



A health behaviour pandemic: The COVID-19 pandemic has impacted the physical activity, sleep, and sedentary behaviour of already-struggling Canadians

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ABSTRACT

Objectives: The Canadian 24-Hour Movement Guidelines (24HMG) provide evidence-based recommendations for health behaviours, including light physical activity, moderate-to-vigorous physical activity (MVPA), sedentary behaviour (SB), sleep, and muscle strengthening activities. These behaviours likely changed as a result of public health measures implemented throughout the COVID-19 pandemic. We aimed to understand how Canadians' health behaviours changed during the pandemic.

Methods: We conducted a nationwide survey asking Canadians aged 18–64 to report their health behaviours according to the 24HMG at three timepoints: 1) immediately prior to the pandemic, 2) the most restricted timepoint of the pandemic, and 3) more recently, in March 2022.

Results: We received 494 eligible responses from across Canada. Prior to the pandemic, only 7.7% of respondents were able to meet all 24HMG, which reduced to 3.8% during the most restricted phase of the pandemic ($p < 0.01$). During this timepoint, self-reported MVPA decreased by -21.9 ± 55.6 weekly minutes, muscle strengthening decreased by -0.34 ± 0.94 weekly sessions, and SB increased by 0.88 ± 2.04 daily hours ($p < 0.00001$ for all), with nonsignificant increases in nightly sleep. At the more recent March 2022 timepoint, mild recoveries were observed in all health behaviours, however remained significantly lower than baseline levels, with the exception of sleep, which decreased significantly (-0.18 ± 1.42 nightly hours, $p = 0.005$).

Conclusions: Unfavourable health behaviour changes among Canadians were observed throughout the COVID-19 pandemic, which increases the risk for acute and long-term health conditions. Improved education, infrastructure, and support from public and private sectors can reverse the negative risk factors that arise from these health behaviour changes, and can improve the culture of proactive health behaviours in Canada.

1. Introduction

The COVID-19 pandemic has resulted in numerous public health and policy changes aimed at protecting the well-being of Canadians, and minimizing the risk of viral spread [1]. Early in the pandemic, social distancing and “lockdown” measures were

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implemented in every Canadian province and Territory to minimize the risk of disease transmission [2]. Variations of lockdowns have since been periodically applied on provincial or regional levels to minimize community spread of disease. During these lockdown measures, access to non-essential businesses, services, and activities have been limited or halted. Stockwell et al. conducted a systematic review including data from 86,000 people, and found that worldwide, reductions in physical activity and increases in sedentary behaviour (SB) were observed throughout the pandemic [3]. With reduced time at places of work or leisure spaces, and more time spent at home, it is likely that Canadians also followed these patterns, however there is no available literature to support this. This has the potential for immediate and long-term health effects for individuals and society, and is most likely to disproportionately disadvantage marginalized groups [4]. It is also relatively unknown how Canadians are able to meet evidence-based specific health recommendations during times of normal social function, and in the context of a pandemic. Understanding the current state of health behaviours in Canada more recently and prior to the pandemic, can help guide decisions towards areas of priority and cultural change in improving individual and wide-scale improvements in public health.

The current state of chronic conditions carries a major financial and healthcare burden in Canada, costing over \$190 billion annually [5], and costing over 200,000 person-years in disability-related absenteeism annually [6]. Chronic disease accounts for millions of potential years of life lost [7], disability [8], and reduced quality of life [9] in Canada. The Canadian 24-Hour Movement Guidelines (24HMG), established in by the Canadian Society of Exercise Physiology (CSEP), are targets for health behaviours to reduce risk of chronic disease, and improve health [10]. For adults aged 18–64 years, these behaviours include a moderate-to-vigorous physical activity (MPVA) target of 150 min per week, a target of 7–9 nightly hours of sleep, and minimizing SB to less than 8 h per day. Achieving these targets is associated with reduced risk of morbidity [11], mortality [12,13], adverse events [14], frailty [15], chronic disease [16,17], and improvements short- and long term mental [18,19], cognitive [20,21], and physical health outcomes [22–25], as well as quality of life [26,27]. This list of benefits is not exhaustive, as there are numerous benefits gained by progressing towards meeting or exceeding health behaviour guidelines, and every incremental improvement comes with increased health benefits [28]. The threat of the COVID-19 pandemic creating a reversal of these desirable behaviours may present with immediate and long-term consequences for individuals, the Canadian economy, and health care systems in Canada.

The purpose of this study was to understand the initial health behaviours of Canadians prior to the COVID-19 pandemic, as well as the self-reported changes in these behaviours that occurred as a result of the COVID-19 pandemic restrictions imposed to reduce viral transmission. There is a potential unintended consequence of reduced physical activity, and increased SB, which would likely result in increased risk for chronic disease in an entire cohort of Canadians. We hypothesize that during the COVID-19 pandemic, most Canadians decreased their MVPA time, experienced increased SB, and increased sleeping time. We also hypothesize that the proportion of Canadians able to meet all health behaviours incorporated within the Canadian 24HMG decreased as a result of the social measures applied throughout the COVID-19 pandemic.

2. Methods

We used a nationwide survey to understand the impact of the COVID-19 pandemic on the ability of 18–64-year-old people living in Canada to meet the Canadian 24HMG. We assessed three timepoints: immediately prior to the pandemic (prior to March 2020), at the most restricted time of the pandemic (self-identified), and more recently (in the month of March 2022). This study has been reviewed and approved by the University of Prince Edward Island Research Ethics Board (project number 6010414). All participants provided informed consent through selection of understanding the conditions of the letter of information.

The data collected in this study was sourced through a Google Forms online survey to allow access to as many of the Canadian habitants as possible. The survey was promoted by the principal investigator and an undergraduate student that co-developed the survey. The survey was shared to every provincial health authority in Canada and uploaded to public access social media platforms such as Reddit, Instagram, Facebook, and sourced to several minority representative groups to obtain diverse and representative responses.

2.1. Survey development

The survey was constructed based on components from the Physical Activity and Sedentary Behaviours Questionnaire (PASB-Q) and the modified Leisure-Time Physical Activity Questionnaire (mLTPA-Q), both of which are self-reported questionnaires developed by CSEP, and previously validated against accelerometry and physiological fitness data [29].

2.2. Sample size calculation

We used the following formula (Equation 1) to determine the minimum sample size for a confidence level of 95%, assuming an infinite population size, a margin for error of 5%, and a proportion of 0.5. These parameters provided for the most conservative estimate of sample size. Using this formula, we obtained a sample size of 385 respondents.

$$\text{Equation 1. Sample size} = \frac{Z_{\text{score}}^2 \times \text{proportion}(1 - \text{proportion})}{\text{Margin of error}^2}$$

2.3. Demographic outcomes

To obtain the information on the effect of restrictions related to the COVID-19 pandemic on Canadians' abilities to meet the Canadian 24HMG, we used 35 multiple-choice and 3 open-ended questions in our survey. Basic demographic and socioeconomic, and health information was obtained using questions related to province of residence, urban or rural region, ethnic and racial background, employment status, household income, and comorbidities.

2.4. Health behaviour outcomes

The primary outcomes of MPVA time, muscle strengthening activities, nightly sleep time, and SB, as well as other outcomes such as light physical activity (LPA) and screen time, were obtained via self-report.

2.5. Moderate-to-vigorous physical activity

MVPA was defined to the respondents as "roughly the intensity of a brisk walk or harder, or what most would describe as 'somewhat hard'." Based on the 6–20 Borg Scale of Rating of Perceived exertion, "somewhat hard" represents an intensity of 12–14 on the Borg Scale, which is agreed to represent the threshold of moderate intensity [30]. The Canadian 24HMG recommend a minimum of 150 min of MVPA per week.

Table 1
Demographics of the study sample.

	N	Percent	Mean	SD	Range
Age (years)	484		35.0	11.2	18–65
Gender	489				
Cisgender woman	306	62.6%			
Cisgender man	159	32.5%			
Non-binary	17	3.5%			
Transgender woman	4	0.8%			
2-Spirit Indigenous	2	0.4%			
Transgender man	2	0.4%			
Province of Residence	494				
British Columbia	50	10.1%			
Alberta	34	6.9%			
Saskatchewan	33	6.7%			
Manitoba	101	20.4%			
Ontario	101	20.4%			
Quebec	51	10.3%			
New Brunswick	11	2.2%			
Nova Scotia	30	6.1%			
Prince Edward Island	68	13.7%			
Newfoundland & Labrador	12	2.4%			
Yukon	2	0.4%			
Northwest Territories	1	0.2%			
Setting	394				
Urban	289	73.3%			
Rural	99	25.1%			
Unsure	6	1.5%			
Racial Identity	483				
White	409	84.6%			
Indigenous	25	5.1%			
Mixed-Race	21	4.3%			
South Asian	8	1.6%			
East Asian	7	1.4%			
Black	4	0.8%			
Arab	4	0.8%			
Southeast Asian	2	0.4%			
Latin	2	0.4%			
West Asian	2	0.4%			
Household Income (CAD)	453		\$106,302	\$63,798	\$10,000-\$250,000+
<\$50,000	89	19.6%			
\$50,000-\$99,999	150	33.1%			
\$100,000-\$149,999	115	25.3%			
\$150,000-\$199,999	53	11.7%			
\$200,000-\$249,999	22	4.9%			
>\$250,000	24	5.3%			

2.6. Muscle strengthening activity

Muscle strengthening activity was defined as “intentional exercise involving pushing against resistance to a reasonable degree of fatigue”, adapted from the definition proposed by the American College of Sport Medicine [31]. The Canadian 24HMG recommend a minimum of two weekly muscle strengthening activities.

2.7. Sleep

Sleep was defined as “on a typical night ... the time you spend asleep, not the time you spend in bed” based on the definition provided by Kline (2013) [32]. The Canadian 24HMG recommend between 7 and 9 h of sleep per night (not including daytime naps).

2.8. Sedentary Behaviour

SB was defined as “any time spent sitting or lying down (not sleeping).” Based on the definition provided by Tremblay et al. (2017) [33]. The Canadian 24HMG recommend minimizing SB to less than 8 h per day.

2.9. Statistical analysis

We processed all recorded responses and analyzed the data using descriptive statistics, repeated measures t-tests, and analysis of variance (ANOVA) for continuous measure to determine the measurable impact of the pandemic on the ability of people living in Canada to meet 24HMG. Chi-Square test was used to analyze dichotomous outcomes (ex: meeting exercise guidelines or not). SPSS 25 was used for all statistical analyses (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). For a specific list of all questions and available options for the survey, please see the Appendix.

3. Results

We obtained eligible responses from 494 participants with regards to questions surrounding health behaviours. Some participants opted not to answer questions regarding their demographics. The amount of responses and the category of response can be found in Table 1. In general, respondents were predominantly white (83.0%), cis-gendered women (61.7%), average age of 35.0 ± 11.2 years (mean \pm standard deviation), living in an urban setting (73.3%), with a median annual household income of $(\$106,302.42 \pm \$63,798.14)$. We received responses from residents of all Canadian provinces, and Territories, with the exception of Nunavut. Demographic data are summarized in Table 1.

3.1. Moderate-to-vigorous physical activity

Respondents self-reported an average of 89.2 ± 50.7 (mean \pm standard deviation) minutes of MVPA per week prior to the onset of the pandemic in Canada, with 141 of 494 (28.5%) respondents meeting the recommendation of 150 min per week. When restrictions were felt to be at their highest, respondents self-reported MVPA as 68.3 ± 53.6 min per week, with 82 of 494 (16.6%) respondents meeting the recommendation of 150 min per week. During the month of March 2022, coinciding with the easing of restrictions of most provinces in Canada, individuals self-reported an average of 84.0 ± 52.5 min/week of MVPA with 124 of 494 (25.1%) respondents meeting the recommendation of 150 min per week. Repeated measures ANOVA revealed a significant of difference between timepoints ($p < 0.00001$), which represented a 23% drop of self-reported MVPA when comparing pre-pandemic levels to MVPA during the peak of

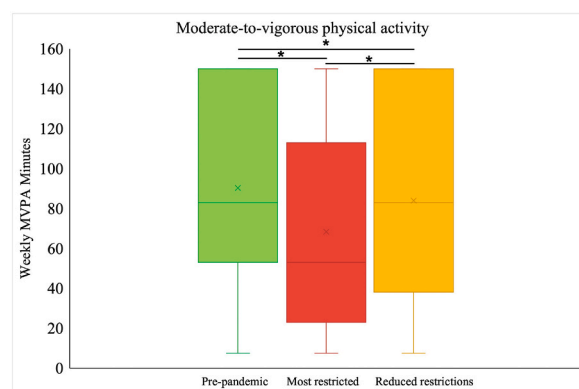


Fig. 1. Box plot demonstrating mean (x), median (horizontal line), quartiles, and range of weekly moderate-to-vigorous physical activity minutes at three timepoints: 1) prior to the pandemic, 2) at the most restricted time of the pandemic, and 3) more recently in March 2022. An asterisk indicates a significant difference between timepoints.

restrictions. During the month of March 2022, a recovery of MVPA time was demonstrated, however still 5.8% lower than baseline levels. These results are visualized in Fig. 1.

3.2. Muscle strengthening activity

Participation in muscle strengthening activities prior to the onset of the COVID-19 pandemic were reported by respondents to be at an average of 1.20 ± 0.94 sessions per week, with 34% of respondents meeting the recommendation of at least 2 sessions per week. When public health restrictions were felt to be at their highest, these activities fell to an average of 0.86 ± 0.88 sessions per week, with 21% of respondents meeting the recommendation of at least 2 sessions per week. In the third timepoint, the month of March 2022, muscle strengthening activities had increased to an average of 1.07 ± 0.96 times per week, with 31% of respondents meeting the recommendation of at least 2 sessions per week. The change in muscle strengthening activity at any timepoint has been deemed to be statistically significant based on repeated measures ANOVA ($p < 0.0001$).

3.3. Sleep

Nightly sleep time prior to the onset of the pandemic was reported at 6.84 ± 1.06 h of sleep per night, with 45% of respondents meeting the recommendation of 7–9 h of sleep per night. During the time when restrictions were felt to be at their highest, sleep time increased to 6.96 ± 1.64 h per night, with 50% of respondents meeting the recommendation of 7–9 h of sleep per night. More recently, during the month of March 2022, respondents reported an average of 6.77 ± 1.35 h of sleep per night, with 47% of respondents meeting the recommendation of 7–9 h of sleep per night. Based on repeated measures ANOVA, the change in sleep time was considered to be statistically significant ($p = 0.02$). Post hoc paired-samples t-tests revealed that this difference was explained by the decrease in sleep time between the most restricted timepoint and the most recent timepoint ($p = 0.005$).

3.4. Sedentary behaviour

Prior to the onset of pandemic-related health measures, daily SB was reported to be an average of 5.3 ± 2.4 h, with 78% of respondents meeting the recommendation of staying under 8 h of SB per day. At the height of the restrictions, there was an increase in SB to an average of 6.2 ± 2.3 h per day, with 63% of respondents meeting the recommendation of staying under 8 h of SB per day. In the month of March 2022, SB among respondents reduced to an average of 5.5 ± 2.4 h per day, with 75% of respondents meeting the recommendation of staying under 8 h of SB per day. Repeated-measures ANOVA revealed that this change was statistically significant ($p = 0.00001$). These results are visualized in Fig. 2.

3.5. Meeting all recommended Canadian 24-Hour Movement Guidelines

Prior to the onset of public health measures related to COVID-19 in Canada, only 38 out of 494 (7.7%) respondents of the survey were able to meet all of the primary Canadian 24HMG, consisting of achieving 150 min of weekly MVPA, taking part in two muscle strengthening sessions per week, obtaining an average of 7–9 h of sleep on a nightly basis, and minimizing SB to under 8 h per day. At the most restricted time of the pandemic, only 19 of 494 (3.8%) respondents were able to meet all of these guidelines. For the timepoint of March 2022, this rose slightly to 29 out of 494 respondents (5.9%). Chi-Square test revealed a significant differences between timepoints for meeting Canadian 24HMG ($p = 0.03$). These results are visualized in Fig. 3.

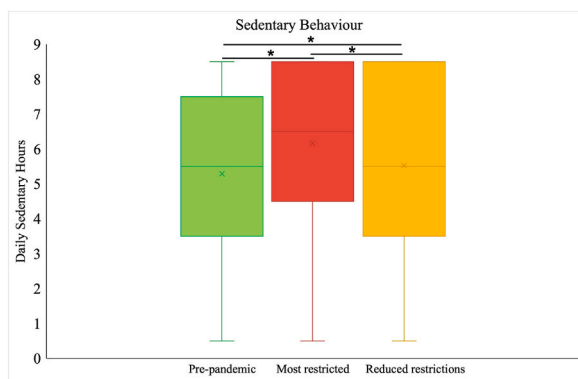


Fig. 2. Box plot demonstrating mean (x), median (horizontal line), quartiles, and range of daily sedentary behaviour hours at three timepoints: 1) prior to the pandemic, 2) at the most restricted time of the pandemic, and 3) more recently in March 2022. An asterisk indicates a significant difference between timepoints.

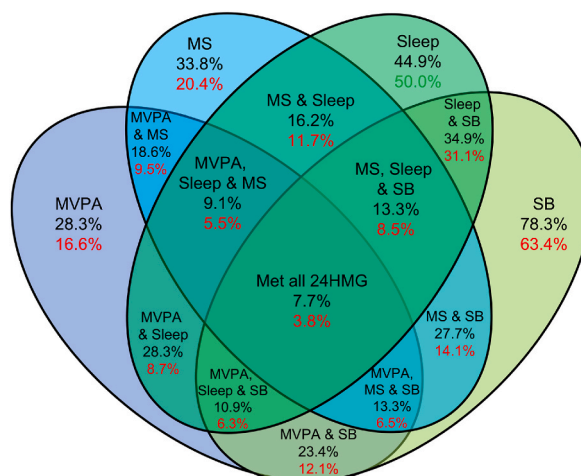


Fig. 3. Venn diagram demonstrating the proportion of respondents that were able to achieve the 24HMG recommendations for individual or combinations of health behaviours. Percentages prior to the pandemic are represented in black, and for the most restricted timepoint are represented in red (decrease) or green (increase). MVPA = moderate-to-vigorous physical activity, SB = sedentary behaviour, MS = muscle strengthening activity.

3.6. Light physical activity & screen time

Prior to the pandemic, respondents self-reported an average of 7.7 ± 4.9 h of LPA per week. When restrictions were felt to be at their highest, LPA levels decreased to an average of 6.1 ± 4.5 weekly hours. During the month of March 2022, when restrictions in most areas in Canada began to ease, LPA increased to an average of 7.0 ± 4.7 h/week. Repeated measures ANOVA revealed a significant difference in LPA volume between timepoints ($p < 0.0001$).

SB attributed to recreational screen time averaged 2.3 ± 0.9 h per day prior to the pandemic, with 72% of respondents staying below the recommended limit of 3 h per day. When restrictions were at their greatest, recreational screen time increased to an average of 2.9 ± 0.9 h per day, with only 42% of respondents staying below the recommended limit. Most recently, in March 2022, recreational screen time had changed to 2.5 ± 0.9 h per week, with 64% of respondents staying below the recommended limit. The difference in daily recreational screen times over these time points was considered significant ($p < 0.0001$).

4. Discussion

Across this sample of respondents with representation from nearly all Canadian provinces and territories, there was a consistent significant decrease in MVPA and muscle strengthening activities throughout the pandemic, and significant increases in SB. There was also a significant decrease in nightly sleep time moving from the most restrictive phase of the pandemic to the most recent timepoint, in March of 2022. Our secondary outcome measures also followed similar trends, with significant decreases in LPA and increased screen time throughout the most restricted time in the pandemic. These changes carry short- and long-term consequences for individuals and society moving forward, and pose an eventual threat to the already overburdened healthcare system in Canada.

Looking at individual health behaviours, there was a substantial and statistically significant decrease in MVPA of -21.9 min (95% CI: $[-26.8; -17.0]$ minutes) when comparing pre-pandemic MVPA levels compared to the most restrictive timepoint. Based on retrospective studies, this comes with a 20% increased risk of all-cause mortality [34] for an entire cohort of Canadians during this period, and based on recent estimates from the Canadian government, this will result in nearly 2000 Canadians developing cardiovascular disease over the next three years, which is directly attributable to the decrease in physical activity due to the pandemic [35]. This change in MVPA minutes during protective measures throughout the pandemic may be related to a dependence of accessible recreational facilities, social systems, and exercise related to commuting. Unfortunately, there was no increase in LPA to mitigate the changes in MVPA, as there was a reduction of -1.57 $[-1.98; -1.16]$ weekly hours of LPA in the most restricted timepoint of the pandemic. Promoting more independent and enjoyable means to meet exercise guidelines at home or in one's neighbourhood may result in improved ability to meet MVPA guidelines. For example, established virtual cycling platforms such as Peloton and Zwift experienced three- or fourfold increases in their company value over the course of the pandemic, as people turned to more accessible means to remain active. While this is a solution for some, these subscriptions and equipment required are costly. Other virtual exercise platforms that don't require expensive equipment may be a more affordable alternative for many, and with the uptake of group-based classes, a sense of community and belonging can be fostered, much like in a fitness centre or a recreational sports team.

There was also a substantial and significant decrease in the participation of muscle strengthening activities, with an average of -0.34 $[-0.42; -0.26]$ weekly sessions lost. Prior to the pandemic, one in three respondents were able to meet the recommendation of two muscle strengthening activities per week, while this fell to one in five during the most restricted time of the pandemic. Maintenance of strength and muscle mass, or at least minimization of sarcopenia and dynapenia with age, is an important component of

maintenance of mobility and independence. Compared to people who forego muscle strengthening activities, people who participate in regular strengthening activities reduce their risk of developing functional limitations by nearly 40% compared to those who do not over the course of 25 years [36]. Even with short term reductions in strengthening habits, detraining effects have been shown to decrease and decreases in mobility, strength, balance, and even executive function in just 1–4 months of detraining [37,38].

Among all of the changes in health behaviours reported by responders throughout the pandemic, the increase in SB was most pronounced, with 0.88 [0.70; 1.06] additional daily hours on average among respondents. This was also a conservative estimate, and likely underreported, as the maximum value that respondents could report was “more than 8 h” of daily SB. Still, only two thirds of respondents were able to remain below the 8 h of recommended SB. Increases in recreational screen time likely accounted for much of this increase in SB, as there was nearly an increase of 0.57 [0.49; 0.65] daily hours of recreational screen time at the most restricted timepoint of the pandemic, with less than half of respondents staying below the recommended maximum of 3 h of recreational screen time per day. This is concerning, as it has been demonstrated that people who watch more than 4 h of television per day are at 50% greater risk of all-cause mortality to people who do so for less than 2 h daily [39]. Increased SB is associated with reduced cognitive function, mental health, and increases in disability, and is inversely related to physical activity and health-related quality of life [27]. Specifically, sedentary lifestyles are associated with increased risk for cardiovascular disease, diabetes, cancer, and premature death [40]. Even acute changes in SB are related to short-term physiological changes, which can accumulate over time [22]. Coupling these changes with the observed reductions in MVPA and LPA from this sample throughout the pandemic produce additive effects on risk of acute and chronic health conditions that will likely lead to increased burden on healthcare systems that may continue to manifest for years to come.

Curiously, there was a slight increase in nightly sleep time at the most restricted timepoint of the pandemic, albeit not statistically significant. This was followed by a significant decrease in nightly sleep time of -0.18 [-0.31 ; -0.06] nightly hours in the most recent timepoint of March 2022. This was potentially due to an increase in demands and changes in lifestyle for many people returning to work or finding new work in some format, as well as the increased stress of all of these increased demands in the context of a pandemic. Unfortunately, at every timepoint, the mean nightly sleep time fell below the minimum recommendation of 7 h of sleep per night, which means the majority of respondents are not meeting their sleep needs. Chronic sleep deprivation is associated with unfavourable long-term outcomes like all-cause mortality and morbidity [41,42], and acute sleep deprivation is associated with poor work and psychomotor performance, and increased risk of motor vehicle accidents [43]. Providing Canadians with more free time to meet minimum sleep guidelines, such as later work times, and promotion of behaviour-change methods for better sleep hygiene could improve the wide scale sleep deprivation that this sample demonstrates among Canadians [44].

The most striking result from this survey is that the overwhelming majority of Canadians 18–64 are not meeting the Canadian 24HMG. Even prior to the pandemic, more than nine out of ten respondents indicated they were not able to achieve what is meant to be a reasonable and evidence-based target to provide immediate health benefits and reduce risk of chronic disease. Throughout the pandemic, less than one in twenty respondents indicated they were meeting the guidelines. Given the commonality of this problem, these are likely not individual failures, but more likely indicate a need for policy, education, and infrastructural change. This could include promotion of awareness of the benefits of exercise behaviours, including exercise, SB, and sleep, at all stages of school curricula.

Canadians have more than one recovery to face as we move into the next phase of the pandemic; there are social, financial, and wide-scale health implications as described in this manuscript, as well as other emerging epidemiological threats. The federal and provincial governments have demonstrated their ability to provide financial relief in the time of wide-scale crisis [45]. Perhaps it is time to for policymakers to explore incentives or rebates on exercise equipment or fitness memberships, which have proven to be feasible [46], or even establishing public access exercise facilities for lower income households. Trialing shorter work-weeks to increase free time to pursue healthy activities and improved work-life balance has proven to be an effective measure in the UK, with Henley Business School reporting improved satisfaction, reduced absenteeism, and increased productivity and cost-effectiveness in a large sample of UK businesses, and with 49% of respondents using part of their free day to participate in fitness-related activities [47]. Use of active or public transit systems has also been demonstrated to be associated with improved health behaviours and outcomes [48, 49], and investment into these systems would provide a multifaceted benefit to the health, financial, and social well-being of Canadians [50]. Having clear, evidence-based guidelines in place, and staged approaches to lockdown requirements while safely sparing exercise facilities or promoting home exercise platforms would provide more opportunity for the public to meet the Canadian 24HMG in the context of a pandemic, and would contribute to reduced disability and public health challenges in the future [51,52]. Future research in this area should focus on understanding which social determinants of health are related to changes in health behaviours during a pandemic, favourable or otherwise. Several respondents were actually able to improve their health behaviours during this time, and it would be helpful to understand which internal or external mechanisms can facilitate these changes, and how they can be applied to individuals or groups that struggle to improve their health behaviours. It would also be important to understand changes in health behaviours between “essential” and “nonessential” healthcare workers earlier in the pandemic. While continuing to work may offer increased opportunities for mobility, increasing LPA hours, however, the increased demands and expectations also has the potential to affect other health behaviours, such as sleep, MVPA, or muscle strengthening activities, which mostly require intentional efforts and free time to include in ones’ weekly schedule. Creating new or more feasible risk minimization strategies to reduce exposure to transmissible pathogens would also be of benefit, so that people could access exercise facilities and feel confident that they are not substantially increasing their risk of contracting viral or bacterial infections while trying to improve their health.

Strengths of this self-reported survey include a geographically representative sample, with proportional representation from all provinces and all but one territory. This is also the first study evaluating the proportion of Canadians that actually meet individual health behaviour recommendations, or all Canadian 24HMG as a whole. The results of this study is consistent with a worldwide

systematic review conducted by Stockwell et al., in 2021 [3], who also found consistently rising SB and decreases in physical activity in developed countries across the globe. Limitations however include answer format provided for many of the health behaviour related questions, as we opted to cap answers based on the recommendations, not allowing respondents to freely report physical activity, sleep, muscle strengthening, or SB any more specifically than “*more than 150 min of MVPA*” or “*more than 8 h of sedentary time*” for example. This however led to conservative results, and free responses may have resulted in even more drastic reports of decreases in physical activity or increases in SB. Other limitations include the sociodemographic representation, which was predominantly white, cis-gendered people of European or North American heritage. While this proportion is not far from the actual Canadian demographic statistic, more representation from minority and marginalized groups would have offered an opportunity to analyze sociocultural differences in changes in health behaviours throughout the pandemic. Another limitation is the self-reported nature of the data. All results presented are self-reported, which are almost certainly different than actual measures of health-behaviours on an individual level, and also subject to recall bias. However, people tend to overestimate their healthy behaviours [53,54] and underestimate their time spent in a sedentary state [55]. If objectively measured data were able to be acquired at the timepoints discussed in the present study, it is possible that even greater changes in health behaviours would be observed.

These results suggest that Canadians who were already failing to meet the majority of the expertly established Canadian 24HMG prior to the COVID-19 pandemic, strayed even further from these recommendations throughout the pandemic. Although there was a trend towards partial recovery of most of these health behaviours, the majority of participants were still falling below baseline pre-pandemic values, and on average were well below the suggested targets in the 24HMG. As mentioned, this carries several immediate and long-term health risks, which at this rate, will undoubtedly create increased demands on healthcare systems in Canada, and create a growing burden on the physical and quality of life of individuals. Fortunately, health behaviours can change, and many of these risks can be reversed over time. Promoting more focus on health behaviours at home and in the workplace would be of benefit to Canadians and the Canadian economy, as this would result in reduced healthcare costs and work absenteeism, improved quality of life, and increased life expectancy. Public and private sectors would benefit from focused benefits and an incorporation of exercise programs in the workplace [56], even in remote work or hybrid settings [57]. The fact that the vast majority of Canadians are failing to meet health behaviour guidelines is a result of a systemic failure to promote a culture of well-being in Canada, in the public sector, private sector, and on a community level as well. This shortfall is even further threatened by the current inflationary challenges faced today. Rising costs will require many Canadians to seek out more opportunities to increase their income, creating time and stress barriers to increasing physical activity, reducing SB, and obtaining sufficient sleep and muscle strengthening activity.

Ethics statement

This study has been reviewed and approved by the University of Prince Edward Island Research Ethics Board (project number 6010414). All participants provided informed consent via indicating understanding the conditions of the letter of information prior to beginning the survey.

Author contribution statement

Dr. Hayden F. Atkinson: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Mr. Alexander Norris: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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