A National Longitudinal Study of the Association Between Hours of TV Viewing and the Trajectory of BMI Growth Among US Children

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Objectives To assess the association between hours of TV viewing and the trajectory of BMI growth from Kindergarten to Grade 5 among a national longitudinal cohort of 7,334 US children.

Methods Multilevel growth curve modeling was used to estimate children’s BMI growth trajectories as a function of hours of TV viewing over time while controlling for gender, race/ethnicity, SES, birth weight, and baseline age. Results Hours of TV viewing were significantly positively associated with the acceleration of BMI growth from Kindergarten to Grade 5. Conclusions Hours spent watching TV may be contributing to the recent dramatic increase in the prevalence of overweight and obesity among children.

Key words children; longitudinal research; obesity.

The prevalence of childhood obesity in the United States has been increasing, and the rate of increase appears to be accelerating (Dietz & Gortmaker, 2001; Ogden et al., 2006; Ogden, Flegal, Carroll, & Johnson, 2002; Troiano & Flegal, 1998). Childhood obesity dramatically increases the probability of obesity in adulthood, with all of its attendant health problems (Must, Jacques, Dallal, Bajema, & Dietz, 1992). Equally alarming, childhood obesity is itself associated with several health risks including hyperlipidemia, glucose intolerance, high blood pressure, asthma, sleep apnea, and depression (Dietz, 1998; Freedman, Dietz, Srinivasan, & Berenson, 1999; Gidding, Y. Bao, Srinivasan, & Berenson, 1995; Reilly et al., 2003; Stunkard, Faith, & Allison, 2003). Therefore, it is critical to determine not only who is at risk for developing obesity in childhood but also what steps parents and children can take to minimize this risk (AAP, 2003; Dietz & Gortmaker, 2001).

Since the increased prevalence of childhood obesity is a recent phenomenon, its etiology is not well understood and much of the literature on its potential causes is of limited quality (Reilly, Ness, & Sherriff, 2007). Recent reviews of this literature have called for more prospective studies, with larger samples and more sophisticated longitudinal analyses that control for potentially confounding factors such as SES, race/ethnicity, gender, and birth weight, all of which have been individually associated with obesity (Moore, Howell, & Treiber, 2002; Must & Tybor, 2005; Reilly et al., 2007).

The possible role of increases in sedentary behavior in the development of obesity among children and adolescents is receiving increased attention, and time spent viewing TV has emerged as a key independent predictor of weight status in several recent studies (Delva, Johnston, & O’Malley, 2007; Fleming-Moran & Thiagarajah, 2005; Henderson, 2007; Jago, Baranowski, Baranowski, Thompson, & Greaves, 2005; O’Brien et al., 2007; Proctor et al., 2003; Reilly et al., 2005). Among adolescents, for example, those who watch more TV are more likely to be overweight (Delva et al., 2007) or obese (Fleming-Moran & Thiagarajah, 2005) and the amount of TV watched by white girls at age 10 is significantly associated with a steeper BMI growth trajectory over the next 4 years (Henderson, 2007). At younger ages, overweight children were found to watch more TV after school than children of normal weight (O’Brien et al., 2007), and, among 4-year-old children followed until they were 11, those who watched the most TV showed greater increases in skin-fold measures of body fat (Proctor et al., 2003). And finally, in a small but very well-designed longitudinal study of 149 young children from ages 3–4 to 6–7, Jago et al. (2005) reported that hours of TV viewing...
were positively associated with BMI, even after controlling for diet and physical activity. In the latter study, the association between TV and BMI became stronger across this narrow age span and the authors speculated that ages 6 or 7 may be a critical age when the effects of sedentary behavior on BMI begin to become more evident.

In summary, it appears that sedentary behaviors such as TV viewing are linked to BMI growth, that this association is evident prior to adolescence, and that TV is one of many factors that may be contributing to the recent rise in the prevalence of obesity among children. The present study differs from most previous research on TV viewing and obesity in that it is longitudinal, is based on a larger more nationally representative sample of children, controls for more potential covariates, and uses multilevel growth curve techniques to model children’s BMI growth trajectories from Kindergarten to Grade 5 as a function of TV viewing measured at multiple time points.

Previous research with children and adolescents indicates that BMI often differs as a function of gender, race/ethnicity, SES, and birth weight. Males are sometimes reported to have higher BMIs (Crespo, Smit, Troiano, Bartlett, Macera, & Andersen, 2001; Delva et al., 2007) but not always (Hanson & Chen, 2007); minority children and those from lower SES families are more likely to be overweight (Delva et al., 2007; Dwyer et al., 1998; Freedman, Khan, Serdula, Ogden, & Dietz, 2006); and high birth weight is frequently reported to be associated with childhood BMI (Parsons, Power, & Manor, 2001). However, there are too few comprehensive longitudinal studies of BMI growth in children to confidently predict how these variables would influence BMI trajectories in a predictive model that includes TV viewing. The major hypothesis of the present study is that, even after controlling for these potential correlates of BMI, hours of TV viewing per day would be significantly positively associated with the acceleration of BMI growth trajectories.

Method

Data Source

Data were derived from the Early Childhood Longitudinal Study (ECLS-K) that began in 1998 with a nationally representative sample of US Kindergarten children. The children in the ECLS-K study came from both public and private schools, were from diverse socioeconomic and racial/ethnic backgrounds, were selected to represent the entire population of US Kindergarten children in 1998, and have been followed from Kindergarten through Grade 5. Details of the sampling procedure, study design, and measures are available through the National Center for Educational Statistics (NCES, 2006). Careful measurements of the children’s height and weight were taken on five occasions (Fall Kindergarten, Spring Kindergarten, Spring Grade 1, Spring Grade 3, and Spring Grade 5), and the children’s parents provided information about each child’s TV and all other video viewing at these same time points.

Sample

Children were selected for inclusion if they were first-time Kindergartners at the beginning of the study, had parent interview data at all 5 time points, and had complete data on all of the selected BMI predictor variables (gender, race/ethnicity, SES, birth weight, age at the beginning of the study, and TV hours at each time point). These inclusion criteria resulted in a final sample of 7,334 children. Table I presents comparative data on the demographic characteristics of the population of all first-time Kindergartners and those children who were selected for the current analyses. Due to attrition, whites and higher SES children were somewhat over-represented in the final sample and African Americans and lower SES children were under-represented in comparison to the full sample of all first-time Kindergartners.

Assessments

Gender, race/ethnicity, SES, birth weight, and baseline age were available in the database. The primary source of this information was the parent who, in ~90% of the cases, was the mother. SES was computed at the household level and was based on the parent’s education, occupation, and household income (ECLS-K, 2001). The resulting range of SES scores was converted by ECLS-K researchers into a 5-quintile scale representing increasing levels of SES from a low of 1 to a high of 5.

Birth weight of the child was reported in pounds and ounces by the child’s parent. Height and weight were measured twice by trained assessors at each wave of data collection using the Shorr Board (accuracy = 0.01 cm) and a Seca digital bathroom scale (accuracy = 0.1 kg). A BMI for each time point was calculated for each child from the average of these two height and weight measurements as follows: BMI = [(weight in kgs)/(height in meters)^2]. Age at the time of the first Kindergarten data collection was reported in months.

At each time point, parents were asked about their child’s typical viewing habits for TV, videos, DVDs etc, during specific segments of weekdays, Saturdays, and Sundays. For weekdays, parents reported viewing times in
hours and minutes between wake-up and school, after school and dinner, and between dinner and bedtime. For weekends, they separately reported total hours and minutes of TV for Saturday and Sunday. Average TV hours per day was calculated as follows: 

\[ \frac{5 \times \text{(weekday total hours)} + \text{Saturday hours} + \text{Sunday hours}}{7} \].

Results

Data analyses proceeded in two steps. First, simple descriptive analyses were done of children’s BMI and obesity status in Kindergarten and in Grade 5 as a function of gender, race/ethnicity, SES, and birth weight. The second set of analyses focused on how children’s TV hours per day related to the trajectory of their BMI growth from Kindergarten to Grade 5, while controlling for gender, race/ethnicity, SES, birth weight, and baseline age. These analyses were addressed with growth curve modeling using HLM 6 software and procedures described by Raudenbush and Bryk (2002) and Singer and Willett (2003). The HLM program is a flexible statistical package that allows one to assess the effects of both time invariant variables (such as gender) and time-varying variables (such as hours of TV measured at multiple times) on longitudinal change.

Table II presents both Kindergarten and Grade 5 BMI and obesity status as a function of gender, race/ethnicity, SES, and birth-weight category. Children were considered obese if their BMI exceeded the 95th percentile for their age and gender. Within each column and demographic category, different subscripts indicate Bonferroni-corrected significant differences at \( p < .01 \).
The equations for this unconditional model were as follows:

Level—1 Model

\[ Y_i = \pi_{0i} + \pi_{1i} \times (\text{Time}) + \pi_{2i} \times (\text{Time})^2 + e_i \]

Level—2 Model

Kindergarten Intercept : \( \pi_{0i} = \beta_{00} + r_{0i} \)

Slope : \( \pi_{1i} = \beta_{10} + r_{1i} \)

Acceleration : \( \pi_{2i} = \beta_{20} + r_{2i} \)

Time was set at zero for Fall Kindergarten and one for Spring Kindergarten. The time interval between these two waves of data collection was ~6 months and subsequent waves of data were collected in the Spring of grades 1, 3, and 5. The Time values for the latter three waves were, therefore, 3, 7, and 11, respectively, reflecting the number of 6-month units that had elapsed since the initial Fall Kindergarten time point, and \((\text{Time})^2\) was simply the square of each Time value.

Results from Model 1 (Table III) indicated that there was significant \((p < .001)\) variance in the intercept (Fall Kindergarten start point), slope (rate of increase of BMI over time), and acceleration (change in rate of increase of BMI over time), so all three of these parameters were retained for further analyses. The mean BMI trajectory was estimated to start at 16.193 in the Fall of Kindergarten, to slope upward at a rate of 0.210 BMI units for each 6-month unit of time, and to accelerate this growth by 0.016 BMI units of time squared. The correlation between the intercept i.e., Fall Kindergarten, and the growth rate slope was .45, indicating that those children who started with higher BMIs in Kindergarten had steeper BMI slope trajectories.

Model 2 added TV hours per day at Level 1 as a time-varying covariate and in interaction terms with both time (BMI slope) and time squared (BMI acceleration). These TV by time and TV by time squared interaction terms were added to determine if, over time, TV hours per day significantly interacted with either the BMI slope or its acceleration. In this model (results not shown), the TV by time squared interaction was significant \((p < .001)\) but the TV by time slope was not significant, so the latter interaction term was dropped. The results of this trimmed model are presented as Model 3 (Table IV). There was a significant \((p < .001)\) TV by time squared interaction, which indicates that, over time, TV hours were significantly and positively associated with increased BMI acceleration.

In order to determine if this association between TV hours and BMI acceleration was still present after accounting for gender, race/ethnicity, SES, birth-weight, and baseline age, all of the latter variables were added as grand-mean-centered time-invariant predictors in Model 4 (results not shown). Gender and race/ethnicity were entered as dummy codes, with males and whites as reference groups. SES was entered using the previously described ECLS-K 5-point scale, representing increasing social class quintiles 1 through 5. The child’s birth weight was entered in pounds, and baseline age was entered in months. In the final model, labeled Model 5 (Table V), all nonsignificant demographic predictors were removed. The TV hours by time squared interaction remained significant \((p < .001)\), confirming the hypothesis that hours of TV would be significantly and positively associated with increased BMI acceleration, after controlling for gender, race/ethnicity, SES, birth weight, and baseline age.

Coefficients from Model 5 were used to illustrate how two different levels of TV viewing (1 hr/day vs. 4 hr/day) are predicted to relate to BMI trajectories from Kindergarten to Grade 5. Separate calculations were done for males (Fig. 1) and females (Fig. 2) since normal BMI growth differs somewhat by gender. Each figure includes an obesity risk reference line that represents age- and gender-adjusted
85th percentiles for BMI (NCES, 2000). The 85th percentile was chosen because children who exceed this BMI level for their age and gender are considered to be overweight and at risk for obesity (Morgan, Tanofsky-Kraff, Wilfley, & Yanovski, 2002; Nader et al., 2006; Ogden et al., 2002). As indicated in Figs 1 and 2, it was estimated that watching 4 hr of TV per day would result in the average child reaching or exceeding the 85th BMI percentile by Grade 5.

**Discussion**

The results of the present study both confirm and extend previous research on correlates of the disturbing trend toward accelerating childhood obesity. They confirm that race/ethnicity, SES, and birth weight are significantly related to BMI. Males, African Americans, Native Americans and Hispanics, children from lower SES families, and those with higher birth weights had significantly higher BMIs and a greater prevalence of obesity at the beginning of the study.

**Figure 1.** Trajectory of BMI growth among males from Kindergarten through fifth grade as a function of 1 or 4 hr of TV/day. SES, birth weight, and initial age all set at their means. Obesity risk reference line represents the age- and gender-adjusted 85th percentile for BMI.

**Figure 2.** Trajectory of BMI growth among females from Kindergarten through fifth grade as a function of 1 or 4 hr of TV/day. SES, birth weight, and initial age all set at their means. Obesity risk reference line represents the age- and gender-adjusted 85th percentile for BMI.
After controlling for these population status variables, hours of TV per day were significantly positively related to the acceleration of children’s BMI growth trajectory from Kindergarten to Grade 5—roughly from ages 5 and 6 to 10 and 11. This significant association between hours of TV and BMI acceleration was estimated to add ~.42 Units of BMI by Grade 5 for the average child who watched 4 hr of TV/day rather than 1 hr/day, an amount which would be sufficient to push him or her up to or beyond the 85th BMI percentile, a level that is widely considered to place a child at risk for obesity.

The present study has several important limitations. First, like most previous studies of TV viewing and BMI, it relied upon parental reports of children’s viewing time rather than direct observation. Recent evidence indicates that parental reports compared with objective measures both over and underestimate actual viewing time somewhat, depending upon whether or not children have TVs in their bedrooms (Robinson, Winiewicz, Fuerch, Roemmich, & Epstein, 2006). Since more than a third of young children in the US now have TVs in their rooms (Vandewater et al., 2007), it is likely that there was more measurement error variance than desirable. Such uncontrolled measurement error in this key TV variable makes it more difficult to detect significant associations between TV viewing and BMI trajectories and the actual degree of association may differ somewhat from that reported here.

Second, the study relied on arbitrary BMI cutoffs to indicate potentially unhealthy levels of weight. These cutoffs and the BMI measure itself provide only crude approximations of body types and body fat distribution (Flegal, Tabak, & Ogden, 2006), although they are routinely used in population-based studies such as this one. Third, there are many other potential covariates of BMI growth than the demographic variables used as controls in the present study. While some attempts were made by the ECLS-K researchers to gather information on the children’s typical levels of physical activity and their food intake, these data were not as systematically collected as was the TV information, and, therefore, were not included as controls in the predictive models presented here. It is important to note, however, that at least one study that controlled for physical activity and nutrition also reported a significant association between TV viewing and BMI (Jago et al., 2005).

And finally, the ECLS-K study did not begin until children were already in Kindergarten. This means that potentially large influences on children’s BMI might have already taken place. Indeed, 11.6% of the children were already obese when the study began. This is particularly important, since the growth models presented here indicate that those who began the study with higher BMIs had steeper subsequent BMI growth trajectory slopes and are at greater risk for later obesity, therefore.

While the ECLS-K data set used here has some limitations, it also has some noteworthy strengths. It began with a large nationally representative sample of children and followed them longitudinally across a relatively understudied age range. Although attrition made it no longer completely representative, its broad sampling frame increases the validity of the generalization of results to the larger population of US children. It also contained carefully repeated assessments of BMI and systematically collected information about children’s viewing habits from multiple time points rather than a single time, and both of these time-varying measures were incorporated into a multilevel longitudinal analysis.

Conclusion

After controlling for gender, race/ethnicity, SES, birth weight, and minor variations in age at the beginning of the study, hours of TV per day were significantly associated with an increased rate of BMI acceleration from ages 5–6 to 10–11 among a large sample of US children. One cannot be certain about either the causal direction of this association or its underlying source. It is also not clear how much of this apparent association might be due to TV’s influence on energy intake via food advertising directed at children (Gamble & Cotugna, 1999; Kraak & Pelletier, 1998) or its possible displacement of more healthful physical activity (Taveras et al., 2007). In either case it would seem that reductions in TV viewing are a logical target for interventions to reduce childhood obesity (Dietz & Gortmaker, 2001). Indeed, one of the few small studies that has actually assessed the impact of reductions in TV viewing on BMI found that a 1-year intervention that successfully encouraged third- and fourth-grade children to reduce their TV, video-tape, and video game use resulted in slower gains in BMI compared with a control group (Robinson, 1999). The results of the present study suggest that interventions beginning at a younger age might be more effective, as TV time was most strongly associated with the acceleration parameter, that is, the rate of change of BMI over time. If this association is valid, then the effects of TV viewing on BMI accumulate over time and might best be countered by early intervention.

Future studies of the associations between TV use and the growth of BMI among children should start with
younger children than the present study, as there were already large differences in BMI at age 5 when the ECLS-K study began and initial levels of BMI were quite high. Attempts should also be made to control for nutritional intake and physical activity levels as these factors clearly affect the energy balance equation (Reilly et al., 2007) and they are associated with TV viewing. However, there is now sufficient evidence to conclude that reducing TV time among children is a promising avenue for obesity intervention research, particularly in light of the consistent finding of positive associations between time watching TV and BMI among children (Must & Tybor, 2005) and their current high rates of TV and other media use (Vandewater et al., 2007).

Conflicts of interest: None declared.

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References


