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Relationship Between Meeting 24-hour Movement Guidelines and Cardiometabolic Risk Factors in Children

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Abstract

Background—The purpose was to evaluate the relationship between adherence to pediatric 24-hour movement guidelines (moderate-to-vigorous physical activity (MVPA), sedentary behavior and sleep) and cardiometabolic risk factors.

Methods—The sample included 357 white and African American children aged 5-18 years. Physical activity, TV viewing and sleep duration were measured using questionnaires, and the 24-hour guidelines were defined as: 60 min/day of MVPA on 5 days/week, 2 h/day of TV, and sleeping 9-11 h/night (ages 5-13 y) or 8-10 h/night (ages 14-18 y). Waist circumference, body fat, abdominal visceral (VAT) and subcutaneous adipose tissue (SAT), blood pressure and fasting triglycerides, HDL-cholesterol and glucose were measured in a clinical setting.

Results—A total of 26.9% of the sample met none of the guidelines, whereas 36.4%, 28.3% and 8.4% of the sample met 1, 2 or all 3 guidelines, respectively. There were significant associations between the number of guidelines met and BMI, SAT, VAT, triglycerides, and glucose. There were no associations with blood pressure or HDL-cholesterol.

Conclusions—Meeting more components of the 24-hour guidelines was associated with lower levels of obesity and several cardiometabolic risk factors. Future efforts should consider novel strategies to simultaneously improve physical activity, sedentary time and sleep in children.

Keywords

physical activity; obesity; sedentary behaviour; pediatrics; risk factors; sleep

Physical activity guidelines for children and youth typically focus on increasing moderate-to-vigorous intensity physical activity levels. The current guidelines are relatively harmonized across countries and call for at least 60 minutes of moderate-to-vigorous physical activity (MVPA) daily in school-aged children.^{1,2} In recent years there has been increasing interest in also addressing the risks associated with excessive sedentary behaviors (too much sitting) in children. In 2011, Canada released sedentary behavior guidelines alongside their physical activity guidelines, which called for no more than 2 hours of recreational screen time in children 5-17 y of age.³

In addition to MVPA and sedentary behavior, there is significant interest in understanding the health effects of human movement across the entire 24 hour period, including sedentary behavior, all levels and intensities of physical activity (light, moderate, vigorous), and sleep.^{4,5} To address this issue, the *Canadian 24-Hour Movement Guidelines for Children and Youth* were recently developed by the Canadian Society for Exercise Physiology (CSEP).⁶ These new 24-hour guidelines provide recommendations for decreasing sedentary behavior, increasing light activity, increasing MVPA, and improving sleep hygiene in children and youth. Although specific quantitative recommendations are not provided for overall sedentary behavior and light physical activity, the guidelines call for at least 60 minutes of daily MVPA, no more than 2 hours of recreational screen time per day, and uninterrupted 9 to 11 hours of sleep per night for those aged 5–13 y and 8 to 10 hours per night for those aged 14–17 y.⁶

One recent study demonstrated that only 7.2% of 10-y old children from 12 countries were meeting the 24-hour guidelines; however, those children who met the guidelines had a lower average BMI and a lower odds of obesity.⁷ Further, a recent study using data from the Canadian Health Measures Survey (CHMS) reported that 17% of 6–17 y old children were meeting the guidelines, and those that met all three components of the guidelines scored better on several health indicators than those meeting fewer components of the guidelines.⁸ The purpose of this study was to determine the association between meeting the 24-hour guidelines and cardiometabolic risk factors in white and African American children and adolescents.

Materials and Methods

Participants

The sample included 357 white and African American children and adolescents aged 5–18 y recruited from Baton Rouge LA. Recruitment occurred through radio and television advertisements and through pediatricians' offices. Participants provided written assent, and parents or guardians provided informed consent. All study procedures were approved by the Pennington Biomedical Research Center institutional review board. Data collection occurred between January 2010 and August 2011.

Components of 24-Hour Guidelines

Information on physical activity, recreational screen time and sleep duration were obtained using a written lifestyle questionnaire, which was completed by the child with parental assistance if necessary. Physical activity status was obtained using the following question adapted from the National Health and Nutrition Examination Survey (NHANES) 2009–2010 questionnaire:⁹ “During the past 7 days, how many days were you physically active for a total of at least one hour (60 minutes) per day? Add up all the time spent in any kind of physical activity that increased your heart rate and made you breathe hard some of the time.” An overall measure of recreational screen time was not available, so self-reported television viewing was used as a measure of screen time. Participants reported TV viewing by answering the following question adapted from the NHANES 2009–2010 questionnaire:⁹ “During the past 30 days, on average how many hours per day did you sit and watch TV or

videos?" The response categories were: none; less than 1 hour; 1 hour; 2 hours; 3 hours; 4 hours; 5 hours or more. Sleep duration (hours) was obtained using the following question adapted from the Pittsburgh Sleep Quality Index (PSQI): "During the past month, on average, how many hours of actual sleep did you get each night? (This may be different than the number of hours you spent in bed)".¹⁰

Meeting the 24-hour guidelines was defined as: 60 min/day of MVPA on at least 5 days per week, 2 h/day of TV time, and sleeping 9-11 h/night (ages 5-13 y) or 8-10 h/night (ages 14-18 y).⁶

Cardiometabolic Risk Factors

Height and weight were measured in the outpatient clinic using standard procedures. The BMI was calculated (kg/m^2) and BMI percentiles were computed using the SAS program for the 2000 Centers for Disease Control and Prevention (CDC) Growth Charts for the United States.¹¹ Obesity was defined as 95th percentile. Waist circumference was measured at the level of the superior iliac crest using an inelastic anthropometric tape.

Total body fat (kg) was measured by DXA using a Hologic QDR 4500A whole-body scanner (Bedford, MA, USA) following standard procedures.¹² The scans were analyzed using QDR software for Windows V11.2. Two distinct energies were used to determine body mineral and soft tissue content. Variations of the attenuation ratio (determined from known tissue content) established the fat content of the tissue at each pixel. Abdominal subcutaneous (SAT) and visceral adipose tissue (VAT) were measured from cross-sectional MRI scans obtained from a General Electric (GE) Signa Excite (3.0 Tesla) (GE Medical Systems, Milwaukee, WI, USA) scanner.¹² An eight channel torso-array coil was placed over the participant's chest/abdomen area while the participant lay motionless on the scanner table wearing no metal containing objects. A series of scans from the highest point of the liver to the bottom pole of the right kidney were acquired. Images were analyzed using the AnalyzeVR software package (CNSoftware, Rochester, MN, USA) on a computer workstation by one trained technician. Analyzed slices were 4.78 cm (28 slices) apart and included between five and eight slices depending on the participant's stature. SAT and VAT areas were manually drawn, and the number of pixels was multiplied by voxel width and voxel height for each slice to compute area measured in square centimeters. To estimate total abdominal SAT or VAT volume, the area from each slice was multiplied by the number of slices separating each slice (28 slices), then multiplied by 0.000001 by the voxel depth. The five to eight slice volumes were summed to calculate total volume of SAT or VAT in liters (L) for each participant.

Resting blood pressures were measured with a standard mercury manometer, and the averages of two systolic and diastolic measurements were used for analysis (or the closest two of three if difference exceeded 10 mm Hg). A blood sample was drawn using venipuncture following an overnight fast. HDL-C was assayed using Trinity DXC600; serum triglycerides and glucose were obtained on a Beckman Coulter DXC600.

A continuous cardiometabolic risk score was computed following the recommendations of Eisenmann¹³ as follows: BMI, mean arterial pressure ($\text{MAP} = ((2 \times \text{DBP}) + \text{SBP})/3$), HDL-C,

fasting blood glucose, and triglycerides were regressed on age, sex and race, and the standardized residuals were summed (HDL-C was multiplied by -1). Elevated cardiometabolic risk factors were defined as follows:¹⁴ BMI ≥ 85th percentile; HDL-C <45 mg/dl; triglycerides ≥ 75 mg/dl (in 5-9 y olds) or ≥ 90 mg/dl (in 10–18 y olds); fasting blood glucose ≥ 100 mg/dl; and high blood pressure if systolic or diastolic blood pressure ≥ 90th percentile for age, sex and height. Participants with ≥ 2 cardiometabolic risk factors were considered to be at elevated cardiometabolic risk.

Statistical Analysis

Statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC, US). Means and standard deviations of descriptive characteristics were computed. Associations between the number of guidelines components met (0, 1, 2, or all 3) and cardiometabolic risk factors were assessed using general linear models (PROC GLM) with a test for linear trend across the groups. In supplemental analyses, the association between meeting each individual component of the guidelines and the cardiometabolic risk factors was also tested using general linear models, adjusting for age, sex, race and the other two components. The odds of obesity and elevated cardiometabolic risk associated with meeting each guideline component and the number of guideline components met were obtained using logistic regression (PROCLOGISTIC), with the zero category acting as the reference group. Sex and race interactions were included in preliminary models but they were not significant so they were removed, and sex- and race-specific analyses were not performed. Age, sex and race were included as covariates in all models. The level of significance was set at $p < 0.05$.

Results

The descriptive characteristics of the sample are presented in Table 1. The average age of the sample was 12.3 y, and the average BMI percentile was 72.7. The percentages of the sample meeting different combinations of the guidelines are presented in Table 2. A total of 26.9% of the sample met none of the 3 guidelines, whereas 36.4%, 28.3% and 8.4% of the sample met 1, 2 or all 3 of the guidelines, respectively. The sleep guideline was met by the most participants, whereas the MVPA guideline was met by the least participants.

The results of the general linear models are presented in Table 3. In general, there were significant associations between the number of components of the guidelines that were met and lower levels of the cardiometabolic risk factors. The only risk factors that did not show a beneficial association with the number of guideline components met were blood pressure and HDL cholesterol. The associations between meeting each individual component of the guidelines and cardiometabolic risk factors are shown in Supplementary Table 1. In general, the associations are in the expected direction; however, the level of statistical significance varies across components and risk factors.

Figure 1 presents the associations between meeting specific guideline components and the odds of obesity and elevated cardiometabolic risk. There was a lower odds of obesity associated with meeting all three separate guidelines; however, only meeting the sleep guideline was associated with a statistically significantly lower odds (OR = 0.59; 95% confidence interval = 0.37 – 0.95). There was less of an effect of meeting the three specific

guidelines on elevated cardiometabolic risk, and none of the odds ratios were statistically significant. The odds of obesity and elevated cardiometabolic risk associated with meeting 0, 1, 2 or 3 of the guidelines are presented in Figure 2. There was a significant linear trend across the number of guideline components met for the odds of obesity ($p=0.03$) but not for the odds of elevated cardiometabolic risk.

Discussion

The results of this study demonstrate that only a small proportion of children in this sample (8.4%) were meeting the 24-hour movement guidelines. Further, those who met a greater number of the components of the 24-hour guidelines had lower levels of general and abdominal adiposity, blood triglycerides and glucose as well as lower levels of a continuous cardiometabolic risk score and a lower odds of obesity. However, there was no association with elevated cardiometabolic risk *per se*.

The results of this study corroborate those of two previous studies that found a low proportion of children meeting the 24-hour movement guidelines. For example, Carson and colleagues reported that 17% of 6-17 y old Canadian children were meeting the guidelines,⁸ and Roman-Vinas and colleagues found that 7.2% of 10-y old children from 12 countries met the guidelines.⁷ In the 12-country study, the proportions of children meeting the guidelines in Canada and the U.S. were 14% and 2.1%, respectively.⁷ It should be noted that the results of the two studies that included Canadian samples used accelerometry to measure MVPA, whereas the current study relied on self-reported data, which may partially explain the differences in the reported proportions.

In general, the evidence suggests that there is a significant association between meeting the 24-hour guidelines and obesity and/or risk factors. The present findings are supported by those of Roman-Vinas and colleagues who reported that meeting several combinations of the guideline components was associated with lower odds of obesity among 10-y old children.⁷ Further, Carson and colleagues reported that meeting a greater number of components of the guidelines was associated with lower BMI z-score and lower waist circumference in 6-17 y old Canadian children.⁸ We are not aware of any previous studies of the 24-hour guidelines that have included direct measures of total or regional adiposity as was done in the present study.

To the best of our knowledge, the only previous study that has specifically examined the association between meeting the 24-hour guidelines and cardiometabolic risk factors was published by Carson and colleagues.⁸ Their results were similar to ours in that meeting more components of the guidelines was associated with lower levels of serum triglycerides and insulin (as opposed to glucose); however, they also found significant associations with HDL-C and blood pressure. In addition to this one published study that specifically examined associations with the 24-hour guidelines, several studies have reported associations between different combinations of lifestyle behaviors and risk factors in children.¹⁵ Using data from 20,871 children 4-18 y of age, Ekelund reported that higher MVPA was associated with lower systolic blood pressure and triglycerides and higher HDL-C within tertiles of sedentary time; however, there was no association between sedentary behavior and risk

factors after adjusting for MVPA.¹⁶ A single study has examined the association between changes in multiple behaviors and changes in cardiometabolic risk using a longitudinal study design.¹⁷ In that study, children in the most favourable tertiles of changes in MVPA, sedentary time and sleep duration had a 3.3 unit reduction in a composite metabolic syndrome score relative to children in the opposite tertiles.¹⁷

Self-reported television viewing was used to capture recreational screen-time in the present study. In cross-sectional studies, television viewing has shown significant relationships with higher fat mass, body mass index, and cardiovascular risk factors including elevated blood pressure and cholesterol levels in children and adolescents.¹⁸ However, the reliance on self-reported television viewing as a measure of sedentary behavior is a limitation of the present study. A recent systematic review indicated there is not a clear association between objectively measured sedentary behavior and adiposity or cardiometabolic outcomes in children and adolescents independent of MVPA.¹⁹ Further research is required to better understand the associations among different domains of sedentary behaviour and health outcomes in children.

Furthermore, measuring screen-time based on self-reported television viewing can be problematic given the multitude of platforms and the sporadic and multi-tasking nature of children's media use. Recent estimates based on a probabilistic sample of U.S. youth in 2015 indicate that television viewing accounted for 52% of children's screen-time (out of a total of 276 minutes/day) and 39.5% of adolescents' screen-time (out of a total of 400 minutes/day).²⁰ A prior study of 1803 adolescents aged 12-19 y from the U.S. National Health and Nutrition Examination Survey indicated that daily screen time, including television viewing, computer use, and video game play, was associated with elevated cardiovascular risk and this association was independent of self-reported physical activity.²¹ While television remains the most common household device among youth ahead of smartphones or other media platforms,²⁰ future research should examine total recreational screen-time and its relationship with health factors.

A systematic review of longitudinal studies indicated that children who sleep less than the recommended guidelines have twice the odds of being overweight or obese compared to those who meet recommended sleep levels.²² The 24-hour movement guidelines call for uninterrupted sleep with consistent bed and wake-up time but these sleep hygiene characteristics were not collected in the present study. A second systematic review indicated that inadequate sleep measured as short duration and/or poor quality was linked to higher odds of obesity cross-sectionally.²³ The role of sleep quality, problems, and patterns and its relationship with children's health warrants further research.²² Further, there may be interactions between sleep, screen-time, and physical activity. An international cross-sectional study of 5777 children aged 9-11 y observed an inverse relationship between sleep and MVPA,²⁴ and similarly a systematic review observed an association of higher amounts of screen-time with short sleep duration.²⁵ The interaction of sleep, physical activity, and screen-time may be future intervention targets.

This study has several strengths and weaknesses that warrant discussion. The use of clinical measurements of total body fat using DXA and abdominal fat using MRI as well as clinical

laboratory measurements of other risk factors is a marked strength of the study. Another key strength is the diversity of the sample, which included white and African American boys and girls between the ages of 5-18 y. However, the collection of information about meeting the 24-hour guidelines was done using self-report questionnaires which are limited by recall and may introduce bias. The questions used were obtained from existing population surveys; however the reliability and validity of the individual questions is not known. Further, the cross-sectional study design does not allow for cause-and-effect inferences, and we cannot exclude the possibility that unmeasured confounding variables may explain some of the observed associations.

In summary, only a small percentage of children in this sample met all 3 components of the 24-hour guidelines. Meeting more components of the guidelines was associated with lower levels of obesity and several cardiometabolic risk factors. Future efforts should consider novel strategies to simultaneously improve physical activity, sedentary time and sleep in children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Odds of obesity (top panel) and elevated cardiometabolic risk (bottom panel) according to meeting the moderate-to-vigorous physical activity (MVPA), sleep and TV guidelines. Error bars represent 95% confidence intervals.

Figure 2. Odds of obesity (top panel) and elevated cardiometabolic risk (bottom panel) according to the across number of 24-hour guideline components met. Error bars represent 95% confidence intervals.

Table 1

Descriptive characteristics of the sample.

	Mean (S.D.)
N	357
Age (years)	12.3 (3.5)
Body Mass Index (kg/m ²)	23.1 (6.7)
BMI Percentile	72.7 (27.9)
Waist Circumference (cm)	75.9 (17.5)
Total Fat Mass (kg)	16.9 (12.0)
Subcutaneous Adipose Tissue (L)	4.29 (3.92)
Visceral Adipose Tissue (L)	0.15 (0.16)
Systolic Blood Pressure (mmHg)	103.6 (11.0)
Diastolic Blood Pressure (mmHg)	64.4 (9.0)
Triglycerides (mg/dL)	67.3 (36.2)
HDL-Cholesterol (mg/dL)	53.6 (12.2)
Glucose (mg/dL)	88.6 (6.6)

Table 2

Proportion of the sample meeting the moderate-to-vigorous physical activity (MVPA), Television (TV), and sleep recommendations from the 24-hour guidelines.

	Boys	Girls	Total
None (%)	25.6	28.0	26.9
MVPA (%)	36.3	25.9	30.8
TV (%)	34.5	35.5	35.0
Sleep (%)	51.8	52.9	52.4
MVPA + TV (%)	17.3	11.1	14.0
MVPA + Sleep (%)	20.8	15.9	18.2
TV + Sleep (%)	19.6	22.8	21.3
All Three Recommendations (%)	9.5	7.4	8.4

Table 3

Associations between cardiometabolic risk factors and meeting components of the 24-hour guidelines.*

	None	One	Two	Three	P for Trend
N	96	130	101	30	
Body Mass Index (kg/m ²)	24.4 ± 0.6	23.2 ± 0.5	22.3 ± 0.6	20.5 ± 1.1	0.002
Waist Circumference (cm)	79.2 ± 1.6	76.3 ± 1.3	73.9 ± 1.5	69.2 ± 2.8	0.002
Total Body Fat (kg)	19.3 ± 1.1	17.4 ± 0.9	14.8 ± 1.1	11.9 ± 2.0	0.0005
Subcutaneous Adipose Tissue (L)	5.11 ± 0.37	4.51 ± 0.31	3.52 ± 0.36	2.59 ± 0.66	0.0004
Visceral Adipose Tissue (L)	0.18 ± 0.02	0.16 ± 0.01	0.14 ± 0.02	0.09 ± 0.03	0.006
Systolic Blood Pressure (mmHg)	104.7 ± 1.0	104.0 ± 0.8	102.1 ± 1.0	103.2 ± 1.8	0.30
Diastolic Blood Pressure (mmHg)	64.2 ± 0.9	65.4 ± 0.7	63.4 ± 0.8	63.7 ± 1.5	0.53
Triglycerides (mg/dL)	78.1 ± 3.6	63.7 ± 3.0	66.9 ± 3.4	54.2 ± 6.3	0.003
HDL-Cholesterol (mg/dL)	52.6 ± 1.2	54.1 ± 1.0	53.2 ± 1.2	54.3 ± 2.2	0.58
Glucose (mg/dL)	89.4 ± 0.7	88.7 ± 0.6	88.6 ± 0.7	86.4 ± 1.2	0.04
Cardiometabolic Risk Score	13.7 ± 4.8	-3.4 ± 4.0	-2.4 ± 4.6	-19.5 ± 8.5	0.001

* These values are age, sex and race-adjusted means and standard errors obtained from general linear models.