

Original article

# Sensor-based physical activity, sedentary time, and reported cell phone screen time: A hierarchy of correlates in youth

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## Abstract

**Background:** Evidence on correlates relies on subjective metrics and fails to include correlates across all levels of the ecologic model. We determined which correlates best predict sensor-based physical activity (PA), sedentary time (ST), and self-reported cell phone screen time (CST) in a large sample of youth, while considering a multiplicity of correlates.

**Methods:** Using sensor-based accelerometry, we assessed the PA and ST of 2179 youths. A  $\chi^2$  automatic interaction detection algorithm was used to hierarchize the correlates associated with too much ST (> 50th percentile), insufficient moderate-to-vigorous PA (MVPA) (<60 min/day), and prolonged CST ( $\geq 2$  h/day).

**Results:** Among youth 10–14 years old, the correlates for being inactive consisted of being a girl, not having sport facilities in the neighborhood, and not perceiving the neighborhood as a safe place, whereas in the youth 15–18 years old, the correlate for being inactive was not performing sports (9.7% chance of being active). The correlates for predicting high ST in the younger group was not performing sports (55.8% chance for high ST), and in the older group, the correlates were not owning a pet, perceiving the neighborhood as safe, and having inactive parents (63.7% chance for high ST). In the younger group, the greatest chances of having high CST were among those who were in the last elementary school years, who were girls, and who did not have friends in the neighborhood (73.1% chance for high CST), whereas in the older group, the greatest chance for having high CST was among those who were girls and had a TV in the bedroom (74.3% chance for high CST).

**Conclusion:** To counteract ST and boost MVPA among youths, a specific focus on girls, the promotion of sport participation and facilities, neighborhood safety, and involvement of family must be prioritized.

**Keywords:** Adolescents; Environment; Objective; Sedentary behavior; Socioecologic model

## 1. Introduction

Global physical inactivity is responsible for more than 5 million deaths,<sup>1</sup> and cross-sectional evidence has found both low physical activity (PA) and high sedentary time (ST) to be important risk factors for chronic disease in youth,<sup>2</sup> although the associations for ST with health parameters seem to be fairly dependent on PA levels.<sup>3</sup> Indeed, PA levels can predict the future health of youth.<sup>4</sup> Hence, understanding which modifiable and nonmodifiable factors (i.e., correlates) can impact PA levels in this population is paramount.<sup>5</sup> There are

correlates that seem to affect the PA of youth,<sup>5–8</sup> but current findings are less consistent than those in adults,<sup>9,10</sup> which can be justified by the lower number of investigations using sensor-based PA data in youth.

Even though there is evidence suggesting that PA is a better predictor of health in youth than ST,<sup>3</sup> the great percentage of time spent in sedentary behavior (SB)<sup>11</sup> justifies a closer look into the correlates that can impact this potential deleterious behavior. Considering that SB is a distinct concept separate from physical inactivity,<sup>12</sup> it is plausible that correlates may be specific for this behavior. For example, a meta-analysis<sup>13</sup> found that interaction with friends and colleagues had no impact on ST, but with regard to PA, social support was associated with more PA.<sup>14,15</sup> In youth, there are different levels of factors that can influence ST, such as sociodemographic correlates (e.g.,

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gender and household income),<sup>16</sup> environmental correlates (e.g., neighborhood connectivity and safety),<sup>17</sup> and household correlates, such as the existence and number of screens at home.<sup>18</sup> The socioecologic model of health behavior recognizes that particular behaviors such as SB operate in, and are influenced by, environmental and policy contexts.<sup>19</sup> This model places the individual at the center of an ecosystem and provides a better understanding of the several factors and barriers that impact a particular behavior.<sup>19</sup> Thus, using the socioecologic model to examine and hierarchize different levels of correlates as a hypothesis-generating framework is paramount.<sup>20</sup>

When looking at correlates, it is also important to go deeper into the type of behavior that is being analyzed. For instance, more education has been related with more computer time<sup>21</sup> and less TV viewing time.<sup>22</sup> In youth, interactions between correlates for a given outcome may also exist.<sup>23</sup> For example, a higher income is associated with less ST,<sup>16</sup> but a higher income can potentiate the presence of a TV in the bedroom which, in turn, can potentially increase ST.<sup>18</sup> Thus, it is important to consider simultaneously the relative importance of different types of correlates and hierarchize them. Most evidence on the correlates of PA and ST in youth have relied on subjective metrics for ST and PA,<sup>7,24,25</sup> which may induce an assessment bias.<sup>26</sup> Among the studies using sensor-based data, often only a unique type of correlate is considered<sup>27</sup> (e.g., environmental correlates). Therefore, when looking at the correlates of PA and ST in youth, investigations that use sensor-based data<sup>6,17,28,29</sup> and that identify correlates across all levels of the socioecologic model<sup>30</sup> are warranted.

Recently, there has been a growing concern with cell phone screen time (CST) in youth, with young individuals spending progressively more time in this sedentary pursuit.<sup>31</sup> However, most investigations have focused on overall screen time<sup>8,23,31</sup> and have failed to consider a wider spectrum of correlates.<sup>32</sup> It is likely that the correlates for PA, ST, and CST differ,<sup>33</sup> but previous investigations have not simultaneously considered these independent behaviors using a large sample of youth varying in age. Thus, this is the first investigation to use the socioecologic model in a large sample of youth to determine and hierarchize the correlates that best predict sensor-based PA, ST, and self-reported CST while simultaneously considering intrapersonal, interpersonal, and neighborhood-physical environmental factors.

## 2. Materials and methods

### 2.1. Participants and study design

This investigation included a total of 2179 youths living in Portugal (i.e., 97.4% were Portuguese) from a subsample of a nationwide cross-sectional survey that aimed to examine PA levels using sensor-based data. In the Portuguese school system, the architecture and contextual settings of the elementary school (where students are 10–14 years old) and high school (where students are 15–18 years old) substantially change. Thus, analyses were performed separately for these 2 age groups. Data were collected during physical education classes in public schools between March 2017 and November 2018. All

participants were informed about the project's protocol, and written consent was obtained from the students' legal guardians prior to their participation. The participants who did not comply with accelerometer criteria (i.e., 3 valid days with at least 1 weekend day) and/or did not answer one of the questions on the questionnaire were excluded, which left a total sample of 2179 participants. The investigation protocol was approved by the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon (CEFMH-Approved; #19/2017).

### 2.2. Body composition

All participants were weighed to the nearest 0.01 kg on an electronic scale (Model 799; Seca GmbH, Hamburg, Germany) while wearing minimal clothing and without shoes. Height was measured to the nearest 0.1 cm with a portable stadiometer (Model 220; Seca GmbH).<sup>34</sup> All measurements were performed twice, and the mean of the 2 measurements was recorded. Body mass index was calculated as body mass/height<sup>2</sup> (kg/m<sup>2</sup>).

### 2.3. Accelerometer analysis

Total moderate-to-vigorous PA (MVPA) and ST were assessed by a sensor-based approach using accelerometry (GT3X model; ActiGraph, Fort Walton Beach, FL, USA). Participants were instructed to wear the device for 7 consecutive days, on the right side near the iliac crest, and were informed to remove the accelerometers during sleep and all water-based activities. The accelerometers were initialized to start recording at 8 a.m. on the evaluation day of each participant. The devices were activated on raw mode with a 100-Hz frequency and posteriorly downloaded into 15-s epochs (ActiLife Version 6.9.1; ActiGraph). Periods of at least 60 consecutive minutes of 0 count were considered as nonwear time. A valid day was considered when wear time was  $\geq 10$  h. To be included in the analysis, the participants had to present at least 3 valid days (with at least 1 weekend day). Activity intensity thresholds were defined according to Evenson et al.<sup>35</sup> Accelerometer counts  $\geq 100$  counts/min were identified as active time, and MVPA ( $\geq 2296$  counts/min). The time spent  $< 100$  counts/min was identified as ST.<sup>35</sup>

### 2.4. Sociodemographic, behavioral, and health-related characteristics

Data on the following participant characteristics were collected: sociodemographic variables (e.g., age, gender, school year, parents' ages and education levels, living with 1 or both parents, having siblings or being the only child, and having lots of friends to play with), health status (e.g., presence of disease, smoking habit, and perception of quality of health/life/sleep), behavioral status (e.g., sport participation, type of activity most performed during recess at school, SB patterns, parents' performing exercise or not, friends' exercising or not, and owning a pet to walk), and contextual variables (e.g., characteristics of neighborhood, such as safety, proximity of sports facilities, existence of violence, traffic levels, cycling paths,

not having a green park in the neighborhood, opportunities to play outdoors, having a TV in the bedroom, number of TVs and computers in the house, and parents owning a car).

Sociodemographic variables were collected, and gender was dichotomized as girl or boy. The current school year was coded as the corresponding number (e.g., the 4th grade as 4). The education levels of mother and father were assessed separately and recoded as having no education (1), primary school (2), middle school (3), middle school (professional courses) (4), high school (5), or university graduation (6).

Household characteristics (living with both parents or not, living with siblings or being the only child) were determined according to an adapted question (“Who do you live with?”) from the Health Behavior in School-aged Children (HBSC) questionnaire<sup>36</sup> and then recoded as living with 1 parent or any other family member (0) or living with both parents (1). Furthermore, being the only child was categorized as 0, while living with at least 1 sibling was categorized as 1. Perception of quality of health was assessed by the question “How do you characterize your health?” adapted from the self-report of the Portuguese KIDSCREEN-10 questionnaire, which was recoded in a 5-point Likert scale as follows: *poor* (1), *fair* (2), *good* (3), *very good* (4), or *excellent* (5).<sup>37</sup> Using the same scale, perceptions related to quality of life and quality of sleep were also assessed. Smoking habit was determined using an adapted question from the HBSC questionnaire (“Do you currently smoke?”),<sup>36</sup> and the answer was dichotomized as no or yes. A question about the existence of any diagnosed disease was asked, and the answer was coded as no or yes.

Sport participation was assessed based on the question “Do you perform any regular and structured sport during your leisure time?” and the answer was recoded as no or yes. The type of activity most performed during recess was assessed by the question “What is the activity that you do most during recess?” and the answer was recoded for one of 4 specific activities: sitting while talking with colleagues (1), standing while talking with colleagues (2), exercising or playing games with colleagues (3), and other activities (4). In addition, the manner in which ST was accumulated throughout the day was determined using the question “During the day, do you usually sit for a long period of time or do you break this behavior often?” and the answer was recoded for one of 3 specific items: several hours without breaking sitting time (1), breaking-up sitting every hour (2), or breaking-up sitting more often (3).

### 2.5. Contextual characteristics of neighborhood and social environment

We assessed the basic characteristics of neighborhood through 8 items: “Is it safe to walk in the street anytime?”; “Is there easy access to sports infrastructures?”; “Do you have outdoor places where you can play?”; “Is there a lot of traffic?”; “Do you have many friends living close that you can play with?”; “Is there any risk of being beaten or robbed?”; “Are there suitable paths for cycling?”; and “Are there no green areas?”. For all these questions, a 2-point Likert scale (agree or disagree) was used.<sup>36</sup> Adapted questions from the HBSC

questionnaire were also used to determine the number of home TVs (“How many TVs do you have at home?”) and computers (“How many computers do you have at home?”).<sup>36</sup> Several social-environment variables were assessed across 5 domains (“Do you have a TV in your bedroom?”; “Do your friends usually exercise?”; “Do your parents usually exercise?”; “Do you walk your pet in the street?”; and “Do your parents own a car?”), which were further recoded into 2 categories (no or yes).<sup>36</sup> All questions were asked in face-to-face interviews in which well-trained interviewers were instructed to use the same vocabulary and terminology.

### 2.6. Statistical analysis

Statistical analyses were completed using SPSS (Version 24.0; IBM Corp., Armonk, NY, USA). Descriptive analysis included mean and SD for all variables. To identify and hierarchize the correlates associated with too much ST, insufficient MVPA, and prolonged CST, an independent  $\chi^2$  automatic interaction detection (CHAID) algorithm with a growing method was performed for each outcome.<sup>38</sup> The CHAID analysis generates a tree that hierarchically splits the data on the basis of the exposures into homogeneous subgroups. This allows for the identification of population subdivisions that have a higher likelihood of presenting an outcome (e.g., fulfilling MVPA recommendations). The resulting tree supports direct interpretation of complex interactions and is based on Bonferroni type-I error to discriminate the correlate and subdivide the data according to its categories.<sup>38</sup> In order to apply the CHAID algorithm, participants were dichotomized into low or high ST based on having low (<50 percentile) or high ( $\geq$ 50 percentile) amount of sensor-based ST, with the percentiles for ST being obtained after adjustment for gender and age. For MVPA, the current guidelines for youth were considered in order to differentiate between inactive (MVPA < 60 min/day) and active (MVPA  $\geq$  60 min/day) participants. For self-reported CST, we used the cut-off of 2 h/day to distinguish between low (<2 h/day) and high ( $\geq$ 2 h/day) CST, which parallels the new Canadian 24-Hour Movement Guidelines for Children and Youth, which states that youth should limit their screen time to a maximum of 2 h/day.<sup>39</sup> The time spent looking at the cell phone is the most prevalent type of screen time in youth,<sup>31</sup> which explains why we chose this domain solely. Because gender was included in the models as one of the 31 correlates, the analyses were not stratified by gender. However, we separated the analyses based on 2 age groups: 10–14 years old and 15–18 years old). Statistical significance was set at 5%.

## 3. Results

Details on the 2179 participants’ demographic characteristics by age group are presented in Table 1. Almost all the participants were Portuguese (i.e., 97.4% of the overall sample), with only 57 youth (2.6%) being born in other countries but living in Portugal for a number of years. In the age group that was 10–14 years old, 29.8% of the participants were currently studying in the 5th and 6th grades, whereas 70.2% were in the 7th to 9th grades. In the age group that was 15–18 years old,

Table 1  
Participants' characteristics by age group ( $n = 2179$ , mean  $\pm$  SD or %).

	10–14 years old ( $n = 1186$ )	15–18 years old ( $n = 993$ )
Age (year)	12.3 $\pm$ 1.33	16.04 $\pm$ 0.97
Height (m)	1.56 $\pm$ 0.10	1.67 $\pm$ 0.09
Body mass (kg)	49.1 $\pm$ 12.2	61.4 $\pm$ 12.3
BMI (kg/m <sup>2</sup> )	19.9 $\pm$ 3.62	21.9 $\pm$ 3.47
ST (min/day)	572.9 $\pm$ 81.6	633.4 $\pm$ 81.4
MVPA (min/day)	44.1 $\pm$ 21.1	43.0 $\pm$ 21.5
Total wear time (min/day)	820.6 $\pm$ 67.9	837.2 $\pm$ 79.2
Valid days ( $n$ /week)	4.74 $\pm$ 1.09	4.83 $\pm$ 1.16
Cell phone screen time (min/day)	108.9 $\pm$ 116.5	165.4 $\pm$ 147.9
Father's age (year)	44.5 $\pm$ 5.90	47.8 $\pm$ 6.07
Mother's age (year)	42.5 $\pm$ 10.4	45.6 $\pm$ 5.37
TVs at home ( $n$ )	2.78 $\pm$ 1.26	2.97 $\pm$ 1.35
PCs at home ( $n$ )	1.97 $\pm$ 1.22	2.30 $\pm$ 1.28
Gender (% female)	51.7	57.6
Living with 2 parents (%)	82.3	78.0
Siblings (% yes)	72.7	67.5
Sport participation (%)	64.3	61.6
Diagnosed disease (%)	12.8	14.5
Taking medicine (%)	9.5	9.1
Smoking (%)	0.1	4.5
Safe neighborhood (% agree)	60.2	71.8
Sport facilities (% agree)	68.7	70.9
Outdoor space to play (% agree)	93.4	91.4
High traffic (% agree)	28.8	34.0
Lots of friends (% agree)	73.3	64.9
Violent neighborhood (% agree)	22.2	26.0
Easy to bike (% agree)	61.7	63.3
No green spaces (% agree)	13.9	13.5
TV in the bedroom (% yes)	47.5	48.2
Friends exercising (% agree)	90.9	88.7
Parents exercising (% agree)	55.9	49.7
Parents' car ownership (% yes)	95.4	96.4
Pet to walk (% yes)	35.4	38.2

Abbreviations: BMI = body mass index; MVPA = moderate-to-vigorous physical activity; PC = personal computer; ST = sedentary time; TV = television.

the majority of the participants were in high school (the 10th grade: 49.4%; the 11th grade: 26.5%; the 12th grade: 24.1%). Overall, in the younger group, 20.7% attained MVPA recommendations, whereas 50.2% were classified as being highly sedentary ( $\geq 50$  percentile), and 40.4% spent more than 2 h/day in CST. In the older group, 19.8% attained MVPA recommendations, 49.7% were classified as being highly sedentary, and 62.1% spent more than 2 h/day in CST.

Based on the decision-tree model and as shown in Fig. 1, in order to increase the odds of youth 10–14 years old being physically active ( $\geq 60$  min/day), the correlates that were hierarchically most important were (1) being a boy, (2) performing any kind of sport, and (3) perceiving the neighborhood as a safe place, with 37.4% of youth fulfilling all these factors and, thus, being classified as physically active. Those classified as most inactive were (1) girls, (2) reporting not having sport facilities in their neighborhoods, and (3) not perceiving the neighborhood as a safe place (0% chance of being active). Looking deeply into the analyses (Supplementary Fig. 1), girls who reported having sport infrastructures nearby their houses and who were in the first 2 years of elementary school (i.e., 5th and 6th grades)

had higher chances of being active (31.2%) compared to the older girls in the next 5 school years (12.2%). For the boys who did not perform any type of sport, their activity during recess at school was an important predictor of their achieving the PA guidelines, with boys who reported playing during recess having a 31.5% chance of being active compared to only a 12.4% chance when boys reported engaging mainly in sitting or standing activities during recess (Supplementary Fig. 1).

As shown in Fig. 1, in order to increase the odds of being physically active ( $\geq 60$  min/day) between the ages of 15 and 18 years, youth have to (1) perform any kind of sport, (2) be a boy, and (3) perceive the neighborhood as having lots of traffic, with 46.2% of youth fulfilling all these factors being classified as physically active. For being classified as inactive, the most important and unique correlate for this age group was “not performing any sport” (regardless of gender or any other correlate) (9.7% chance of being active). Examining in more detail the CHAID decision tree (Supplementary Fig. 2), for the girls 15–18 years old who performed sports, living with both parents reduced the odds of being active (14.2% chance of being active) compared with the girls who lived with only 1 parent or any other family member (e.g., aunt, grandmother) (26.7% chance of being active).

As shown in Fig. 2, to be classified as low sedentary, youth 10–14 years old in elementary school must (1) perform any kind of sport, (2) perceive the neighborhood as a place where violence can occur, and (3) be a girl (71.1% chance of being classified as low sedentary if all these factors are fulfilled). To be classified as high sedentary in this age group, the only and most important correlate was not partaking in any kind of sport, regardless of all the other correlates (55.8% chance of being high sedentary). The original decision tree can be found in Supplementary Fig. 3.

As shown in Fig. 2, having a pet to walk is the first correlate derived from the hierarchy that decreases the odds (from 53.5% to 43.7%) of youth 15–18 years old being classified as high sedentary. The odds of youth being classified as high sedentary further decrease if they perceive their health as excellent (32.2%). Youth 15–18 years old classified as high sedentary were those that (1) did not own a pet to walk, (2) perceived their neighborhood as a safe place, and (3) reported that parents do not exercise (63.7% chance of being high sedentary). Looking in more detail into the CHAID decision tree and its secondary branches (Supplementary Fig. 4), for participants who did not have a pet to walk and simultaneously did not perceive their neighborhood as safe, the odds of being classified as high sedentary were higher (49.2%) if they lived with siblings compared to being an only child (32.1%). For youth 15–18 years old who simultaneously had a pet to walk and did not perceive their health to be excellent, those who reported having good cycling paths had lower odds of being in the high sedentary category (42.6%) compared to the those reporting not having good cycling paths in the neighborhood (54.6%) (Supplementary Fig. 4).

As shown in Fig. 3, the most important correlate impacting the CST of youth 10–14 years old was the year in school, rising from the first 2 years (17% chance of spending more than



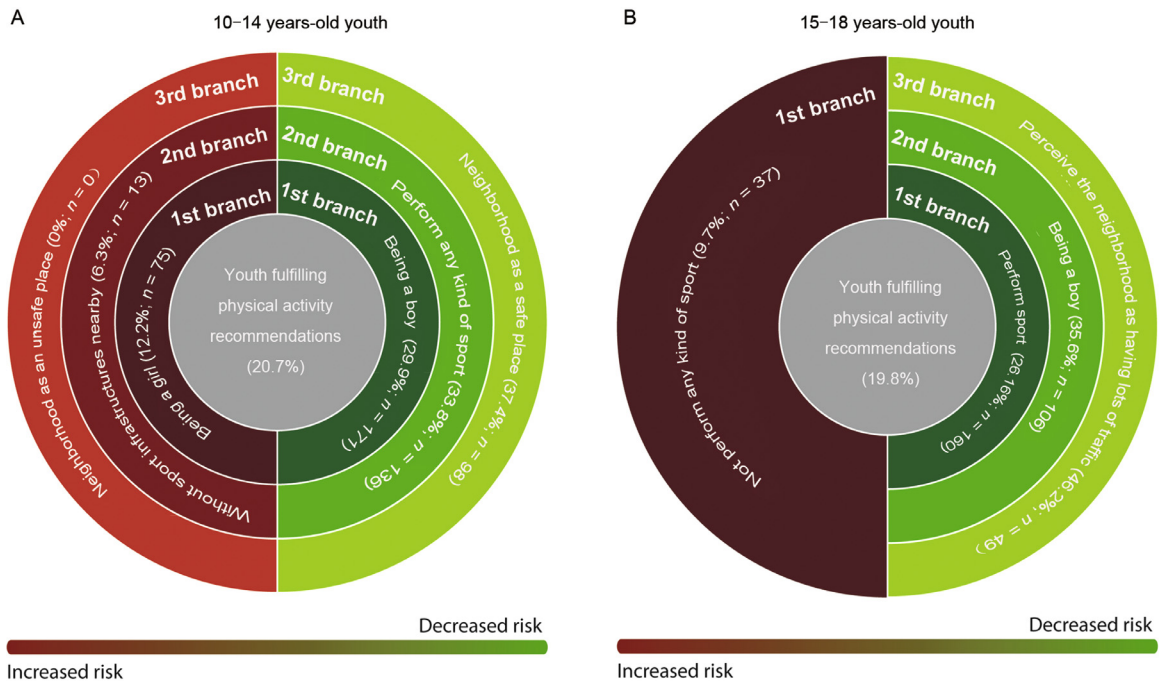


Fig. 1. Hierarchy of correlates favoring and reducing youth's chances of fulfilling physical activity recommendations by age group: (A) 10–14 years old, (B) 15–18 years old.

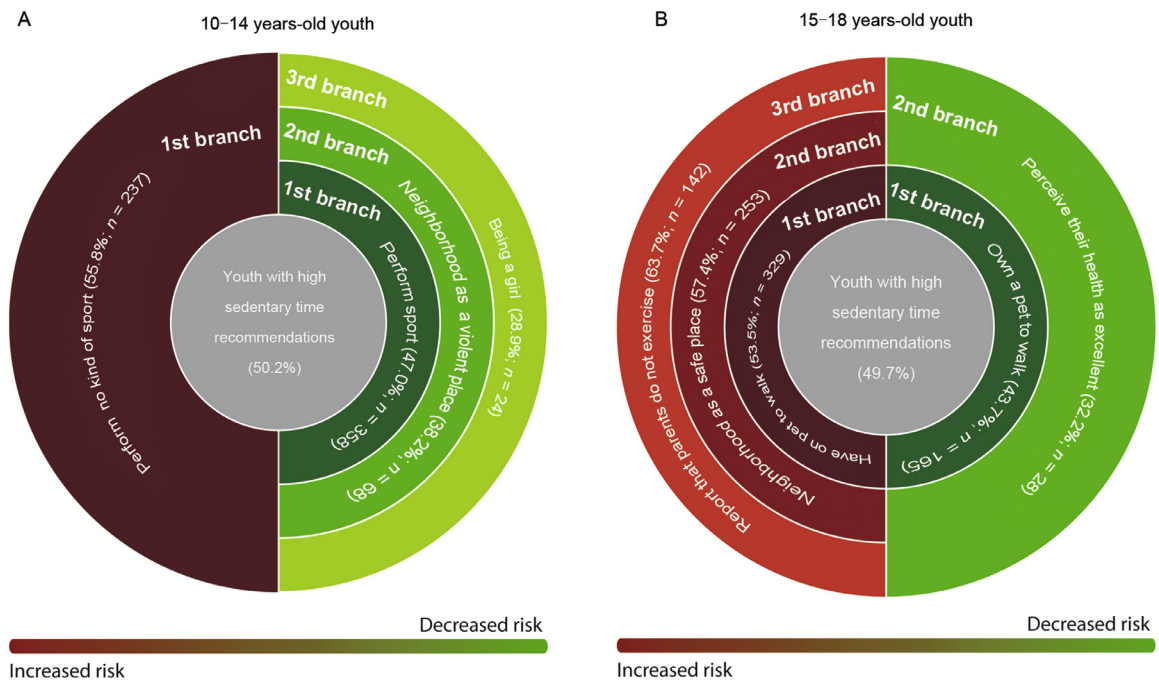


Fig. 2. Hierarchy of correlates favoring and reducing youth's chances of having high sedentary time by age group: (A) 10–14 years old, (B) 15–18 years old.

2 h/day) to the last 3 years (54.2% chance of spending more than 2 h/day). The lowest odds for spending more than 2 h/day in CST occurred when (1) youth were in the first 2 years of elementary school and (2) simultaneously did not perceive their neighborhood as a violent place (13.5%). The highest odds for youth 10–14 years old to spend more than 2 h/day in CST were when they (1) were in the last 3 years of elementary

school, (2) were girls, and (3) reported that they did not have lots of friends in the neighborhood (73.1%). As shown in Supplementary Fig. 5, for the girls 10–14 years old in the last 3 years of elementary school, having lots of friends living near their house reduced the odds of spending more than 2 h/day in CST from 73.1% to 57.4%. Finally, in the 6th grade, youth who spent their recess in active behaviors (i.e., playing and

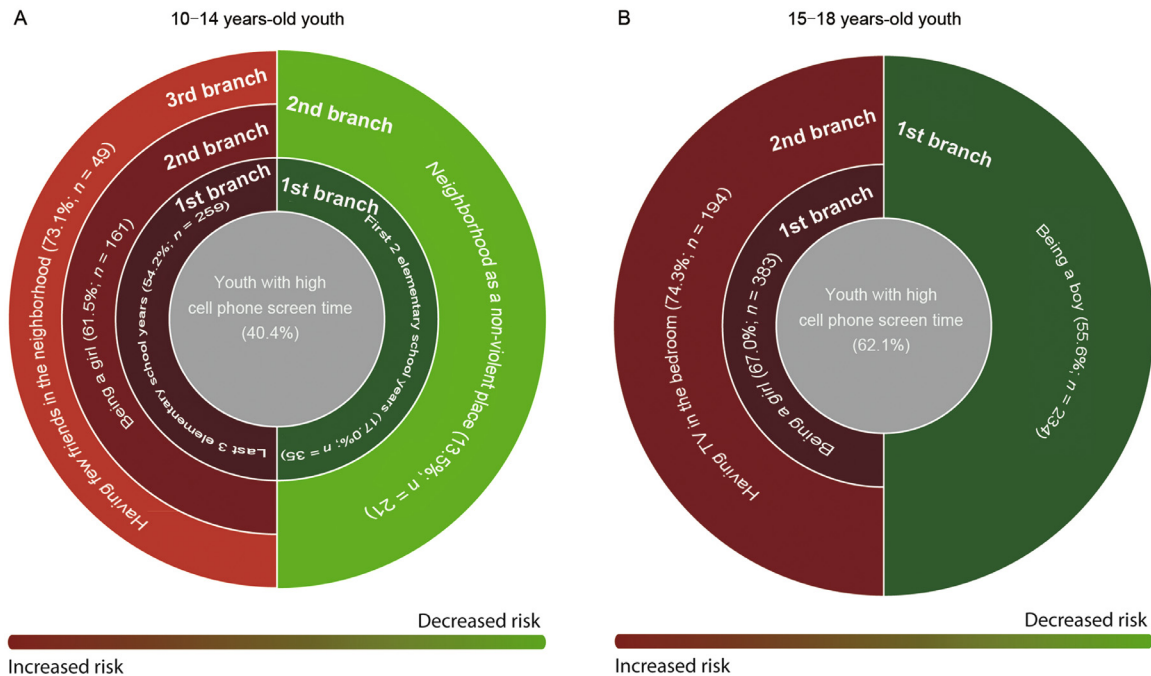


Fig. 3. Hierarchy of correlates favoring and reducing youth's chances of having high cell phone screen time by age group: (A) 10–14 years old, (B) 15–18 years old.

walking) had lower odds of spending more than 2 h/day in CST (18.9%) compared to those spending their recess mostly in sitting and standing activities (Supplementary Fig. 5).

As shown in Fig. 3, the highest odds for youth 15–18 years old to spend more than 2 h/day in CST was dependent on (1) being a girl and (2) simultaneously having a TV in the bedroom (74.3%). The lowest odds (55.6%) for spending more than 2 h/day in CST occurred when participants were boys, regardless of the other correlates. As shown in the CHAID decision tree (Supplementary Fig. 6), for the girls who did not have a TV in the bedroom, being the only child increased the odds of spending more than 2 h/day in CST (70.9%) compared to those living with siblings (56.9%).

#### 4. Discussion

The aim of this investigation was to use sensor-based ST, MVPA, and self-reported CST data from a large sample of youth, while taking into account the interactions among a variety of correlates comprising a socioecologic model. The novelty of this investigation is our use of a socioecologic approach that simultaneously considered correlates from individuals, social environments, and physical environments<sup>20</sup> while using sensor-based data for 2 independent health-related outcomes (i.e., ST and MVPA) and a prevalent behavior in youth, CST. Findings from this investigation suggest that, depending on the specific aims, outcomes, and age categories, the hierarchy of impactful correlates changes, although the hierarchy for some correlates seem to repeat for certain behaviors.

Gender emerged as an important factor for MVPA and favored boys. This confirms previous findings suggesting that girls tend to be more inactive than boys.<sup>15,16</sup> A reduction in

PA attractiveness (enjoyment) and a lower psychosocial profile of girls approaching biologic maturity may explain the decreasing rate of PA participation.<sup>40</sup> However, for sensor-based ST, especially in the 10–14-year-old youths, we found an opposite trend, with girls being less sedentary than boys, which contradicts prior findings showing that girls spend more time in sensor-based ST.<sup>41</sup> On the other hand, being a girl increased the odds of spending more than 2 h/day in CST in both age categories, which is in accordance with the existing evidence showing that girls are more prone to spend higher amounts of time in screen-based activities.<sup>42,43</sup> Thus, based on our findings and those from prior studies,<sup>44</sup> gender plays varying roles depending on the specific behavior being investigated. This reinforces the necessity for future studies to use a socioecologic approach when exploring the role of gender as a correlate for sensor-based MVPA, ST, and SBs, such as CST.

Perceived neighborhood safety also presented as a crucial correlate for determining CST and sensor-based ST and MVPA levels in youth, which supports the findings from previous investigations.<sup>17,32,45–47</sup> However, the direction of the association between perceived neighborhood safety and sensor-based MVPA and ST was inconsistent. Similar to previous findings,<sup>6,8</sup> neighborhood safety was an important correlate favoring MVPA in the younger age group. In our study, however, the perception among older active boys that their neighborhood had lots of traffic was a positive correlate for increased MVPA levels, which contradicts previous evidence suggesting that more traffic is inversely associated with MVPA levels in youth.<sup>48</sup> We hypothesize that active boys may spend more time in the streets and in the surrounding areas of their neighborhoods, leading them to potentially pay more

attention to the traffic than their less active peers, thus making them more prone to report neighborhood traffic. Also contrary to the literature,<sup>17</sup> our study found that perceived neighborhood safety increased the risk of being highly sedentary in the older group, whereas perceived neighborhood violence decreased ST in the younger group. Inconsistencies in the role that neighborhood safety plays in the levels of MVPA and ST among youth have been previously reported,<sup>49</sup> and it has been suggested that this may be partly attributed to measurement limitations.<sup>49</sup> The fact that many investigations employ generic safety measurements that make implicit references to crime or use composite variables that lack specificity are some of the proposed reasons.<sup>49</sup> Our results suggest that a sense of neighborhood security can drive youth to spend more time in MVPA but can also simultaneously promote more ST outside their homes, whereas a perception that the environment is unsafe favors low-intensity, nonsedentary activities instead of ST.

Sport participation was an important correlate related to increased MVPA levels in both younger and older youth. Moreover, in the younger age group, sport participation was the most important correlate for reducing the odds of being sedentary, thus suggesting that sport participation may be important in both MVPA and ST.<sup>33</sup> Evidence suggests that an independence exists between ST and MVPA and their associations with health,<sup>43,50</sup> but our findings are in line with those from a previous investigation,<sup>33</sup> suggesting that sport participation can be both a strategy to reduce ST and to improve MVPA levels in youth, because these authors found that sport participation emerged as a strong correlate of low screen-based SB in youth.<sup>33</sup> This suggests that sport participation may be a viable way to reduce SB, thus contradicting previous evidence suggesting that participation in sport appears to be unrelated to ST.<sup>50</sup> Furthermore, a lack of sport facilities nearby was identified as the second most important correlate for decreasing youth's chances of attaining MVPA recommendations. Our findings concur with the findings from previous investigations, suggesting that having sport infrastructures nearby is an important factor favoring youth's PA levels.<sup>51,52</sup> Proximity to sport facilities has been associated not only with higher levels of MVPA among youth,<sup>48,53</sup> but it also seems to moderate the associations between psychosocial factors (i.e., support of friends or modeling by parents) and MVPA levels among youth. For example, the positive associations between youth's MVPA and the norms support and attitudes of friends were strengthened for adolescents living in neighborhoods with high vs. low availability of PA resources.<sup>53</sup>

Previous evidence has highlighted the importance of family structure<sup>24,54</sup> and social correlates<sup>45,55</sup> in PA and ST levels. However, most studies have considered screen time to be a measure of SB, which does not cover all ST. Evidence on the impact of family structure on ST among youth in relation to data gathered through the use of sensor-based measures is scarce.<sup>56</sup> In our study, we found that living with a single parent and living with siblings impacted youth's sensor-based MVPA, ST, and CST. Evidence suggests that parents' direct involvement (i.e., instrumental support such as providing transport) and encouragement (i.e., motivational support) are

linked to youth's MVPA levels.<sup>57</sup> Nevertheless, there is a significant degree of heterogeneity in the results from studies of the relationship of family structure and PA levels,<sup>58</sup> with one study finding that regardless of whether youth lived with both parents or with a single parent, it was a nondeterminant factor for PA levels of youth.<sup>15</sup> We found, however, that living with a single parent was associated with a higher chance of attaining MVPA recommendations. A potential explanation for this observation may be related to the fact that youth living with a single parent (i.e., in cases in which parents are divorced) may be more prone to counteract parents' behaviors instead of emulating them. By acknowledging that most adults do not attain PA recommendations, one can hypothesize that living with both parents can increase the odds of following a "bad example" in terms of the parents' PA profile. In fact, reporting that their parents did not exercise was the third most important correlate for increasing the odds of being classified as high sedentary, which emphasizes that in addition to family structure, family behaviors can also impact youth's ST.<sup>42,59</sup>

Beyond the influence of parents, siblings can have an effect on youth's ST. Mixed findings on the association between ST and having siblings have been reported in the literature, with some investigations showing that having siblings increases ST, whereas other studies show the opposite effect.<sup>56</sup> In the older youth, we found that living with siblings increased the odds of being sedentary. It is possible that when there are no siblings living in the same house, youth will have to search for other ways to socialize (e.g., friends), which can imply leaving the house, thus potentially reducing their ST. However, we found that being a girl without siblings increased CST. One can hypothesize that girls without siblings may need to contact friends and other people not living in their homes, thus potentially causing them to spend more time on their cell phones. Our findings suggest that a specific feature (i.e., not having siblings) may be protective for a specific behavior (i.e., sensor-based ST) but still promote other sedentary pursuits (e.g., CST). This reinforces the importance of examining several outcomes (i.e., sensor-based ST, self-reported CST) in the same dataset so that discrepancies are not attributed to different population groups. For example, having friends living nearby (i.e., a social correlate) was found to influence CST. Our findings extend those of previous investigations that have shown that not having close neighbors increases overall SB,<sup>55</sup> thus supporting the idea that a youth's social network is paramount. Youth who do not have friends living close by may spend more time on their cell phones in order to maintain contact with their friends.

Other important correlates of youth PA and ST that were identified in the current investigation included owning a pet to walk, perception of health, and having a TV in the bedroom. In older youth, owning a pet to walk decreased the odds of being classified as high sedentary. To our knowledge, no previous investigation has considered this correlate for sensor-based ST levels in youth. However, a previous study did find that youth who walked a dog had 7%–8% more min/day of MVPA than non-dog walkers.<sup>60</sup> In addition to owning a dog, youth who perceived their health as excellent were those presenting

lower ST, which is similar to findings for the general population.<sup>15</sup> People who perceive that their health as being good have a greater predisposition to engage in nonsedentary activities, thus decreasing their time spent in sedentary pursuits.<sup>15</sup> Parents are naturally concerned with their youth's health, but educators and parents should additionally be aware of their youth's perceptions of their health because this may be a correlate for their ST levels. Last, we found that CST was increased in older girls who had a TV in their bedroom. Having a TV in the bedroom has consistently been associated with higher screen time.<sup>18,30,46,61</sup> Thus, our results confirm the findings from previous studies. There is also evidence showing that greater access to bedroom media sources is associated with higher screen time.<sup>42</sup> Therefore, parents can play a decisional role in youth's screen time by simply removing or at least limiting media sources in their youth's bedrooms. Notably, a previous investigation found that decreasing the number of TVs at home could improve the ST profiles of youth,<sup>47</sup> and another recent investigation found that media accessibility can increase overall screen time.<sup>31</sup>

The findings from the present investigation contribute greatly to the field because evidence is scarce in relation to socioecologic and other correlates of youth's PA and ST derived from sensor-based measurements, as well their self-reported CST. The use of the CHAID analysis allowed us to examine different levels of correlates in the same dataset, which is paramount for establishing an order of importance from a high number of multidomain correlates. However, this study is not without limitations. First, there is subjectivity associated with the questionnaires that were used to collect information on the correlates, even though this is the only way of collecting some of these data. In addition, the cross-sectional nature of the data does not allow for the establishment of causality. Thus, future studies should similarly use sensor-based metrics for ST and PA outcomes and aim for longitudinal protocols so that causality can be established. Finally, even though we included 31 correlates from distinct domains, there may be other relevant factors that we did not include.

## 5. Conclusion

Distinctive factors from the socioecologic model can influence sensor-based ST, PA, and self-reported CST in youth, such as sociodemographic correlates (i.e., gender, sport participation), environmental correlates (i.e., neighborhood safety, access to sport facilities), and family and social correlates (i.e., presence of siblings, parents' exercise habits, friends living nearby, having a pet to walk), as well as some other more specific correlates (i.e., having a TV in the bedroom). Public and governmental strategies to counteract SB and boost youth's PA levels should focus on girls, emphasize neighborhood safety and improved access to sport facilities, and promote overall sport participation, as well as extend these strategies to family and friends in order to change youth's habits. Also, simple plans, such as endorsement of pet ownership and limiting access to TVs in the bedroom, may help to attain better health profiles in today's youth.

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## Authors' contributions

PBJ, JPM, GBR, and DHN conducted fieldwork; LBS developed the conceptual model and conducted mapping; PBJ and MHR performed data analyses. All authors discussed the results, contributed to the writing of the manuscript. All authors have read and approved the final manuscript, and agree with the order of the presentation of authors.

## Competing interests

The authors declare that they have no competing interests.

## Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:[10.1016/j.jshs.2020.03.003](https://doi.org/10.1016/j.jshs.2020.03.003).

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