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The stability of children's weight status over time, and the role of television, physical activity, and diet

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ABSTRACT

Weight-related behaviors such as sedentary activity, physical activity, and diet have been the focus of efforts to prevent and reduce the occurrence of obesity and overweight in children, but few longitudinal studies have examined the effects of weight-related behaviors on changes in weight status over time in children. This study examines the effects of weight-related behaviors on subsequent changes in weight during childhood. We used the Early Childhood Longitudinal Study Kindergarten Cohort (ECLS-K), a nationally representative prospective cohort of children in the United States. Data, including anthropometric measures, were collected six times across 1998–2007 (analytic sample = 4938). We employed an autoregressive cross-lagged model in a structural equation model framework to assess the effects of behavioral factors -intake of fruit, vegetables, fast food and sugar-sweetened beverages, television viewing, and physical activity - on weight stability over time. BMI z-scores were highly stable throughout childhood: the standardized parameter estimates of BMI z-scores on subsequent-period BMI z-scores ranged from 0.79 to 0.86. BMI z-scores were least stable between Kindergarten and 1st grade but became highly stable between 3rd and 5th grades. After accounting for prior weight, behavioral factors had little effect on subsequent weight. The most important behavioral factor was TV viewing in the 1st and 3rd grades: an additional hour of daily TV viewing was associated with 0.04 higher BMI z-score. It is important to prevent excessive weight gain early in childhood, as weight patterns are long-lasting; the most important behavioral factor may be limiting children's screen time.

1. Introduction

Childhood obesity has become a major public health concern, with recent estimates in the United States showing 18% of children between the ages of 6 and 11 are obese (Ogden et al., 2014). Obesity in children is associated with a number of serious health problems, including asthma and sleep-disordered breathing, menstrual abnormalities, early onset of type 2 diabetes, and metabolic disorders (Institute of Medicine, 2005), as well as psychological risks such as depression and anxiety (Storch et al., 2007).

Evidence suggests that weight trajectories are established early in childhood (Franzese et al., 1998; Hesketh et al., 2004) and obesity in childhood is difficult to reverse (Kamath et al., 2008) and often persists into adulthood (Singh et al., 2008). For example, body mass index (BMI) at school entry is a strong predictor of obesity in adolescence (Niclasen et al., 2007). Studies beginning even earlier in life have shown that infants with high BMI are at higher risk of obesity later in childhood and adulthood compared with other children (Baird et al., 2005; Vogels et al., 2006). Many mechanisms have been suggested to explain the early development of weight trajectory, such as genetic and epigenetic factors, breastfeeding and early feeding practices, and family and environmental factors (Carnell et al., 2012; Skelton et al., 2011).

Although prior weight is a strong predictor of subsequent weight, not all children who become overweight or obese remain at the upper end of weight distribution throughout childhood (Huang et al., 2011). For example, in one study, about 13% of children who were overweight at age 7 became normal weight by age 11 (Wright et al., 2010). Weight-related behaviors, such as screen time, physical activity, and dietary choices, may play a role in the development or reversal of obesity (Carson et al., 2016; Danner, 2008; Janssen and Leblanc, 2010; Malik et al., 2006; Thibault et al., 2010). To some degree, behavior may overcome underlying predisposition to obesity, including genetic vulnerability. For example, evidence suggests that physical activity (Ahmad et al., 2013) and dietary restraint (Vogels et al., 2006) can attenuate genetic risk of obesity. Numerous interventions have been developed to target changing weight-related behaviors among school-aged children, but, so far, their effectiveness has been limited (Kamath et al., 2008). The persistence of obesity suggests the importance of investigating early causes and possible avenues of early intervention.

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Given the emphasis placed on behavior change in childhood obesity prevention interventions and policy recommendations (Waters et al., 2011; World Health Organization, 2016), the aim of this study was to explore the stability of weight and the effects of weight-related behaviors in determining children's weight status in elementary and middle school. We also aimed to investigate whether – contrary to current thinking - associations between presumed weight-related behaviors and weight status may be partly driven by reverse causality: i.e., a cross-sectional association between weight status and television viewing may be due in part to children who are already obese choosing to watch more television, rather than the accepted wisdom that watching more television leads to obesity (Carson et al., 2016). To examine such relationships, we used data from the Early Childhood Longitudinal Study (ECLS-K), a large and nationally representative longitudinal survey of children followed from elementary to middle school. We estimated an autoregressive cross-lagged panel model in a structural equation-modeling (SEM) framework that allowed us to examine changes in children's BMI z-score in relation to weight-related behaviors across time (Biesanz, 2012). By controlling for the previous period's measures, we aimed to assess whether behaviors believed to be related to weight, such as television viewing, physical activity, and dietary intake, predict changes in weight, or whether weight itself predicts changes in these behaviors.

2. Data and methods

The Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS-K), developed by the National Center for Education Statistics, followed a nationally representative cohort of children from kindergarten into eighth grade. During Kindergarten and grades 1, 3, 5, and 8, the survey included one-on-one direct child assessments, interviews with parents, teachers, and principals, and, in grades 5 and 8, interviews with children (Tourangeau et al., 2009). The ECLS-K is the only nationally representative longitudinal survey with objectively measured height and weight in this age group; these measures were collected twice per wave by trained assessors (U.S. Department of Education, 2004), thereby avoiding the bias of self-reported weight and height (Bogaert et al., 2003).

2.1. Variables

Height and weight were collected at each round in the ECLS-K. Using the 2000 CDC Growth Charts, we calculated standardized BMI using sex and age in months (Vidmar et al., 2013). We used the standard cutoffs of 95th and 85th percentiles to identify obesity and overweight, respectively.

We calculated hours of television viewing per day based on numerous indicators. In the Kindergarten wave of data collection, parents were asked how many hours per day the child watched television during weekdays and during the weekend. In 1st, 3rd, and 5th grades, parents were asked how much television the child watched per day during particular segments of the day during weekdays, and separately on Saturdays and Sundays. In 8th grade, children were asked how many hours of television they watched per day during weekdays and on weekends. During this wave, 58 children reported implausible viewing amounts; we top-coded the number of hours of television per day for these individuals at 18 h. For Kindergarten, 1st grade, 3rd grade, and 5th grade, there were 2, 3, 3, and 1 individuals with top-coded values, respectively.

In Kindergarten, grade 3, and grade 5, parents were asked: "In a typical week, on how many days does (CHILD) get exercise that causes rapid breathing, perspiration, and a rapid heartbeat for 20 continuous minutes or more?" In 8th grade, a similar question was asked of the children instead of the parents: "On how many of the past 7 days did you exercise or participate in physical activity for at least 20 minutes that made you sweat and breathe hard, such as basketball, soccer, running, swimming laps, fast bicycling, fast dancing, or similar aerobic exercise?".

In the 5th and 8th grades, children were asked how many times in the past week they consumed certain foods; we grouped foods together as healthy choices (fruits, green salads, carrots, and other vegetables) and as less healthy choices (fast food and sugar-sweetened beverages, including soda and juice drinks) and quantified servings per day. For green salad, for example, children were asked: "During the past 7 days, how many times did you eat green salad?" The responses were coded as: "I did not eat green salad during the past 7 days" (0 servings per day), "1 to 3 times during the past 7 days" (2/7), "4 to 6 times during the past 7 days" (5/7), "1 time per day" (1), "2 times per day" (2), "3 times per day" (3), "4 or more times per day" (4). Although children were also asked about purchases of snacks, sweets, and drinks at school, due to the large proportion of students who were unable to purchase these items at school (ranging from 61% in grade 5 to 23% in grade 8), we did not include these indicators.

When estimating the full model, we also included relevant covariates that may be associated with weight or with weight-related behaviors, including gender (male vs. female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and other), and socioeconomic status. Socioeconomic status at each grade was available as a composite continuous measure provided by the ECLS-K based on parent education, occupation, and household income at the time of interview.

2.2. Analysis

We used ECLS-K survey weights to maintain the nationally representative nature of the data across all waves of data collection, and produced survey-adjusted results. There were 4938 children with valid longitudinal sample weights and non-missing data for all variables at all waves.

After descriptive analyses, we constructed a cross-lagged longitudinal model to investigate the stability of children's weight over time and (1) whether weight-related behaviors were associated with subsequent BMI after accounting for the previous period's BMI, or (2) whether BMI was associated with subsequent weight-related behaviors. Our model, using a structural equation modeling framework, featured observed variables for physical activity, television and BMI z-score and latent variables for dietary quality based on observed measures for fruit, vegetables, sugar-sweetened beverages, and fast food consumption. At each time point, BMI z-score and weight-related behaviors were allowed to co-vary. We used robust maximum likelihood, also called pseudo-maximum likelihood (PML), to account for the complex survey design in the ECLS-K (Oberski, 2014). PML scales the chi-square model statistic and derived model fit measures and provides robust standard errors. We evaluated overall model fit, which was acceptable according to the root mean squared error of approximation (RMSEA) and the comparative fit index (CFI) (West et al., 2012) (Browne et al., 1993). The measurement models for healthy (fruit and vegetables) and unhealthy (sugar-sweetened beverages and fast food) dietary behavior had acceptable fits to the data. We used Stata 13.1(StataCorp, 2013) to produce descriptive statistics and R (3.1.1) (R Core Team, 2014) and R packages lavaan (0.5-17) (Rosseel, n.d.), survey (3.30-3) (Lumley, 2014), and lavaan.survey (1.1) (Oberski) to produce the survey-adjusted analytic models.

3. Results

In this cohort representative of U.S. children who entered Kindergarten in 1998 or first grade in 1999, 49% were boys; 60% non-Hispanic white, 14% non-Hispanic black, 19% Hispanic, and 7% other race/ethnicity (Table 1). The percent of children at or above the cut-offs for obesity ranged from a low of 12.5% in Kindergarten to a high of 21.7% in 5th grade.

Table 1
Characteristics in Kindergarten, at average age 5.6 years.
Data source: Early Childhood Longitudinal Study, Kindergarten Class of 1998–1999, U.S. cohort followed 1998–2007 (n = 4938).

Characteristic	Mean or %	SE
Gender		
Male	48.8	0.9
Female	51.2	0.9
Race/ethnicity		
Non-Hispanic White	60.3	1.8
Non-Hispanic Black	14.3	1.1
Hispanic	18.8	1.6
Other	6.6	0.7
Weight status in Kindergarten		
Normal	73	0.9
Overweight	14.5	0.7
Obese	12.5	0.7
BMI z-score in Kindergarten	0.415	0.03

Survey-adjusted results.

In fifth grade, the majority of children had sugar-sweetened beverages (85%) and fast food (72%) at least once a week (Table 2). Approximately 62% of children reported eating less than one serving of fruit each day, 91% of children reported less than one serving of green salad per day, 88% of children reported less than one serving of carrots per day, and 74% reported less than one serving of other vegetables per day. These proportions remained unchanged in eighth grade.

Parents reported that their children watched an average of 2 h of television daily in Kindergarten, 1st grade, 3rd grade, and 5th grade; children reported watching over 3 h of television daily in 8th grade.

Children engaged in at least 20 min of vigorous physical activity on approximately 4 days per week in Kindergarten, 3rd grade, and 5th grade, according to their parents; when children were asked in 8th grade, they reported engaging in vigorous physical activity nearly 5 days per week (Table 3).

BMI was highly stable throughout childhood (Fig. 1) after accounting for weight-related behaviors, gender, race, and socioeconomic status. The standardized parameter estimates for autoregressive relationships were all significant. In particular, the standardized parameter estimates for BMI were substantial, ranging from 0.79 to 0.86 ($p < 0.001$). These values indicate that the relative rank order of BMI z-scores stayed largely the same across time, even if individuals were increasing in weight. BMI z-score was most stable between 3rd and 5th grades, and least stable between Kindergarten and 1st grade. The overall variance explained by the model for 1st, 3rd, 5th and 8th grade BMI z-score was 63.5%, 65.2%, 76.1% and 74.5%, respectively.

After accounting for previous BMI z-score, behavioral factors including food and drink consumption, TV viewing, and physical activity had little impact on a child's BMI z-score between Kindergarten and 8th grade. For example, of the weight-related behaviors examined, only television viewing was significantly associated with subsequent BMI z-score. In 1st and 3rd grades, hours of daily television viewing was a significant predictor of BMI z-score in the 3rd (0.04, $p = 0.020$) and 5th (0.04, $p = 0.016$) grades, respectively. This indicates that a 1-h increase in daily TV viewing was associated with a 0.04 increase in BMI z-score in the subsequent grade, while a change in BMI z-score of >0.5 is considered clinically meaningful (Reinehr and Andler, 2004). Across all ages, physical activity and dietary choices were not significantly associated with subsequent BMI z-score.

In addition to testing whether weight-related behaviors influenced subsequent BMI z-score, we also tested whether BMI z-score influenced subsequent weight-related behaviors, to examine the potential role of reverse causality. Although the effects were small, BMI z-score appeared to impact subsequent physical activity and television viewing. BMI z-score in 1st grade was a significant predictor of physical activity in the 3rd grade (−0.05, $p = 0.026$), with higher BMI z-score associated with lower subsequent physical activity. BMI z-score in 3rd grade was a significant predictor of TV in 5th grade (0.06, $p = 0.001$), with greater BMI z-score associated with subsequently greater television viewing.

Table 2
Food and drink patterns in fifth and eighth grade, at average ages 11 and 14 years.
Data source: Early Childhood Longitudinal Study, Kindergarten Class of 1998–1999, U.S. cohort followed 1998–2007 (n = 4938).

Characteristic	5th grade Percent	SE	8th grade Percent	SE
Sugar-sweetened beverages				
Did not drink during past 7 days	15.2	0.88	14.55	0.77
1 to 3 times per week	39.94	1.03	42.96	1.05
4 to 6 times per week	17.27	0.66	16.3	0.81
1 time per day	10.09	0.49	10.93	0.62
2 times per day	7.72	0.6	8.24	0.58
3 times per day	3.15	0.35	4.04	0.37
4 or more times per day	6.63	0.63	2.98	0.41
Fast food				
Did not eat during past 7 days	28.27	1.06	28.57	1.32
1 to 3 times per week	51.75	1.33	54.71	1.22
4 to 6 times per week	10.35	0.74	9.38	0.59
1 time per day	4.89	0.51	3.62	0.45
2 times per day	2.11	0.39	2.13	0.42
3 times per day	0.66	0.19	1.07	0.35
4 or more times per day	1.96	0.36	0.52	0.14
Fruits				
Did not eat during past 7 days	8.64	0.52	7.95	0.61
1 to 3 times per week	31.63	1.09	27.07	0.92
4 to 6 times per week	21.48	0.97	24.86	1.04
1 time per day	13.82	0.81	15.67	0.79
2 times per day	11.92	0.8	14.42	0.78
3 times per day	5.68	0.39	5.36	0.47
4 or more times per day	6.84	0.46	4.67	0.6
Green salads				
Did not eat during past 7 days	50.68	1.18	36.81	1.03
1 to 3 times per week	32.81	1.21	40.42	1.12
4 to 6 times per week	7.33	0.47	11.4	0.63
1 time per day	6.15	0.44	7.36	0.57
2 times per day	1.41	0.15	2.32	0.36
3 times per day	0.48	0.11	0.79	0.23
4 or more times per day	1.15	0.25	0.9	0.3
Carrots				
Did not eat during past 7 days	46.21	1.03	51.41	1.3
1 to 3 times per week	32.2	1.1	35.47	1.15
4 to 6 times per week	9.35	0.55	6.77	0.46
1 time per day	5.93	0.46	3.87	0.39
2 times per day	1.97	0.22	1.11	0.22
3 times per day	1.66	0.27	0.7	0.14
4 or more times per day	2.68	0.37	0.67	0.17
Other vegetables				
Did not eat during past 7 days	17.3	0.89	12.09	0.78
1 to 3 times per week	36.83	1.05	36.34	1.06
4 to 6 times per week	20.24	0.83	25.01	0.9
1 time per day	12.07	0.71	14.46	0.72
2 times per day	6.66	0.6	7.76	0.54
3 times per day	3.02	0.37	2.69	0.38
4 or more times per day	3.88	0.47	1.66	0.31

Survey-adjusted results.

4. Discussion

This study found that children's BMI z-scores are highly stable throughout elementary and middle school. It also found that health behaviors central to recommendations for preventing and reversing childhood obesity - television viewing, physical activity, and dietary choices - were largely not significant predictors of subsequent BMI z-score, after controlling for prior weight status. The one exception was screentime: hours of television viewing in the first and third grades were positively associated with slightly higher subsequent BMI z-scores. Simultaneously, we found that higher BMI z-score was associated with subsequently more television viewing and less exercise, indicating that overweight in children may negatively affect behavior.

Prior BMI was a much stronger predictor of subsequent weight than any weight-related behaviors. This is consistent with other studies that

Table 3
Television and exercise, by weight status and age.
Data source: Early Childhood Longitudinal Study, Kindergarten Class of 1998–1999, U.S. cohort followed 1998–2007 (n = 4938).

Characteristic	Kindergarten Mean (SE)	1st grade Mean (SE)	3rd grade Mean (SE)	5th grade Mean (SE)	8th grade Mean (SE)
TV per day, hours (all)	2.00 (0.041)	2.14 (0.035)	2.16 (0.028)	2.28 (0.031)	3.32 (0.065)
Normal	1.95 (0.037)	2.08 (0.034)	2.08 (0.031)	2.15 (0.031)	3.23 (0.089)
Overweight	2.01 (0.080)	2.30 (0.139)	2.23 (0.060)	2.33 (0.085)	3.30 (0.116)
Obese	2.28 (0.085)	2.33 (0.069)	2.39 (0.057)	2.61 (0.065)	3.64 (0.116)
Exercise, days per week (all)	3.95 (0.059)	N/A	3.99 (0.038)	3.78 (0.048)	4.65 (0.050)
Normal	3.96 (0.063)	N/A	4.05 (0.048)	3.88 (0.061)	4.72 (0.054)
Overweight	3.94 (0.138)	N/A	4.12 (0.096)	3.86 (0.099)	4.61 (0.090)
Obese	3.94 (0.128)	N/A	3.67 (0.096)	3.46 (0.090)	4.44 (0.117)

Survey-adjusted results. Weight status categories were determined by percentile associated with BMI-z-score (obese ≥95%, overweight 85–94%).

have cast doubt on the impact of lifestyle factors on BMI trajectory (Twisk et al., 1998), as well as prior research indicating the importance of early BMI in the establishment of obesity in childhood (Franzese et al., 1998; Hesketh et al., 2004). Influences on weight that may be set in place prior to school entry include factors such as genetic traits (Skelton et al., 2011) predispositions such as cognitive restraint, disinhibition, hunger, food cue responsiveness, eating rate, satiety responsiveness, and preference for fatty food (Carnell et al., 2012), environmental exposures such as gut microbiota (Skelton et al., 2011), endocrine disruptors (Karoutsou and Polymeris, 2012), or other chemicals and pollutants (La Merrill and Birnbaum, 2011), intrauterine and neonatal environments including maternal under-nutrition (Ravelli et al., 1976), maternal over-nutrition (Skelton et al., 2011), diabetes (Skelton et al., 2011), breastfeeding (Skelton et al., 2011), and parents' feeding styles (Carnell et al., 2012).

While early-life factors may be of primary importance in the establishment and maintenance of weight trajectories, some of children's behaviors may affect weight. Particularly, TV viewing was associated with slight subsequent BMI increases. This may be due to an obesogenic effect of sedentary time (i.e., fewer calories are expended while seated compared to other activities that may involve standing, walking, or playing); it may be also be linked to the increased caloric intake that occurs during screen time (Rey-Lopez et al., 2008), prompted by lack of attention to portion sizes and advertising cues to consume high-calorie foods. Although the association between television viewing and BMI was too small to be considered clinically meaningful (Reinehr and Andler, 2004), it may be that this and other behaviors have a greater impact on weight change among children who are already at-risk for obesity than among leaner children (Mitchell et al., 2013). For example, children with low social competence are more likely to become overweight or obese (Jackson and Cunningham, 2015), which may be driven by degree of preference for sedentary, solitary activity such as television viewing. Exploring effects of potential weight-related behaviors among population subgroups may be a fruitful direction for future research. In addition, while the present study was only able to examine television viewing, children today are exposed to a greater variety of electronic media, and the combined effects of television viewing and screen time on other devices such as computers, tablets, and cell phones could be explored.

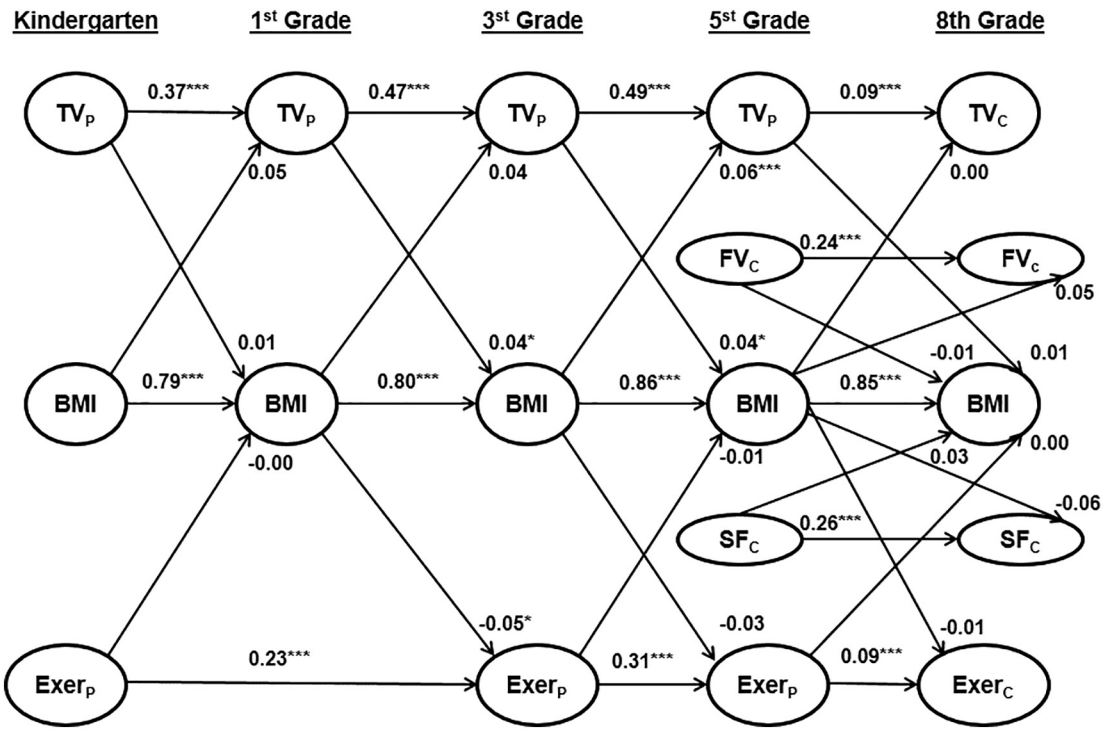

Fig. 1. Relationships between BMI, diet, television and exercise across elementary school: standardized parameter estimates from a cross-lagged autoregressive model. Abbreviations: TV_p: hourly television viewing per day, reported by the parent; TV_c: hourly television viewing per day, reported by the child; $Exer_p$: number of days with ≥20 minutes of exercise, reported by the parent; $Exer_c$: number of days with ≥20 minutesof exercise, reported by the child; BMI: BMI z-score; FV_c: fruit and vegetable intake latent variable (intake reported by the child); SF_c: sugar-sweetened beverages and fast food intake latent variable (intake reported by the child).
Data source: Early Childhood Longitudinal Study, Kindergarten Class of 1998–1999, U.S. cohort followed 1998–2007 (n = 4938).

We also noted that obesity may drive subsequent behavior changes, such that children with higher BMI z-score were more likely to subsequently watch more television and engage in less physical activity. We could conceive of a cycle linking weight and behaviors across childhood in ways that reinforce obesity, in which children's behaviors such as television viewing affect their weight; as they become heavier, physical activity becomes more tiresome and uncomfortable and therefore less frequent (Tucker et al., 2013), leading to further weight gain. In addition, obese children are often subject to weight-related teasing and exclusion, which has been shown to discourage physical activity and encourage sedentary time (Barkley et al., 2012; Storch et al., 2007). This pattern is consistent with a longitudinal study conducted among Australian children, which demonstrated a bi-directional relationship between television and BMI, such that children who watched more television were more likely to gain weight, and heavier children were more likely to watch TV (Fuller-Tyszkiewicz et al., 2012).

This study has limitations. Some variables, such as television viewing and exercise, were parent-reported in grades K through 5, and reported by children in grade 8. The increases in television viewing and exercise reported from fifth to eighth grade, and the simultaneous decreases in parameter estimates, could indicate measurement error due the differences between parent-reported vs. self-reported activities. Such measurement error would only introduce bias if it occurred differently for children who were heavier compared with lighter. A second consideration is that a three-year time lag, such as between fifth and eighth grades, is a long time in the context of child growth and development. Still, during elementary school, children are already developing their sense of identity and establishing self-perceptions (as, for example, a person who is good at sports), and many related perceptions and behaviors are likely to carry through the transition to middle school (Huston and Ripke, 2006). Some of the food measures deviated from the assumption of normality, which may bias parameter and standard error estimates downwards; robust standard errors were used to partially address this issue (Finney and DiStefano, 2006). Another limitation is that measures of food consumption were not available prior to grades five and eight, so any effect of dietary habits in earlier grades was not captured. Future studies would ideally incorporate validated measures of food consumption such as 24-h food recalls, objective measures of physical activity such as accelerometers, and assessments of additional sources of screen time such as computers, tablets, and cell phones.

5. Conclusions

Overall, weight-related behaviors in elementary school appear to have little effect on weight during elementary and middle school, and are largely overshadowed by the effect of prior weight. This research may have implications for child obesity interventions, which have generally failed to achieve substantial impact on BMI (Kamath et al., 2008). Of the weight-related behaviors we examined, television viewing was the only significant predictor of subsequent weight change, and may merit the most attention as an obesity prevention strategy. However, our finding that weight becomes highly stable by the time children reach school-age, with little influence from weight-related behaviors, may indicate that obesity prevention programs should be aimed to reach children younger than age 5. Targeting efforts toward younger children and identifying promising areas for early-life intervention may be key for developing effective policy to reduce childhood obesity.

Conflict of interest

The authors declare they have no conflict of interest.

Transparency document

The Transparency document associated with this article can be found, in the online version.

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