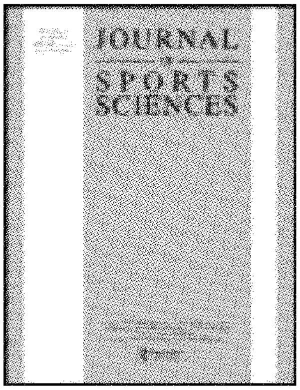


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Sarah C. Ullrich-French [a] , Thomas G. Power [b] , Kenn B. Daratha [c] , Ruth C. Bindler [c] & Michael M. Steele [d]

[a] Educational Leadership and Counselling Psychology, Washington State University, Pullman, Washington

[b] Department of Human Development, Washington State University, Pullman, Washington

[c] College of Nursing, Washington State University, Spokane, Washington

[d] Department of Psychology, Auburn University, Auburn, Alabama, USA

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# Examination of adolescents' screen time and physical fitness as independent correlates of weight status and blood pressure

SARAH C. ULLRICH-FRENCH[1], THOMAS G. POWER[2], KENN B. DARATHA[3], RUTH C. BINDLER[3], & MICHAEL M. STEELE[4]

[1]*Educational Leadership and Counselling Psychology, Washington State University, Pullman, Washington,* [2]*Department of Human Development, Washington State University, Pullman, Washington,* [3]*College of Nursing, Washington State University, Spokane, Washington, and* [4]*Department of Psychology, Auburn University, Auburn, Alabama, USA*

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**Abstract**

Physical fitness performance is an important health correlate yet is often unrelated to sedentary behaviour in early adolescence. In this study, we examined the association of sedentary behaviour (i.e. screen time) with weight-related health markers and blood pressure, after controlling for cardiorespiratory fitness performance. American middle school students ($N = 153$, 56% females) aged 11–15 years (mean 12.6 years, $s = 0.5$) completed assessments of cardiorespiratory fitness performance, screen time, weight status (BMI percentile, waist-to-height ratio), and blood pressure. Multivariate analysis of covariance, controlling for cardiorespiratory fitness performance, found those who met the daily recommendation of 2 h or less of screen time ($n = 36$, 23.5%) had significantly lower BMI ($p < 0.05$) and systolic blood pressure ($p < 0.01$) compared with those who exceeded this recommendation. Findings suggest specific intervention programmes may be designed to target both cardiorespiratory fitness and sedentary behaviours to maximize early adolescent health because these behaviours are likely to have unique and independent effects on youth health markers.

**Keywords:** *Youth, health, physical activity, sedentary*

## Introduction

The health benefits of physical activity in early adolescence are well documented (Davis et al., 2007). Physically active children and adolescents show higher levels of cardiovascular fitness, bone health, and self-esteem, and lower levels of obesity, stress, and blood pressure than their less active peers (e.g. Hallal, Vitora, Azevedo, & Wells, 2006; US Department of Health and Human Services, 2000). Although low levels of activity are associated with poorer health, researchers (e.g. Leatherdale & Wong, 2008; Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009) have recently begun to consider whether participating in low energy expending activities, such as watching television, playing video games, and using a computer (i.e. screen time) constitutes a health risk factor that is independent of lack of physical activity.

Sedentary behaviour has been defined in various ways. Once almost exclusively considered the absence of physical activity, or inactivity, researchers of sedentary behaviour now more often target specific behaviours that include activities such as screen time, time spent reading, and time spent doing homework (Marshall & Welk, 2008). Despite recent interest in the broad concept of sedentary behaviours, it remains a relatively understudied area when compared with physical activity behaviours (Biddle, Gorely, & Stensel, 2004; Iannotti, Kogan, Janssen, & Boyce, 2009). Support is emerging for exploring the independent health links of specific sedentary and physical activity behaviours in early adolescence (e.g. Keeton & Kennedy, 2009; Steele et al., 2009). For example, Leatherdale and Wong (2008) distinguished more productive sedentary activities (e.g. reading and homework) from screen time (e.g. television, video games) in a large sample of adolescents. Screen time was more consistently associated with negative health-related factors than productive sedentary behaviours. Television and other forms of screen time (but excluding computer use) was recently associated with blood pressure in young children (Martinez-Gomez, Tucker, Heelan, Welk, & Eisenmann, 2009). Therefore, the current study targeted non-school-related screen time (i.e.

Correspondence: S. C. Ullrich-French, Educational Leadership and Counselling Psychology, Washington State University, PO Box 641410, Pullman, WA 99164-1410, USA. E-mail: sullrich@wsu.edu

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television, video games, and non-school-related computer use) to represent sedentary behaviour.

Sedentary behaviours can co-exist with varying levels of physical activity. That is, children can show high levels of participation in both physical activities and in sedentary activities. Indeed, physical activity and sedentary behaviours are often either unrelated or have a weak association (Marshall, Biddle, Gorely, Cameron, & Murdey, 2004; Sallis, Prochaska, & Taylor, 2000). It is therefore suggested that these are two *independent* health risk factors (Biddle, Gorely, Marshall, Murdey, & Cameron, 2003; Salmon, Dunstan, & Owen, 2008; Schneider, Dunton, & Cooper, 2007), though relatively few studies have explored this distinction with several health indicators in early adolescence.

Research on sedentary behaviour has largely targeted the association of screen time with weight-related health indicators of body mass index, body fatness, waist circumference, and overweight status (e.g. Hume, Singh, Brug, Mechelen, & Chinapaw, 2009; Leatherdale & Wong, 2008; Marshall et al., 2004; Patrick et al., 2004; Rey-López, Vicente-Rodríguez, Biosca, & Moreno, 2008). Most studies have reported associations of small magnitude for these health indicators. Therefore, an extension of this preliminary work is to consider additional markers of physical health. Some research has begun to explore factors such as blood pressure, but this work is limited. For example, Pardee and colleagues (Pardee, Norman, Lustig, Preud'homme, & Schwimmer, 2007) found increased odds of hypertension (i.e. elevated blood pressure) with greater television viewing time in a sample of obese children and adolescents. More recently, Martinez-Gomez et al. (2009) found the sedentary behaviours of 3- to 8-year-olds to be associated with systolic and diastolic blood pressure after controlling for body composition. Waist-to-height ratio, a weight status indicator, is associated with both youth obesity and cardiovascular risk (Kahn, Imperatore, & Cheng, 2005; Yan et al., 2007), yet has not been explored relative to screen time. Waist-to-height ratio provides an easy and accurate alternative indicator of weight status that is non-age-dependent and increasingly recommended for use with children and adolescents (Yan et al., 2007). Here, we examine early adolescent health by assessing the weight-related health markers of BMI percentile, waist-to-height ratio, and blood pressure.

An important pathway for the beneficial effects of physical activity is through improved physical fitness (Hallal et al., 2006; US Department of Health and Human Services, 2000). Physical activity recommendations have historically focused on cardiorespiratory endurance (US Department of Health and Human Services, 1999), suggesting cardiorespiratory fitness performance may provide a tool for examining the link between physical activity and health outcomes. Cardiorespiratory fitness performance is distinct from, yet is highly related to, physical activity, and may serve as an alternative indicator for moderate to vigorous activity (Fogelholm, 2008). Some researchers would like to see more objective measures of physical activity and sedentary behaviours (Reilly et al., 2008). However, a limitation in using objective measures (e.g. accelerometers, fitness) is the inability to capture information highly relevant to interventions such as the type of (in)activity, which is more easily garnered by self-report measures. In a recent review of physical activity epidemiological research, Blair and Morris (2009) state that fitness performance may be a more accurate representation of physical activity habits than self-reported behaviour, which is more commonly used. Although less scrutinized with children and youth, it is believed that people of all ages experience beneficial physiological responses to physical activity (US Department of Health and Human Services, 1999).

A recent study used accelerometers to indicate activity intensity (sedentary, moderate, vigorous) in an examination of the associations of physical activity, body mass index (BMI), cardiorespiratory fitness, and blood pressure in youth aged 11–17 years (Gaya et al., 2009). Associations varied for different levels of intensity. Increased time spent in sedentary activities was associated with higher systolic blood pressure, whereas increased time spent in moderate physical activities was associated with lower systolic blood pressure. Cardiorespiratory fitness was not associated with blood pressure (systolic or diastolic), whereas diastolic blood pressure was not associated with any measure of activity in this study. Martinez-Gomez et al. (2009) used accelerometer data to represent objectively measured sedentary behaviour, in addition to parent-reported sedentary behaviour. No association was found between sedentary behaviour and blood pressure when measured by accelerometer; the parent-reported sedentary behaviour was positively associated with both systolic and diastolic blood pressure. In addressing how levels of physical activity relate to blood pressure, these studies provided initial evidence that blood pressure is an important health factor for youth. However, there are inconsistent results on the relationships of physical activity, cardiorespiratory fitness performance, and sedentary behaviours with blood pressure in youth, showing this area of inquiry is underdeveloped.

Untangling the role of sedentary behaviours from cardiorespiratory fitness performance among early adolescents has not been clearly accomplished. Therefore, the aims of the present study were to:

(1) describe the association of cardiorespiratory fitness performance with weight-related health markers (BMI percentile and waist-to-height ratio) and systolic and diastolic blood pressure in a sample of early adolescents; and (2) determine the relationship of sedentary behaviour (i.e. screen time) with the previously mentioned weight-related health markers and blood pressure, after controlling for cardiorespiratory fitness performance in a sample of early adolescents.

We hypothesized that those who had higher cardiorespiratory fitness performance would have lower measures of weight status (BMI and waist-to-height ratio) and lower blood pressure. We also hypothesized that those who reported more screen time would demonstrate elevated measures of weight status (BMI and waist-to-height ratio) and blood pressure when controlling for cardiorespiratory fitness performance, supporting the independent health risk of screen time use for early adolescents.



## Methods

### *Participants*

Participants included middle school students ($N = 153$, 56% females) who participated in the US-based Teen Eating and Activity Mentoring in Schools (TEAMS) study aimed at improving health and preventing obesity among middle school students. Students were recruited during parent–teacher night open houses, school-based family barbeques, school newsletters, and by school-based and study personnel in the first month of attendance in the seventh grade. Students with mental or physical conditions that would limit their participation in the larger study activities were not included. Inclusion criteria specifically precluded students with diabetes, cardiovascular disease, and those taking insulin and oral glycaemic medications. Only one student had a cardiovascular condition and no data were collected or reported for this student. Data reported in this study were taken at baseline and do not reflect any potential intervention effects. Students, whose ages ranged from 11 to 15 years (mean 12.6 years, $s = 0.5$), were drawn from four public middle schools in the inland Pacific Northwest. Overall the sample represented moderate socio-economic status as indicated by the Hollingshead index (mean 37.34, $s = 17.29$). The ethnicity reported by the participants was largely white (82%).

### *Procedure and measures*

Following university and school district Institutional Review Board approval, students from four public middle schools in the USA were recruited to participate in the TEAMS project. With parental permission, students were assessed for fitness performance, health behaviours, health biomarkers, and anthropometry.

*Health markers.* Anthropometric measurements were taken, including height, weight, and waist circumference. Height was measured on a standing stadiometer using procedures recommended by the US Centers for Disease Control and Prevention (CDC) (2005). Weight was measured on a Seca digital scale following CDC recommendations. Body mass index was calculated by dividing weight in pounds by height in inches squared and multiplying by a conversion factor of 703 (Cole, Faith, Pietrobelli, & Heo, 2005). Exact percentage for each participant was determined based on CDC growth curves. Waist circumference was measured around the abdomen at the level of the iliac crest with repeated measurements for accuracy, and recorded in centimetres. Waist-to-height ratio was calculated using waist circumference and height. Waist-to-height ratio is a measure of relative overall adiposity and has been found to be highly correlated with other clinical indicators of health in adults and children (e.g. cardiovascular health; Kahn et al., 2005; Srinivasan et al., 2009).

Both systolic blood pressure and diastolic blood pressure were measured following CDC protocols. Three measurements were taken for each participant. Systolic blood pressure was calculated as the average of the second and third systolic measurements. Diastolic blood pressure was calculated as the average of the second and third diastolic measurements. Blood pressure percentiles were established using the National Heart, Lung and Blood Institute blood pressure tables (US Department of Health and Human Services, 2004).

*Cardiorespiratory fitness performance.* Cardiorespiratory fitness performance was assessed using the Progressive Aerobic Cardiovascular Endurance Run (PACER) fitness gram protocol (Meredith & Welk, 2007). This is a multi-stage aerobic capacity test adapted from the 20-m shuttle run that progresses in intensity with higher scores representing greater aerobic capacity. The PACER test is a widely used and well-validated measure (Morrow, Jackson, Disch, & Mood, 2000).

*Screen time.* Participants' self-reported screen time use during average weekday hours (after school) was assessed using three items. Two items were taken from the Youth Risk Behavior Survey (US Centers for Disease Control and Prevention, 2008) regarding time spent during a typical school day: (1) watching television and (2) playing video or computer games not related to school work. A third item was adapted from the 1999 Youth Risk Behavior Surveillance Systems on average school day hours watching television or playing video games. In the present study, these items were averaged to form an internally consistent indicator of screen time hours for a typical school day ($\alpha = 0.88$).

*Data analysis*

Means and standard deviations among study variables were calculated for descriptive purposes. Bivariate correlations were calculated among the study variables to describe the association of cardiorespiratory fitness performance with weight-related health markers (BMI percentile and waist-to-height ratio) and systolic and diastolic blood pressure. Multivariate analysis of covariance was used to compare those who met sedentary behaviour recommendations with those who exceeded this recommendation on BMI percentile, waist-to-height ratio, systolic blood pressure, and diastolic blood pressure, with gender, socioeconomic status (using Hollingshead score), school, and cardiorespiratory fitness performance (aerobic capacity) as covariates. Appropriate follow-up analyses were conducted and estimated marginal means, adjusted for covariates, were examined.

## Results

*Descriptive statistics*

The cardiorespiratory fitness performance scores ranged widely with an average of 19.27 ($s = 18.28$). Only 24% of participants' scores fell within the recommended healthy fitness zone (Meredith & Welk, 2007). Descriptive statistics (i.e. means, standard deviations, and bivariate correlations) were calculated (see Table I).

Overall, the participants reported high levels of screen time (mean $3.44\ \text{h} \cdot \text{day}^{-1}$, $s = 1.82$). Unfortunately, this variable did not function well as a continuous measure (i.e. was non-normal, had limited variability, and did not correlate with other variables). Current recommendations from the Council on Sports Medicine and Fitness and Council on School Health (2006) and the American Academy of Pediatrics Committee on Nutrition (2003) call for no more than 2 h of non-school-related screen time per day. Given the limitations noted above, we used a cut point of less than $2\ \text{h} \cdot \text{day}^{-1}$ to create a dichotomous variable to determine whether a participant met recommended levels of non-school-related screen time. This variable was used in the present study to represent screen time. A small percentage (23.5%, $n = 36$) of the sample met recommended levels (no more than $2\ \text{h} \cdot \text{day}^{-1}$) of non-school-related screen time. The cardiorespiratory fitness performance score was used as a covariate.

Average weight status scores were 72.17 for BMI percentile ($s = 26.28$) and 0.50 for waist-to-height ratio ($s = 0.08$). Average blood pressure scores (systolic: mean 104.7 mmHg, $s = 10.70$; diastolic: mean 65.6 mmHg, $s = 9.47$) fell within the normal ranges for this age group (National Heart, Lung and Blood Institute, 2005).

*Cardiorespiratory fitness associations*

Significant bivariate correlations with cardiorespiratory fitness were small to moderate in magnitude (see Table I). As expected, greater cardiorespiratory fitness was associated with lower BMI percentile, waist-to-height ratio, and diastolic blood pressure. Of note was the non-significant correlation between cardiorespiratory fitness and both non-school-related screen time and systolic blood pressure.

*Independent screen time effects*

Multivariate analysis of covariance was used to compare those who met the recommendation of

Table I. Means, standard deviations, and bivariate correlations among study variables.

| | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1 | BMI percentile | | | | | | |
| 2 | Waist-to-height ratio | 0.71** | | | | | |
| 3 | Systolic blood pressure | 0.39** | 0.38** | | | | |
| 4 | Diastolic blood pressure | 0.27** | 0.26** | 0.40** | | | |
| 5 | Cardiorespiratory fitness | −0.30** | −0.23** | −0.09 | −0.36** | | |
| 6 | Screen time# | −0.18* | −0.13 | −0.26** | −0.07 | 0.05 | |
| | *N* | 155 | 153 | 153 | 153 | 153 | 153 |
| | mean | 72.17 | 0.50 | 104.70 | 65.60 | 19.27 | – |
| | *s* | 26.28 | 0.08 | 10.70 | 9.47 | 18.28 | – |

*Note*: Pearson product–moment correlations are reported, except #point-biserial correlation was used for this dichotomous variable.
*$P < 0.05$, **$P < 0.01$.

2 h or less of sedentary behaviour per day with those who exceeded this recommendation on the various health indicators (BMI percentile, waist-to-height ratio, systolic blood pressure, and diastolic blood pressure) after controlling for gender, socioeconomic status (using Hollingshead score), school, and cardiorespiratory fitness performance (aerobic capacity). The gender, socioeconomic status, and school covariates were not significant, and were thus removed to maximize power. In this new model, the cardiorespiratory fitness performance covariate was significant (Pillai's Trace = 0.19, $F_{4,147} = 8.72$, $P < 0.01$, $\eta_p^2 = 0.19$), with significant between-participants effects for BMI percentile ($F_{1,150} = 14.98$, $P < 0.01$, $\eta_p^2 = 0.09$), waist-to-height ratio ($F_{1,150} = 8.32$, $P < 0.01$, $\eta_p^2 = 0.05$), and diastolic blood pressure ($F_{1,150} = 21.93$, $P < 0.01$, $\eta_p^2 = 0.13$). Greater cardiorespiratory fitness performance was associated with lower BMI percentile, waist-to-height ratio, and diastolic blood pressure.

The omnibus test for meeting non-school-related screen time recommendations was significant (Pillai's Trace = 0.08, $F_{4,147} = 3.10$, $P < 0.05$, $\eta_p^2 = 0.08$). Follow-up analyses indicated significant between-participants differences for BMI percentile ($F_{1,150} = 4.72$, $P < 0.05$, $\eta_p^2 = 0.03$) and systolic blood pressure ($F_{1,149} = 10.69$, $P < 0.01$, $\eta_p^2 = 0.07$). See Table II for group estimated marginal means. Estimated marginal means, adjusting for the cardiorespiratory fitness performance covariate, indicated that the group that met sedentary recommendations had lower BMI and systolic blood pressure compared with the group that exceeded sedentary recommendations. That is, early adolescents with higher than recommended levels of sedentary behaviour had worse health outcomes for weight status and blood pressure, regardless of cardiorespiratory fitness performance.

## Discussion

The present study extends past research by exploring the unique effects of sedentary behaviour, after controlling for cardiorespiratory fitness, on youth weight-related health markers and blood pressure. As a topic of great interest to policy makers and health and education professionals, it is imperative that the independent contributions of cardiorespiratory fitness and sedentary behaviours to youth health be untangled so that specific intervention programmes can be designed to maximize youth health.

Our results largely supported the study hypotheses, albeit with modest effect sizes. The first objective of the study was to describe and thus confirm that cardiorespiratory fitness performance was associated with health markers. Cardiorespiratory fitness performance was associated with lower BMI percentile, diastolic blood pressure, and waist-to-height ratio as expected, but was not associated with systolic blood pressure. The second objective of the study was to determine the independent association of non-school-related screen time on health markers. Non-school-related screen time exhibited independent effects with BMI percentile and systolic blood pressure, such that those who met screen time recommendations had lower BMI percentile and systolic blood pressure than the group who exceeded screen time recommendations, while controlling for cardiorespiratory fitness performance. Although both were linked with BMI, cardiorespiratory fitness was uniquely salient to the waist-to-height ratio and diastolic blood pressure, whereas non-school-related screen time was uniquely associated with systolic blood pressure.

Blood pressure is an important health risk factor for children and adolescents (Muntner, Cutler, Wildman, & Whelton, 2004; National Heart, Lung and Blood Institute, 2005). In the current study, diastolic blood pressure was associated with cardiorespiratory fitness performance and systolic blood pressure was linked with sedentary behaviour. Evidence suggests weight status is consistently linked with elevated blood pressure, but there is limited evidence for specific links to physical activity and sedentary behaviour. Weight loss is currently the strongest predictor of improving blood pressure status for adolescents (see National Heart, Lung and Blood Institute, 2005). Modifiable lifestyle

Table II. Estimated marginal means and 95% confidence intervals.

| | Mean (95% CI) | |
|---|---|---|
| | $\leq 2$ h · day$^{-1}$ ($n = 36$) | $>2$ h · day$^{-1}$ ($n = 117$) |
| BMI percentile* | 64.38 (56.19 to 72.56) | 74.68 (70.14 to 79.22) |
| Waist-to-height ratio | 0.48 (0.46 to 0.51) | 0.50 (0.49 to 0.52) |
| Systolic blood pressure** | 99.76 (96.34 to 103.17) | 106.22 (104.33 to 108.12) |
| Diastolic blood pressure | 64.73 (61.81 to 67.67) | 65.85 (64.22 to 67.47) |

*Note*: Marginal means are adjusted for the cardiorespiratory fitness covariate.
*$P < 0.05$, **$P < 0.01$.

factors used to achieve healthy weight status include regular physical activity, reduced sedentary behaviour, and a diet that is low in sodium but high in fruit and vegetables, fibre, and low-fat dairy (National Heart, Lung and Blood Institute, 2005). Pardee et al. (2007) found increased odds of having hypertension with greater television viewing in an obese sample; however, the study did not establish separate links with diastolic and systolic blood pressure or include non-obese youth.

The current findings support those of Gaya et al. (2009), who found more sedentary behaviour to be associated with higher systolic blood pressure. However, in contrast to the current findings, Gaya and colleagues found that systolic blood pressure was also linked with moderate physical activity, cardiorespiratory fitness was not predictive of blood pressure, and diastolic blood pressure was not implicated by any activity intensity. Guillaume and colleagues (Guillaume, Lapidus, Bjorntorp, & Lambert, 1997) identified a borderline relationship between television viewing and systolic blood pressure, for boys only, in a sample of youth from a region in Belgium with a high prevalence of cardiovascular risk factors. Martinez-Gomez et al. (2009) linked sedentary behaviours to systolic and diastolic blood pressure, using a sample of younger children (age 3–8 years). Based on the results reported above, the type and intensity of activity together with participants' gender and age/stage of development are factors to consider in future work. A greater understanding of how sedentary and physical activities impact blood pressure is an important priority given that blood pressure is considered a long-term health risk factor in youth, tracking through adolescence into adulthood (Chen & Wang, 2008).

Promotion of active lifestyles (i.e. increased physical activity and fitness, decreased screen time) is warranted and supported by researchers considering the independent roles of physical and sedentary activities on youth health risk (National Heart, Lung and Blood Institute, 2005; Nelson & Gordon-Larsen, 2006). The modest findings of the current study are supportive of such interventions, though clearly more youth-based research is necessary. A recent review concluded that sedentary behaviour may contribute to obesity by way of several pathways, but support is primarily found for increased consumption of unhealthy foods with sedentary pursuits such as television viewing (see Rey-López et al., 2008). There are a number of studies that have controlled for weight status, finding independent contributions of physical activity and/or sedentary behaviour (e.g. Leary et al., 2008; Martinez-Gomez et al., 2009). These findings suggest alternative pathways to health risk. Further exploration of more precise means (e.g. via metabolic or lifestyle factors) by which sedentary activities affect youth health would help in the design of more specific interventions.

Limitations of the study include a limited sample size and representation from a single geographic area. Although representative of the particular school district, the sample was largely white and had little representation at the lowest levels of socioeconomic status. The covariates of gender and socioeconomic status were not significant in the current study, although the links between socioeconomic status and both physical activity and health have been clearly established and should be pursued further (e.g. Strauss & Pollack, 2001; Walters, Barr-Anderson, Wall, & Neumark-Sztainer, 2009).

The modest effect sizes also suggest caution in interpreting results and larger samples and precise measurement are encouraged in future work. The use of self-reports for sedentary behaviours (i.e. reported screen time) should be used with caution, as validity of this measure was not confirmed. Although this study used an objective measure of cardiorespiratory fitness performance, a better understanding of different types of indicators of physical activity and fitness is important. For example, using accelerometers to track physical activity behaviour may provide an enhanced picture of how different patterns of intensity of physical and sedentary activities link with one another and with youth health. However, information more easily garnered by self-report, such as the type of activity, may be highly relevant to intervention work.

Overall, the present study contributes unique information regarding youth health. It is hoped that researchers will further pursue our understanding of the unique effects of different types of physical and sedentary behaviours on a variety of health markers. In particular, the current work further supports the use of blood pressure as a valuable health marker for youth. Future research on youth activity and health markers can aid in the development of targeted interventions to improve youth health by clarifying the roles of physical activity, fitness, and sedentary behaviour patterns.

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