3.2 Range in child age for exposure and outcome

1 year interval	TV minimum to <maximum Age, months	BMI-z minimum to maximum Age, months
TV 3 y (36 m) to overweight 4 y (48 m)	33 to <45	45 to 51
TV 4 y (48 m) to overweight 5 y (60 m)	45 to <57	57 to 63
TV 5 y (60 m) to overweight 6 y (72 m)	57 to <69	69 to 75
TV 6 y (72 m) to overweight 7 y (84 m)	69 to <81	81 to 87

Main Outcome: Change in Weight Status

The main outcome was the yearly development of overweight, which we assessed 4 times from age 4 years (we used the closest BMI z-score to 48 months, range 45-51 months) to 7 years (closest BMI z-score to 84 months, range between 81-87 months). Trained research assistants measured standing and sitting height, and weight at the early and mid-childhood in-person study visits. To ensure measurement validity, research assistants completed biannual trainings in standardized measurement techniques. Inter- and intra-rater measurement errors were within published reference ranges [88]. The research assistants measured height to the nearest 0.1 cm using a calibrated stadiometer and weight to the nearest 0.1 kg using a calibrated scale.

We used clinical measurements of height and weight when research measurements were not available. We limited both research and clinical height and weight measurements to those that were +/- 3 months from the target age each year (see table 3.2). To ensure consistency, when multiple clinical measurements were available, we used the measurement closest to the target age.

We used measured height and weight to compute body mass index (BMI) with the formula: BMI = weight/height^2 (kg/m^2). Because BMI varies with both age and sex in children, we calculated age-sex specific BMI z-scores using the 2000 Centers for Disease Control and Prevention growth reference data [89]. Transforming age-sex specific BMI into a z-score represents the child's weight, adjusted for height, sex, and age, relative to a distribution in the CDC's U.S. reference population [90].

Overweight was defined as a BMI z-score equal or greater than the 85th percentile for age and sex on the CDC 2000 growth charts (BMI z-score =>1.04) [91]. In a recent analysis of this cohort, Boeke et al. found BMI to be highly correlated with total fat mass as measured by DXA at the mid-childhood visit (r = 0.83), indicating BMI to be a reasonable measure of adiposity in these children [88].

The primary outcome was becoming overweight between successive surveys. We censored children who were overweight or obese at the beginning of each survey (i.e. eligible sample was at risk for becoming overweight between successive anthropometric measurements). If overweight children became normal weight on a successive survey, they were eligible again for analysis. In secondary analyses, we focused on change in BMI z-score between assessments. We included children who were overweight or obese at the beginning of the time-period in the BMI z-score change analyses.

Mediators

Sleep Duration

We measured sleep at each survey period. Mothers reported sleep in response to the question "In the past month, on average, how long does your child sleep in a usual 24-hour period? Please include morning naps, afternoon naps, and nighttime sleep." For the three-and 4-year-old visits, mothers selected from categories of sleep, ranging from less than 9 hours to 14 or more hours per 24-hour period. For all other survey periods (5 and 6 years), mothers reported sleep as average hours and minutes in a 24-hour period. Mothers reported sleep hours separately for weekdays and weekend days on the 3 and 4-year old surveys. We did not differentiate between weekdays and weekend days on the 5-year and 6-year old surveys. We considered sleep as a continuous variable in hours/day.

Dietary intake

We measured some aspects of dietary intake, such as types of beverages consumed daily and frequency of dining out, at each survey period. In the present analysis, we focused on sugar-sweetened beverage (SSB) and fast food intake. We measured SSB intake at each survey period beginning with the early childhood (3-year) questionnaire using maternal response to a food frequency questionnaire on child diet. We combined responses to frequency of fruit drinks and full sugar soda to create the average servings of SSB per day at each survey period. We treated SSB as a continuous variable in the analysis.

We measured fast food intake using maternal report about the child's average fast food intake in the past month. Mothers reported fast food on each survey beginning with the early childhood questionnaire. Their responses were never/less than once per month, 1-3 times per month, once per week, 2-4 times per week, 5-6 times per week, and once per day or more. We treated fast food as a continuous variable in average servings/week.

Covariates

We adjusted all analyses for the child's age, sex, and time period (as a categorical variable with the baseline ages 3-4 year interval as the reference). We considered the following covariates for possible confounding: maternal education, marital status pre-pregnancy BMI, pregnancy weight gain during pregnancy, and smoking during pregnancy and child's sex and race/ethnicity.

Data Analysis

Descriptive Statistics and Bivariate associations

We assessed frequencies or means/SD of all exposure, outcomes, mediators, and covariates at each survey period. We used Spearman correlation matrix and correlation coefficients to assess bivariate associations between study variables. We conducted all analyses using SAS 9.3 (Cary, N.C.)

General statistical approach

We fit generalized linear models with unstructured covariance for longitudinal binary data using generalized estimating equations (GEE) to model incident overweight from one survey to the next. GEE allow for time-varying covariates in an unbalanced data design and missing data. We assumed missing data was missing at random. In the entire population (including those with BMI z-score => 1.04, we fit linear mixed effects models with random intercept and unstructured covariance to assess change in BMI z-score between successive surveys using Proc MIXED. We allowed television, sleep, SSB, and fast food to vary at each time point. To assess for mediation, we fit adjusted models with and without sleep, SSB, and fast food intake and we compared the beta-coefficients between models. We examined sleep, SSB and fast food as continuous variables. We excluded marital status, pregnancy weight gain and maternal smoking during pregnancy from the final models, as they did not change the results.

Results

At age 3 years, amongst those who were not overweight at baseline (BMI Z < 1.04), 225 (51%) of the participants were female and 302 (69%) were white, 53 (12%) black, and 83 (19%) other race/ethnicity. 324 (74%) of the mothers had a college degree and 413 (95%) of the mothers were married or cohabitating at the study enrollment. Over the 4 years of the study, 105 (9%) of the children became overweight (BMI =>85th percentile for age and sex). At age 3 years, the children watched an average of 1.6 hours (SD 1.0) television/day (table 3.6 in supplemental materials for paper three). They slept an average of 11.2 hours (SD 1.2) per day, consumed 0.2 (SD 0.4) sugar sweetened beverages/ day and had 0.6 servings (SD 0.6) of fast food/week.

Table 3.3 shows the sample characteristics stratified by television exposure. At age 3 years, 51% of the children watched more than the recommended amount (>2 hours a day) of television. Television watching decreased among school age children (ages 5 to 7), with only 15% watching more than the recommended amounts at age 6 years. Males and females spent a similar amount of time watching television.

Compared to their peers, children who watched more than the recommended amount of television had a lower percentage of college-educated mothers (table 3.3). They consumed slightly more SSB/day, and had higher weekly fast food intake than low watchers. Hours of television watched and sleep were not strongly correlated (Spearman r=-.06 at 3 years, and r=-0.14, at 6 years (supplemental table 3.6). There were no differences in mean hours of sleep by those who watched more than the recommended amount of television (11.1 hours (SD 1.2)) versus those who watched less (11.3hours (SD 1.1)) at age 3 (table 3.3).

Table 3.3 Participant characteristics, total and according to TV exposure, at each time interval (N=540 incident overweight analysis)

	TV 3 years h/d		TV 4 years h/d		TV 5 years h/d		TV 6 years h/d	
	N=438		N=308		N=213		N=208	
TV hours/day recommendation	>=2 hours	< 2 hours	>=2	<2	>=2	<2	>=2	<2
N (%)	n=225 (51)	n=213 (49)	n=86 (28)	n=222 (72)	n=44 (21)	n=169 (79)	n=32 (15)	n=176 (85)
Age at start, mo	37.7 (1.7)	37.9 (1.7)	49.2 (1.0)	49.1 (0.7)	61.6 (1.0)	61.4 (0.8)	73.0 (0.4)	73.1 (0.7)
Change in age, mo	10.9 (1.9)	10.8 (1.9)	11.4 (1.2)	11.6 (1.2)	11.5 (1.4)	11.5 (1.2)	11.8 (1.2)	11.8 (1.2)
BMI-z start	-0.00 (0.71)	-0.02 (0.79)	0.11 (0.70)	0.00 (0.71)	0.23 (0.72)	-0.01 (0.75)	-0.05 (0.71)	-0.00 (0.75)
BMI-z end	0.18 (0.82)	0.13 (0.81)	0.16 (0.77)	0.01 (0.80)	0.41 (0.77)	-0.03 (0.75)	-0.10 (0.76)	-0.09 (0.74)
Change in BMI-z	0.18 (0.60)	0.16 (0.64)	0.05 (0.52)	0.01 (0.46)	0.18 (0.46)	-0.02 (0.42)	-0.05 (0.45)	-0.09 (0.42)
Overweight at end of interval, %.	31 (13.8)	26 (12.2)	9 (10.5)	18 (8.1)	7 (15.9)	5 (3.0)	2 (6.3)	7 (4.0)
Obese at end, %	3 (1.3)	5 (2.3)	1 (1.2)	0 (0.0)	1 (2.3)	1 (0.6)	1 (3.1)	0 (0.0)
Sleep duration, h/d	11.1 (1.2)	11.3 (1.1)	10.7 (1.2)	10.9 (1.0)	10.3 (1.1)	10.7 (1.0)	10.3 (1.1)	10.3 (0.9)
SSB, serv/d	0.3 (0.5)	0.2 (0.3)	0.3 (0.5)	0.2 (0.8)	0.7 (1.1)	0.2 (0.5)	0.7 (1.3)	0.3 (0.5)
Fast food, serv/wk	0.7 (0.7)	0.4 (0.5)	0.8 (1.1)	0.4 (0.4)	0.8 (0.7)	0.4 (0.4)	0.7 (0.7)	0.4 (0.4)
Female (%)	116 (51.6)	109 (51.2)	34 (39.5)	114 (51.4)	22 (50.0)	89 (52.7)	12 (37.5)	86 (48.9)
Race/ethnicity, %								
. Black	30 (13.3)	23 (10.8)	17 (19.8)	23 (10.4)	2 (4.5)	11 (6.5)	1 (3.1)	15 (8.6)
. White	148 (65.8)	154 (72.3)	48 (55.8)	160 (72.4)	34 (77.3)	126 (74.6)	27 (84.4)	131 (74.9)
. Other	47 (20.9)	36 (16.9)	21 (24.4)	38 (17.2)	8 (18.2)	32 (18.9)	4 (12.5)	29 (16.6)
Maternal BMI, kg/m2 (SD)	24.6 (4.6)	23.9 (5.0)	24.7 (5.4)	23.6 (4.5)	23.8 (4.2)	23.8 (4.4)	23.5 (3.9)	23.3 (4.0)
College graduate, %	152 (67.6)	172 (81.1)	49 (57.0)	176 (80.0)	26 (59.1)	133 (78.7)	19 (59.4)	141 (80.6)

SSB consumption was moderately correlated with hours of television, ranging from Spearman r=0.19 at age 3 years to r=0.29 at age 6 years (supplemental table 3.6). Frequency of fast food consumption each month also had moderate positive correlations with hours of television watched (supplemental table 3.6). Both SSB and fast food were moderately correlated with each other (Spearman r=0.32 at age 3 years) and inversely correlated with sleep.

In the sex and age-adjusted model, children who watched more than the recommended amount of television had 1.46 (95% CI 0.96, 2.24) times the odds of becoming overweight for each time interval. After adjusting for time period, maternal pre-pregnancy BMI and education, and child sex and race/ethnicity, there was a suggestion that children who watched more than the recommended amount of television had an increased risk of becoming overweight over each one year time interval (odds ratio(OR)=1.36, 95% confidence interval (CI) 0.89, 2.08; table 3.4). Sleep, SSB and fast food intake did not substantially attenuate the association between higher than recommended television viewing and odds of becoming overweight. After adjusting for all covariates, including the potential mediators sleep, SSB and fast food, there was a suggestion that children who watched more than the recommended amount of television were 40% more likely to become overweight each year (OR 1.40, 95% CI 0.90, 2.16). For all children, including those who were overweight or obese, we did not observe a significant gain in BMI Z score each year (b =0.01(-0.04, 0.07)) among those who watched more hours of television than the AAP recommends compared to those watchers who met the recommendations in the fully adjusted models (table 3.5).

Discussion

In this prospective cohort study, we found that children ages 3 to 7 years who watched more than the AAP recommended amount of television each day may be more likely had 36% to become overweight. We did not observe mediation by sleep, sugar sweetened beverage intake or fast food intake from ages 3 to 7 years, despite the fact that TV viewing was (weakly) positively correlated with SSB consumption and fast food consumption and weakly negatively correlated with hours of sleep. We also observed a small increase in BMI-z score each year among children who watched more than the recommended amounts of television.

Table 3.4 Odds ratios for becoming overweight for exceeding versus meeting American Academy of Pediatrics' television viewing recommendations

Model[a]	Exposure	OR (95% CI)
Model 1. Unadjusted	TV > recommendation	1.80 (1.21, 2.68)
Model 2. Adjusted for age and sex	TV > recommendation	1.46 (0.96, 2.24)
Model 3. Model 2 + covariates[b]	TV > recommendation	1.36 (0.89, 2.08)
Mediators		
Model 4. Model 3 + sleep duration h/d	TV > recommendation	1.38 (0.90, 2.11)
	Sleep duration h/d	0.98 (0.80, 1.18)
Model 5. Model 3 + SSB serv/d	TV > recommendation	1.39 (0.91, 2.12)
	SSB serv/d	1.06 (0.75, 1.50)
Model 6. Model 3 + fast food serv/wk	TV > recommendation	1.35 (0.88, 2.08)
	Fast food serv/wk	1.04 (0.78, 1.38)
Model 7. Model 3 + sleep duration h/d + SSB serv/d + fast food serv/wk	TV > recommendation	1.40 (0.90, 2.16)
	Sleep duration h/d	0.99 (0.82, 1.20)
	SSB serv/d	1.03 (0.73, 1.48)
	Fast food serv/wk	1.04 (0.79, 1.38)

[a]Data from eligible population (excludes those with BMI Z => 1.04), N=540 participants
[b]Model adjusted for sex, age, time-period, child race/ethnicity, maternal education and maternal pre-pregnancy BMI

Table 3.5 Model for yearly change in BMI-z score for exceeding compared to meeting AAP television viewing recommendations

Model[a]	Exposure	β (95% CI)
Model 1. Unadjusted	TV > recommendation	0.08 (0.02, 0.13)
Model 2. Adjusted for age and sex	TV > recommendation	0.04 (-0.01, 0.10)
Model 3. Model 2 + covariates[b]	TV > recommendation	0.01 (-0.04, 0.07)
Mediators		
Model 4. Model 3 + sleep duration h/d	TV > recommendation	0.01 (-0.04, 0.07)
	Sleep duration h/d	-0.01 (-0.04, 0.02)
Model 5. Model 3 + SSB serv/d	TV > recommendation	0.02 (-0.04, 0.07)
	SSB serv/d	0.00 (-0.03, 0.03)
Model 6. Model 3 + fast food serv/wk	TV > recommendation	0.02 (-0.04, 0.07)
	Fast food serv/wk	-0.02 (-0.05, 0.02)
Model 7. Model 3 + sleep duration h/d + SSB serv/d + fast food serv/wk	TV > recommendation	0.02 (-0.04, 0.08)
	Sleep duration h/d	-0.01 (-0.04, 0.02)
	SSB serv/d	0.00 (-0.03, 0.03)
	Fast food serv/wk	-0.02 (-0.05, 0.02)

[a]Data from entire population (includes those with BMI Z => 1.04), N=670 participants
[b]Model adjusted for sex, age, time-period, child race/ethnicity, maternal education and maternal pre-pregnancy BMI

Our finding of a suggested increase in the odds of overweight among children who exceed the AAP recommendations for childhood television time support keeping television hours within the recommended limits. Higher television exposure in children under age 5 is associated with other negative health outcomes such as decreased vocabulary, math and attention skills [92], increased developmental and behavioral problems [93], and detrimental effects on cognitive development [94].

Television viewing may increase the risk of overweight and obesity through multiple mechanisms including increased food consumption and disrupted sleep patterns. In 2009 the Nielsen company reported that 97% of children's (ages 2-11) viewing was through live television that includes commercials [95]. Additionally, kids ages 2-6 years watched more commercials both through live television and through playback on DVD, VOD and DVR than kids ages 6-11 years [95]. According to the World Health Organization, food dominates marketing to children, with the majority of advertisements focusing on soft drinks, sugary cereals, candy, snacks and fast food restaurants [96]. This food marketing may affect childhood adiposity by leading children to increase their requests for purchase of energy dense foods, and increased consumption preference for such foods [96, 97]. As Nielsen stated in a report for marketers, "After all, how can any parent say no to the toddler pitching a fit for a box of cereal, the latest toy, or a new video game? [98]."

Indeed, a 2012 systematic review of eleven studies on television and diet in children ages 2-6 found increased TV viewing to be associated with adverse dietary patterns including increased consumption of energy dense foods and drinks [99]. In an analysis of the Early Childhood Longitudinal Survey-Kindergarten Cohort and Nielsen data, exposure to 100 incremental TV ads for SSB and fast food from 2002 to 2004 was associated with a 9.4% rise in children's soft drink consumption and a 1.1% rise in fast food consumption in 2004 [100]. Several longitudinal studies suggest a potential mediating relationship of diet on the association between television and adiposity in children [101, 102]. In the Longitudinal Study of Australian Children (LSAC), dietary intake of high fat and high sugar foods (such as potato chips, juice and soft drinks) mediated the effects of television on adiposity in children at age 6 years (B=-.01), but not in younger children [103].

There is some evidence in the literature for increased television watching leading to shorter sleep duration and subsequent increased risk of overweight in children. Magee et al. found that sleep duration at age 4 years among the 2984 LSAC children was inversely associated with higher BMI at age 8 (B=-.07) [104]. Sleep duration at age 4 years was also inversely associated with television viewing at age 6 years (B=-.07), and television viewing at 6 years attenuated the association between sleep duration and BMI (B=-.01). Several cross-sectional and prospective studies have associated shorter sleep durations with increased BMI-Z scores and increased risk for overweight and obesity in childhood [105-112]. Studies have also linked increased television time with decreased sleep [79, 104]. Nevertheless, we did not find that sleep mediated the relationship between television viewing and excess weight gain. We did not observe strong correlations between the amount of television watched and hours of sleep over time in the cohort. It is possible that the mediation by sleep on the association between television and weight gain becomes stronger in later childhood and early adolescence.

Strengths and Limitations

Our study has several strengths. We evaluated television, weight status, sleep, and many of the covariates annually, allowing us to assess the impact of changes in the exposure over time and better control for time varying confounding. The longitudinal study design allowed us to assess incident changes in weight status; it eliminates the possibility of reverse causation between exposure and outcome seen in cross-sectional studies [113]. We minimized measurement error in the outcome by using research measurements when available and clinical measurements at the other time points. In the Avon Longitudinal study, the use of clinically measured height and weight in infants and children over age 8 months was found to have a high level of agreement with research measured anthropometrics and no systematic bias [114].

One limitation to our study is that the television viewing data were available only as maternal report, and may be subject to under- or over-reporting. However, validation studies of maternal recall of child TV time in other cohorts indicate it correlates well with more objective measures of TV time, such as video-taped observation [86]. Another limitation was that we changed the categorical responses for television time between the 3-year survey and the subsequent year. As a result, we assigned a value of 2 hours for children in the 3-4 year interval whose mothers reported 1-3 hours of television a day. We classified these children as exceeding the AAP guideline of < 2 hours a day of television, when they may have been watching less than recommended. An additional limitation is that the children in Project Viva were born in the eastern Massachusetts area and most are from families with relatively high socioeconomic status. As a result, findings from the current study may or may not be generalizable to other children. Nonetheless, the sample was racially and socioeconomically diverse.

Conclusion

In this longitudinal birth cohort of U.S. children, watching two or more hours of television a day from 3 to 7 years may be associated with increased risk of overweight in children. Sleep, sugar sweetened beverage, and fast food intake do not appear to mediate the association between television viewing and overweight in early childhood. These findings support the American Academy of Pediatrics recommendations that children two and over limit their screen time to less than 2 hours a day.

Appendix: Supplemental Materials

Table 3.6 Spearman Correlation for each study year

N=540 *(Incident overweight analysis dataset(excluded if OW at start)*					TV h/d	Sleep h/d	SSB serv/d	FF serv/wk	BMI-z start	BMI-z end	Change BMI-z
Interval		N	Mean	SD	Spearman r						
TV 3 y to overweight 4 y	TV h/d	438	1.59	0.96	1.00	-0.06	0.19	0.24	-0.02	0.02	0.00
	Sleep h/d	432	11.16	1.16		1.00	-0.18	-0.06	0.00	0.02	-0.01
	SSB serv/d	436	0.21	0.43			1.00	0.32	-0.07	-0.06	0.02
	FF serv/wk	436	0.56	0.64				1.00	0.00	-0.01	-0.03
	BMI-z start	438	-0.01	0.75					1.00	0.68	-0.25
	BMI-z end	438	0.16	0.82						1.00	0.46
	Change BMI-z	438	0.17	0.62							1.00
TV 4 y to overweight 5 y	TV h/d	308	1.66	0.99	1.00	-0.02	0.28	0.24	0.08	0.07	0.03
	Sleep h/d	298	10.84	1.06		1.00	-0.07	-0.09	0.04	0.00	-0.04
	SSB serv/d	308	0.26	0.69			1.00	0.32	-0.02	0.00	0.03
	FF serv/wk	308	0.55	0.72				1.00	-0.03	0.02	0.11
	BMI-z start	308	0.04	0.71					1.00	0.78	-0.12
	BMI-z end	308	0.05	0.80						1.00	0.46
	Change BMI-z	308	0.02	0.48							1.00
TV 5 y to overweight 6 y	TV h/d	213	1.57	0.91	1.00	-0.16	0.26	0.30	0.12	0.21	0.17
	Sleep h/d	211	10.61	1.03		1.00	-0.16	-0.20	-0.06	-0.10	-0.10
	SSB serv/d	212	0.33	0.68			1.00	0.33	0.06	0.06	0.04
	FF serv/wk	212	0.48	0.49				1.00	0.10	0.14	0.12
	BMI-z start	213	0.04	0.75					1.00	0.83	-0.20
	BMI-z end	213	0.06	0.77						1.00	0.31
	Change BMI-z	213	0.02	0.44							1.00
TV 6 y to overweight 7 y	TV h/d	208	1.43	0.82	1.00	-0.14	0.29	0.30	0.03	0.03	-0.03
	Sleep h/d	207	10.33	0.89		1.00	-0.19	-0.09	0.04	0.07	0.08
	SSB serv/d	207	0.32	0.66			1.00	0.19	-0.04	-0.04	-0.01
	FF serv/wk	208	0.47	0.50				1.00	0.16	0.18	-0.02
	BMI-z start	208	-0.01	0.74					1.00	0.84	-0.24
	BMI-z end	208	-0.09	0.74						1.00	0.25
	Change BMI-z	208	-0.08	0.42							1.00

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