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ABSTRACT

Background

The *Canadian 24-Hour Movement Guidelines for Adults (18-64 years* and *65 years or older)* were launched in October 2020 and provide evidence-based recommendations for physical activity, sedentary behaviour and sleep. The purpose of this study was to examine whether meeting the 24-Hour Movement Guidelines overall, and different combinations of recommendations within the guidelines, was associated with health indicators in a representative sample of Canadian adults.

Data and methods

Participants were 8,297 adults aged 18 to 79 from cycles 1 to 3 of the Canadian Health Measures Survey. They were classified as meeting or not meeting each of the recommendations required for overall guideline adherence: moderate-to-vigorous physical activity (150 minutes or more per week), sedentary behaviour (8 hours or less per day or 9 hours or less per day of sedentary time, including 3 hours or less per day of recreational screen time) and sleep duration (7 to 9 hours per day for adults 18 to 64 years old, 7 to 8 hours per day for adults aged 65 years or older). A combination of self-reported and device-based measures were used. Indicators of adiposity (n=2), aerobic fitness (n=1) and cardiometabolic health (n=7) were measured.

Results

A total of 19.1% of the sample met none of the recommendations, 43.9% met one of them, 29.8% met two and 7.1% met all three. Compared with meeting no recommendations, meeting one, two and all three recommendations was associated with better health for one, six and seven health indicators, respectively ($p < 0.05$). Compared with adults meeting two or fewer recommendations, those who met all three recommendations had more favourable body mass index; waist circumference; aerobic fitness scores; and triglyceride, insulin, C-reactive protein and serum glucose levels ($p < 0.05$).

Interpretation

These findings provide support for the 24-Hour Movement Guidelines and show that less than 1 in 10 Canadian adults are meeting all three of the healthy movement behaviour guidelines.

Keywords

physical activity, sedentary behaviour, screen time, sleep, movement behaviours, public health recommendations, risk factors, adult population, epidemiology

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What is already known on this subject?

- Adequate physical activity, low sedentary time and sufficient sleep duration are all separately associated with better health among adults.
- The Canadian 24-Hour Movement Guidelines for Adults (18-64 years and 65 years or older) were launched in October 2020 and provide evidence-based recommendations for physical activity, sedentary behaviour and sleep.
- It is important to examine whether meeting the overall guidelines, and different combinations of recommendations within the guidelines, is associated with health indicators in Canadian adults.

What does this study add?

- Of adults aged 18 to 79 years, 7.1% were meeting all of the recommendations within the 24-Hour Movement Guidelines.
- Compared with adults who did not meet the overall guidelines, those who did had more favourable body mass index (BMI); waist circumference; aerobic fitness scores; and triglyceride, insulin, C-reactive protein and serum glucose levels.
- Compared with meeting at least one recommendation, meeting no recommendations was deleteriously associated with BMI, waist circumference, aerobic fitness, C-reactive protein and insulin.

Adequate physical activity, low sedentary time and sufficient sleep duration are all separately associated with better health status among adults and older adults.[1-6] These individual behaviours—collectively referred to as 24-hour movement behaviours—are inherently codependent with one another within the fixed 24-hour time frame. Because of this, a new public health promotion approach focusing on the integration of all movement behaviours over the whole day has been gaining momentum. Recently, several studies have investigated how different combinations or "cocktails" of 24-hour movement behaviours relate to health among adults and older adults. Evidence suggests that the time-use composition (mixture) of healthy movement behaviours across the full 24-hour day is associated with a range of health outcomes, including all-cause mortality, adiposity, cardiometabolic biomarkers and mental health in adults.[7-9] Consistent with this integrated movement behaviour paradigm, Canada recently developed and released the *24-Hour Movement Guidelines for Adults (18-64 years* and *65 years or older)* (24hrMG) in October 2020.[10]

The new Canadian guidelines for adults were developed following well established, comprehensive, robust and transparent processes that are thoroughly documented and publicly available.[1-3,7,10-14] These guidelines provide evidence-based recommendations for a healthy day (24 hours), comprising benchmarks for sleep, sedentary behaviour (SB), light-intensity and moderate-to-vigorous physical activity (MVPA) (https://csepguidelines.ca).[10]

The 24hrMG provide specific targets for each movement behaviour, towards which Canadians can work to achieve better health, and also establish measurable thresholds for monitoring and surveillance. Recently, a number of studies have examined whether meeting 24hrMG for children and youth and each of the component recommendations is associated with desirable health indicators in children and youth.[8] Current evidence indicates that children and youth who met some or all of the 24hrMG generally reported better overall health than those who met none of them.[8] With the new adult 24hrMG it is important to gain a more thorough understanding of the proportion of Canadian adults who achieved all of the movement behaviour recommendations and the associations between meeting various combinations of the recommendations and health indicators.

Therefore, the objective of this study was to examine whether meeting the new Canadian 24hrMG, and different combinations of physical activity, SB and sleep duration recommendations within the guidelines, is associated with health indicators in a representative sample of Canadian adults aged 18 to 79 years. Adherence to the 24hrMG was expected to be associated with better indicators of health.

Data and methods

Data source

This study used data from the Canadian Health Measures Survey (CHMS), an ongoing repeated cross-sectional survey.[15] The CHMS collects health data from a representative sample of the Canadian population. Its target population includes Canadians aged 3 to 79 who live in the 10 Canadian provinces. It excludes those living in the three territories, persons living on reserves and other Aboriginal settlements, full-time Canadian Forces members, the institutionalized population and residents of certain remote regions.[15] This study also excluded pregnant women (n=48) and those with severe mobility issues (n=122).

The CHMS uses an interviewer-delivered questionnaire, administered in each respondent's home, followed by the collection of physical measures during a visit to a mobile examination centre (MEC). Following their MEC visit, ambulatory respondents are requested to wear an Actical accelerometer (Philips Respironics, Oregon, United States) over their right hip on an elasticized belt for seven consecutive days while awake. Written informed consent and assent were obtained from all participants. Approval for the conduct of the CHMS was obtained from Health Canada's Research Ethics Board.

Data from cycles 1 (2007 to 2009), 2 (2009 to 2011) and 3 (2012 to 2013) were combined and analyzed for this study. The study population was limited to respondents aged 18 years or older who had a minimum of four valid days of accelerometer data.[16,17] A valid day was when the respondent had 10 or more hours of wear time while awake.[16,17] Data were collected in one-minute epochs. Non-wear time was defined as 60 consecutive minutes or more of zero counts, with an allowance of up to two minutes of counts between 0 and 100. To calculate sedentary time, the number of wear time minutes when counts per minute (cpm) were between 0 and 100 (the sedentary cut point) were summed.[18] The MVPA cut point used for adults aged 18 to 19 was 1,500 cpm,[19] while for adults aged 20 to 79, a cut point of 1,535 cpm was used.[20] The overall response rates for the CHMS cycles used in this study—representing the proportion of respondents who completed the household questionnaire, MEC visit and had sufficient valid days of accelerometer data—were 41.8% from 2007 to 2009, 42.4% from 2009 to 2011, and 38.8% from 2012 to 2013. The accelerometer subsample survey weights provided by Statistics Canada were used for all analyses. Cycles 1, 2 and 3 of the CHMS were combined following Statistics Canada guidelines, including the adjustment of survey weights by dividing cycle-specific weights by the number of cycles used.[21] Survey weights account for the potential bias introduced because of nonresponse at all stages of the survey and ensure the sample is representative of Canadian adults.[22-24]

Independent variables

Physical activity and sedentary behaviour

MVPA and sedentary time were both measured using accelerometers.[16] The average daily minutes of MVPA were calculated as the total of all MVPA minutes measured on valid days, divided by the number of valid days. MVPA recommendation adherence (150 minutes or more per week) was determined if the average daily minutes of MVPA was 21.43 minutes or more per day (150 minutes divided by 7 days). Average sedentary time per day was calculated as the average of the hours per day across valid days, and used to determine if respondents met the SB recommendation (8 hours or less or 9 hours or less of sedentary time), with those failing to meet the recommendation used as the reference group. To be consistent with surveillance recommendations provided by Ross et al.,[10] which noted that "the 8-hour sedentary time threshold (in the 24-Hour Movement Guidelines) reflects a blending of results from accelerometer-measured sedentary time, where the threshold was 9 hours, and self-reported sitting time, where the threshold was around 7 hours," data were analyzed using a 9-hour cutoff. Results using an 8-hour cutoff were also calculated for comparison.

Screen time

The 24hrMG provide a specific recommendation about recreational screen time: 3 hours or less per day as a subcomponent of the sedentary recommendation (i.e., in addition to the 8-hour sedentary time recommendation). In the CHMS, recreational screen time was assessed via self-report using the following questions in the household interview about sedentary activities during leisure time: 1) "In a typical week in the past three months, how much time did you usually spend on a computer, tablet or iPad including watching videos, playing computer games, emailing or using the Internet?" 2) "In a typical week in the past three months, how much time did you usually spend playing other types of video games on a game console or hand-held electronic device?" 3) "In a typical week in the past three months, how much time did you usually spend watching television, DVD's or videos?" In Cycle 1, categorical response options were provided for these questions ("none," "less than 1," "1 to 2," "3 to 5," "6 to 10," "11 to 14," "15 to 20," "20 or more" hours); however, in cycles 2 and 3, respondents were provided with a continuous response option. For Cycle 1, mid-point values of the six response options (0, 0.5, 1.5, 4, 8, 12.5, 17.5, 20) were assigned to treat recreational screen time as a continuous variable.[25] The time spent on each screen-based activity was summed to yield a total daily recreational screen time estimate. Screen time was categorized as a binary variable based on meeting (vs. not meeting) the recommendation.

Sleep duration

Sleep duration was self-reported in the CHMS household questionnaire using the following question: "*How many hours do you usually spend sleeping in a 24-hour period, excluding time spent resting?*" Responses were reported as a continuous variable and rounded to the nearest half-hour by the interviewer. Sleep was coded as a binary variable to compare those meeting age-specific recommendations (i.e., 7 to 9 hours per day for adults aged 18 to 64 years; 7 to 8 hours per day for adults aged 65 years or older) with those not meeting the recommendations.

Meeting 24hrMG

Adults were considered to have met the 24hrMG if they met recommendations for MVPA, SB (including both total sedentary time 8 hours or less, or 9 hours or less, and recreational screen time) and sleep duration described above.[10]

Table 1
Participant characteristics

Variables	Full sample (n = 8,297)	95% confidence interval from	to	Fasting subsample (n = 4,140)	95% confidence interval from	to
Age, years	44.6	44.0	45.3	45.1	43.8	46.5
Sex, %						
Male	49.8	...	...	50.2	...	...
Female	50.2	...	...	49.8	...	...
Household income quintile, %						
1	13.2	...	...	12.3	...	...
2	18.4	...	...	18.9	...	...
3	20.2	...	...	19.9	...	...
4	19.9	...	...	19.2	...	...
5	28.4	...	...	29.6	...	...
Movement behaviours						
Daily sleep, h/day	6.8	6.6	7.1	6.8	6.5	7.2
Daily sedentary time, h/day	9.8	9.7	9.9	9.8	9.7	9.9
Daily screen time, h/day	2.5	2.4	2.6	2.5	2.3	2.7
Daily MVPA, min/day	16.9	15.3	18.5	16.9	14.7	19.0
Health indicators						
BMI, kg/m^2	26.2	25.9	26.5	26.0	25.6	26.3
Waist circumference, cm	92.0	91.1	92.9	91.7	90.4	92.9
Systolic blood pressure, mmHg	110.0	109.3	110.8	108.8	107.9	109.7
Diastolic blood pressure, mmHg	70.5	70.0	71.0	69.8	69.3	70.3
Aerobic fitness score	366.9	361.5	372.3	369.0	360.2	377.8
HDL cholesterol, mmol/L	1.3	1.3	1.4	1.3	1.3	1.3
C-reactive protein, mg/L	1.3	1.2	1.4	1.3	1.1	1.4
Triglycerides, mmol/L [‡]	...	...	...	1.1	1.1	1.2
Insulin, pmol/L [‡]	...	...	...	55.0	51.7	58.3
Serum glucose, mmol/L [††]	...	...	...	4.9	4.8	5.0

... not applicable
[‡] only measured in fasted subsample
[††] only measured in fasted subsample of cycles 2 and 3
Notes: BMI = body mass index; HDL = high-density lipoprotein cholesterol; MVPA = moderate-to-vigorous physical activity. Data presented as medians (95% confidence intervals) for continuous variables and percentages for categorical variables.
Source: Canadian Health Measures Survey.

Dependent variables

Adiposity outcomes

Details of the protocols used for all measures and tests performed at the MEC are published.[22-24] Respondent body mass index (BMI) (weight in kilograms divided by height in metres squared) was calculated using measurements of height and weight taken by trained interviewers at the MEC. Waist circumference measurements were also taken by trained interviewers at the MEC. In cycles 2 and 3, waist circumference measurements followed protocols from the National Institutes of Health (NIH).[26] In Cycle 1, the waist circumference measurements followed protocols from the World Health Organization,[27] but were adjusted to align with those of the NIH protocol.[28]

Cardiometabolic biomarkers

Systolic and diastolic blood pressure were measured using defined protocols using an oscillometric blood pressure measurement device. Following a five-minute rest period, a series of measurements were taken at one-minute intervals; the final five were used to determine blood pressure results. Blood samples were collected from all eligible respondents at the MEC visit. A sample of respondents were randomly assigned to fast overnight, prior to the MEC appointment. High density lipoprotein levels and C-reactive protein levels were measured on all respondents. Triglyceride and insulin levels were measured among fasted participants. Serum glucose was only measured in cycles 2 and 3, and for this analysis serum glucose was only examined in fasted participants within these two cycles.

Cardiorespiratory fitness

During the MEC visit, eligible respondents completed the modified Canadian Aerobic Fitness Test (mCAFT), used to calculate an aerobic fitness score. The mCAFT is a step test that progresses participants from an age- and sex-dependent starting cadence through sequential three-minute stepping stages until participants reach 85% of age-predicted maximum heart rate. The mCAFT was only conducted in CHMS cycles 1 and 2.

Covariates

Potential covariates included age, sex (male vs. female), household income quintile (adjusted for household size), ethnicity (White vs. non-White), having a chronic condition (yes vs. no), smoking status (daily or occasional smoker vs. non-smoker) and self-rated health (fair or poor vs. good, very good or excellent). All covariates were self-reported. The covariates were considered for the models because of their known potential to influence any of the outcomes and for their bivariate association with meeting 24hrMG recommendations.

Table 2
Proportion of participants meeting the moderate-to-vigorous physical activity, sedentary behaviour, and sleep duration recommendations and combinations of these recommendations in the full sample

	Full sample (n = 8,297)	95% confidence interval		Full sample (n = 8,297)	95% confidence interval	
Meeting recommendation	8 h/day SB	from	to	9 h/day SB	from	to
Specific combinations of movement behaviours, %						
MVPA and SB and sleep	2.6	2.0	3.2	7.1	6.4	7.9
MVPA and SB only	1.7	1.0 [E]	2.4 [E]	3.0	2.2	3.9
MVPA and sleep only	25.4	22.7	28.2	20.9	18.3	23.4
SB and sleep only	1.4	1.0	1.8	5.9	4.7	7.0
MVPA only	11.8	10.1	13.5	10.4	8.9	12.0
SB only	0.8	0.5 [E]	1.1 [E]	2.8	2.1	3.5
Sleep only	35.2	32.7	37.7	30.7	28.8	32.7
None	21.1	18.9	23.2	19.1	17.1	21.1
General combinations of movement behaviours, %						
All three	2.6	2.0	3.2	7.1	6.4	7.9
Two out of three	28.6	25.9	31.3	29.8	27.6	32.0
One out of three	47.8	45.5.	50.0	43.9	42.2	45.7
None	21.1	18.9	23.2	19.1	17.1	21.1

[E] use with caution
Notes: MVPA = moderate-to-vigorous physical activity; SB = sedentary behaviour.
Source: Canadian Health Measures Survey.

Statistical analysis

Respondents missing any of the independent variables (n=2 for screen time, n=5 for sleep duration) were excluded from the analyses. Descriptive analyses generated proportions or means and 95% confidence intervals (CIs) for all independent, covariate and dependent variables. Results were considered statistically significant when $p < 0.05$ (two-sided tests).

Initially, unadjusted linear regression was used to assess the associations between meeting individual and different combinations of the 24hrMG recommendations and each of the individual health indicators. Waist circumference, systolic blood pressure, diastolic blood pressure, triglycerides, C-reactive protein and insulin were log-transformed in the regression models to better meet assumptions of normality. Skewness values ranged from 0.38 to 7.61 prior to log transformation and -0.12 to 0.50 after log transformation. Kurtosis values ranged from 0.56 to 109.54 prior to log transformation and -0.56 to 0.59 after log transformation. The final multivariable models for each health indicator were adjusted for age, sex, household income, ethnicity, having a chronic condition, smoking status and self-rated health. Multivariable model betas and their 95% CIs were reported. Main analyses were performed using a 9-hour cutoff for the sedentary time recommendation; however, results using the 8-hour cutoff were also calculated for comparison.

To account for survey design effects, analyses were conducted using survey procedures in SAS EG version 5.1 (SAS Institute Inc., Cary, North Carolina), incorporating appropriate survey and bootstrap weights provided by Statistics Canada for accelerometer data from the combined CHMS cycles 1, 2 and 3. Standard errors, coefficients of variation and 95% CIs were estimated using bootstrap techniques with 35 degrees of freedom. For analyses involving aerobic fitness and glucose, the degrees of freedom were reduced to 24, as data for these variables were from only two cycles of the CHMS (cycles 1/2 and 2/3, respectively).

Results

Of the 8,477 eligible participants for this study aged 18 to 79, 8,297 participants in the full sample and 4,140 participants in the fasting subsample had complete data for the primary variables of interest and were included in the analyses. Participant characteristics of the full and fasting sample are presented in Table 1. Within the full sample, 50.2% of participants were female and the median age was 44.6 years. In the full sample, the median nightly sleep was 6.8 hours and median daily sedentary time and screen time were 9.8 hours and 2.5 hours, respectively. The median daily MVPA was 16.9 minutes.

The proportion of the full sample meeting specific and general combinations of the recommendations within the guidelines, using a 9-hour cutoff for the sedentary time recommendation, is presented in Table 2. As can be seen, 19% of the sample met none of the recommendations, 43.9% met one recommendation, 29.8% met two recommendations and 7.1% met all three recommendations. Of those that met one recommendation, sleep was the most prevalent (30.7%), followed by MVPA (10.4%) and SB (2.8%). Of those that met two recommendations, MVPA and sleep were the most prevalent (20.9%), followed by SB and sleep (5.9%) and MVPA and SB (3.0%). Results using the 8-hour cutoff for the sedentary time recommendation are also presented in Table 2.

The associations between both the specific and general combinations of movement behaviours and health indicators for adults aged 18 to 79 are presented in Tables 3 and 4. Meeting all three recommendations, compared with meeting two or fewer, was significantly associated with better health for 7 out of 10 health indicators, including BMI, log waist circumference, aerobic fitness, log triglycerides, log C-reactive protein, log insulin and serum glucose. Meeting no recommendations, compared with meeting at least one recommendation, was significantly associated with worse health for 5 of the 10 health

indicators, including BMI, log waist circumference, aerobic fitness, log C-reactive protein and log insulin.

For meeting vs. not meeting specific movement behaviours in isolation, significant favourable associations with health indicators were observed for MVPA only (7/10 associations) and significant unfavourable associations were observed for sleep only (7/10 associations) and SB only (2/10 associations). With regard to meeting vs. not meeting any two movement behaviours in isolation, significant favourable associations with health indicators were observed for meeting MVPA and SB only (4/10 associations) and MVPA and sleep only (4/10 associations), whereas a significant unfavourable association was found for SB and sleep only (1/10 associations).

Compared with meeting no recommendations, meeting one, two and all three of the recommendations were significantly associated with better health for one, six and seven health indicators, respectively. Results using the 8-hour cutoff for the sedentary time recommendation are also presented in Tables 3 and 4.

Discussion

Using a representative sample of Canadian adults aged 18 to 79, the present study examined whether meeting individual and combinations of recommendations within the new Canadian 24hrMG was associated with a variety of health indicators. The findings indicate that, while the majority of adults (80.8%) were meeting at least one of the recommendations, only 7.1% of adults were meeting all of the recommendations within the 24hrMG.

Compared with adults aged 18 to 79 not meeting the Canadian 24hrMG recommendations, those who met the overall guidelines had more favourable BMI; waist circumference; aerobic fitness scores; and triglyceride, insulin, C-reactive protein and serum glucose levels. The findings, herein, are consistent with a previous investigation utilizing the CHMS dataset that found consistent associations between the 24-hour time-use composition of movement behaviours and health indicators among adults aged 18 to 64; however, the associations were diminished or absent in adults aged 65 years

Table 3
Associations between meeting the moderate-to-vigorous physical activity, sedentary behaviour, and sleep duration recommendations and combinations of these recommendations with health indicators in the full sample of adults aged 18 to 79 years

	BMI			Log WC			Log SBP			Log DBP			Aerobic fitness		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Recommendation	β	from	to	β	from	to	β	from	to	β	from	to	β	from	to
Specific combinations of movement behaviours															
MVPA and SB and sleep															
8 h/day SB	-0.46	-1.44	0.52	-0.02	-0.05	0.01	0.01	-0.005	0.03	0.02	-0.003	0.04	13.89	-2.87	30.64
9 h/day SB	-1.04 ‡	-1.68 ‡	-0.40 ‡	-0.03 ‡	-0.06 ‡	-0.01 ‡	-0.01	-0.02	0.003	-0.01	-0.03	0.01	13.90 ‡	4.09 ‡	23.71 ‡
MVPA and SB only															
8 h/day SB	-0.23	-1.88	1.42	-0.03	-0.06	0.01	0.00	-0.03	0.03	0.02	-0.01	0.05	30.16 ‡	16.10 ‡	44.22 ‡
9 h/day SB	-0.96	-2.41	0.50	-0.04 ‡	-0.07 ‡	-0.004 ‡	-0.002	-0.02	0.02	0.02	-0.01	0.04	27.08 ‡	15.36 ‡	38.80 ‡
MVPA and sleep only															
8 h/day SB	-1.08 ‡	-1.64 ‡	-0.53 ‡	-0.04 ‡	-0.05 ‡	-0.02 ‡	-0.01	-0.02	0.01	-0.004	-0.02	0.01	9.43 ‡	3.45 ‡	15.42 ‡
9 h/day SB	-0.85 ‡	-1.49 ‡	-0.21 ‡	-0.03 ‡	-0.05 ‡	-0.01 ‡	0.001	-0.01	0.01	0.001	-0.01	0.01	6.67 ‡	0.59 ‡	12.75 ‡
SB and sleep only															
8 h/day SB	0.51	-0.83	1.85	0.02	-0.02	0.06	-0.02	-0.05	0.01	0.004	-0.03	0.04	-1.63	-18.43	15.17
9 h/day SB	-0.09	-1.00	0.82	-0.002	-0.03	0.02	-0.0003	-0.02	0.02	0.001	-0.02	0.02	-0.25	-10.46	9.96
MVPA only															
8 h/day SB	-1.65 ‡	-2.18 ‡	-1.13 ‡	-0.04 ‡	-0.06 ‡	-0.03 ‡	-0.01	-0.03	0.01	-0.01	-0.03	0.01	14.39 ‡	7.10 ‡	21.68 ‡
9 h/day SB	-1.58 ‡	-2.25 ‡	-0.90 ‡	-0.04 ‡	-0.06 ‡	-0.02 ‡	-0.01	-0.03	0.01	-0.01	-0.03	0.01	12.26 ‡	3.47 ‡	21.05 ‡
SB only															
8 h/day SB	0.27	-1.53	2.06	0.01	-0.03	0.05	0.05	-0.01	0.11	0.05	-0.03	0.12	6.16	-14.86	27.19
9 h/day SB	-0.14	-1.20	0.92	-0.01	-0.04	0.02	0.03 ‡	0.01 ‡	0.06 ‡	0.05 ‡	0.01 ‡	0.08 ‡	2.83	-10.73	16.40
Sleep only															
8 h/day SB	1.06 ‡	0.62 ‡	1.51 ‡	0.03 ‡	0.02 ‡	0.05 ‡	0.00	-0.01	0.01	-0.01	-0.02	0.01	-11.89 ‡	-17.88 ‡	-5.89 ‡
9 h/day SB	1.19 ‡	0.70 ‡	1.69 ‡	0.04 ‡	0.03 ‡	0.05 ‡	-0.0002	-0.01	0.01	-0.01	-0.02	0.01	-12.94 ‡	-20.28 ‡	-5.59 ‡
None															
8 h/day SB	0.82 ‡	0.12 ‡	1.52 ‡	0.02 ‡	0.01 ‡	0.04 ‡	0.01	-0.01	0.02	0.01	-0.01	0.03	-12.44 ‡	-18.84 ‡	-6.04 ‡
9 h/day SB	0.93 ‡	0.17 ‡	1.69 ‡	0.03 ‡	0.01 ‡	0.04 ‡	0.01	-0.01	0.02	0.004	-0.01	0.02	-14.14	-20.41 ‡	-7.87 ‡
General combinations of movement behaviours															
All three															
8 h/day SB	-1.18	-2.36	0.00	-0.04 ‡	-0.07 ‡	-0.003 ‡	0.01	-0.01	0.03	0.01	-0.02	0.04	24.41 ‡	8.65 ‡	40.18 ‡
9 h/day SB	-1.82 ‡	-2.78 ‡	-0.86 ‡	-0.06 ‡	-0.08 ‡	-0.03 ‡	-0.01	-0.03	0.003	-0.01	-0.04	0.02	25.40 ‡	17.24 ‡	33.56 ‡
Two out of three															
8 h/day SB	-1.41 ‡	-2.19 ‡	-0.63 ‡	-0.04 ‡	-0.06 ‡	-0.03 ‡	-0.01	-0.03	0.004	-0.01	-0.03	0.01	18.19 ‡	11.01 ‡	25.36 ‡
9 h/day SB	-1.40 ‡	-2.31 ‡	-0.49 ‡	-0.04 ‡	-0.06 ‡	-0.02 ‡	-0.004	-0.02	0.01	-0.001	-0.02	0.01	18.82 ‡	11.22 ‡	26.41 ‡
One out of three															
8 h/day SB	-0.54	-1.26	0.19	-0.01	-0.03	0.01	-0.01	-0.02	0.01	-0.01	-0.03	0.01	8.27 ‡	0.94 ‡	0.59 ‡
9 h/day SB	-0.56	-1.32	0.20	-0.01	-0.03	0.004	-0.004	-0.02	0.01	-0.01	-0.02	0.01	8.94 ‡	1.48 ‡	16.40 ‡

‡ Statistically significant associations ($p < 0.05$)

Notes: β = unstandardized beta coefficients (95% confidence intervals); BMI = body mass index; DBP = diastolic blood pressure; MVPA = moderate-to-vigorous physical activity; SB = sedentary behaviour; SBP = systolic blood pressure; WC = waist circumference. All models were adjusted for age, sex, household income, ethnicity, having a chronic condition, smoking status and self-rated health.

Source: Canadian Health Measures Survey.

or older.[29] Future studies should consider stratifying by age group to assess the associations between 24hrMG adherence and health indicators separately for adults aged 18 to 64 years and adults aged 65 years or older. It would be wise to delve deeper into the different age categories, namely those aged 65 years or older, when more CHMS cycles are available or in a study focused on the unique characteristics of older Canadians.

Since the 24hrMG were just released,[10] this represents the first study to examine associations between meeting the guidelines and multiple health indicators. Nonetheless, these findings are consistent with those of two recent systematic reviews that provide convincing evidence that the composition of time spent in all movement behaviours across a 24-hour period is associated with risk of all-cause mortality, as well as adiposity, fitness and cardiometabolic health indicators among adults.[7,8] Because the recommendations within the new 24hrMG were in part derived from this evidence,[10] it is not surprising that in our study the health indicator scores were more favourable in participants meeting all 24hrMG recommendations, compared with participants who did not meet the guidelines in full. These findings are also congruent with two recent studies that demonstrated meeting the overall 24hrMG recommendations was associated with a reduced risk of all-cause mortality in U.S. adults,[30] as well as higher psychological well-being in a sample of Canadian postsecondary students.[31]

Findings indicated that meeting only the sleep recommendation was associated with adverse health indicators in 18- to 79-year-olds. Specifically, adults who met the sleep duration recommendation had higher adiposity, lower aerobic fitness and worse cardiometabolic health than those who did not. A previous study, utilizing the CHMS dataset to examine the associations between the 24-hour time-use composition of movement behaviours and health indicators among adults, found that more time spent sleeping relative to other movement behaviours was deleteriously associated with aerobic fitness, HDL cholesterol, insulin and C-reactive protein.[29] This finding may be attributable to reverse causation or behavioural displacement from MVPA. Further, it is important to note that

Table 4

Associations between meeting the moderate-to-vigorous physical activity, sedentary behaviour, and sleep duration recommendations and combinations of these recommendations with blood sample health indicators in adults aged 18 to 79 years

	Log triglycerides††			HDL			Log CRP			Log insulin††			Serum glucose‡‡		
		95% confidence level			95% confidence level			95% confidence level			95% confidence level			95% confidence level	
Recommendation	β	from	to	β	from	to	β	from	to	β	from	to	β	from	to
Specific combinations of movement behaviours															
MVPA and SB and sleep															
8 h/day SB	-0.08	-0.22	0.07	0.19	-0.20	0.59	-0.14	-0.37	0.08	-0.07	-0.27	0.14	-0.23 ‡	-0.42 ‡	-0.03 ‡
9 h/day SB	-0.12 ‡	-0.21 ‡	-0.02 ‡	0.12	-0.04	0.28	-0.16 ‡	-0.32 ‡	-0.01 ‡	-0.26 ‡	-0.39 ‡	-0.14 ‡	-0.26 ‡	-0.4 ‡	-0.13 ‡
MVPA and SB only															
8 h/day SB	-0.16	-0.40	0.07	0.004	-0.16	0.17	-0.26	-0.72	0.20	-0.26 ‡	-0.40 ‡	-0.11 ‡	0.11	-0.25	0.48
9 h/day SB	-0.21 ‡	-0.38 ‡	-0.04 ‡	0.02	-0.07	0.11	-0.26	-0.68	0.16	-0.32 ‡	-0.52 ‡	-0.12 ‡	-0.04	-0.27	0.18
MVPA and sleep only															
8 h/day SB	-0.11 ‡	-0.18 ‡	-0.04 ‡	0.03	-0.07	0.13	-0.17 ‡	-0.31 ‡	-0.02 ‡	-0.14 ‡	-0.21 ‡	-0.07 ‡	-0.17 ‡	-0.27 ‡	-0.06 ‡
9 h/day SB	-0.08	-0.17	0.001	0.02	-0.09	0.13	-0.14	-0.29	0.01	-0.06	-0.15	0.04	-0.12 ‡	-0.22 ‡	-0.01 ‡
SB and sleep only															
8 h/day SB	-0.07	-0.27	0.14	-0.14	-0.28	0.001	0.21	-0.11	0.52	-0.04	-0.27	0.18	0.25	-0.27	0.77
9 h/day SB	-0.08	-0.20	0.04	-0.11 ‡	-0.18 ‡	-0.04 ‡	0.11	-0.06	0.28	-0.03	-0.17	0.12	0.01	-0.27	0.29
MVPA only															
8 h/day SB	-0.12 ‡	-0.20 ‡	-0.03 ‡	0.11 ‡	0.03 ‡	0.19 ‡	-0.30 ‡	-0.47 ‡	-0.13 ‡	-0.21 ‡	-0.29 ‡	-0.14 ‡	-0.12	-0.31	0.08
9 h/day SB	-0.09 ‡	-0.18 ‡	-0.004 ‡	0.12 ‡	0.02 ‡	0.21 ‡	-0.30 ‡	-0.48 ‡	-0.11 ‡	-0.18 ‡	-0.28 ‡	-0.08 ‡	-0.09	-0.32	0.13
SB only															
8 h/day SB	-0.06	-0.30	0.17	0.01	-0.12	0.13	-0.20	-0.65	0.26	-0.06	-0.40	0.28	0.11	-0.36	0.57
9 h/day SB	0.02	-0.13	0.17	0.02	-0.06	0.11	-0.13	-0.45	0.19	0.04	-0.18	0.26	0.06	-0.25	0.37
Sleep only															
8 h/day SB	0.11 ‡	0.04 ‡	0.18 ‡	-0.11 ‡	-0.17 ‡	-0.04 ‡	0.22 ‡	0.11 ‡	0.32 ‡	0.16 ‡	0.09 ‡	0.23 ‡	0.12	-0.01	0.25
9 h/day SB	0.13 ‡	0.06 ‡	0.21 ‡	-0.09 ‡	-0.16 ‡	-0.03 ‡	0.22 ‡	0.11 ‡	0.32 ‡	0.18 ‡	0.10 ‡	0.25 ‡	0.13	-0.02	0.28
None															
8 h/day SB	0.08	-0.003	0.16	0.02	-0.09	0.14	0.11 ‡	0.03 ‡	0.19 ‡	0.11 ‡	0.01 ‡	0.21 ‡	0.08	-0.14	0.31
9 h/day SB	0.08	-0.01	0.17	0.02	-0.10	0.15	0.13 ‡	0.04 ‡	0.23 ‡	0.11 ‡	0.01 ‡	0.22 ‡	0.08	-0.16	0.33
General combinations of movement behaviours															
All three															
8 h/day SB	-0.15	-0.29	0.001	0.17	-0.26	0.60	-0.24 ‡	-0.47 ‡	-0.01 ‡	-0.17	-0.39	0.06	-0.30 ‡	-0.58 ‡	-0.01 ‡
9 h/day SB	-0.19 ‡	-0.31 ‡	-0.07 ‡	0.09	-0.14	0.32	-0.27 ‡	-0.46 ‡	-0.09 ‡	-0.35 ‡	-0.49 ‡	-0.21 ‡	-0.32 ‡	-0.56 ‡	-0.08 ‡
Two out of three															
8 h/day SB	-0.16 ‡	-0.25 ‡	-0.06 ‡	-0.003	-0.15	0.14	-0.21 ‡	-0.33 ‡	-0.08 ‡	-0.21 ‡	-0.31 ‡	-0.11 ‡	-0.17	-0.4	0.06
9 h/day SB	-0.16 ‡	-0.26 ‡	-0.05 ‡	-0.03	-0.17	0.12	-0.20 ‡	-0.33 ‡	-0.07 ‡	-0.17 ‡	-0.29 ‡	-0.05 ‡	-0.14	-0.4	0.11
One out of three															
8 h/day SB	-0.04	-0.13	0.04	-0.04	-0.15	0.06	-0.06	-0.16	0.05	-0.07	-0.17	0.04	-0.04	-0.27	0.19
9 h/day SB	-0.02	-0.12	0.07	-0.03	-0.15	0.08	-0.08	-0.18	0.03	-0.05	-0.16	0.07	-0.03	-0.28	0.23

‡ Statistically significant associations ($p < 0.05$)

†† only measured in fasted subsample

‡‡ only measured in fasted subsample of cycles 2 and 3

Notes: β = unstandardized beta coefficients (95% confidence intervals); CRP = C-reactive protein; HDL = high-density lipoprotein cholesterol; MVPA = moderate-to-vigorous physical activity; SB = sedentary behaviour. All models were adjusted for age, sex, household income, ethnicity, having a chronic condition, smoking status and self-rated health.

Source: Canadian Health Measures Survey.

sleep duration is not indicative of sleep quality; despite reporting sufficient sleep duration to meet the recommendation, individuals may lack adequate sleep quality. For instance, in a recent study examining a representative sample of Canadian adults aged 18 to 79, 40% to 43% of men and 55% to 59% of women reported trouble going to sleep or staying asleep.[32]

Meeting only the MVPA recommendation was consistently associated with favourable adiposity, fitness and cardiometabolic health indicators for adults. It is well established that MVPA is associated with numerous physical and psychosocial health benefits.[1,4] This finding also reaffirms evidence from previous compositional and isotemporal substitution studies that have shown a strong association between MVPA and markers of obesity and cardiometabolic health in adults.[9,29,33-35]

There were no clear health benefits associated with meeting the SB recommendation in isolation. This is in contrast to previous evidence, which has shown that individuals who accumulate high levels of SB are at increased risk of all-cause mortality and several chronic diseases.[1,3,5] However, a recent study examining the time-use composition of movement behaviours in adults also reported no statistically significant associations between greater sedentary time relative to other movement behaviours and health indicators.[29] In the current study, participants were considered to have met the SB guideline if they met the time-specific recommendations for total sedentary time and recreational screen time.[10] Future investigations are needed to examine the relative contribution of each sedentary component and associations between meeting vs. not meeting each of these and health indicators in the adult population. To the authors' knowledge, no studies exploring the combined effect of 24-hour movement behaviours on health have examined the influence of screen time in adults. However, dose-response evidence for recreational screen time from recent meta-analyses showed that the risk of all-cause mortality, cardiovascular disease mortality and type 2 diabetes increases above a threshold of 3 to 4 hours per day of TV viewing.[5,36-38] Recently, Prince et al.[25] reported that total leisure screen time has increased, with a larger proportion of time spent engaged with different types of screens (e.g., tablets, smartphones) for different purposes (e.g., games, shopping, communication), reflecting a shift in the ways Canadians are spending their free time.

For specific combinations of 24hrMG recommendations, it was observed that meeting the MVPA and SB recommendations was beneficially associated with specific cardiometabolic health indicators (i.e., triglycerides, insulin), as well as adiposity and aerobic fitness for adults aged 18 to 79 years. Meeting both the MVPA and sleep recommendations was associated with lower adiposity, higher aerobic fitness and lower serum glucose for adults. These findings further substantiate that meeting the MVPA recommendation was associated with the greatest and clearest benefits for health.

The findings herein provide preliminary support for the integrated paradigm that underpins the new 24hrMG with a focus on the combined or synergistic effects of movement behaviours on health.[10] The gradient of an increased number of beneficial health associations with an increased number of guidelines met in adults aged 18 to 79 provides such support. Given the low levels of meeting both the individual and overall guideline recommendations, implementation strategies and dissemination approaches to encourage uptake and adoption among stakeholders and the general public are necessary. It is anticipated that these guideline recommendations will stimulate further investigation on the health impact of 24-hour movement behaviours across the adult life span, and serve to accelerate research efforts to challenge and refine these guidelines.

The evidence that led to the selection of the 8 hours or less per day sedentary time cut point for the 24hrMG was based on an amalgamation of results from studies that used accelerometer measures of sedentary time and self-reported measures of sitting time,[3,10] with lower thresholds for increased risk observed for self-reported SB, and higher thresholds observed for accelerometer-measured sedentary time. To be consistent with surveillance recommendations provided by Ross et al.[10] and because a very small proportion of adults met the SB recommendation when an 8-hour cut point was used—contributing to a lack of power—main analyses for this study were performed using a 9-hour threshold for the sedentary time recommendation. The authors' findings demonstrate that when device-based measures of daily sedentary time are used to assess adherence to the SB recommendation within the 24hrMG, a greater number of health associations were observed between meeting vs. not meeting the overall guidelines when a higher cut point of 9 hours per day was used. Additional studies are required to determine the ideal cut point to define excessive sedentary time and to examine potential differential associations between self-reported and device-based measures.

Further research, including longitudinal and intervention studies, is required to confirm and expand the evidence base on associations between meeting vs. not meeting the 24hrMG and a wide range of health indicators (e.g., mental and social health) in adults. Future studies should also examine effect sizes and the significance (e.g., clinical) of observed associations to a greater degree, as well as whether interventions targeting changes in 24-hour movement behaviours translate to meaningful changes in health indicators. Additionally, potential moderating effects of sex, age, race and ethnicity, and socioeconomic status on associations between guideline adherence and health indicators warrants investigation. The observed associations should be confirmed using national data collected after the guidelines were released, as well as other population-based datasets that assess all movement behaviours in Canada and in other countries. For the purpose of population health surveillance, there is a need for the development of updated self-report instruments better suited to measure screen time and to accurately capture time spent on different screen-based devices across various platforms and activities.

Strengths of this study include the consideration of adiposity, cardiometabolic and aerobic fitness health indicators, objective measures of MVPA and SB, the large sample size and the nationally representative dataset. Limitations include the cross-sectional design (e.g., precluding causal inferences from being made, possibility of spurious associations) and the self-reported nature of screen time and sleep data. Measurement error and recall bias associated with these subjective measures may have influenced the results. Although this study accounted for several potential covariates, it is possible that the associations observed may have been influenced by residual confounders (e.g., diet, other health-compromising behaviours).

Conclusion

Our findings support the recommendations contained within the new Canadian 24hrMG. Meeting the overall 24hrMG recommendations was associated with favourable health indicators in a large representative sample of Canadians aged 18 to 79. Given that less than 1 in 10 Canadian adults met all 3 recommendations, efforts are needed to promote the adoption of these new guidelines.

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