Greater Screen Time is Associated with Adolescent Obesity: A Longitudinal Study of the BMI Distribution from Ages 14 to 18

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Objective: Previous research has examined the association between screen time and average changes in adolescent body mass index (BMI). Until now, no study has evaluated the longitudinal relationship between screen time and changes in the BMI distribution across mid to late adolescence.

Design and Methods: Participants (n = 1,336) were adolescents who were followed from age 14 to age 18 and surveyed every 6 months. Time spent watching television/videos and playing video games was self-reported (<1 h day⁻¹, 1 h day⁻¹, 2 h day⁻¹, 3 h day⁻¹, 4 h day⁻¹, or 5+ h day⁻¹). BMI (kg m⁻²) was calculated from self-reported height and weight. Longitudinal quantile regression was used to model the 10th, 25th, 50th, 75th, and 90th BMI percentiles as dependent variables. Study wave and screen time were the main predictors, and adjustment was made for gender, race, maternal education, hours of sleep, and physical activity.

Results: Increases at all the BMI percentiles over time were observed, with the greatest increase observed at the 90th BMI percentile. Screen time was positively associated with changes in BMI at the 50th (0.17, 95% CI: 0.06, 0.27), 75th (0.31, 95% CI: 0.10, 0.52), and 90th BMI percentiles (0.56, 95% CI: 0.27, 0.82). No associations were observed between screen time and changes at the 10th and 25th BMI percentiles.

Conclusions: Positive associations between screen time and changes in the BMI at the upper tail of the BMI distribution were observed. Therefore, lowering screen time, especially among overweight and obese adolescents, could contribute to reducing the prevalence of adolescent obesity.

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Introduction

In recent decades, increases in the use of electronic media have paralleled the increase in adolescent obesity (1,2). While these ecological data suggest that greater time spent in screen-based sedentary behavior may have contributed to the high prevalence of adolescent obesity, a recent review of longitudinal association studies concluded that there was insufficient evidence (3). Further, in one longitudinal study the association between screen time and changes in mean BMI was positive when the participants were children, but null when the participants were adolescents (4).

Disparate findings across studies and developmental periods may be explained, in part, by how changes in BMI were statistically modeled. Previous longitudinal studies involving adolescents have modeled average changes in BMI (4-6), but there is evidence from cross-sectional studies that screen time is not uniformly associated with BMI across the BMI distribution in young children (7). Therefore, the purpose of the present longitudinal study was to determine if screen time was associated with changes in the BMI distribution in a sample of adolescents from ages 14 to 18.

Methods and Procedures

The participants were sampled from four high schools in suburban Philadelphia. A total of 1,517 children were identified through class rosters at the beginning of 9th grade. Those with a special classroom placement, and who spoke English as a second language were ineligible to participate. Based on this selection criteria 98% of the adolescents were eligible (n = 1,487). Parental consent was obtained on 99% of the eligible adolescents (n = 1,478), and 97% of the eligible participants completed the baseline survey (n = 1,429). A total of 30 adolescents were absent on the assent/survey day, and a further 19 were not interested in the study. The participants who completed the baseline survey were followed-up every 6 months over a 4-year period. The University of Pennsylvania Institutional Review Board granted ethical approval for the study.

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The participants self-reported their height and weight, from which BMI (kg m\(^{-2}\)) was calculated. It has been shown that self-reported and measured BMI’s are highly correlated (8). The height and weight data were compared to CDC growth charts, to help identify any excessive high and low self-reported values (9).

Time spent watching television/videos and playing video games, on a week night during the school-term, was self-reported by the participants (<1 h day\(^{-1}\), 1 h day\(^{-1}\), 2 h day\(^{-1}\), 3 h day\(^{-1}\), 4 h day\(^{-1}\), or >5 h day\(^{-1}\)). The questions used to capture screen time have previously been validated (10).

Gender, race, and maternal education (marker for socioeconomic status) were included as covariates in the present study. We also adjusted for time spent in moderate to vigorous physical activity (MVPA) and hours of sleep, to determine if any associations between screen time and changes in BMI were independent of MVPA levels and sleep duration.

Longitudinal quantile regression was used to investigate changes in the BMI distribution over time. This statistical approach is an extension of ordinary least square regression and models the effect of predictors across the distribution of continuous outcome variables; in the present study the 10th, 25th, 50th, 75th, and 90th BMI quantiles were specified in the models (11). BMI was modeled as the dependent variable, with study wave (coded: 0, 1, 2...6, and 7) and gender included as independent variables, to describe changes in the BMI distribution over time (model 1). Screen time was added as an independent variable to determine if screen time was associated with changes in the BMI distribution over time (model 2). Race and maternal education (model 3), hours of sleep (model 4), and MVPA (model 5) were also added as independent variables; the purpose of models 3 to 5 was to determine if any association between screen time and changes in BMI remained after adjustment for the covariates. A first order autoregressive correlation structure was used, and 95% confidence intervals were calculated using 500 bootstrap samples, to take into account the repeated measures on individuals (11). All analyses were conducted using Stata 12.0 (StataCorp LP, College Station, TX).

Results

A total of 1,336 participants provided valid BMI data at baseline, and at the 8th study data collection wave 1,089 participants had valid BMI data. The sample was approximately split in terms of gender, the majority of the sample was white (>75%), and most participants had mothers with an education level beyond high school (>70%). Descriptive changes in the BMI distribution, adjusted for gender, are described in Table 1 (model 1). Increases in BMI were greater at the upper versus the lower tail of the BMI distribution (Table 1, model 1). For example, at the 90th BMI percentile BMI increased 0.35 \((95\% \text{ CI: } 0.25, 0.44)\) kg m\(^{-2}\) per 6 months, compared to 0.22 \((95\% \text{ CI: } 0.18, 0.26)\) kg m\(^{-2}\) per 6 months at the 10th BMI percentile (Table 1, model 1).

Screen time was positively associated with changes in BMI at the 50th, 75th, and 90th BMI percentiles; and the association was progressively stronger towards the upper tail of the BMI distribution (Table 1, model 2). At the 90th BMI percentile, each unit increase in screen time was associated with a 0.54 \((95\% \text{ CI: } 0.30, 0.78)\) kg m\(^{-2}\) increase in BMI, compared to a 0.18 \((95\% \text{ CI: } 0.09, 0.28)\) kg m\(^{-2}\) increase in BMI at the 50th BMI percentile (Table 1, model 2). The associations between screen time and change in BMI at the 50th, 75th, and 90th BMI percentiles remained similar after adjusting for the demographic factors (Table 1, model 3), hours of sleep (Table 1, model 4), and self-reported MVPA (Table 1, model 5). There were no associations observed between screen time and changes in BMI at the 10th and 25th BMI percentiles (Table 1, models 2-5). A visual representation of our findings is presented in the Supporting Information Figure.

Discussion

Our study provides the first evidence of differential associations between the amount of screen time and changes in BMI for adolescents between the ages of 14 and 18 years old. Greater screen time was more strongly associated with increases in BMI at the upper tail of the BMI distribution, and was not associated with increases in BMI at the lower tail of the BMI distribution. This means that meeting the screen time recommendation (≤2 h day\(^{-1}\)) is especially important for those in the upper half of the BMI distribution (12), and targeting screen time reductions in overweight and obese adolescents could contribute to reducing the prevalence of adolescent obesity.

To the best of our knowledge the analytical approach we used to determine the relationship between screen time and BMI has only been used in cross-sectional studies involving children (7). Our longitudinal findings are consistent with the cross-sectional results, showing that screen time was more strongly associated with BMI at the upper tail of the BMI distribution (7). A review of longitudinal studies concluded that there was insufficient evidence that greater screen time leads to increases in BMI in adolescents (3). Some studies reported weak positive associations between screen time and changes in mean BMI (5,6), whereas others have reported null associations (4). On the basis of our findings, those past studies likely underestimated the importance of screen time regarding adolescent obesity. We speculate that those previous longitudinal studies in adolescents may have observed stronger positive associations between screen time and BMI at the upper tail of the BMI distribution, had the BMI distribution been studied.

Fundamentally, a positive energy balance underlies the development of obesity. More screen time could contribute to a positive energy balance, either by decreasing energy expenditure, as a consequence of increased sedentary behavior; or increasing energy intake, as a consequence of snacking and exposure to food advertisements. To explain the differential associations we observed, it is possible that adolescents in the lower tail of the BMI distribution, compared to those in the upper tail, spend less time sitting per hour of screen time (i.e., more breaks in sedentary behavior) (13); and/or consume fewer calories per hour of screen time. Alternatively, our observations could be explained by gene-environment interactions, whereby those at the upper tail are more susceptible to developing obesity per hour of screen time.

There are several potential limitations of the present study. Participants self-reported their height and weight for the calculation of BMI, and replication of our findings with objectively measured BMI
is needed. Additional research using more direct measures of adipose tissue would also advance this area of research. Our screen time measure does not include all potential exposure to screen-based technology (e.g., computer use and smartphone use), and additional studies incorporating all screen time exposure would further this area of research. Although the race and ethnic distribution of our sample was similar to the US population as a whole, it would be of interest to determine if similar associations are observed in more diverse populations of adolescents. In addition, we did not assess weight during the summer and research has shown that weight gain is greater in the summer than during the school year (14). Finally, our study is observational and causal inference between television viewing and changes in BMI cannot be made. Therefore, future studies are warranted.

To conclude, screen time is an important adolescent obesity risk factor. Our findings add to the literature by showing that greater screen time was associated with increases in BMI at the upper tail of the BMI distribution from ages 14 to 18. Targeting reductions in screen time, especially among overweight and obese adolescents, could contribute to lowering the prevalence of adolescent obesity (15).

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TABLE 1 Changes in the BMI distribution and the influence of screen time

| Body mass index (kg m⁻²) | 10th Percentile | 25th Percentile | 50th Percentile | 75th Percentile | 90th Percentile |
|--------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Model 1⁴:                |                 |                 |                 |                 |                 |
| Intercept                | 18.1 (17.8, 18.4) | 19.6 (19.4, 19.8) | 21.5 (21.1, 21.8) | 24.2 (23.7, 24.7) | 27.8 (27.0, 28.6) |
| Wave                     | 0.22 (0.18, 0.26) | 0.22 (0.19, 0.25) | 0.24 (0.21, 0.28) | 0.24 (0.18, 0.30) | 0.35 (0.25, 0.44) |
| Screen time              | 0.02 (–0.05, 0.09) | 0.06 (–0.02, 0.14) | 0.18 (0.09, 0.26) | 0.30 (0.12, 0.49) | 0.54 (0.30, 0.78) |
| Model 2⁵:                |                 |                 |                 |                 |                 |
| Intercept                | 18.0 (17.7, 18.4) | 19.4 (19.1, 19.7) | 20.9 (20.5, 21.3) | 23.3 (22.6, 24.0) | 26.0 (24.9, 27.1) |
| Wave                     | 0.23 (0.19, 0.26) | 0.23 (0.20, 0.25) | 0.26 (0.23, 0.29) | 0.26 (0.20, 0.32) | 0.40 (0.31, 0.49) |
| Screen time              | 0.02 (–0.05, 0.06) | 0.06 (–0.02, 0.14) | 0.18 (0.09, 0.26) | 0.30 (0.12, 0.49) | 0.54 (0.30, 0.78) |
| Model 3⁶:                |                 |                 |                 |                 |                 |
| Intercept                | 18.0 (17.6, 18.4) | 19.4 (19.1, 19.8) | 20.8 (20.4, 21.2) | 22.8 (22.0, 23.5) | 25.9 (24.7, 27.0) |
| Wave                     | 0.23 (0.19, 0.26) | 0.21 (0.19, 0.24) | 0.25 (0.22, 0.28) | 0.27 (0.21, 0.33) | 0.40 (0.31, 0.49) |
| Screen time              | 0.03 (–0.05, 0.11) | 0.06 (–0.03, 0.14) | 0.15 (0.05, 0.26) | 0.34 (0.15, 0.52) | 0.55 (0.30, 0.78) |
| Model 4⁷:                |                 |                 |                 |                 |                 |
| Intercept                | 18.5 (17.8, 19.3) | 20.4 (19.5, 21.3) | 22.0 (21.1, 23.0) | 25.0 (23.4, 26.5) | 28.1 (26.2, 30.0) |
| Wave                     | 0.22 (0.18, 0.25) | 0.21 (0.18, 0.24) | 0.24 (0.21, 0.28) | 0.23 (0.17, 0.29) | 0.35 (0.25, 0.44) |
| Screen time              | 0.02 (–0.06, 0.10) | 0.06 (–0.02, 0.14) | 0.15 (0.05, 0.25) | 0.31 (0.10, 0.51) | 0.58 (0.32, 0.85) |
| Model 5⁸:                |                 |                 |                 |                 |                 |
| Intercept                | 18.2 (17.3, 19.0) | 20.4 (19.6, 21.2) | 21.8 (20.8, 22.7) | 24.9 (23.4, 26.4) | 28.6 (26.8, 30.5) |
| Wave                     | 0.24 (0.20, 0.28) | 0.22 (0.19, 0.25) | 0.25 (0.22, 0.28) | 0.24 (0.18, 0.30) | 0.31 (0.20, 0.42) |
| Screen time              | 0.04 (–0.04, 0.12) | 0.07 (–0.02, 0.15) | 0.17 (0.06, 0.27) | 0.31 (0.10, 0.52) | 0.56 (0.29, 0.82) |

Data presented are coefficients and 95% confidence intervals. Wave is coded 0, 1, 2, 3, 4, 5, and 6 to represent each study wave, and so the time coefficients are interpreted as change in BMI per 6 months. Screen time is coded 1, 2, 3, 4, 5, and 6 to represent each category increase in screen time.

1: 1, 2, 3, 4, 5, and 6 to represent each category increase in screen time.
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4: Wave is coded 0, 1, 2, 3, 4, 5, and 6 to represent each study wave, and so the time coefficients are interpreted as change in BMI per 6 months. Screen time is coded 1, 2, 3, 4, 5, and 6 to represent each category increase in screen time.
5: Wave is coded 0, 1, 2, 3, 4, 5, and 6 to represent each study wave, and so the time coefficients are interpreted as change in BMI per 6 months. Screen time is coded 1, 2, 3, 4, 5, and 6 to represent each category increase in screen time.
6: Wave is coded 0, 1, 2, 3, 4, 5, and 6 to represent each study wave, and so the time coefficients are interpreted as change in BMI per 6 months. Screen time is coded 1, 2, 3, 4, 5, and 6 to represent each category increase in screen time.
7: Wave is coded 0, 1, 2, 3, 4, 5, and 6 to represent each study wave, and so the time coefficients are interpreted as change in BMI per 6 months. Screen time is coded 1, 2, 3, 4, 5, and 6 to represent each category increase in screen time.
8: Wave is coded 0, 1, 2, 3, 4, 5, and 6 to represent each study wave, and so the time coefficients are interpreted as change in BMI per 6 months. Screen time is coded 1, 2, 3, 4, 5, and 6 to represent each category increase in screen time.
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