Screen Time and Metabolic Risk Factors Among Adolescents

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Objective: To examine the association between screen time (ST) (ie, television/DVD/video and computer use) guidelines and risk factors for cardiovascular disease, type 2 diabetes mellitus, and fatty liver diseases in mid-adolescence.

Design: Cross-sectional.

Setting: High schools in Sydney, Australia.

Participants: Grade 10 students (N=496; 58% boys; mean [SD] age, 15.4 [0.4] years).

Main Exposures: Body mass index, waist circumference, cardiorespiratory endurance, dietary factors, socioeconomic status, and pubertal status.

Main Outcome Measures: Screen time was categorized as less than 2 hours per day or 2 or more hours per day and calculated for weekday, weekend, and the entire week. Fasting blood samples were analyzed for levels of high-density lipoprotein and low-density lipoprotein cholesterol, triglycerides, insulin, and glucose; homeostasis model assessment of insulin resistance (HOMA-IR); levels of alanine aminotransferase, γ-glutamyltransferase, and high-sensitivity C-reactive protein; and blood pressure. Abnormal results were categorized according to published guidelines.

Results: Mean ST for all students was 3.1 hours per day and for weekdays and weekend days, 2.6 hours per day and 4.4 hours per day, respectively. Boys were more likely to exceed ST guidelines than girls (odds ratio [OR], 2.71; 95% confidence interval [CI], 1.67-4.38). There were no significant associations between ST guidelines and metabolic risk factors among girls. After adjusting for potential confounders, boys who exceeded ST guidelines on weekdays were more likely to have elevated HOMA-IR (adjusted OR, 2.42; 95% CI, 1.11-5.28) and insulin levels (adjusted OR, 2.73; 95% CI, 1.43-5.23).

Conclusions: Adolescent boys with ST of 2 or more hours per day on weekdays have twice the risk of abnormal levels of insulin and HOMA-IR compared with peers with ST less than 2 hours per day on weekdays. These results suggest there is an increased risk of insulin resistance among adolescent boys who do not meet ST guidelines on weekdays.


The World Health Organization estimates that 1.9 million deaths worldwide are attributable to physical inactivity each year. Among adults, sedentarity is associated with a higher risk of premature mortality and cardiovascular disease, overweight and obesity, and insulin resistance. In addition, these consequences are more prevalent among adults who spent greater amounts of time sedentary as children, reinforcing the importance of limiting sedentary time among young people.

Of all sedentary activities, screen time (ST) (ie, watching television/DVDs/videos and computer use) is the most popular, with reports that the majority of Australian, European, and North American teenagers spend more than 2 hours per day in front of screens. Among children, ST is associated with the development of obesity and poor dietary habits. In adults, there is strong evidence that prolonged ST (television viewing in particular) is independently associated with biomarkers of metabolic and cardiovascular disease, but only a few studies have examined the association between ST and metabolic risk among children and adolescents and the findings of these studies are mixed. Different study outcomes may be because these studies did not account for all confounding factors such as diet and cardiorespiratory fitness and examined only television viewing, which is one component of ST. As children move into adolescence, television viewing declines and computer use increases, so in studies of adolescents, it is important to consider computer time as an important factor contributing to their ST.

Concerns about young people’s ST have encouraged several countries to publish guidelines that recommend young people limit entertainment media to less than 2 hours per day. One cross-sectional
study has shown that adolescents who exceed the guideline have lower levels of cardiovascular endurance and 1 longitudinal study showed an association with greater body mass index (BMI) and elevated cholesterol levels in adulthood.

To our knowledge, no studies have examined the relationship between the ST guideline and a range of metabolic markers for chronic disease in adolescents. Therefore, the purpose of this study was to describe the associations between the ST guideline and metabolic risk factors for cardiovascular disease, fatty liver disease, and type 2 diabetes mellitus among 15-year-old adolescents, controlling for important confounders.

**METHODS**

**DESIGN**

The biomarker study, presented herein, was a substudy of a larger, representative cross-sectional survey of school students in New South Wales, Australia (Schools Physical Activity and Nutrition Survey 2004). The biomarker substudy involved collecting overnight fasting blood samples from 500 grade 10 students (mean age, 15.4 years) attending high schools (N = 28) in the Sydney, Australia, metropolitan area. Written informed consent by students and their carers was a requirement for participation. The University of Sydney Human Research Ethics Committee, the New South Wales Department of Education and Training, and the New South Wales Catholic Education Commission approved each study.

**MEASURES**

Students reported their sex, date of birth, postcode of residence, and language spoken at home. Postcode of residence was used as a proxy for socioeconomic status (SES) based on the Australian Bureau of Statistics Index of Relative Socioeconomic Disadvantage, which describes the socioeconomic aspects of geographical areas and includes indexes on income, educational attainment, unemployment, and proportion of people in unskilled occupations. Language spoken at home was used to categorize students into English-speaking and non–English-speaking backgrounds. Height and weight were measured, BMI was calculated as weight in kilograms divided by height in meters squared, and students were categorized according to international guidelines as either not overweight/obese or overweight/obese. Nonextensible steel tape measures were used to measure waist circumference (in centimeters) at the narrowest point between the lower costal border and iliac crest.

**BLOOD COLLECTION, BLOOD PRESSURE, AND BIOCHEMICAL ANALYSIS**

After an overnight fast, approximately 20 mL of venous blood were taken and analyzed for biomarkers that determine the risk of cardiovascular disease (ie, levels of high-density lipoprotein and low-density lipoprotein cholesterol), diabetes (ie, glucose and insulin levels), and nonalcoholic fatty liver disease (levels of liver enzymes alanine aminotransferase and γ-glutamyltransferase) and high-sensitivity C-reactive protein, which is a novel marker that indicates inflammation and risk of future cardiac disease and diabetes. Blood pressure was measured manually using a mercury sphygmomanometer on the right arm after the student had been sitting quietly for at least 10 minutes.

The specimens were transported by the pathology collectors to a National Association of Testing Authorities–accredited pathology laboratory for analysis. Levels of glucose, cholesterol, high-density lipoprotein and low-density lipoprotein cholesterol, triglycerides, alanine aminotransferase, and γ-glutamyltransferase were measured using standard techniques. Plasma insulin concentration was measured with the Bayer Advia Centaur Immunoassay with Bayer Centaur Reagent (Bayer Healthcare, Leverkusen, Germany). High-sensitivity C-reactive protein concentration was measured using an Immage automated nephelometer (Beckman-Coulter, Sydney, Australia) with the use of an ultrasensitive assay. The coefficient of variation was 7.4% for interassay variation, based on that achieved with a commercial control at a mean level of 0.89 mg/mL, performed on 15 different occasions. Details of the biomarker cut points have been published elsewhere and are summarized in Table 1.

**Table 1. Biomarker Cut Points and Reference Source**

<table>
<thead>
<tr>
<th>Biomarker</th>
<th>Cut Point</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin level</td>
<td>&gt;90.28 µU/mL (75th percentile for boys); &gt;97.23 µU/mL (75th percentile for girls)</td>
<td>Lambert et al, Frontini et al</td>
</tr>
<tr>
<td>Glucose level</td>
<td>&gt;110 mg/dL</td>
<td>American Academy of Pediatrics</td>
</tr>
<tr>
<td>HOMA-IR level</td>
<td>2.0</td>
<td>Schwimmer et al</td>
</tr>
<tr>
<td>ALT level</td>
<td>&gt;30 U/L</td>
<td>Prati et al, Rochling</td>
</tr>
<tr>
<td>GGT level</td>
<td>&gt;30 U/L</td>
<td>Rochling</td>
</tr>
<tr>
<td>HDL-C level</td>
<td>&gt;40 mg/dL</td>
<td>American Academy of Pediatrics Committee on Nutrition</td>
</tr>
<tr>
<td>LDL-C level</td>
<td>&gt;130 mg/dL</td>
<td>American Academy of Pediatrics</td>
</tr>
<tr>
<td>Triglyceride level</td>
<td>&gt;199 mg/dL</td>
<td>Haffner</td>
</tr>
<tr>
<td>hs-CRP level²</td>
<td>&gt;10 mg/L</td>
<td>Pearson et al</td>
</tr>
<tr>
<td>Systolic BP</td>
<td>&gt;90th percentile</td>
<td>National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents</td>
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<tr>
<td>Diastolic BP</td>
<td>&gt;90th percentile</td>
<td>National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents</td>
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</tbody>
</table>

Abbreviations: ALT, alanine aminotransferase; BP, blood pressure; GGT, γ-glutamyltransferase; HDL-C, high-density lipoprotein cholesterol; HOMA-IR, homeostasis model assessment of insulin resistance; hs-CRP, high-sensitivity C-reactive protein; LDL-L, low-density lipoprotein cholesterol. SI conversion factor: To convert insulin to picomoles per liter, multiply by 6.945; glucose to micromoles per liter, multiply by 0.0555; ALT and GGT to microkatal per liter, multiply by 0.0167; HDL-C and LDL-C to micromoles per liter, multiply by 0.0259; triglycerides to micromoles per liter, multiply by 0.0113; hs-CRP to nanomole per liter, multiply by 9.524.

²Levels greater than 10 mg/L may reflect an acute-phase response to infectious disease. Six students were therefore excluded according to this definition.
SCREEN TIME

Screen time (ie, watching television/DVDs/videos and using a computer for recreation) was measured using the Adolescent Sedentary Activity Questionnaire,47 which has good reliability for ST (intraclass correlation coefficient range, 0.76-0.90) and face validity. Briefly, students report the time they usually spent engaged in a range of sedentary activities including ST, before and after school, separately for each day of the week and each weekend day. Mean ST (hours per day) and proportion of students meeting national ST guidelines (< or =2 hours per day)27,28 were calculated separately for the whole week, weekdays, and weekend days.

CARDIORESPIRATORY ENDURANCE

Cardiorespiratory endurance (ie, fitness) was assessed using the 20-m multistage shuttle run test.48 Students were divided into groups of 15 to 20 to complete the test and field staff instructed students regarding the test and pacing. The test was terminated when a student could no longer follow the set pace within the given period on 2 successive shuttles or they withdrew voluntarily. Scores were recorded as the level and shuttle reached in the test and then converted to the number of laps completed to provide a continuous variable for analysis.49 The prevalence of “fitness” was determined using age- and sex-adjusted criteria.49

DIETARY HABITS

Students were asked to report on their usual consumption of soft drinks (response categories: “I don’t drink soft drinks”; “<250 mL/d”; “between 250 and 400 mL/d”; “between 400 mL/d and 1 L/d”; and “>1 L/d”) and energy-dense, nutrient-poor (EDNP) foods, including confectionery, hot chips/french fries, and salty snacks (response categories: “never or rarely”; “less than once per week”; “about 1-3 times/week”; “about 4-6 times/week”; and “every day”). For the analysis, the soft drink categories were collapsed into less than 250 mL/d or 250 mL/d or more and food categories were collapsed into less than 1 per week or 1 or more per week. Responses were summed to generate an EDNP food score (range, 0-5) and dichotomized as “daily consumption of EDNP foods” and “not daily consumption of EDNP foods.”

PUBERTAL MATURATION

Direct assessment of pubertal maturation was not permissible, so adolescents were asked to self-report their stage of pubertal development using the descriptions provided by Tanner.30 Although self-assessment has limitations, instructions for completing the form were given to each student individually in private by a registered nurse (E.D.W.). Male students were asked to report their stage of pubic hair and genital development, while female students reported their age at menarche onset and were asked to describe their stage of breast development.

DATA ANALYSIS

Data were analyzed using SAS for Windows version 9.1 (SAS Institute Inc, Cary, North Carolina). The analysis of the biomarkers was performed after categorizing each as high (or low in the case of high-density lipoprotein cholesterol) or normal for adolescents according to evidence-based reference standards where possible (Table 1). For the analysis, homeostasis model assessment of insulin resistance (HOMA-IR) was calculated (fasting insulin level × fasting glucose level/22.5).31 For the descriptive analyses, means and proportions were calculated to assess the difference between ST guidelines and sample characteristics, separately for boys and girls. Mean differences were assessed by analyses of variance and associations tested using \chi^2 tests.

The number and proportion of students with abnormal biomarker values were tabulated by ST category (ie, <2 or =2 hours per day) separately for estimates calculated across the whole week, weekdays, and weekend days and stratified by sex. For each biomarker, univariate associations with ST were assessed using unadjusted (crude) odds ratios (ORs). Multiple logistic regression models were constructed for each biomarker with significant univariate associations adjusting for adiposity (separately from BMI and waist circumference), SES, cardiorespiratory endurance, pubertal status, and EDNP food score and adjusted ORs and 95% confidence intervals (CIs), calculated. Associations between biomarkers and ST were assessed using the SURVEYMEANS and SURVEYLOGISTIC procedures (SAS Institute Inc), which adjust for the complex cluster design of the survey.

RESULTS

Of the 500 blood samples collected, 2 were excluded because of the presence of preexisting type 1 diabetes and 2 were missing anthropometric data, leaving a final sample of 496 available for analysis. The response rate was 53% (boys: 59%; girls: 42%). The mean age of students was 15.4 years (range, 14-3-17.1 years), approximately 21% were from non–English-speaking backgrounds, and 27.6% and 19.4% of boys and girls, respectively, were overweight/obese. The majority of boys (75.2%) and girls (60.3%) reported pubertal stages of Tanner 4 and 5.

Bivariate analysis showed that there were no significant differences between students who exceeded the ST guideline and BMI status, waist circumference, Tanner stage, and the prevalence of abnormal biomarkers compared with students who met the ST guideline (Table 2). In contrast, exceeding the ST guideline was strongly associated with higher EDNP food scores (P = .01 for boys and P < .001 for girls) and, for girls, lower cardiorespiratory endurance (P < .001) and low/middle SES background (P < .01), compared with peers who met ST guidelines.

Table 3 shows the mean time (hours per day) and the proportion of boys and girls who reported exceeding the ST guidelines by different periods (ie, whole week, weekday, and weekend days), separately for total ST, watching television/videos/DVDs, and using a computer recreationally. Television viewing was the dominant ST activity, accounting for approximately two-thirds of ST. Overall, irrespective of the screen medium, significantly more boys reported significantly higher ST than girls (all P < .001), except for weekday television time (1.9 hours per day vs 1.7 hours per day; P = .06), although a higher proportion of boys reported spending 2 or more hours per day on weekday television (44.5% vs 35.1%; P < .05).

Crude ORs were calculated to examine the associations between ST guidelines for the whole week, weekdays, and weekend days and biomarkers. There were no associations between exceeding ST guidelines for the whole week or weekend days and biomarkers, only for exceeding ST guidelines on weekdays. The unadjusted and adjusted ORs (95% CI) of exceeding ST guidelines on weekdays and metabolic risk factors are reported in Table 4. Exceeding ST guidelines on weekdays was significantly associated with abnormal levels of insulin (OR, 1.88; 95% CI, 1.09-3.22), HOMA-IR (OR, 1.97; 95% CI, 1.12-3.48),


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levels of high-sensitivity C-reactive protein (OR, 2.94; 95% CI, 1.12-7.70), and diastolic blood pressure (OR, 3.30; 95% CI, 1.35-8.12) among boys, but not girls.

Among boys, there was an independent association between exceeding ST guidelines on weekdays and elevated insulin levels and HOMA-IR, after adjusting for adiposity, cardiorespiratory endurance, EDNP food score, pubertal status, and SES. In the BMI-adjusted model (model 1), the odds of elevated insulin level were 2.73 (95% CI, 1.43-5.23; P < .05) and HOMA-IR, 2.42 (95% CI, 1.11-5.28; P < .05), among boys who exceeded ST guidelines on weekdays. In model 2, adiposity was adjusted by waist circumference; there was a 20% to 30% increase in the odds of elevated insulin level (OR, 3.04; 95% CI, 1.47-6.29; P < .05) and HOMA-IR (OR, 2.64; 95% CI, 1.35-5.28; P < .05).

**COMMENT**

**PRINCIPAL FINDINGS**

The findings presented herein show that, after adjustment of potential confounders including different indices of adiposity, fitness, diet, puberty, and SES, adolescent boys who exceed ST guidelines on weekdays were more than twice as likely to have abnormal levels of insulin and HOMA-IR compared with their male peers who meet ST guidelines on weekdays. These results suggest there is an increased risk of insulin resistance among adolescent boys with ST of 2 or more hours per day during weekdays and this provides further support for practitioners to endorse and promote current ST guidelines, especially for teenage boys.

Interestingly, the findings were stronger when waist circumference rather than BMI was controlled for as a measure of adiposity. This finding probably reflects the fact that waist circumference is considered a more accurate predictor of metabolic risk in adolescents than general obesity as measured by BMI.

That these associations were evident for only weekdays and not when examined for weekend days, or for the whole week, is potentially important in terms of contributing toward understanding the effects of sedentariness on adolescents’ health. A possible explanation for this finding may be the joint effect of spending additional sitting time in front of screens after spending prolonged periods sitting during school time. While it was assumed that boys and girls spent equal time in class, a greater proportion of boys exceeded ST guidelines on weekdays compared with girls (66% vs 48%), giving boys higher exposure to longer, and potentially sustained, bouts of sitting.

Furthermore, there were significant sex differences on weekdays according to the ST medium. The proportion of boys who reported recreational computer use was 3 times higher than girls (12.8% vs 3.9%), and boys spent significantly more time (30 minutes per day) using computers for recreation. Although this study could not distinguish the type of recreation in which students engaged (eg, games, e-mail, surfing the Internet), other research shows boys are more likely to use computers to play games. Future research needs to examine whether there are differential health effects according to different screen media that may explain sex differences and risk of adverse metabolic profiles.

The evidence for what constitutes a deleterious period of sitting has not been examined among youth, but the concept has been explored in adults. There may be significant physiological differences between prolonged and intermittent bouts of sitting. It is possible that the weekday effects on metabolic risk reported herein among boys reflect different sitting behaviors during a week compared with weekend sitting patterns. That is, bouts of sitting on a weekend are more likely to be intermittent compared with the prolonged bouts of sitting required during class time on school days. Further studies using objective measures of sedentariness (eg, inclinometers, triaxial accelerometers) are required to examine patterns of sitting time (intermittent vs prolonged bouts) and negative health effects among young people.

**OTHER RESEARCH FINDINGS**

While there is strong evidence in adults that prolonged ST, and television viewing in particular, is independently associated with biomarkers of metabolic and cardiovas-
cular diseases,5,6,13-16 the evidence in young people is limited. Of the few studies among youth, cross-sectional studies have shown an independent association between television viewing and hypercholesterolemia,55 hypertension,20,56 and fasting insulin level.19 These studies, however, have been primarily among young children and generally examined single risk factors and did not control for all potential confounders. Of the 2 studies that did include adolescents, the European Youth Heart Study19 examined a range of metabolic risk factors and reported that only fasting insulin level was independently associated with television viewing, while Sugiyama et al57 reported that ST was independently associated with systolic blood pressure. In the current study, neither hypercholesterolemia nor blood pressure was associated with ST, after adjusting for potential confounders.

Our understanding of the immediate and long-term effects of sedentary behaviors on health is only emerging. Sedentary behaviors and physical activity are distinct classes of behavior and potentially have different metabolic pathways associated with health outcomes.58 Future research on the metabolic effects of sedentaryness including ST is required, particularly among youth, and research would benefit from longitudinal studies based on birth cohorts.

LIMITATIONS AND STRENGTHS

There are several study limitations that need to be considered when interpreting these findings. The cross-sectional design of the study prohibits any inference of the causal relationship between ST and the biomarkers; this may only be confirmed by longitudinal studies. The low response rate (56%) was a study limitation. The magnitude of potential selection and nonresponse bias was assessed using BMI because many of the biomarkers are...
strongly associated with overweight and obesity and these students may decline health surveys. There was no difference in the prevalence of overweight or obesity among students who did and did not participate in the biomarker sub-study. Although a measure of diet was included, the EDNP food score may not have adequately accounted for food habits. Screen time was measured by a reliable and valid questionnaire, although self-report instruments often lack precision, leading to increased measurement error. The Adolescent Sedentary Activities Questionnaire does ask students to report ST separately for each day of the week, rather than asking students to estimate the usual time per week, which can improve recall and time estimates. Further, if students were multitasking (eg, watching television and using a computer at the same time), they were asked to estimate the time they spent on each activity separately, to reduce overestimation.

In terms of biomarkers, the time between identifying risk factors and the onset of chronic disease among adolescents is not clear, which makes the selection of cut points for biomarker risk factors difficult in children and adolescents. The cut points used in this study were selected from a review of the literature and, where possible, derived from evidence-based recommendations. Insulin was the only biomarker for which there are no international guidelines; however, the 75th percentile has been used previously as a cut point and was therefore adopted for the purpose of this study. Both fasting insulin level and HOMA-IR were used as surrogate measures of insulin resistance because more sensitive measures of insulin resistance are impractical in epidemiological studies.

The current study has several strengths. The sample comprised a large, representative, nonclinal population of free-living adolescents. Further, the analyses adjusted for a range of important potential confounders not considered by other studies, including different measures of adiposity (BMI and waist circumference), to investigate the independent association between different ST patterns (ie, weekday, weekend days, weekly) and a large number of metabolic risk factors.

This study provides preliminary evidence that the addition of prolonged bouts of sitting associated with high ST on school days among boys is deleterious to their health. Future research needs to determine how much (or how little) sitting time constitutes health risk among young people. The findings support interventions that promote the ST guideline and encourage young people to reduce excessive ST, especially during the week when they have spent the majority of their day sitting in class. Screen time is a modifiable behavior and interventions to reduce the recreational use of small screens during weekdays may help reduce the risk of progression of insulin resistance to type 2 diabetes.

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Drafting of the manuscript: Hardy, Thrift, and Baur. Critical revision of the manuscript for important intellectual content: Hardy, Denney-Wilson, Okely, and Baur. Statistical analysis: Thrift. Administrative, technical, and material support: Denney-Wilson. Study supervision: Baur.

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