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Social determinants of long-term reported changes in physical activity and healthy eating during the COVID-19 pandemic in Canada: multiple cross-sectional surveys analysis from the iCARE study

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Abstract

The long-term consequences of COVID-19 on healthy behaviours (physical activity practice and healthy eating) among Canadians remain largely unexplored. The objectives were (i) to describe the proportion of Canadians who reported a change in healthy behaviours, 9 and 20 months since the beginning of COVID-19; and (ii) to identify the social determinants associated with healthy behaviour changes. Using two representative Canadian surveys from the *International COVID-19 Awareness and Responses Evaluation study* (January 2021, $n = 3000$; November 2021, $n = 3002$), reported changes in healthy behaviours were assessed as follows: "In general, how have the following behaviours changed since the start of COVID-19?": (1) Increase; (2) No change; and (3) Decrease. The association between individual determinants and changes in healthy behaviours was analyzed using weighted univariate polytomous logistic regression models. In January 2021, 41% and 22% of respondents reported a decline in physical activity and healthy eating, respectively, while in November 2021, 34% and 20% of respondents reported a decline in physical activity and healthy eating, respectively. The main determinants associated with changes in healthy behaviours were younger age (18–25 years), area of residency, student status, changes in bodyweight, financial concerns/insecurity, anxiety/depression, and ethnicity. Changes in healthy behaviours were also associated with household composition, presence of chronic diseases, and occupation. In sum, this study depicted long-term changes in healthy behaviours during COVID-19, with differential changes according to social determinants of health. This study highlighted the presence of health inequalities in Canada during COVID-19 and supports the implementation of personalized programs in prevention of healthy behaviour degradation.

Key words: physical activity, exercise, sedentary behaviour, dietary pattern, diet, SARS-CoV-2

Introduction

Healthy behaviours, such as regular participation in physical activity and healthy eating, represent modifiable risk factors in prevention/management of chronic diseases (World Health Organization 2013). However, in 2012–2013, approximately four Canadians out of five reported the adoption of at least one unhealthy behaviour (low level of physical activity, unbalanced diet, excess consumption of alcohol, or tobacco use) (Public Health Agency of Canada 2016). With the advent of the COVID-19 pandemic, Canada reacted promptly by imposing national lockdowns, closing non-essential shops and businesses, imposing a vaccinal passport, and promoting COVID-19 prevention behaviours (hand washing, wearing face masks, etc.) (World Health Organization 2020; Canadian Public Health Association 2021). These measures had important impacts on Canadians' lives, such as job loss and reduced income, increased housing and food insecurity, a reduction of social contacts, and a more important exposition to stress associated with lockdowns (school/work at home and familial pressures) (Canadian Public Health Association 2021). The pandemic context highlighted significant inequalities according to social determinants of health, with higher COVID-19-related mortality rates among Canadians living in lower income neighbourhoods, neighbourhoods with higher levels of ethno-cultural composition, or among men compared with women (Public Health Agency of Canada 2022).

Few months after the imposition of sanitary measures in response to the COVID-19 pandemic, many high-income countries have reported a global decrease in the practice of physical activity (Górnicka et al. 2020; Karageorghis et al. 2021;

Sonza et al. 2021, p. 19) and changes in meal routines and types of food eaten (Górnicka et al. 2020; Ruíz-Roso et al. 2020; Janssen et al. 2021). Early impacts of COVID-19 on healthy behaviours varied greatly according to social determinants of health, such as area of residency, age, gender, or health status (Ruíz-Roso et al. 2020; Stanton et al. 2020; Blom et al. 2021; Janssen et al. 2021; van der Werf et al. 2021). Changes in healthy behaviours were also exacerbated by mental health issues, anxiety related to the pandemic situation, or socio-economical factors, such as financial situation, education, physical access to grocery stores or food installations, occupation, or household composition, as examples (Górnicka et al. 2020; Stanton et al. 2020; Blom et al. 2021; Janssen et al. 2021; Sonza et al. 2021; van der Werf et al. 2021). Although Canadian data are limited, some pieces of evidence suggest a deterioration of healthy eating and physical activity levels at the beginning of the COVID-19 pandemic, especially among families (parents and children), young adults, and women (Carroll et al. 2020; Zajacova et al. 2020; Andreacchi et al. 2022).

Given that the actual Canadian evidence mostly focuses on the first months of the COVID-19 pandemic, many questions remain on the long-term impacts of sanitary measures on healthy behaviours and social inequalities later on during the pandemic in Canada. Therefore, this study sought (i) to describe the proportion of Canadians who reported a change (increase/decrease) in health behaviours (physical activity and healthy eating) 9 months (January 2021) and 20 months (November 2021) following the onset of the pandemic in Canada and (ii) to identify social determinants associated with reported changes in these health-related behaviours.

Materials and methods

The iCARE study

This study is a secondary analysis from the *International COVID-19 Awareness and Responses Evaluation study* (iCARE). The iCARE study is a Canadian initiative from the *Montreal Behavioural Medicine Center* (MBMC) composed of multiple cross-sectional surveys conducted at different moments during the COVID-19 pandemic, with a team of 200 international collaborators from 42 countries, including Canada (www.mbmc-cmcm.ca/covid-19). The iCARE study began at the onset of the pandemic (March 2020) and is still ongoing (Bacon et al. 2021). The main objective of the iCARE study is to examine attitudes, knowledge, and adherence to preventive sanitary measures to limit the transmission of COVID-19 (physical distancing, wearing a mask, washing hands, isolation, vaccination, etc.). The surveys also include a variety of questions on how COVID-19 impacted the respondents' lives, including changes in healthy behaviours. Before the completion of surveys, a summary of the project was presented to the participants, along with the required time to complete the surveys (15–20 min). The participants who consented were invited to initiate the survey. The participation was voluntary, and no monetary compensation was offered. All data collected were anonymous. The study was approved by the ethics committee of the Centre Intégré Universitaire de santé et services sociaux du Nord de l'île de Montréal (CIUSSS-NIM) (REB No.: 2020-2099/03-25-2020) and the ethics committee of the Institut Universitaire de cardiologie et de pneumologie de Québec approved this secondary analysis (F9-35881). Supplementary details on the iCARE study are available online: https://osf.io/nswcm/.

Data sources

We used two representative Canadian sampling surveys from the iCARE study, obtained through a web panel of a polling firm (Leger©): the fourth wave survey (January 2021, $n = 3000$) and the eighth wave survey (November 2021, $n = 3002$). The fourth survey data collection occurred during the second wave of COVID-19 in Canada, during which the stringency index in many provinces was the highest following the relaxations of the first sanitary measures during the summer 2020 (Detsky and Bogoch 2021). Although policy responses in Canada have been divergent during the COVID-19 pandemic between provinces, new closures of non-essential services and restrictions of social gathering occurred from November 2020 up to February 2021 in many provinces, some of which had imposed a curfew such as Quebec (Cameron-Clarke et al. 2021). This period was also prior to the onset of the global vaccination campaigns in Canada (Cameron-Clarke et al. 2021). The eighth survey corresponds to the pre-omicron period, during which 78% of Canadians had two doses of the COVID-19 vaccines (IHME 2023), and during which most sanitary restrictions were lifted. We chose these two key periods to better understand how long-term changes in sanitary measures impact Canadian lives, the first survey in a more coercive period and the second following a global relaxation of public health measures throughout the country. The secondary analysis was registered on 1 June 2021 on the iCARE Study Analysis Plans platform (Number: iCARE_SOC-0032): https://www.mbmc-cmcm.ca/2021/covid19/icare-soc-0032-exploring-factors-associated-with-lifestyle-behavior-changes-during-the-covid-19-pandemic-in-canada/.

Variables of interest

Changes in healthy behaviours

The outcomes of this study were the reported changes in physical activity and healthy eating since the beginning of the COVID-19 pandemic. For both surveys, each healthy behaviour change was questioned as follows: "In general, how have the following behaviours changed since the start of COVID-19?" Behaviours were "doing physical activity" and "eating a healthy diet". For the analyses, answer choices were aggregated in three categories for both physical activity and healthy eating: (1) increase in the behaviour (I do this a lot more/I do this more); (2) no change (I do this as much as before/I don't do this); and (3) decrease in the behaviour (I do this a lot less/I do this less). We combined respondents who reported no change and those who reported not doing the behaviour since this latter category imposes an absence of

change per se. No information about the behaviours prior the pandemic was available.

Social determinants of healthy behaviour changes

According to the *Let's Get moving* framework for increasing physical activity from the Public Health Agency of Canada (Public Health Agency of Canada 2018*a*) and the *Sociological and Environmental Factors Influencing Eating Food Behaviour Framework* proposed by Marcone et al. (2020), we identified the following key social determinants of physical activity and healthy eating, which were available from the iCARE questionnaires: age, gender, cultural/racial groups, household composition (living with at least one kid or living alone), and rural/urban area of residency (all postal codes with a "0" in second position were considered as rural geographical areas (Statistics Canada 2007). We also examined socio-economical information: highest level of education completed (primary/high school, college/university degree, or graduate/post-graduate degree), total household income before taxes according to the poverty thresholds in 2020–2021 in Canada (<40 000$CAD; 40 000$CAD to <100 000$CAD; ≥100 000$CAD (Statistics Canada 2023)), and occupation (workers (full-time, part-time, or self-employed), students, not working (retired, unemployed of receiving governmental support)). We also compiled data on the presence of at least one metabolic disease (cardiovascular disease, chronic lung disease, hypertension, or diabetes) and known depressive/anxiety disorders diagnosed by a physician or a healthcare professional. Finally, we explored the influence of the following COVID-19-related variables that could influence the capacity to adopt healthy lifestyles: concerns of not having enough money for food/rent and inability to pay for food. The detailed items, answer choices, and adjustments for analyses are available in Table S1.

Statistical analyses

Each survey and healthy behaviour were analyzed separately, although presented conjointly. The dependant variables (changes in physical activity and healthy eating) had small proportions of missing data (<2%) (Table S1), we therefore removed these observations from analyses.

For our first objective, we calculated proportions of change (with 95% confidence intervals (CI)) in reported healthy behaviours for each survey. For our second objective, we first calculated the distribution of social determinants according to the reported changes in healthy behaviours (decrease, no change, and increase). Regarding social determinants, missing data ranged between 0% and 11% (Table S1). After comparing observations with/without missing data, we observed differences in the observed characteristics of individuals with missing data for income. For the analyses, we assumed that missing data could be explained by observed variables (missing at random), although the possibility of missing not-at-random could not be verified nor totally excluded (Austin et al. 2021). We used multiple imputations by chained equations with 50 iterations, including all social determinants and changes in healthy behaviours for imputing missing values in multivariate regression models (Austin et al. 2021). We then combined the imputed datasets using the MI and MIANALYSE procedures in the SAS v9.4 software (SAS Institute Inc., Cary, NC, USA).

Social determinants were presented for each category of reported changes in physical activity and healthy eating (decrease, no change, and increase) as proportions, using imputed data. To examine the association between social determinants and changes in healthy behaviours (increase vs. no change; decrease vs. no change), we used univariate polytomous logistic regression models with "no change" as the reference category. Each social determinant was assessed individually as an independent variable in association with changes in healthy behaviours. For all models, we used a sampling weight obtained as follows: (i) The results were weighted for each province according to the gender and age of each participant to make the respondent profile representative of the actual population in each Canadian province; and (ii) the weight of households with/without children, the language spoken, and the level of education were adjusted at the national level, ensuring the results remained representative of the Canadian population. Results for polytomous regressions were considered statistically significant with a $p < 0.0014$, after a Bonferroni correction for multiple testing. Individual associations were reported as odd ratios with 99.86% CI and presented as forest plots. As a sensitivity analysis, we repeated the same methods using a complete data analysis approach, by removing respondents with missing data for each social determinant. All analyses were conducted with the SAS v9.4 software (SAS Institute Inc., Cary, NC, USA).

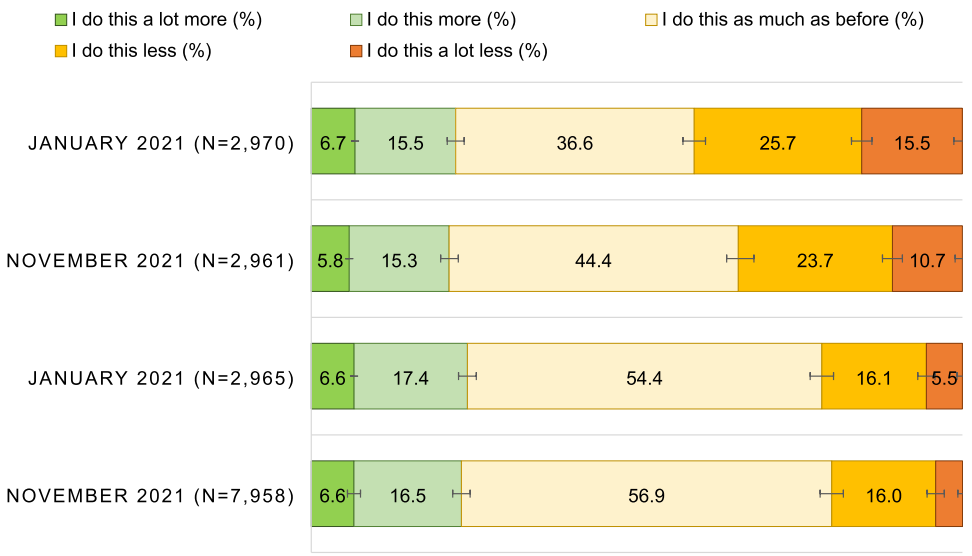
Results

From the 3000 respondents in the January 2021 survey, a total of 2970 participants had complete data for physical activity, and 2965 had complete data for healthy eating. From the 3002 respondents in November 2021 survey, a total of 2961 and 2958 participants had complete data for physical activity and healthy eating, respectively. Figure 1 presents the unweighted proportions of changes in physical activity and healthy eating in January 2021 and November 2021. In January 2021, 41% ($n = 1223$) of Canadians reported a decline in physical activity practice, while 22% reported an increase ($n = 659$). Healthy eating deteriorated among 22% ($n = 640$) of the respondents, while 24% ($n = 711$) reported an improvement. In November 2021, 34% ($n = 1109$) of the respondents reported a decline in physical activity, while 20% ($n = 682$) reported a deterioration of their diet since the beginning of the pandemic.

Social determinants associated with changes in physical activity

Table S2 presents the distributions of social determinants according to reported changes in physical activity in January and November 2021, using imputed data. Figures 2A and 2B depict the association between individual social determi-

Fig. 1. Unweighted reported changes* in physical activity and healthy eating since the beginning of the COVID-19 pandemic in January and November 2021 in Canada. *Proportions with 95% confidence intervals.



nants and changes (decrease/increase) in reported physical activity.

In January 2021, as presented in Table S2 and Fig. 2A, older adults (≥65 years) were less likely to report changes (both increase and decrease) in physical activity when compared to adults aged between 25 and 65 years, while younger adults (18 to <25 years) were more likely to report changes (increase and decrease). Respondents from rural areas were less likely to report changes in physical activity (increase and decrease), in comparison with those living in an urban area. Students, respondents reporting a change in their bodyweight, those who had concerns of not having enough money for food, and those reporting an inability to pay for food/rent were more likely to report changes in physical activity (both increase and decrease).

Having a known diagnosis of depression/anxiety was associated with a decrease in physical activity in January 2021. Belonging to Asian/Middle Eastern ethnic groups, in comparison with other ethnicities, was associated with an increase in physical activity, while belonging to the Caucasian ethnicity and respondents who were not working at the time of the survey were less likely to report an increase in physical activity (Fig. 2A).

In November 2021, as presented in Table S2 and Fig. 2B, older adults (≥65 years), in comparison with adults between 25 and 65 years, and respondents who were not working at the time of the survey compared to students or workers, were less likely to report changes in physical activity (increase and decrease). In contrast, students, respondents reporting an increase in their bodyweight, those who had concerns of not having enough money for food, and those reporting an inability to pay for food/rent were more likely to report changes in physical activity (increase and decrease).

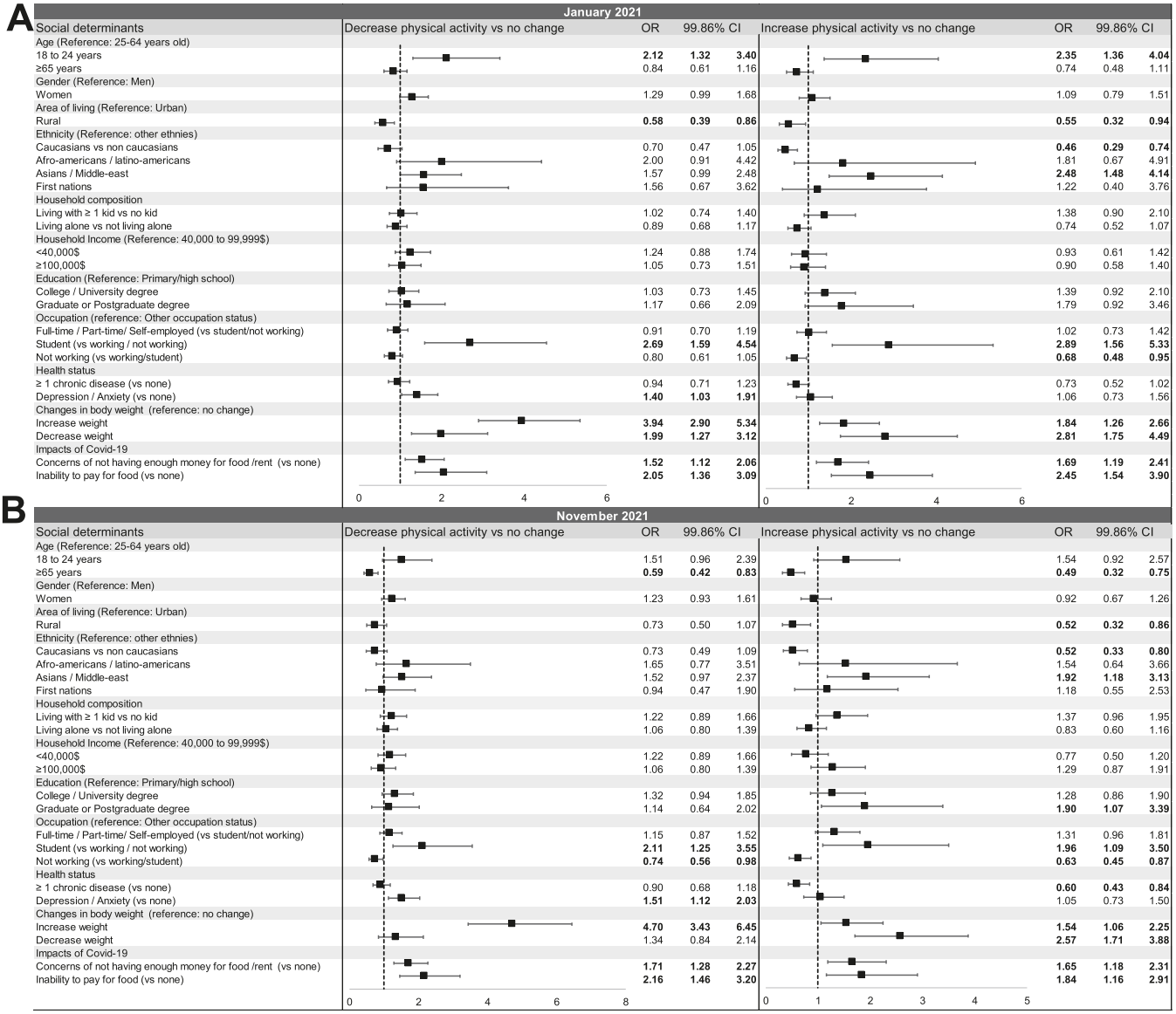
Having a known diagnosis of depression/anxiety was associated with a decrease in physical activity in November 2021. Belonging to Asian/Middle Eastern ethnic groups, in comparison with other ethnicities, was associated with an increase in physical activity, along with those having a graduate/postgraduate degree and reporting a decrease in bodyweight. In contrast, respondents that identified themselves as Caucasian were less likely to report an increase in physical activity, along with respondents with at least one chronic disease (Fig. 2B). No association was observed for gender, household composition, household income, or workers. Similar results were found using complete data analysis (Table S4, Figs. S1A and S1B).

Social determinants associated with changes in healthy eating

Table S3 presents the social determinants according to reported changes in healthy eating in January and November 2021. Figures 3A and 3B depict the association between individual social determinants and changes (decrease/increase) in reported healthy eating.

In January 2021, as presented in Table S3 and Fig. 3A, older adults (≥65 years) in comparison with adults from 25 to 65 years were less likely to report changes in healthy eating (both increase and decrease). Respondents who were not working at the time of the survey (compared with students or workers) and Caucasians (compared with other ethnic groups) were less likely to report changes (increase and decrease). Belonging to Asian/Middle Eastern ethnicities (compared with other ethnic groups), students, those with a known diagnosis of depression/anxiety, those reporting an increase in their bodyweight, and respondents who had concerns of not having enough money for food and inability to pay for food/rent were more likely to report changes in healthy eating (both increase and decrease).

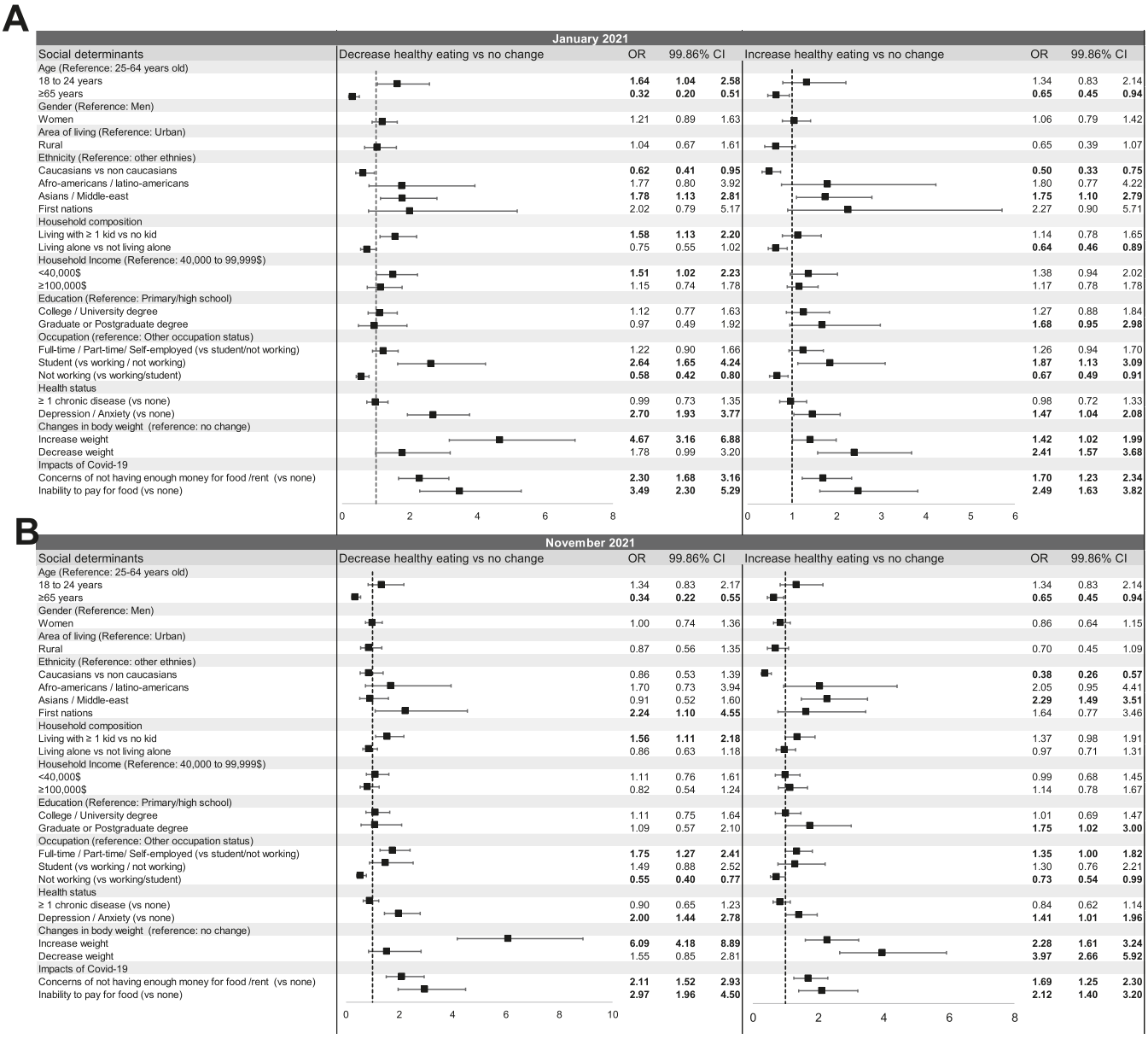
Fig. 2. (A and B) Association between social determinants of health and reported changes in physical activity in January 2021 (pane A) and November 2021 (pane B). Results presented as weighed unadjusted odd ratios with 99.86% confidence intervals, after Bonferroni correction. Results from combined datasets from multiple imputations by chained reactions (50 imputations). CI, confidence intervals; OR, odd ratio.



Younger adults (18–25 years), in comparison with adults between 25 and 65 years, were more likely to report a decrease in healthy eating, along with respondents with an annual income of <40 000$ and respondents living with at least one child in January 2021. Finally, reporting a decrease in bodyweight was associated with an increase in healthy eating, while respondents living alone were less likely to report an increase in healthy eating.

In November 2021, as presented in Table S3 and Fig. 3B, older adults (≥65 years) in comparison with adults between 25 and 65 years were less likely to report changes (increase/disease) in healthy eating, along with respondents who were not working at the time of the survey. Respondents who reported working at the time of the survey, those with a known diagnosis of depression/anxiety, those reporting an increase in their bodyweight, and respondents who had concerns of not having enough money for food and inability to pay for food/rent were more likely to report changes in healthy eating (both increase and decrease). Respondents from the First Nations (compared with other ethnic groups) and respondents living with at least one child were more likely to report a decrease in healthy eating in November 2021. Finally, belonging to Asian/Middle Eastern ethnicities (compared with other ethnic groups), having a graduate/postgraduate degree, and reporting a decrease in bodyweight were associated with an increase in healthy eating, while those who belong to the Caucasian ethnicity were less likely to report an increase in healthy eating (Fig. 3B). Similar results were found using complete data analysis (Table S5, Figs. S2A and S2B).

Fig. 3. (A and B) Association between social determinants of health and reported changes in healthy eating in January 2021 (pane A) and November 2021 (pane B). Results presented as weighed unadjusted odd ratios with 99.86% confidence intervals, after Bonferroni correction. Results from combined datasets from multiple imputations by chained reactions (50 imputations). CI, confidence intervals; OR, odd ratio.



Discussion

The results of this study depicted that more than one third of respondents reported a decline in physical activity, 9 months and 20 months after the onset of the COVID-19 pandemic, while around one fifth of respondents reported a deterioration in healthy eating. In contrast, more than 20% of respondents reported an improvement in physical activity practice and healthy eating during the same period, highlighting the presence of health inequalities in these lifestyle habits adoption in reaction to the COVID-19 pandemic in Canada.

Our data suggest differential responses to COVID-19 towards physical activity practice and healthy eating, with similar proportions of change in January and November 2021. To our surprise, multiple social determinants of health were associated with both a degradation and an improvement in healthy behaviours, such as age, area of living, ethnicity, student status, mental health, bodyweight changes, or financial concerns related to the COVID-19 pandemic. Health inequalities have persistently been present in Canada, resulting in socio-economical or political differences among subgroups of the population in comparison with others (Public Health Agency of Canada 2018*b*). The advent of the COVID-19 pandemic highlighted these social disparities, notably with increased COVID-19 mortality rates among the more deprived subgroups (Public Health Agency of Canada 2022).

Some social determinants of health are strongly intercorrelated, sometimes with synergetic influences on healthy behaviours, which bring important challenges when comes the time to study them as a whole (MSSS 2012; Pampalon et al. 2013). As such, complex interactions that we could not capture in the present study could explain why we observed both improvement and degradation of healthy behaviours. Indeed, in the current study, social determinants were examined independently and some were not covered in the surveys (marital status, neighborhood composition, food skills, health literacy, friends and family networks, religious context, immigration status, housing, environmental facilitators and barriers of healthy behaviours, and food marketing, to name a few) (Kelly et al. 2009; Public Health Agency of Canada 2018*a*; Marcone et al. 2020). Given the lack of more complete information, predictive models would not have been enough informative or valid, which limited our exploration to univariate models instead. To explain the changes in both directions that we observed, we thus suspect there could be unobserved interactions with other key social determinants that the surveys were not able to capture.

In current study, we identified key determinants that were consistently associated with healthy behaviour changes, such as age, area of residency, occupation, presence of diagnosed depression/anxiety, financial concerns, or difficulties related to the COVID-19 pandemic, among others. Similar to our results, data collected from the BC Speak Survey from British Columbia Centre for Disease Control at the early stages of the COVID-19 pandemic noted a decline by 26% of physical activity for transport among younger adults (18–30 years), especially among those living in an urban area of residency, those reporting a change in their mental health, and respondents without children (Samji et al. 2021). A cross-sectional study from four high-income countries (USA, UK, France, and Australia) during the early COVID-19 period observed a decline in physical activity in the USA and Australia in comparison with the pre-COVID era, where younger adults had a greater decline compared with other age groups. Although France had an increase in physical activity compared with the pre-COVID era, younger French adults had the lowest levels of unplanned physical activity in comparison with other countries (Karageorghis et al. 2021). These drops in physical activity practice at the beginning of the COVID-19 pandemic were consequent with the tremendous changes occurring in the structures and resources for an active lifestyle, notably the closure of universities and the encouragement to study at home (Samji et al. 2021). Regarding healthy eating, a decline in fruits and vegetables consumption by 13% was observed among younger Canadian adults, in comparison with 11% for the global population (Samji et al. 2021). This study also observed that younger adults and students were keener to report an improvement in physical activity, suggesting other social determinants within age groups that may have interacted with the pandemic context (Samji et al. 2021). At an international level, a systematic review including 24 studies observed an overall reduction of diet quality among college students, with more binge eating, snacking, skipping breakfast, or increased cooking at home (Jehi et al. 2023). Data at the beginning of the COVID-19 pandemic from Germany also noted that individuals who reported emotionally driven changes in their dietary intake were more likely to be younger adults, but also women, immigrants, and individuals with a higher body mass index (Bühlmeier et al. 2022). Interestingly, data from the province of Quebec, Canada, suggested that students had increased symptoms of depression and anxiety in 2021, in comparison with prior to COVID-19 (Gouin et al. 2023). Other early COVID-19 Canadian studies reported similar results regarding age groups, student status, or area of residency (Dubé et al. 2020*a*; Bertrand et al. 2021).

While COVID-19 had an important impact on physical activity practice, Canadians reported both improvement and degradation of healthy eating, with approximately 50% who did not report any change. A cohort study conducted in Quebec observed an overall small increase in diet quality during the first COVID-19 lockdown, with a higher intake in greens and beans, vegetables, dairy products, proteins, and whole grains (Lamarche et al. 2021). Interestingly, improved diet quality was more prevalent among younger adults, individuals with obesity, and lower education (Lamarche et al. 2021). Early COVID-19 evidence suggests both favorable and detrimental consequences of lockdowns on eating habits. As examples, adults were more likely to cook at home (Kaddatz and Badets 2020; Lamarche et al. 2021), to prioritize local food products and to improve their food/cooking skills at home (Nielsen et al. 2022). In comparison with Canadian data, a cross-sectional study from the Netherlands done at the beginning of COVID-19 observed similar proportions in healthy eating changes, where healthy changers (improvement in healthy eating) were more likely to favorize essential than non-essential food products and had overall more diverse dietary patterns than those who reported not changing their diet (Dijksterhuis et al. 2022). Among 16 European countries during the first COVID-19 lockdown, an overall higher adherence to the Mediterranean diet (index of healthy eating) was observed among adults, notably with reduced frequency of eating out and more cooking at home. Countries with the highest levels of restrictions were more likely to have an improvement in their dietary behaviours, with increased fruits, vegetables, or fish intake (Molina-Montes et al. 2021). On the other hand, COVID-19 also had negative impacts on healthy eating habits. An online survey conducted in May 2020 among adults from Quebec, Canada, revealed an overall increase in eating frequency and higher desire of eating comfort/enjoyment foods, which could be correlated to higher stress levels during the same period (Nielsen et al. 2022). Early COVID-19 data in the USA also suggested an increase in unhealthy weight control behaviours among young adults (mostly females), such as increased food consumption, snacking, reduction of dietary intake due to alteration in appetite, using food to cope with stress, or increase in eating disorder symptoms. These changes in eating behaviours were strongly associated with financial difficulties, food insecurity, or depressive/anxiety symptoms (Simone et al. 2021).

Additionally, we observed recurrent associations between financial concerns and difficulty to pay for food/rent and reported changes in healthy behaviours in both surveys.

Evidence from the Canadian literature suggests that COVID-19 had consequences on food access and financial security to buy food, especially at the beginning of the pandemic (Dubé et al. 2020*b*). Interestingly, in fall 2020, approximately 10% of Canadians aged 12 or older reported having some level of food insecurity in the last year, in comparison with 13% in 2017/2018, which was more prominent among respondents who were younger, were less educated, those receiving social assistance/employment insurance, lone parents, or those identifying as Afro-Americans or indigenous ethnic groups (Polsky and Garriguet 2022). In the USA, COVID-19 hit students hard with drops in income from job loss combined with high expenses for scholarships and limited access to food pantries or federal nutrition assistance, which led to a rise in food insecurity among this subgroup of the population (Laska et al. 2020). At the beginning of the pandemic, nearly a third of American households were food insecure (Schanzenbach and Pitts 2020), which resulted in increasing snacks and processed foods in detriment of fresh foods (González-Monroy et al. 2021; Lee et al. 2023). Similarly with Canadian data, other social determinants of health associated with food insecurity in the USA include ethnicity (non-Hispanic blacks or Hispanic), living in households with children, loss of income, lower age, and lower education (Ng et al. 2023). Food insecurity during lockdown has also been associated with increased risk of mental illness among American low-income households, with 2.6- and 2.5-fold increases in anxiety and depression, respectively (Fang et al. 2021; Talham and Williams 2023). In Quebec, data from 2020 to 2021 suggested that young adults experiencing financial or food insecurity had an increase in depressive/anxiety symptoms during this time (Gouin et al. 2023). Again, the associations between financial insecurity and both improvement and degradation of healthy behaviours highlight that the social inequalities affected specific subgroups of the population differently, probably according to unobserved interactions with other social determinants of health in the current study.

Although published literature on the early impacts of COVID-19 pandemic is widespread, data on the long-term impact of the COVID-19 pandemic remain scarce. A report from the Institut National de Santé Publique du Québec observed a decline of 45% in physical activity in comparison with pre-COVID-19 era among adults in Quebec in February 2021. Young adults were also keener to report both a deterioration and an improvement in physical activity practice in comparison with older age groups. This report also observed both improvement and degradation of healthy eating later during the COVID-19 pandemic (fast food and fruits and vegetable consumption), where age, immigration status, gender, financial concerns, and household composition were identified as potential key determinants of eating behaviour changes (Durette et al. 2021). Unfortunately, the impact of COVID-19 on physical activity and healthy eating during the pre-omicron period remains largely unexplored.

This study has numerous strengths. First, we used large and representative samples of the Canadian population. We also used two surveys with identical items and questions, which allowed us to explore potential variations in respondents' habits at different moments during the COVID-19 pandemic. This study is also a rare exploration of long-term impacts of the pandemic on healthy behaviours and their social determinants in Canada, which gives additional insights about the importance of health inequalities in response to COVID-19. This study also has limits. First, the cross-sectional nature of both surveys should be considered in the interpretation of associations, which could be bidirectional and precludes any causal inferences. Although surveys were identical, the respondents were not the same and thus, we could not compare changes in healthy behaviours between periods. Longitudinal studies with pre-COVID-19 data would have been optimal to better assess trends of changes in healthy behaviours, along with studying the causal relationship with social determinants. Second, the iCARE study was not initially designed to assess healthy behaviour changes. Consequently, the methods used to assess changes in physical activity or healthy eating were not validated or optimized. For example, we observed smaller proportions of respondents reporting changes in physical activity in November 2021 in comparison with January 2021, which was unexpected given the question formulation. The answers in November 2021, especially for physical activity, seemed more associated with recent changes rather than depicting the overall change since the beginning of the pandemic, which suggests the presence of a potential confusion on the temporal referent. Validated tools such as accelerometers, food frequency questionnaires, 24 h food recalls, or objective biomarkers would have been more informative about changes in food quality, nutrients intake, or metabolic equivalents, although the fast-changing evolution of the COVID-19 pandemic and the constant adaptation of surveys required more adaptative data collection tools. Another limitation is the absence of information with pre-pandemic behaviours, which limits our capacity to appreciate the importance of change reported. For example, an athlete with an important decline in physical activity would be classified in the same behaviour change category as a student who stopped walking to school. This problem is also present with respondents reporting not doing the behaviour prior the onset of the COVID-19 pandemic, which were classified in the "no change" category.

Nine and 20 months after the beginning of the COVID-19 pandemic, we observed differential changes in physical activity and healthy eating, with both an improvement and degradation in healthy behaviours. These behavioural changes were associated with key social determinants, including age, area of residency, ethnicity, socio-economical factors or health status, and food or financial insecurities, as examples. Interestingly, this study also observed unequal distributions of social determinants associated with healthy behaviour changes, suggesting that COVID-19 had long-term consequences on both improvement and degradation in healthy behaviours among Canadians' lives and highlighting the persistence of health inequalities in Canada during the pandemic. Although additional longitudinal studies covering the whole COVID-19 are warranted, this study supports the development and implementation of preventive, supporting, or legislative programs personalized to specific subgroups to decrease social inequalities in health when

confronted to an emergency state like COVID-19. The pandemic still ongoing, national and community efforts should be driven towards tackling these discrepancies, to prevent further degradation in healthy behaviours for future pandemic states.

Take-home message

Canadians reported both an improvement and degradation in physical activity and healthy eating during COVID-19. These behavioral differences suggest health inequalities in the Canadian population in reaction to the pandemic.

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Data availability

The iCARE data were acquired after the approval of a Research Material Distribution Agreement with the Montreal Behavioural Medicine Centre, with legal prohibition to any transfers, sharing, release, or distribution of research material to any entity or individual.

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Supplementary material

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