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Health associations with meeting new 24-hour movement guidelines for Canadian children and youth

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ABSTRACT

The study objective was to examine whether meeting the new Canadian 24-hour movement guidelines was associated with health indicators in a representative sample of Canadian children and youth. Cross-sectional findings are based on 4157 (1239 fasting subsample) children and youth aged 6–17 years from cycles 1–3 of the Canadian Health Measures Survey (CHMS). Sleep and screen time were subjectively measured while moderate-to vigorous-intensity physical activity (MVPA) was accelerometer-determined. Health indicators in the full sample (body mass index (BMI) *z-scores*, waist circumference, blood pressure, behavioral strengths and difficulties score (lower = better), and aerobic fitness) and fasting subsample (triglycerides, high-density lipoprotein (HDL)-cholesterol, C-reactive protein, and insulin) were measured. Meeting the overall guidelines was defined as: 9–11 hour/night (5–13 years) or 8–10 hour/day (14–17 years) of sleep, ≤2 hour/day of screen time, and ≥60 minute/day of MVPA. Compared to meeting all three recommendations, meeting none, one, and two recommendations were associated with a higher BMI z-score, waist circumference, and behavioral strengths and difficulties score and lower aerobic fitness in a gradient pattern ($P_{trend} < 0.05$). Additionally, compared to meeting all three recommendations, meeting none and one recommendation were associated with higher systolic blood pressure and insulin ($P_{trend} < 0.05$). Finally, compared to meeting all three recommendations, meeting no recommendations was associated with higher triglycerides and lower HDL-cholesterol ($P_{trend} < 0.05$). Collectively, meeting more recommendations within the 24-hour movement guidelines was associated with better overall health. Since a small proportion (17%) of this representative sample was meeting the overall guidelines, efforts to promote adoption are needed.

1. Introduction

Sleep, sedentary behavior, and physical activity are time-dependent behaviors that provoke distinct physiological processes that interact throughout the day (24-hour period), resulting in an aggregated biological stimulus. Sleep, sedentary behavior, and physical activity have recently been referred to as "movement behaviors" because they fall on a movement/non-movement continuum based on intensity (Tremblay et al., 2016). New research that has applied an integrated approach suggests that the composition and combinations of movement behaviors within a 24-hour period may have important health implications for children and youth (Carson et al., 2016b; Saunders et al., 2016). Therefore, examining the health implications of movement behaviors in isolation, which has traditionally been done, may miss valuable information that can be used to inform efforts aimed at optimizing the health of the pediatric population.

Canada is currently facing a health crisis, given 32% of school-aged children and youth have overweight or obesity (Roberts et al., 2012) and are at risk for a variety of short- and long-term health complications (Reilly et al., 2003; Reilly and Kelly, 2011). Consequently, a new approach that will have a larger impact over current approaches is desperately needed. In line with an integrated versus segregated movement behavior paradigm, new 24-hour movement guidelines for children and youth (aged 5 to 17 years) were developed and subsequently released in Canada in June 2016 (Tremblay et al., 2016). These new guidelines were informed by evidence from four systematic reviews (Carson et al., 2016a; Chaput et al., 2016; Poitras et al., 2016; Saunders et al., 2016), novel compositional data analyses (Carson et al., 2016b), a stakeholder survey (Tremblay et al., 2016), focus groups and interviews with stakeholders (Faulkner et al., 2016), and expert input from national and international researchers (Tremblay et al., 2016). The guidelines represent a new approach to health promotion by including several general

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recommendations for a healthy 24-hour period, and specific recommendations on time spent in sleep, screen-based sedentary behavior, and moderate- to vigorous-intensity physical activity (MVPA; Tremblay et al., 2016).

Now that the new guidelines have been developed and released, it is important to examine the associations between meeting the guideline recommendations, or portions thereof, with health indicators to support efforts for guideline adoption. Furthermore, given the guidelines include multiple recommendations across the movement behaviors, examining associations of meeting different combinations of recommendations with health indicators can contribute to the limited knowledge base on how movement behaviors interact and relate to pediatric health. Therefore, the study objective was to examine the associations of meeting the new Canadian 24-hour movement guidelines and different combinations of sleep, sedentary behavior, and physical activity recommendations within the guidelines with health indicators among a representative sample of Canadian children and youth.

2. Methods

2.1. Participants

Participants were 6 to 17 year old children and youth from cycles 1 (2007–2009), 2 (2009–2011), and 3 (2012 − 2013) of the Canadian Health Measures Survey (Tremblay and Connor Gorber, 2007; CHMS). The CHMS is a repeated cross-sectional survey that collects data from a nationally representative sample of 3–79 year olds (6–79 year olds in cycle 1) living in private households. CHMS data collection involves an interview administered in the participant's home followed by a randomly assigned fasting or non-fasting physical health examination conducted at a mobile examination center. Participants assigned to the fasting appointment were asked to fast for at least 10 hours (Statistics Canada, 2015). At the mobile examination center, participants were given an accelerometer and asked to wear it during waking hours for 7 consecutive days. A total of 5217 children and youth aged 6 to 17 years across the three CHMS cycles were eligible and participated in the study.

Ethics approval was obtained from Health Canada and the Public Health Agency of Canada Research Ethics Board (Day et al., 2007). Children aged 6 to 13 years provided written informed assent and their parent or guardian provided written informed consent. Youth aged 14 to 17 years provided written informed consent. Further details regarding all three cycles of the CHMS are available elsewhere (Statistics Canada, 2011; Statistics Canada, 2013; Statistics Canada, 2015; Statistics Canada, 2016).

2.2. Canadian 24-Hour Movement Guidelines for Children and Youth

For surveillance of the new *Canadian 24-Hour Movement Guidelines for Children and Youth*, it has been recommended that three recommendations, one per behavior, be included (Tremblay et al., 2016). Specifically, within a healthy 24-hour period, children and youth should accumulate at least 60 minutes of MVPA, engage in no more than 2 hours of recreational screen time, and obtain uninterrupted sleep of 9 to 11 hours for those aged 5 to 13 years and 8 to 10 hours for those aged 14 to 17 years. We classified participants as meeting the overall guidelines if they met all three recommendations.

2.3. Sleep

Typical sleep duration was assessed as part of the in-home interview. Parents/guardians for those aged 6 to 11 years and participants aged 12 to 17 years were asked: “How many hours do you (your child) usually spend sleeping in a 24-hour period, excluding time spent resting?” The interviewer recorded responses to the nearest half hour.

2.4. Screen time

Average daily screen time was also assessed as part of the in-home interview. Parents/guardians of those aged 6 to 11 years were asked two questions: “On average, how many hours a day does your child…” 1) “…watch TV or videos or playing video games?” and 2) “…spend on a computer?”. Six response options were provided for each question; however, the response options differed between cycle 1 and 2 (none, <1, 1 to 2, 3 to 4, 5 to 6, 7 or more) and cycle 3 (none, <1, 1 to <3, 3 to <5, 5 to <7, 7 or more). Consistent with previous CHMS research (Colley et al., 2013), we calculated the mid-point of the response category (i.e., 0, 0.5, 1.5, 3.5, 5.5 and 7 hours for the respective categories) for both questions in cycles 1 and 2. To be consistent, we assigned the same mid-point values to the six response options for cycle 3. We then calculated average daily screen time by adding the mid-point responses for the two questions. Participants aged 12 to 17 years were asked three questions: “In a typical week in the past three months how much time did you usually spend…” 1) “…watching television, videos, or DVDs?”, 2) “…on a computer?”, and 3) “…playing video games?”. For cycle 1, eight response options were provided for each question (none, <1, 1 to 2, 3 to 5, 6 to 10, 11 to 14, 15 to 20, >20). We calculated the mid-point of the response category (i.e., 0, 0.5, 1.5, 4, 8, 12.5, 17.5, 20). For cycle 2 and 3, the three questions were open-ended and response options were not provided. We then calculated average daily screen time by adding the responses for the three questions and dividing by 7. In cycle 3, the video games question was separated into active video games that require physical activity and other video games. Responses to the time spent playing active video games were not included in the average daily screen time calculation for cycle 3 participants because it does not meet the definition of sedentary behavior (Sedentary Behaviour Research Network, 2012) used in the guidelines (Carson et al., 2016a).

2.5. MVPA

Average daily MVPA was measured using waist-worn Actical accelerometers (Philips Respironics, Oregon, USA). Data were collected in 1 minute epochs and non-wear time was defined as ≥60 consecutive minutes of zero counts, with allowance for 2 minutes of counts between zero and 100 (Colley et al., 2010). Participants were required to have ≥4 valid days defined as ≥10 hours of wear time (Colley et al., 2010). MVPA was defined as ≥1500 counts per minute (cpm) (Puyau et al., 2004). We calculated average minutes per day across valid days.

2.6. Health indicators

Health indicators were chosen to capture adiposity, cardiometabolic health, fitness, and social and emotional health based on their availability within the CHMS.

2.7. Adiposity

Body mass index (BMI) z-scores in the full sample and waist circumference in the cycle 2 and 3 subsample were the adiposity measures used. Height was measured using a ProScale M150 digital stadiometer (Accurate Technology Inc., Fletcher, USA) and weight was measured using a Mettler Toledo VLC with Panther Plus terminal scale (Mettler Toledo Canada, Mississauga, Canada) according to Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) 3rd edition protocols (Canadian Society for Exercise Physiology, 2003). Age- and sex-specific BMI z-scores were calculated following World Health Organization (WHO) growth standards (de Onis et al., 2007). Waist circumference was measured at the level of the iliac crest according to the National Institute of Health protocols in cycles 2 and 3 (National Insitutes of Health, 2000). Cycle 1 waist circumference measures were not included because measurement occurred at the midpoint between the last palpable rib and the iliac crest, according to WHO protocols (World Health Organization, 2008). Certified and trained health measures specialists with relevant university degrees completed all measures.

2.8. Fitness

Aerobic fitness in the cycle 1 and 2 subsample was the fitness measure used. Aerobic fitness was measured by health measures specialists using the modified Canadian Aerobic Fitness Test (mCAFT) (Canadian Society for Exercise Physiology, 2003). The mCAFT is a step test that progresses participants from an age- and sex-dependent starting cadence through sequential 3-minute stepping stages until participants reach 85% of age-predicted maximum heart rate. Only children and youth ≥8 years were eligible for this test. Aerobic fitness was not measured in cycle 3.

2.9. Cardiometabolic health

Systolic and diastolic blood pressure in the full sample and high-density lipoprotein (HDL)-cholesterol, triglycerides, insulin, and C-reactive protein (CRP) measures in the fasting subsample were the cardiometabolic health measures used. Systolic and diastolic blood pressures were measured using the BpTRU™ BPM-300 (BpTRU Medical Devices Ltd., Coquitlam, British Columbia) according to a CHMS specific protocol (Bryan et al., 2010). In line with a previous report (Campbell et al., 2005), the protocol entailed taking six measurements at 1 minute intervals after 5 minutes of rest. Systolic and diastolic blood pressures were based on an average of the last five measurements. Measures were completed by health measures specialists. HDL-cholesterol, triglycerides, insulin, and CRP were measured in serum in all three cycles. Since different methods and instruments were used to measure insulin in cycle 1 compared to cycle 2 and 3, a correction equation was applied to the data from cycle 1 (Dion, 2013).

2.10. Social and emotional health

Behavioral strengths and difficulties scores in the full sample was the social and emotional measure used. This measure was based on the established Strengths and Difficulties questionnaire (Goodman, 1997), which was completed by a parent or guardian. The questionnaire includes six sub-scales including emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and pro-social behavior. Total behavioral strengths and difficulties scores were calculated by adding responses from each sub-scale; lower scores represented better social and emotional health.

2.11. Covariates

Age, sex, and highest household education were included as covariates based on previous research examining the association between movement behaviors and health in children and youth (Saunders et al., 2016) and availability of measures within the CHMS. Highest household education was recoded into 10 categories ranging from “grade 8 or lower” to “university degree or certificate above bachelor's degree”. For descriptive purposes, highest household education was categorized into four categories (“less than secondary school graduation”, “secondary school graduation”, “some post-secondary”, and “post-secondary graduation”).

2.12. Statistical analyses

Statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC). We first calculated descriptive statistics, including medians, standard errors, and frequencies. We then conducted a series of linear regression models to examine the associations between meeting specific (i.e., MVPA only, screen time only, sleep only) and general (i.e., all three, two out of three, one out of three, none) combinations of movement behavior recommendations with each health indicator. For specific combinations of movement behaviors, meeting the recommendation (s) was the reference group and for the general combination of movement behaviors, meeting all three of the recommendations was the reference group. Waist circumference, systolic blood pressure, diastolic blood pressure, behavioral strengths and difficulties scores, triglycerides, CRP, and insulin were log-transformed to meet the assumption of normality of residuals in the regression models. All regression models were adjusted for age, sex, and highest household education. Negative beta coefficients indicated better health and positive beta coefficients indicated worse health relative to the reference group, except for HDL-cholesterol and fitness where the opposite was true. Lastly, we conducted a linear trend test for the general combinations of movement behaviors and each health indicator.

Accelerometer survey weights for combined cycles were used in all analyses to ensure the sample was representative of Canadian children and youth. To account for survey design effects, variance measures were estimated with the bootstrap technique (Rao et al., 1992; Rust and Rao, 1996), using specific degrees of freedom outlined by the CHMS data user guide (Statistics Canada, 2015). Analyses that included participants from two cycles (i.e., waist circumference and aerobic fitness) used 24 degrees of freedom and analyses that included participants from three cycles used 35 degrees of freedom. Statistical significance was set at $P < 0.05$.

3. Results

Of the 5217 eligible participants aged 6 to 17 years for this study, 4157 participants in the full sample and 1239 participants in the fasting subsample had complete data for the variables of interest and were

Table 1
Weighted participant characteristics of the 2007/09, 2009/11 and 2012/13 Canadian Health Measures Survey.

Variables	Full sample ($n = 4157$)	Fasting subsample ($n = 1239$)
Age, years	11.4 (0.1)	12.4 (0.2)
Sex, %		
Male	51.3	48.3
Female	48.7	51.7
Highest household education, %		
Less than secondary school graduation	2.9	3.0[d]
Secondary school graduation	10.2	9.3[d]
Some post-secondary	3.9	2.4[d]
Post-secondary graduation	83.0	85.3
Movement behaviors		
Average daily sleep, hr/day	8.8 (0.02)	8.6 (0.05)
Average daily screen time, hr/day	2.2 (0.1)	2.8 (0.3)
Average daily MVPA, min/day	50.9 (1.5)	47.8 (1.8)
Health indicators		
BMI z-score	0.4 (0.04)	–
Waist circumference, cm; $n = 2734$[a]	67.3 (0.4)	–
Systolic blood pressure, mmHg	94.5 (0.2)	–
Diastolic blood pressure, mmHg	60.3 (0.3)	–
Behavioral strengths and difficulties scores, range:0–32; $n = 3912$[b]	4.6 (0.2)	–
Aerobic fitness score, age: 8–17 years; $n = 2010$[c]	503.8 (2.2)	–
HDL cholesterol, mmol/L	–	1.3 (0.02)
C-reactive protein, mg/L	–	0.4 (0.04)
Triglycerides, mmol/L	–	0.8 (0.02)
Insulin, pmol/L	–	59.9 (1.8)

MVPA = moderate- to vigorous-intensity physical activity; BMI = Body mass index; HDL = High-density lipoprotein cholesterol. Data presented as median (standard error) for continuous variables and percentages for categorical variables.
[a] Waist circumference includes participants from cycle 2 and 3 only.
[b] Some parents or guardians of 12–17 year olds were not available to complete the questionnaire.
[c] Aerobic fitness includes participants from cycle 1 and 2 only.
[d] Interpret with caution (coefficient of variation 16.6% to 33.3%).

Table 2
Proportion of participants meeting the sleep, screen time, and MVPA recommendations and combinations of these recommendations in the full sample of the 2007/09, 2009/11 and 2012/13 Canadian Health Measures Survey.

Meeting recommendation	Full sample ($n = 4157$)
Specific combinations of movement behaviors, %	
Sleep and screen time and MVPA	17.1
Screen time and MVPA only	2.9
Sleep and MVPA only	11.3
Sleep and screen time only	22.8
MVPA only	5.2
Screen time only	5.4
Sleep only	24.3
None	11.0
General combinations of movement behaviors, %	
All three	17.1
Two out of three	37.0
One out of three	34.9
None	11.0

MVPA = moderate- to vigorous-intensity physical activity.

included in the analyses. Additional subsamples were used for waist circumference ($n = 2734$), behavioral strengths and difficulties scores ($n = 3912$), and fitness ($n = 2010$). Participant characteristics of the full and fasting sample are presented in Table 1. Within the full sample, 48.7% of participants were female and the median age was 11.4 years. Additionally, in the full sample, the median nightly sleep was 8.8 hours and median daily screen time and MVPA were 2.2 hours and 50.9 minutes, respectively.

The proportion of full sample meeting specific and general combinations of the recommendations within the guidelines is presented in Table 2. Eleven percent of the sample met none of the recommendations, 71.9% met either one or two recommendations, and 17.1% met all three recommendations. Of the 34.9% than met one recommendation, meeting the sleep recommendation was the most prevalent (24.3%). Of the 37% that met two recommendations, meeting the sleep and screen time recommendations was the most prevalent (22.8%).

The associations between the specific combinations of movement behaviors and the health indicators are presented in Table 3 for the full sample and Table 4 for the fasting subsample. Meeting two or fewer recommendations compared with meeting all three recommendations (reference group) was significantly associated with worse health for five out of ten health indicators, including BMI z-scores, waist circumference, behavioral strengths and difficulties scores, aerobic fitness, and insulin. In line with these findings, meeting at least one recommendations compared with meeting no recommendations (reference group) was significantly associated with better health for seven out of the ten health indicators, including BMI z-scores, waist circumference, systolic blood pressure, behavioral strengths and difficulties scores, aerobic fitness, triglycerides and insulin.

Few significant associations with health indicators and no clear pattern were observed between meeting and not meeting specific movement behaviors in isolation, including MVPA only (3/10 associations), screen time only (1/10 associations), and sleep only (2/10 associations). Similar findings were observed for meeting versus not meeting any two movement behaviors in isolation, including screen time and MVPA only

Table 3
Associations between meeting the sleep, screen time, and MVPA recommendations and combinations of these recommendations with health indicators in the full sample ($n = 4157$) of the 2007/09, 2009/11 and 2012/13 Canadian Health Measures Survey.

Recommendation	BMI z-score	Log WC[a]	Log SBP	Log DBP	Log SD[b]	Aerobic fitness[c]
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
Specific combinations of movement behaviors						
Sleep and screen time and MVPA						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	**0.36 (0.19, 0.54)**	**0.04 (0.02, 0.07)**	0.01 (0.00, 0.02)	0.00 (−0.01, 0.02)	**0.18 (0.07, 0.28)**	**-14.05 (−20.89, −7.21)**
Screen time and MVPA only						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	0.21 (−0.14, 0.55)	0.03 (−0.02, 0.08)	0.01 (−0.01, 0.04)	−0.00 (−0.04, 0.04)	**−0.26 (−0.45, −0.07)**	−1.99 (−22.78, 18.79)
Sleep and MVPA only						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	0.07 (−0.15, 0.29)	0.01 (−0.02, 0.03)	**0.01 (0.00, 0.02)**	**0.02 (0.01, 0.04)**	0.01 (−0.13, 0.16)	**−11.39 (−20.46, −2.32)**
Sleep and screen time only						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	0.15 (−0.02, 0.32)	**0.02 (0.00, 0.04)**	0.00 (−0.01, 0.01)	−0.01 (−0.03, 0.00)	**0.10 (0.01, 0.20)**	−0.16 (−7.09, 6.78)
MVPA only						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	0.19 (−0.23, 0.61)	**0.05 (0.00, 0.10)**	0.01 (−0.03, 0.04)	0.02 (−0.03, 0.07)	**−0.29 (−0.54, −0.04)**	**−25.63 (−42.09, −9.18)**
Screen time only						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	−0.13 (−0.56, 0.31)	−0.01 (−0.05, 0.03)	0.00 (−0.02, 0.02)	0.00 (−0.03, 0.03)	−0.08 (−0.29, 0.13)	12.43 (−8.63, 33.49)
Sleep only						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	−0.15 (−0.32, 0.02)	−0.02 (−0.05, 0.00)	−0.01 (−0.02, 0.00)	−0.00 (−0.02, 0.01)	−0.01 (−0.12, 0.10)	**11.60 (4.54, 18.65)**
None						
Yes	Reference	Reference	Reference	Reference	Reference	Reference
No	**−0.64 (−0.93, −0.35)**	**−0.08 (−0.12, −0.04)**	**−0.02 (−0.04, −0.00)**	−0.01 (−0.03, 0.01)	**−0.18 (−0.33, −0.03)**	**13.37 (4.73, 22.01)**
General combinations of movement behaviors						
All three	Reference	Reference	Reference	Reference	Reference	Reference
Two out of three	**0.22 (0.04, 0.41)**	**0.02 (0.00, 0.05)**	0.00 (−0.01, 0.02)	0.00 (−0.01, 0.02)	**0.12 (0.01, 0.24)**	**−9.71 (−16.32, −3.09)**
One out of three	**0.44 (0.25, 0.64)**	**0.05 (0.03, 0.08)**	**0.01 (0.00, 0.03)**	0.00 (−0.02, 0.02)	**0.23 (0.10, 0.37)**	**−16.98 (−25.34, −8.62)**
None	**0.95 (0.61, 1.28)**	**0.11 (0.07, 0.16)**	**0.03 (0.01, 0.05)**	0.01 (−0.01, 0.03)	**0.34 (0.18, 0.50)**	**−25.77 (−37.48, −14.06)**
	$P_{trend} < 0.001$	**$P_{trend} < 0.001$**	**$P_{trend} < 0.001$**	$P_{trend} = 0.332$	**$P_{trend} < 0.001$**	**$P_{trend} < 0.001$**

β (95%CI) = unstandardized beta coefficients (95% Confidence Intervals); BMI = Body Mass Index; WC = Waist Circumference; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; SD = behavioral strengths and difficulties scores; MVPA = moderate- to vigorous-intensity physical activity. All models are adjusted for age, sex, and highest household education. Statistically significant associations ($p < 0.05$) are highlighted in bold.

[a] Waist circumference includes participants from cycle 2 and 3 only ($n = 2734$).
[b] Some parents or guardians of 12–17 year olds were not available to complete the questionnaire ($n = 3912$).
[c] Aerobic fitness included participants aged 8–17 years from cycle 1 and 2 only ($n = 2010$).

Table 4
Associations between meeting the sleep, screen time, and MVPA recommendations and combinations of these recommendations with health indicators in the fasting sub-sample ($n = 1239$) of the 2007/09, 2009/11 and 2012/13 Canadian Health Measures Survey.

Recommendation	Log triglycerides	HDL	Log CRP	Log insulin
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
Specific combinations of movement behaviors				
Sleep and screen time and MVPA				
Yes	Reference	Reference	Reference	Reference
No	0.09 (−0.04, 0.22)	−0.07 (−0.14, 0.00)	0.31 (−0.05, 0.66)	**0.19 (0.04, 0.34)**
Screen time and MVPA only				
Yes	Reference	Reference	Reference	Reference
No	**0.25 (0.05, 0.44)**	−0.15 (−0.33, 0.03)	0.61 (−0.03, 1.25)	0.21 (−0.05, 0.46)
Sleep and MVPA only				
Yes	Reference	Reference	Reference	Reference
No	0.09 (−0.00, 0.19)	0.00 (−0.08, 0.09)	**0.37 (0.01, 0.73)**	0.14 (−0.03, 0.31)
Sleep and screen time only				
Yes	Reference	Reference	Reference	Reference
No	−0.02 (−0.11, 0.06)	−0.01 (−0.08, 0.06)	−0.10 (−0.33, 0.14)	0.12 (−0.01, 0.26)
MVPA only				
Yes	Reference	Reference	Reference	Reference
No	0.13 (−0.07, 0.32)	0.02 (−0.08, 0.12)	0.13 (−0.20, 0.47)	−0.02 (−0.21, 0.16)
Screen time only				
Yes	Reference	Reference	Reference	Reference
No	0.00 (−0.16, 0.16)	**0.11 (0.02, 0.21)**	−0.28 (−0.94, 0.37)	0.05 (−0.14, 0.23)
Sleep only				
Yes	Reference	Reference	Reference	Reference
No	−0.04 (−0.14, 0.07)	−0.02 (−0.09, 0.05)	**−0.32 (−0.55, −0.08)**	−0.13 (−0.28, 0.02)
None				
Yes	Reference	Reference	Reference	Reference
No	**−0.17 (−0.33, −0.01)**	0.09 (−0.00, 0.18)	−0.04 (−0.51, 0.42)	**−0.31 (−0.57, −0.06)**
General combinations of movement behaviors				
All three	Reference	Reference	Reference	Reference
Two out of three	0.05 (−0.07, 0.18)	−0.05 (−0.13, 0.02)	0.17 (−0.17, 0.51)	0.08 (−0.07, 0.22)
One out of three	0.11 (−0.04, 0.26)	−0.08 (−0.17, 0.01)	**0.50 (0.11, 0.89)**	**0.29 (0.11, 0.46)**
None	**0.25 (0.08, 0.42)**	**−0.15 (−0.27, −0.04)**	0.37 (−0.27, 1.01)	**0.49 (0.21, 0.78)**
	$P_{trend} = 0.005$	**$P_{trend} = 0.013$**	$P_{trend} = 0.145$	**$P_{trend} = 0.001$**

β (95%CI) = unstandardized beta coefficients (95% Confidence Intervals); HDL = High-density lipoprotein cholesterol; CRP = C-reactive protein. All models are adjusted for age, sex, and highest household education. Statistically significant associations ($p < 0.05$) are highlighted in bold.

(2/10 associations), sleep and MVPA only (4/10 associations), and sleep and screen time only (2/10 associations).

The associations between the general combinations of movement behaviors and the health indicators for the full sample and fasting subsample are also presented in Tables 3 and 4. Significant trends of worse health when meeting fewer guidelines was observed for eight out of ten of the health indicators, including BMI z-scores, waist circumference, systolic blood pressure, behavioral strengths and difficulties scores, aerobic fitness, triglycerides, HDL-cholesterol, and insulin. Compared to meeting all three recommendations (reference group), meeting two, one, and no recommendations was significantly associated with worse health for four, seven, and eight health indicators, respectively.

4. Discussion

Using a representative sample of Canadian 6 to 17 year olds, the present study examined whether meeting individual and combinations of recommendations within the new Canadian 24-hour movement guidelines was associated with a variety of health indicators. Although only 17% of children and youth in this sample were meeting the overall guidelines, the majority (72%) were meeting one or two of the recommendations. It was observed that meeting or not meeting specific combinations of recommendations in isolation was less important for overall health compared to the number of recommendations met. Across adiposity, social and emotional health, and fitness indicators, meeting fewer recommendations was associated with worse health in a gradient pattern, as indicated by the significant P_{trends}. Similar patterns were seen with some cardiometabolic health indicators; however, when comparing meeting one or two recommendations to meeting all three recommendations, not all associations were significant.

Since the Canadian 24-Hour Movement Guidelines for Children and Youth have just been released (Tremblay et al., 2016), this represents the first study to examine associations between meeting the guidelines and health indicators. However, individual sleep, screen time, and MVPA recommendations exist in other jurisdictions for this age group (Department of Health, 2011; Hirshkowitz et al., 2015; Kahlmeier et al., 2015; American Academy of Pediatrics, 2013; World Health Organization, 2010; U.S. Department of Health and Human Services, 2008). To the authors' knowledge, only two previous studies have examined the association between meeting combinations of sleep, screen time or TV, and MVPA recommendations and health, specifically obesity, in this age group (Laurson et al., 2015; Laurson et al., 2014). In line with the findings of the current study, Laurson and colleagues observed increasing odds of obesity as the number of recommendations met went down in a cross-sectional sample of 7 to 12 year old Americans from two communities (Laurson et al., 2014). Similarly, using representative self-reported data from the Youth Risk Behavior Survey, Laurson and colleagues reported the greatest odds of obesity were those adolescents that met no recommendations compared to those that meet all three recommendations (2015). In contrast to the present study, where no clear pattern across health indicators was observed with specific combinations of movement behaviors were isolated, Laursen and colleagues found those adolescents that met MVPA recommendations, regardless of whether meeting sleep and TV recommendations, were not at increased odds of obesity (Laurson et al., 2015). However, further highlighting the interactions between these movement behaviors, it was also observed that adolescents who did not meet sleep and TV recommendations were more likely to not meet MVPA recommendations (Laurson et al., 2015).

Though few studies have specifically focused on meeting sleep, screen time, and physical activity recommendations, other studies have examined different combinations of sleep, sedentary behavior, and physical activity (Chaput et al., 2014; Hjorth et al., 2014a; Hjorth et al., 2014b) or the clustering of these behaviors (Carson et al., 2015; Ferrar et al., 2013; Olds et al., 2004) with primarily adiposity health indicators. A systematic review on the associations of combinations of these three movement behaviors with health indicators in children and youth concluded that a combination of high sleep, low sedentary behavior, and high physical activity was associated with more favorable measures of adiposity and cardiometabolic health compared with a combination of low sleep, high sedentary behavior, and low physical activity (Saunders et al., 2016). Therefore, the overall findings across studies support the integrated paradigm that underpins the new 24-hour movement guidelines where the focus is on the combined or synergistic effects of movement behaviors on health; rather, than on the individual or independent effects (Tremblay et al., 2016). Findings also support the needed investment of time and resources to promote the adoption of the new Canadian guidelines (Latimer-Cheung et al., 2016).

While relatively consistent findings have been observed across studies, it should be acknowledged that the evidence based on the combined effects of movement behaviors on health in children and youth is still under-studied. Recent developments in statistical methods that overcome previous statistical challenges for examining the combined effects of these co-dependent movement behaviors (Carson et al., 2016b; Chastin et al., 2015) on health and/or the health effects of replacing one movement behavior with another (Buman et al., 2014) will contribute to the growth of future evidence in this area. Given most of the evidence to date is cross-sectional in nature (Saunders et al., 2016), future longitudinal and experimental work is needed to grow and strengthen the evidence base. Finally, future research is also needed using later cycles of CHMS or other national datasets collected after the release of the 24-hour movement guidelines and following dissemination efforts to assess guideline adherence and examine whether the baseline findings observed in the present study have changed.

Strengths of this study include the large and representative sample of children and youth, the number and diversity of health indicators examined, and the objective measures of MVPA. However, objective measures of sleep were not available, and currently an objective measure of screen time suitable for population-based studies does not exist. Nevertheless, measurement error associated with these subjective measures may have influenced the results. The results may have also been influenced by residual confounding due to confounders not being included in the regression models (e.g., diet) because they are not available in the CHMS. Another important limitation of this study was the cross-sectional design. Consequently, causal inferences cannot be made in regards to the associations observed.

5. Conclusion

Meeting more recommendations within the new Canadian 24-Hour Movement Guidelines for Children and Youth was associated with better overall health in a large representative sample of 6 to 17 year olds. Given only 17% of the sample met all three recommendations, efforts are needed to promote adoption of these new guidelines.

Conflict of interest

The authors have no conflicts to declare.

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References

American Academy of Pediatrics. Council on Communications and Media, 2013. Children, adolescents, and the media. Pediatrics 132 (5), 958–961.

Bryan, S., Saint-Pierre Larose, M., Campbell, N., Clarke, J., Tremblay, M.S., 2010. Resting blood pressure and heart rate measurement in the Canadian health measures survey, cycle 1. Health Rep. 21 (1), 71–78.

Buman, M.P., Winkler, E.A., Kurka, J.M., Hekler, E.B., Baldwin, C.M., Owen, N., Ainsworth, B.E., Healy, G.N., Gardiner, P.A., 2014. Reallocating time to sleep, sedentary behaviors, or active behaviors: associations with cardiovascular disease risk biomarkers, NHANES 2005–2006. Am. J. Epidemiol. 179 (3), 323–334.

Campbell, N.R., Joffres, M.R., McKay, D.W., 2005. Hypertension surveillance in Canada: minimum standards for assessing blood pressure in surveys. Can. J. Public Health 96 (3), 217–220.

Canadian Society for Exercise Physiology, 2003. Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA),. 3rd edition. (Ottawa).

Carson, V., Faulkner, G., Sabiston, C.M., Tremblay, M.S., Leatherdale, S.T., 2015. Patterns of movement behaviors and their association with overweight and obesity in youth. Int. J. Public Health 60 (5), 551–559.

Carson, V., Hunter, S., Kuzik, N., Gray, C.E., Poitras, V.J., Chaput, J.P., Saunders, T.J., Katzmarzyk, P.T., Okely, A.D., et al., 2016a. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S240–S265.

Carson, V., Tremblay, M.S., Chaput, J.P., Chastin, S.F., 2016b. Associations between sleep duration, sedentary time, physical activity, and health indicators among Canadian children and youth using compositional analyses. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S294–S302.

Chaput, J.P., Gray, C.E., Poitras, V.J., Carson, V., Gruber, R., Olds, T., Weiss, S.K., Connor Gorber, S., Kho, M.E., et al., 2016. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S266–S282.

Chaput, J.P., Leduc, G., Boyer, C., Belanger, P., LeBlanc, A.G., Borghese, M.M., Tremblay, M.S., 2014. Objectively measured physical activity, sedentary time and sleep duration: independent and combined associations with adiposity in Canadian children. Nutr. Diabetes 4, e117.

Chastin, S.F., Palarea-Albaladejo, J., Dontje, M.L., Skelton, D.A., 2015. Combined effects of time spent in physical activity, sedentary behaviors and sleep on obesity and cardio-metabolic health markers: a novel compositional data analysis approach. PLoS One 10 (10), e0139984.

Colley, R., Connor Gorber, S., Tremblay, M.S., 2010. Quality control and data reduction procedures for accelerometry-derived measures of physical activity. Health Rep. 21 (1), 63–69.

Colley, R.C., Garriguet, D., Adamo, K.B., Carson, V., Janssen, I., Timmons, B.W., Tremblay, M.S., 2013. Physical activity and sedentary behavior during the early years in Canada: a cross-sectional study. Int. J. Behav. Nutr. Phys. Act. 10, 54.

Day, B., Langlois, R., Tremblay, M., Knoppers, B.M., 2007. Canadian health measures survey: ethical, legal and social issues. Health Rep. 18 (Suppl), 37–51.

de Onis, M., Onyango, A.W., Borghi, E., Siyam, A., Nishida, C., Siekmann, J., 2007. Development of a WHO growth reference for school-aged children and adolescents. Bull. World Health Organ. 85 (9), 660–667.

Department of Health, Physical Activity, Health Improvement and Protection, 2011t. Start Active. A report on physical activity for health from the four home countries' Chief Medical Officers, Stay Active.

Dion, S.M., 2013. Analysis of insulin for cycle 2 data of the Canadian Health Measures Survey. Methodology Branch Working Paper HSMD-2013-004E/F. Statistics Canada, Ottawa.

Faulkner, G., White, L., Riazi, N., Latimer-Cheung, A.E., Tremblay, M.S., 2016. Canadian 24-hour movement guidelines for children and youth: exploring the perceptions of stakeholders regarding their acceptability, barriers to uptake, and dissemination. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S303–S310.

Ferrar, K., Olds, T., Maher, C., Maddison, R., 2013. Time use clusters of New Zealand adolescents are associated with weight status, diet and ethnicity. Aust. N. Z. J. Public Health 37 (1), 39–46.

Goodman, R., 1997. The strengths and difficulties questionnaire: a research note. J. Child Psychol. Psychiatry 38 (5), 581–586.

Hirshkowitz, M., Whiton, K., Albert, S.M., Alessi, C., Bruni, O., DonCarlos, L., Hazen, N., Herman, J., Adams Hillard, P.J., et al., 2015. National Sleep Foundation's updated sleep duration recommendations: final report. Sleep Health 1 (4), 233–243.

Hjorth, M.F., Chaput, J.P., Damsgaard, C.T., Dalskov, S.M., Andersen, R., Astrup, A., Michaelsen, K.F., Tetens, I., Ritz, C., et al., 2014a. Low physical activity level and short sleep duration are associated with an increased cardio-metabolic risk profile: a longitudinal study in 8–11 year old Danish children. PLoS One 9 (8), e104677.

Hjorth, M.F., Chaput, J.P., Ritz, C., Dalskov, S.M., Andersen, R., Astrup, A., Tetens, I., Michaelsen, K.F., Sjodin, A., 2014b. Fatness predicts decreased physical activity and increased sedentary time, but not vice versa: support from a longitudinal study in 8- to 11-year-old children. Int. J. Obes. 38 (7), 959–965.

Kahlmeier, S., Wijnhoven, T.M., Alpiger, P., Schweizer, C., Breda, J., Martin, B.W., 2015. National physical activity recommendations: systematic overview and analysis of the situation in European countries. BMC Public Health 15, 133.

Latimer-Cheung, A.E., Copeland, J.L., Fowles, J., Zehr, L., Duggan, M., Tremblay, M.S., 2016. The Canadian 24-hour movement guidelines for children and youth: implications for practitioners, professionals, and organizations. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S328–S335.
Laurson, K.R., Lee, J.A., Eisenmann, J.C., 2015. The cumulative impact of physical activity, sleep duration, and television time on adolescent obesity: 2011 youth risk behavior survey. J. Phys. Act. Health 12 (3), 355–360.
Laurson, K.R., Lee, J.A., Gentile, D.A., Walsh, D.A., Eisenmann, J.C., 2014. Concurrent associations between physical activity, screen time, and sleep duration with childhood obesity. ISRN Obes 2014, 204540.
National Insitutes of Health, 2000. The Practical Guide to the Identification, Evaluation and Treatment of Overweight and Obesity in Adults. National Institutes of Health, Bethesda, Maryland, p. 2000.
Olds, T., Dollman, J., Ridley, K., Boshoff, K., Hartshorne, S., Kennaugh, S., 2004. Children and Sport. Australian Sports Commission, Belconnen, South Australia.
Poitras, V.J., Gray, C.E., Borghese, M.M., Carson, V., Chaput, J.P., Janssen, I., Katzmarzyk, P.T., Pate, R.R., Connor Gorber, S., et al., 2016. Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S197–S239.
Puyau, M.R., Adolph, A.L., Vohra, F.A., Zakeri, I., Butte, N.F., 2004. Prediction of activity energy expenditure using accelerometers in children. Med. Sci. Sports Exerc. 36 (9), 1625–1631.
Rao, J.N.K., Wu, C.F.J., Yue, K., 1992. Some recent work on resampling methods for complex surveys. Surv. Meth. 18, 209–217.
Reilly, J., Kelly, J., 2011. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int. J. Obes. 35 (7), 891–898.
Reilly, J., Methven, E., McDowell, Z.C., Hacking, B., Alexander, D., Stewart, L., Kelnar, C.J., 2003. Health consequences of obesity. Arch. Dis. Child. 88 (9), 748–752.
Roberts, K.C., Shields, M., de Groh, M., Aziz, A., Gilbert, J.A., 2012. Overweight and obesity in children and adolescents: results from the 2009 to 2011 Canadian health measures survey. Health Rep. 23 (3), 37–41.
Rust, K.F., Rao, J.N.K., 1996. Variance estimation for complex surveys using replication techniques. Stat. Methods Med. Res. 5, 281–310.
Saunders, T.J., Gray, C.E., Poitras, V.J., Chaput, J.P., Janssen, I., Katzmarzyk, P.T., Olds, T., Connor Gorber, S., Kho, M.E., et al., 2016. Combinations of physical activity, sedentary behaviour and sleep: relationships with health indicators in school-aged children and youth. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S283–S293.
Sedentary Behaviour Research Network, 2012. Standardized use of the terms "sedentary" and "sedentary behaviours". Appl. Physiol. Nutr. Metab. 37, 540–542.
Statistics Canada, 2011. Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 1. Statistics Canada, Ottawa.
Statistics Canada, 2013. Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 2. Statistics Canada, Ottawa.
Statistics Canada, 2015. Canadian Health Measures Survey (CHMS) Data User Guide: Cycle 3. Statistics Canada, Ottawa.
Statistics Canada, 2016. Canadian Health Measures Survey. Available at: http://www.statcan.gc.ca/chms.
Tremblay, M.S., Carson, V., Chaput, J.P., Connor Gorber, S., Dinh, T., Duggan, M., Faulkner, G., Gray, C.E., Gruber, R., et al., 2016. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. Appl. Physiol. Nutr. Metab. 41 (6 Suppl 3), S311–S327.
Tremblay, M.S., Connor Gorber, S., 2007. Canadian health measures survey: brief overview. Can. J. Public Health 98 (6), 453–456.
U.S. Department of Health and Human Services, 2008. 2008 Physlical Activity Guidelines for Americans.
World Health Organization, 2008. Waist Circumference and Waist–hip Ratio: Report of a WHO Expert Consultation, Geneva, 8–11 December 2008.
World Health Organization, 2010. Global Recommendations on Physical Activiy for Health.