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Meeting Canadian 24-Hour Movement Guideline recommendations and risk of all-cause mortality

Anna E. Clarke¹, Valerie Carson², Jean-Philippe Chaput³, Rachel C. Colley⁴, Karen C. Roberts⁵, Scott Rollo³,
Mark S. Tremblay³, Ian Janssen^{1,6}

¹Department of Public Health Sciences, Queen's University, Kingston, ON, K7L 3N6, Canada.

²Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Edmonton, AB, T6G 2H9, Canada.

³Healthy Active Living and Obesity Research Group, Children's Hospital of Eastern Ontario Research
Institute, Ottawa, ON, K1H 8L1, Canada.

⁴Health Analysis Division, Statistics Canada, Ottawa, Canada.

⁵Centre for Surveillance and Applied Research, Public Health Agency of Canada, Ottawa, Ontario.

⁶School of Kinesiology and Health Studies, Queen's University, Kingston, ON, K7L 3N6, Canada.

Contact for corresponding author:

Ian Janssen, School of Kinesiology and Health Studies, Queen's University, Kingston, ON, Canada, K7L 3N6. Phone: +1(613)533-6000 ext. 78631; Email: ian.janssen@queensu.ca

Contact for other authors: Anna E. Clarke (anna.clarke@queensu.ca), Valerie Carson (vlcarson@ualberta.ca), Jean-Philippe Chaput (jpchaput@cheo.on.ca), Rachel C. Colley (rachel.colley@canada.ca), Karen C. Roberts (karenc.roberts@canada.ca), Scott Rollo (arollo@cheo.on.ca), Mark S. Tremblay (mtremblay@cheo.on.ca)

ABSTRACT

This study determined if meeting the Canadian 24-Hour Movement Guidelines recommendations are associated with all-cause mortality. Participants were 3,471 adults from the 2005-2006 U.S. National Health and Nutrition Examination Survey followed for mortality over 11 years. They were classified as meeting or not meeting recommendations for sleep duration, sedentary behaviour, and moderate-to-vigorous physical activity (MVPA). A total of 63.8%, 35.3%, and 41.5% of participants met recommendations for sleep, sedentary behavior, and physical activity while 12.3% met all three recommendations. The hazard ratio (HR) for all-cause mortality in participants meeting the recommendations relative to those not meeting the recommendations were 0.91 (0.72, 1.16) for sleep, 0.92 (0.61, 1.40) for sedentary behavior, and 0.42 (0.24, 0.74) for MVPA. The HR for meeting none, any one, any two, and all three recommendations were 1.00, 0.86 (0.65, 1.14), 0.49 (0.28, 0.86), and 0.72 (0.34, 1.50). When the cut-point used to denote acceptable sedentary time was changed from ≤ 8 to ≤ 10 hours/day, the HR for meeting none, any one, any two, and all three recommendations were 1.00, 0.83 (0.59, 1.15), 0.57 (0.34, 0.96), and 0.43 (0.20, 0.93). These findings provide some support of the ability of the 24-hour movement guidelines to predict mortality risk.

NOVELTY

- The 24-Hour Movement Guidelines provide recommendations for sleep, sedentary behavior, and physical activity.
- The findings of this study provide some support of the ability of these new guidelines to predict mortality risk.

KEY WORDS: sleep, sedentary behavior, screen time, physical activity, movement, public health recommendations

INTRODUCTION

The *Canadian 24-Hour Movement Guidelines for Adults aged 18-64 years and Adults aged 65 years or older* were released in October, 2020 (Ross et al., 2020). These guidelines, which will henceforth be referred to as the 24-hour Movement Guidelines, were developed using a rigorous, transparent, and evidence-based process (Ross et al., 2020). The 24-hour Movement Guidelines recognize that all intensities of movement influence health and that the composition of movement behaviors across the 24-hour day is important.

A cornerstone of the 24-hour Movement Guidelines is the integration of recommendations for sleep, sedentary behavior (SED), and physical activity. Specifically, the 24-hour Movement Guidelines recommend that adults get 7-9 hours/day of sleep if aged 18-64 years or 7-8 hours/day of sleep if aged 65 or older, limit sedentary time to ≤ 8 hours/day including ≤ 3 hours/day of recreational screen time, and accumulate ≥ 150 minutes/week of moderate-to-vigorous physical activity (MVPA) (Ross et al., 2020). The aforementioned sleep duration recommendation is consistent with that of the US National Sleep Foundation (Hirshkowitz et al., 2015). The sedentary time and recreational screen time recommendations in the 24-hour Movement Guidelines represent the first specific public health targets for SED in adults (Tremblay et al., 2020). Although the recommendation for MVPA in the 24-hour Movement Guidelines is consistent with the MVPA recommendation in the 2018 Physical Activity Guidelines for Americans (U.S. Department of Health and Human Services, 2018), it represents a shift from previous American (U.S. Department of Health and Human Services, 2008), Canadian (Tremblay et al., 2011), and global (World Health Organization, 2010) physical activity guidelines, which all stipulate that MVPA should be accumulated in bouts lasting at least 10 minutes. Thus, in addition to integrating recommendations for different movement behaviors, the 24-hour Movement Guidelines propose new recommendations for SED and a significant modification to the MVPA recommendation.

The development of the Canadian 24-Hour Movement Guidelines was an in-depth, detailed, time-consuming, and expensive undertaking (Ross et al., 2020). In the interest of expediting guideline development, other jurisdictions may choose to adopt and/or adapt (Schunemann et al., 2017) these new Canadian guidelines. Indeed, when Canada launched the 24-Hour Movement Guidelines for Children and Youth (Tremblay et al., 2016) and the Early Years (Tremblay et al., 2017), identical or near identical guideline recommendations were soon after launched in other countries (Australian Government Department of Health, 2017, Draper et al., 2020) and by the World Health Organization (World Health Organization, 2019). Thus, given the novelty and potential widespread use of the Canadian 24-Hour Movement Guidelines, it is important to test their utility at predicting health risk. Therefore, the objectives of this study were to determine if meeting the recommendations in the new 24-Hour Movement Guidelines are associated with a reduction in all-cause mortality risk.

MATERIALS AND METHODS

Data Source and Study Participants

We used data from the 2005-2006 cycle of the US National Health and Nutrition Examination Survey (NHANES), a nationally representative sample that is based on a stratified, multistage probability design of civilian, non-institutionalized participants (Curtin et al., 2012). Data were collected using interviews, questionnaires, physical and biological measures, 7-day accelerometer data collection, and follow-up record linkage for mortality (Zipf et al., 2013). The 2005-2006 cycle was the only cycle that included all measures necessary to evaluate all 24-hour Movement Guideline recommendations. Ethics approval was obtained from the National Centre for Health Statistics. Participants provided written, informed consent.

Participants who were aged 20 years or older, provided consent for mortality follow-up, and were not pregnant or breastfeeding during their NHANES exam were eligible for this study (n=4,641).

Participants with insufficient valid accelerometer data (<1 valid day, n=1,105) or with missing sleep duration (n=5), screen time data (n=2), education (n=2) or smoking (n=1) data were excluded. Twenty participants who died of accidental causes during follow-up were excluded because these deaths were not expected to be related to movement guidelines. Thirty-five participants who died before one year of follow-up were excluded to reduce the misclassification of movement behaviors, which may have been altered close to death. This left a final sample of 3,471. To account for the fact that a large proportion of eligible participants were excluded, we created new sample weights for the 3,471 participants included in the final analysis to ensure that the sample remained nationally representative. The re-weighting accounted for population counts within age, sex, and race/ethnicity subgroups.

Movement Behaviors

Accelerometer measures of sedentary time and MVPA. Participants were instructed to wear a uniaxial accelerometer (Actigraph PAM-7164, Pensacola, FL) for 7 consecutive days on their right hip (Centers for Disease Control and Prevention and U.S. Department of Health and Human Services, June 2008). They were told to only remove the accelerometer at bedtime and when it could get wet. The accelerometers recorded movement intensity over 1-minute epochs.

When processing the accelerometer data, non-wear time, which was defined as ≥ 90 consecutive minutes where the intensity count was zero with up to two consecutive minutes with counts between 1-99, was removed (Choi et al., 2011). Invalid days, when the wear time was <10 hours, were removed and participants with no valid days were removed (Choi et al., 2011, Troiano et al., 2008, Colley et al., 2010). The remaining accelerometer data were used to estimate average daily and weekly time spent sedentary (minutes where the activity count was <100) and in MVPA (minutes where the activity count was ≥ 2020) (Choi et al., 2011, Troiano et al., 2008, Colley et al., 2010).

Questionnaire measures of screen time and sleep duration. Questionnaire items were used to assess screen time and sleep duration. Screen time was estimated from responses to the question "Over

the past 30 days, on average how many hours per day did you sit and watch TV or videos?”. Ordinal response options ranged from none to ≥ 5 hours per day. Sleep duration was estimated from responses to the question “How much sleep do you actually get at night on weekdays or workdays?”. Responses were rounded to the nearest hour.

Meeting the 24-hour Movement Guideline recommendations. Participants were placed into “yes” or “no” groups based on whether or not they met recommendations for sleep duration (7-9 hours/day for adults 18-64 years, 7-8 hours/day for adults ≥ 65 years), SED (≤ 8 hours/day of sedentary time or ≤ 3 hours/day of recreational screen time or both of these recommendations) and MVPA (≥ 150 minutes/week) (Ross et al., 2020). Since the SED recommendation of the guidelines included both a total sedentary time and screen time component, we looked at these two components both individually and in combination. Participants were also grouped according to the total number of guideline recommendations achieved (none, any one, any two, all three). For comparisons based on number of guideline recommendations achieved, we did not compare subgroups of the any one (sleep only, SED only, or MVPA only) or any two (sleep + SED, sleep + MVPA, or SED + MVPA) groups because the sizes of these subgroups were inadequate.

All-Cause Mortality

Probabilistic record matching with the National Death Index was used to determine death status through December 31st, 2015 (National Center for Health Statistics and Office of Analysis and Epidemiology, March 2019). Other sources of mortality information were also used, including a linkage with Social Security files and active follow-up (National Center for Health Statistics and Office of Analysis and Epidemiology, March 2019). The NHANES publicly available mortality file provided information on vital status (alive or deceased), leading cause of death, and follow-up time from the examination date to the date of death or end of the follow-up period.

Covariates

Covariate measures were extracted from self-reported questionnaires, in person interviews, and food recalls. Covariates included age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican-American, other Hispanic, other race including multi-racial), education (<high school, high school graduate, college graduate), poverty-to-income ratio, body mass index (BMI) category based on measured heights and weights (underweight, normal weight, overweight, obesity class I, obesity class II+ (World Health Organization, 1998)), smoking status (non-smoker, former smoker, current smoker), alcohol consumption, and diet quality. Poverty-to-income ratio was calculated by dividing family income by poverty guidelines specific to the year, state, and family size. Alcohol consumption was categorized as non-drinkers, light-to-moderate drinkers (1-14 drinks/week for men, 1-7 drinks/week for women), and heavy drinkers (>15 drinks/week for men, >7 drinks/week for women) (DeSalvo et al., 2016). Diet quality was assessed using a healthy eating index that measures conformance with the 2010 Dietary Guidelines for Americans as captured from two 24-hour food recall assessments and a food frequency questionnaire (Krebs-Smith et al., 2018). For participants with missing values, a 'missing' category was created for poverty-to-income ratio (n=144), BMI (n=13), alcohol consumption (n=245), and diet quality (n=122) as retaining these participants helped preserve statistical power.

Statistical Analysis

Statistical analyses were conducted in SAS version 9.4 (SAS Inc., Carry, NC) and accounted for survey design and sample weights. Conventional descriptive statistics were derived (e.g., means, proportions, death rates). Cox proportional hazards regression models were used to evaluate the relationship between meeting individual recommendations for sleep duration, SED, and MVPA with all-cause mortality. Unadjusted models (e.g., no covariates), partially adjusted models (e.g., meeting MVPA recommendation while controlling for covariates), and fully adjusted models (e.g., meeting MVPA recommendation while controlling for covariates and yes/no to the sleep and SED recommendations) were built. Cox proportional hazards regression models were also used to evaluate the relationship

between meeting none, any one, any two, or all three of the guideline recommendations and mortality risk, prior to and after adjusting for covariates. In the adjusted models, a backward elimination approach with a liberal p-value (0.20) was used to remove covariates unrelated to mortality. If a covariate in any model included a p-value $< .20$, it was included in all adjusted models. The proportional hazards assumption held for the final models. Results of the Cox models are presented as hazard ratios (HR) and their associated 95% confidence intervals (CI).

To explore whether the associations were modified by age and sex, interaction terms between meeting guideline recommendations and sex and age were added to the regression analyses. Sensitivity analyses considered whether the results changed if: 1) the 35 participants who died during the first year of follow-up were included in the analyses, 2) the 159 participants who exceeded the upper sleep duration cut-points (i.e., ≥ 10 hours/day for 18 to 64-year-olds, ≥ 9 hours/day for ≥ 65 -year-olds) were excluded from the analyses, 3) the accelerometer inclusion criterion was changed from a single valid day to at least 4 valid days, and 4) the ≤ 8 hour/day sedentary time cut-point was changed to ≤ 10 hours/day. The process paper describing the development of the 24-hour Movement Guidelines indicates that the ≤ 8 hour/day sedentary time cut-point was based on a blending of results from studies that used self-reported sitting time measures, which suggest a threshold of approximately 7 hours/day, and studies that used accelerometer measures of sedentary time, which suggest a threshold of 9 to 10 hours/day (Ross et al., 2020). Since the current study used accelerometer measures, we wanted to examine the predictive ability of the ≤ 10 hours/day cut-point.

RESULTS

Descriptive Characteristics

Descriptive characteristics at baseline are in Table 1. Participants were aged 46.6 years on average and 51.9% were female. Most were non-Hispanic white (71.8%), high school graduates (83.1%),

had overweight or obesity (66.2%), were non- or former smokers (76.8%), and non-drinkers or light-to-moderate drinkers (85.2%).

Most participants (63.8%) met the sleep duration recommendation while less than half met recommendations for SED (35.3%) and MVPA (41.5%). Only 12.3% met all three recommendations. Average sleep duration, sedentary time, screen time and MVPA values in hours:minutes per day were 6:54, 8:25, 2:12, and 0:23, respectively. Table 2 presents mean levels of sleep duration, sedentary time, screen time, and MVPA according to the number of recommendations met and whether participants met the specific recommendations for sleep, SED, and MVPA.

Mortality Follow-Up

The average follow-up length was 9.4 years and ranged from 1 to 11 years. A total of 470 deaths occurred over 32,657 person-years of follow-up and the death rate was 96 deaths per 10,000 person-years.

All-cause mortality risks associated with meeting guideline recommendations for individual movement behaviors are presented in Table 3. After backwards elimination, the regression models were adjusted for age, sex, family poverty-to-income ratio, education, BMI, smoking status, alcohol consumption, and diet quality. In the fully adjusted model (model 3), meeting the MVPA recommendation (HR=0.42; 95% CI=0.24, 0.74) but not sleep duration (HR=0.91; 95% CI=0.72, 1.16) or SED (HR=0.92; 95% CI=0.61, 1.40) recommendation was associated with a significantly lower mortality risk. For the SED recommendation, meeting the ≤ 8 hour/day sedentary time component was not associated with mortality risk (HR=0.93; 95% CI=0.66, 1.30); nor was meeting the ≤ 3 hour/day recreational screen time component (HR=0.81; 95% CI=0.62, 1.05; $p=0.11$).

All-cause mortality risks associated with the number of movement behavior recommendations met are provided in Table 4. Models wherein only the sedentary time component, only the screen time component, or both components were required for SED adherence are presented. For these three SED

recommendation scenarios, meeting any one guideline recommendation was associated with small and non-significant reductions in mortality risk (HRs=0.77-0.88) while meeting any two guideline recommendations was mostly associated with statistically significant reductions in mortality risk that ranged from 49-62%. Meeting all three guideline recommendations was associated with a significant reduction in mortality risk when the screen time component alone was required for SED guideline adherence (HR=0.37; 95% CI=0.16, 0.85), but not when the sedentary time component alone (HR=0.68; 95% CI=0.34, 1.34) or both the sedentary time and screen time components (HR=0.72; 95% CI=0.34, 1.50) were required for SED guideline adherence.

Additional Analyses

Interaction terms between meeting guideline recommendations and sex and age were added to the regression models. None of the interaction terms were statistically significant indicating that the associations were not modified by sex or age.

Including the 35 participants who died during the first year of follow-up in the analyses did not influence the results. When they were included, meeting any one recommendation was not associated with a significant reduction in mortality risk (HR=0.84; 95% CI=0.62, 1.13), meeting any two recommendations was associated with a statistically significant reduction in mortality risk (HR=0.46; 95% CI=0.27, 0.79), and meeting all three recommendations, including both the sedentary time and screen time components of the SED recommendation, was not associated with a significant reduction in mortality risk (HR=0.81; 95% CI=0.41, 1.62).

When the 159 participants who exceeded the upper sleep duration cut-points (i.e., ≥ 10 hours/day for 18 to 64-year-olds, ≥ 9 hours/day for ≥ 65 -year-olds) were excluded, the HR for mortality in changed minimally from 0.91 (0.72, 1.16) to 0.96 (0.72, 1.29). When examining the number of guideline recommendations met, the HR for 1, 2, and 3 guidelines also changed minimally from 0.89 (0.63, 1.28),

0.52 (0.28, 0.97), and 0.74 (0.37, 1.51), respectively, to 0.86 (0.65, 1.14), 0.49 (0.28, 0.86), and 0.72 (0.34, 1.50).

After changing the accelerometer inclusion criterion from having a single day with ≥ 10 hours of wear time to at least 4 days with ≥ 10 hours of wear time, the number of participants changed from 3,471 to 2,901. All analyses were repeated in this subset of 2,901 participants and these analyses can be found in the Supplemental file (Tables S1-S5). For the most part, the pattern of findings in this subset with ≥ 4 days of valid accelerometer data were comparable to the pattern of findings in participants with as little as a single day of valid accelerometer data.

When the sedentary time cut-point was changed from ≤ 8 hours/day to ≤ 10 hours/day, the proportion of participants who achieved the SED recommendation was 78.2% when based on the sedentary time component alone and 62.5% when based on both the ≤ 10 hours/day sedentary time component and ≤ 3 hours/day recreational screen time component. As seen in Table 5, after adjusting for covariates and meeting the sleep and MVPA recommendations, meeting the ≤ 10 hours/day of sedentary time cut-point was associated with a significant reduction in mortality risk (HR=0.71; 95% CI: 0.51, 0.99). Conversely, meeting both the ≤ 10 hours/day sedentary time and ≤ 3 hours/day recreational screen time cut-points was not associated with a significant change in mortality risk (HR=0.77; 95% CI=0.54, 1.10). When compared to meeting no guideline recommendations, meeting any one recommendation was not associated with a significant reduction in mortality risk (HR=0.83; 95% CI=0.59, 1.15), meeting any two recommendations was associated with a 43% reduction in mortality risk (HR=0.57; 95% CI=0.34, 0.96), and meeting all three recommendations, including both the sedentary time and screen time components of the SED recommendation, was associated with a 57% reduction in mortality risk (HR=0.43; 95% CI=0.20, 0.93). Refer to Table 5 for a comparison of the HRs based on whether the sedentary time cut-point was ≤ 8 hours/day or ≤ 10 hours/day.

DISCUSSION AND CONCLUSION

This study examined whether meeting the recommendations in the Canadian 24-Hour Movement Guidelines are associated with all-cause mortality risk. Meeting the recommendation for MVPA was associated with a large and significant reduction in mortality risk, whereas meeting recommendations for sleep duration and SED were not significantly associated with mortality risk. Meeting any two guideline recommendations was associated with a reduced mortality risk. Meeting all three guideline recommendations was only associated with a reduced mortality risk when adherence to the SED recommendation was based on the recreational screen time component alone, or when the cut-point used to define acceptable sedentary time was increased from ≤ 8 hours/day to ≤ 10 hours/day.

Meta-analyses (Cappuccio et al., 2010, Yin et al., 2017, Garcia-Perdomo et al., 2019) and a recent overview of systematic reviews (Chaput et al., 2020) report that sleep duration is a weak to modest predictor of mortality risk (Cappuccio et al., 2010, Yin et al., 2017, Garcia-Perdomo et al., 2019). In our study, meeting the sleep duration recommendation was associated with reduction in mortality risk but this did not reach statistical significance. Other cohort studies with larger sample sizes and a greater number of deaths have reported comparable HR estimates to that reported in our study but which reached statistical significance. For instance, in a study of 13,423 adults with 530 deaths, the HR for mortality in the group who adhered to the National Sleep Foundation guidelines (which are consistent with the sleep recommendation in the 24-Hour Movement Guidelines) was 0.81 (95% CI=0.67, 0.99) (Hirshkowitz et al., 2015). Our study was limited to 3,471 participants with 470 deaths and may have been insufficiently powered to detect weak associations.

Interestingly, in our study, meeting the ≤ 8 hour/day sedentary time component was not associated with a reduction in mortality risk. However, when the ≤ 8 hour/day cut-point for sedentary time was changed to ≤ 10 hour/day, low sedentary time was associated with a 29% reduction in mortality risk. Furthermore, the relationship between number of guideline recommendations achieved

and mortality risk followed a clear dose-response gradient when a sedentary time cut-point of ≤ 10 hour/day was used; the pattern was less clear when the ≤ 8 hour/day cut-point was used. The evidence that led to the selection of the ≤ 8 hour/day sedentary time cut-point for the 24-hour Movement Guidelines was based on a combination of results from studies that used self-reported measures of sitting time and accelerometer measures of sedentary time (Ross et al., 2020, Saunders et al., 2020), with thresholds for increased risk being 2-3 hours lower for the self-reported measure than the accelerometer measure. A recent meta-analysis based on accelerometer-derived estimates of sedentary time found that mortality risk began to significantly increase at 9 to 10 hours/day (Ekelund et al., 2019). The results of our study are consistent with this meta-analysis. Collectively, these findings suggest that when device-based measures of total sedentary time are used to assess adherence to the SED recommendation contained within the 24-hour Movement Guidelines, a sedentary time cut-point of 8 hours/day is too restrictive for mortality risk and a higher cut-point of 10 hours/day is more appropriate. In the nationally representative sample of American adults examined in our study, shifting the cut-point from 8 to 10 hours/day changed the proportion of participants meeting the sedentary time recommendation from 40.8% to 75.5%.

Participants who met the MVPA recommendation had a greater than 50% reduction in all-cause mortality risk. This observation is consistent with a large body of evidence, primarily of studies that used self-reported measures, that indicate that accumulating 150 minutes/week of MVPA is associated with a meaningful reduction in mortality risk (Warburton et al., 2010, Physical Activity Guidelines Advisory Committee, 2008). An important change to the MVPA recommendation in the 24-hour Movement Guidelines versus earlier physical activity specific guidelines in Canada (Tremblay et al., 2011) and elsewhere (U.S. Department of Health and Human Services, 2008, Bull and Groups, May 2010, World Health Organization, 2010) was the removal of the stipulation that MVPA needs to be accumulated in bouts of at least 10 minutes. This change was made based on evidence from a growing

number of studies reporting that the health benefits of non-bouted MVPA are equivalent to those of bouts MVPA (Clarke and Janssen, 2014, Jakicic et al., 2019). This change has implications for the development of health promotion messages and strategies aimed at getting people to accumulate a sufficiently healthy dose of MVPA. This change also has implications for surveillance of the MVPA recommendation. In Canada, for instance, the prevalence of adults adhering to the 150 minute/week MVPA recommendation increased from 16.4% to 44.8% when the 10-minute bout stipulation was removed (Clarke et al., 2019).

The findings of our study suggest that meeting the recommendation for MVPA has a greater influence on reducing mortality risk than meeting the recommendations for sleep or SED. Meeting any two recommendations from the 24-Hour Movement Guidelines appears to have a greater benefit than meeting only one of these recommendations. When a higher cut-point for sedentary time is used, or when only assessing the screen time component of SED, meeting all three recommendations is associated with the greatest reduction in all-cause mortality risk. Thus, all three movement behaviors should be targeted to promote optimal health. Indeed, the tools and resources and key public facing messages for the 24-Hour Movement Guidelines, such as “Move more. Reduce sedentary time. Sleep well.” and “Make your whole day matter.”, promote all movement behaviours across the full 24-hour period (www.csepguidelines.ca). Furthermore, our results suggest that other organizations and jurisdictions may want to consider a similar approach to Canada and integrate recommendations for sleep, SED, and physical activity into a single guideline.

Our study has several limitations. Recreational screen time and sleep duration were self-reported, which would have introduced measurement error. The recreational screen time measure was based on watching TV and videos and did not include other sources of screen time. Accelerometers were used to derive adherence to the sedentary time recommendation. Accelerometers do not provide an ideal measure of sedentary time as quiet standing is misclassified as SED (Healy et al., 2011).

Furthermore, almost 1 in 4 participants were excluded from the analyses due to insufficient accelerometer data. Although the final sample was re-weighted to ensure that it remained nationally representative, excluding 1 in 4 eligible participants reduced the statistical power and would have resulted in a selection bias if associations between movement behaviors and mortality differed in participants who were and were not included in the analyses. In this paper we compared meeting any one to any two to all three guideline recommendations. There are different intermediate combinations within the any one (sleep only, SED only, MVPA only) and any two (sleep + SED, sleep + MVPA, and SED + MVPA) groups and mortality risk may differ in these intermediate combinations. Unfortunately, the sample size was insufficient to compare risk across all of these intermediate combinations. Although this paper is based on meeting the Canadian 24-hour Movement Guidelines, the analyses are based on an American sample since a dataset of the Canadian population that included appropriate measures of sleep, SED, and MVPA linked to mortality data was not available at the time of this analysis. Finally, a limitation of any prospective cohort is the possibility of a cohort effect such that the results are not generalizable to the current population. In our study this was particularly the case for the screen time results as screen-based technologies and viewing patterns have changed considerably since the 2005-2006 NHANES data were collected (Vizcaino et al., 2019).

CONCLUSIONS

These findings provide insight into the importance of meeting the recommendations contained within the Canadian 24-Hour Movement Guidelines. Of all guideline recommendations, meeting the MVPA recommendation conferred the greatest and clearest benefit. Meeting multiple guideline recommendations may be beneficial, specifically when recreational screen time is the only requirement for SED or when a higher sedentary time cut-point is used. In general, the findings support the notion that the whole day matters for the relationship between movement behaviors and health. More

research is needed to further explore associations with meeting the new integrated 24-Hour Movement Guidelines and various health outcomes. Specifically, future studies should aim to elucidate potential differential associations when self-reported versus device-based measures are used and determine the ideal cut-point to use to define excessive sedentary time.

COMPETING INTERESTS

The authors have no conflicts to declare.

CONTRIBUTIONS

The idea for the study was developed by all authors. AC performed the statistical analysis with guidance from all other authors. AC and IJ wrote the first draft of the paper. VC, J-P C, RC, KR, SR, and MT revised the manuscript for important intellectual content. All authors approved of the final version of the manuscript.

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DATA AVAILABILITY

All NHANES data are publicly accessible at no cost at the following address:

<https://wwwn.cdc.gov/nchs/nhanes/Default.aspx>

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Draft

Table 1. Participant characteristics

Variable	n	Weighted %
Sex		
Male	1,756	48.1
Female	1715	51.9
Age		
20-39 years	1,145	38.0
40-64 years	1,477	44.9
≥65 years	849	17.1
Race/Ethnicity		
Mexican American	682	8.0
Hispanic	104	3.4
Non-Hispanic white	1,732	71.8
Non-Hispanic black	815	11.5
Other (including multi-racial)	138	5.4
Education		
< High school	930	16.8
High school	1,849	57.3
College graduate	692	25.8
Poverty-to-income ratio		
Below poverty threshold (<1)	539	10.1
At or above poverty threshold (≥1)	2,788	86.5
Missing	144	3.3
Movement behaviour recommendation met		
Sleep duration	2,150	63.8
Sedentary behaviour		
Sedentary time	1,481	43.2
Screen time	2,620	78.8
Sedentary time + screen time	1,170	35.3
Moderate-to-vigorous physical activity	1,261	41.5
No. of recommendations		
0	614	15.6
1	1,503	40.6
2	984	31.6
3	370	12.3
Alcohol consumption		
Non-drinker	1,105	26.7
Light-to-moderate drinker	1,869	58.5
Heavy drinker	252	8.8
Missing	245	6.0
Smoking status		
Non-smoker	1,794	51.2
Former smoker	917	25.6
Current smoker	760	23.2

Healthy eating index		
Poor (<50)	1,593	47.6
Needs improvement (50-80)	1,663	46.8
Good (80-100)	93	2.8
Missing	122	2.8
Body mass index		
Underweight	51	1.7
Normal weight	999	31.7
Overweight	1,177	32.3
Obesity class I	712	19.3
Obesity class II +	519	14.6
Missing	13	0.3

Note: 24-Hour Movement Behaviour Guideline recommendations are 7-9 hours/day of sleep for 18-64-year-olds or 7-8 hours/day of sleep for ≥65 year-olds, ≤8 hours/day of sedentary time, ≤3 hours/day of recreational screen time, and ≥150 minutes/week of moderate-to-vigorous physical activity.

Draft

Table 2. Mean movement behavior levels in the total sample and according to movement behavior recommendation achieved.

Guideline recommendation achieved	Movement behavior, hours:mins per day			
	Sleep duration	Sedentary time	Screen time	Moderate-to-vigorous physical activity
Total sample	6:54 (0:02)	8:25 (0:03)	2:12 (0:02)	0:23 (0:01)
Sleep duration				
No (n=1,321)	5:53 (0:03)	8:20 (0:05)	2:18 (0:02)	0:23 (0:01)
Yes (n=2,150)	7:28 (0:01)	8:27 (0:04)	2:09 (0:03)	0:23 (0:01)
Sedentary behavior				
Sedentary time				
No (n=1,990)	6:53 (0:03)	9:52 (0:03)	2:17 (0:03)	0:18 (0:01)
Yes (n=1,481)	6:54 (0:02)	6:30 (0:01)	2:05 (0:03)	0:29 (0:01)
Screen time				
No (n=851)	6:57 (0:03)	8:44 (0:04)	4:31 (0:02)	0:17 (0:01)
Yes (n=2,620)	6:53 (0:02)	8:20 (0:03)	1:35 (0:02)	0:25 (0:01)
Sedentary time + screen time				
No (n=2,301)	6:54 (0:03)	9:28 (0:03)	2:33 (0:03)	0:19 (0:01)
Yes (n=1,170)	6:53 (0:02)	6:30 (0:02)	1:33 (0:03)	0:30 (0:01)
Moderate-to-vigorous physical activity				
No (n=2,210)	6:55 (0:02)	8:49 (0:03)	2:27 (0:02)	0:08 (0:00)
Yes (n=1,261)	6:51 (0:04)	7:51 (0:04)	1:51 (0:03)	0:43 (0:01)
No. of recommendations met				
0 (n=614)	5:58 (0:05)	9:31 (0:05)	2:48 (0:05)	0:08 (0:00)
Any 1 (n=1,503)	6:56(0:03)	9:08 (0:04)	2:31 (0:04)	0:15 (0:01)
Any 2 (n=984)	7:04 (0:03)	7:42 (0:06)	1:47 (0:03)	0:32 (0:01)
All 3 (n=370)	7:30 (0:03)	6:28 (0:03)	1:28 (0:05)	0:45 (0:01)

Notes: Data presented as mean (SE). 24-Hour Movement Behaviour Guideline recommendations are 7-9 hours/day of sleep for 18-64-year-olds or 7-8 hours/day of sleep for ≥65 year-olds, ≤8 hours/day of sedentary time, ≤3 hours/day of recreational screen time, and ≥150 minutes/week of moderate-to-vigorous physical activity.

Table 3. Risk for all-cause mortality according to whether or not participants met the individual movement behavior recommendations contained within the 24-Hour Movement Guidelines.

Guideline recommendation achieved	Deaths per 10,000 person years	Hazard ratio (95% confidence interval)		
		Model 1 ^a	Model 2 ^b	Model 3 ^c
Sleep				
No (n=1,321)	89	1.00	1.00	1.00
Yes (n=2,150)	101	1.14 (0.93, 1.40)	0.93 (0.74, 1.17)	0.91 (0.72, 1.16)
Sedentary behavior				
Sedentary time				
No (n=1,990)	127	1.00	1.00	1.00
Yes (n=1,481)	57	0.37 (0.29, 0.48)	0.86 (0.61, 1.21)	0.93 (0.66, 1.30)
Screen time				
No (n=851)	191	1.00	1.00	1.00
Yes (n=2,620)	72	0.37 (0.29, 0.48)	0.78 (0.59, 1.03)	0.81 (0.62, 1.05)
Sedentary time + screen time				
No (n=2,301)	123	1.00	1.00	1.00
Yes (n=1,170)	49	0.40 (0.27, 0.59)	0.84 (0.54, 1.31)	0.92 (0.61, 1.40)
Moderate-to-vigorous physical activity				
No (n=2,210)	153	1.00	1.00	1.00
Yes (n=1,261)	20	0.13 (0.08, 0.21)	0.42 (0.24, 0.74)	0.42 (0.24, 0.74)

Notes: 24-Hour Movement Behaviour Guideline recommendations are 7-9 hours/day of sleep for 18-64-year-olds or 7-8 hours/day of sleep for ≥65 year-olds, ≤8 hours/day of sedentary time, ≤3 hours/day of recreational screen time, and ≥150 minutes/week of moderate-to-vigorous physical activity.

^a Unadjusted model.

^b Adjusted for sex, age, family poverty-to-income ratio, education, body mass index, smoking status, alcohol consumption, and healthy eating index.

^c Adjusted for Model 2 plus adherence to the other two guideline components (yes/no). For example, sleep duration was also adjusted for meeting recommendations for sedentary behavior and moderate-to-vigorous physical activity.

Table 4. Risk for all-cause mortality according to the number of movement behavior guideline recommendations met.

No. guideline recommendations met according to sedentary behavior requirement	Deaths per 10,000 person years	Hazard ratio (95% confidence interval)	
		Model 1 ^a	Model 2 ^b
Sedentary time only required			
0 (n=534)	170	1.00	1.00
Any 1 (n=1,413)	144	0.85 (0.66, 1.09)	0.88 (0.71, 1.09)
Any 2 (n=1,093)	46	0.27 (0.20, 0.37)	0.55 (0.37, 0.82)
All 3 (n=431)	28	0.17 (0.09, 0.30)	0.68 (0.34, 1.34)
Screen time only required			
0 (n=251)	230	1.00	1.00
Any 1 (n=1,062)	157	0.68 (0.43, 1.07)	0.77 (0.50, 1.18)
Any 2 (n=1,505)	85	0.36 (0.22, 0.60)	0.62 (0.37, 1.02)
All 3 (n=653)	20	0.09 (0.04, 0.18)	0.37 (0.16, 0.85)
Sedentary time + screen time required			
0 (n=614)	163	1.00	1.00
Any 1 (n=1,503)	142	0.87 (0.65, 1.16)	0.86 (0.65, 1.14)
Any 2 (n=984)	35	0.21 (0.14, 0.33)	0.49 (0.28, 0.86)
All 3 (n=370)	31	0.18 (0.10, 0.34)	0.72 (0.34, 1.50)

Notes: 24-Hour Movement Behaviour Guideline recommendations are 7-9 hours/day of sleep for 18-64-year-olds or 7-8 hours/day of sleep for ≥65 year-olds, ≤8 hours/day of sedentary time, ≤3 hours/day of recreational screen time, and ≥150 minutes/week of moderate-to-vigorous physical activity.

^a Unadjusted model.

^b Adjusted for sex, age, family poverty-to-income ratio, education, body mass index, smoking status, alcohol consumption, and healthy eating index.

Table 5. Risk for all-cause mortality according to meeting sedentary time recommendations and the total number of movement behavior guideline recommendations met when sedentary time cut-point was ≤ 8 hours per day or changed to ≤ 10 hours per day.

No. guideline recommendations met according to sedentary behavior requirement	Hazard ratio (95% confidence interval) ^a	
	≤ 8 hours/day sedentary time cut-point	≤ 10 hours/day sedentary time cut-point
Sedentary time only required		
No (n=1,990 and 808)	1.00	1.00
Yes (n=1,481 and 2,663)	0.93 (0.66, 1.30)	0.71 (0.51, 0.99)
Sedentary time + screen time required		
No (n=2,301 and 1,418)	1.00	1.00
Yes (n=1,170 and 1,053)	0.92 (.61, 1.40)	0.77 (0.54, 1.10)
No. guideline recommendations met		
0 (n=614 and 404)	1.00	1.00
Any 1 (n=1,503 and 1,231)	0.86 (0.65, 1.14)	0.83 (0.59, 1.15)
Any 2 (n=984 and 1,275)	0.49 (0.28, 0.86)	0.57 (0.34, 0.96)
All 3 (n=370 and 561)	0.72 (0.34, 1.50)	0.43 (0.20, 0.93)

Notes: 24-Hour Movement Behaviour Guideline recommendations are 7-9 hours/day of sleep for 18-64-year-olds or 7-8 hours/day of sleep for ≥ 65 year-olds, ≤ 8 hours/day of sedentary time, ≤ 3 hours/day of recreational screen time, and ≥ 150 minutes/week of moderate-to-vigorous physical activity.

^a Adjusted for sex, age, family poverty-to-income ratio, education, body mass index, smoking status, alcohol consumption, healthy eating index, meeting the sleep duration recommendation (yes/no), and meeting the moderate-to-vigorous physical activity recommendation (yes/no).