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Stable physical activity patterns predominate in a longitudinal study of physical activity among young adults in Canada from before to during the COVID-19 pandemic

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ABSTRACT

We examined change in walking, moderate-to-vigorous physical activity (MVPA) and meeting MVPA guidelines from before to during the COVID-19 pandemic, and identified factors associated with newly meeting and no longer meeting MVPA guidelines during the pandemic. Complete data were available for 614 young adults participating in the ongoing Nicotine Dependence in Teens (NDIT) study pre-pandemically in 2010–12 and 2017–20, and during the pandemic in 2020–21. Change in physical activity was examined in four sub-groups (i.e., *stable inactive*, *newly met MVPA guidelines*, *no longer met MVPA guidelines*, *stable active*). Factors associated with *newly* and *no longer met MVPA guidelines* were identified in multivariable logistic regression. While walking and MVPA changed little from 2010-2 to 2017–20, both declined during the pandemic (median for both = -30 min/week). 63.3% of participants reported no change in meeting MVPA guidelines during the pandemic, 11.4% *newly met MVPA guidelines* and 25.2% *no longer met MVPA guidelines*. Male sex, not university-educated, amotivated to engage in physical activity reported pre-pandemic, and endorsing physical activity as a COVID-19 coping strategy were associated with *newly met MVPA guidelines*. Male sex, not university-educated, higher problem-focused coping scores and endorsing physical activity as a COVID-19 coping strategy were protective of *no longer met MVPA guidelines*. Increased understanding of why some participants increased or decreased MVPA during the pandemic is needed to inform physical activity-related policy during pandemics.

1. Introduction

Containment measures during the COVID-19 pandemic disrupted many people's usual physical activity routines, at least intermittently (Hargreaves et al., 2021). Closure of gyms and recreation centers during lockdowns limited usual access to organized sports, exercise programs, equipment and trainers (Hargreaves et al., 2021; Stockwell et al., 2021). Working from home or attending school remotely limited active transport (Stockwell et al., 2021). In addition to restrictions in the physical environment, pandemic-related stress, social isolation and other challenges to mental health could have affected physical activity motivation (Marashi et al., 2021), which may have impacted physical activity behaviors (Teixeira et al., 2012).

Conversely, some containment-related changes might have facilitated physical activity. Leisure time available for physical activity may have increased with less commute time. Increased availability of online

Abbreviations: BREQ, the Behavioural Regulation in Exercise Questionnaire; CI, confidence interval; IPAQ-SF, International Physical Activity Questionnaire-Short Form; IQR, interquartile range; MVPA, moderate-to-vigorous physical activity; NDIT, Nicotine Dependence in Teens; OR, odds ratio; SD, standard deviation; CAD, Canadian dollar.

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physical activity classes, strength training and exergaming , may have helped people maintain or even increase physical activity, especially since virtual and remote technologies for physical activity were promoted by public health societies and agencies during the pandemic (Canadian Society for Exercise Physiology, 2020). Finally, some people may have switched from indoor to outdoor settings for physical activity, which aligned better with containment measures (Schweizer et al., 2021).

However, despite possible advantages of containment, accumulating evidence suggests that physical activity levels generally declined during the pandemic. In a recent systematic review, 44 of 45 studies of healthy adults reported decreases in physical activity (Stockwell et al., 2021). Among the 26 studies that reported physical activity changes according to Metabolic Equivalents , minutes per week, minutes per day or steps per day, all but one reported declines in physical activity, and the declines occurred across all physical activity types (i.e., light, moderate, vigorous, walking). Among the 19 studies that reported physical activity changes as a percent, eight reported that >50% of participants decreased physical activity (Stockwell et al., 2021).

A key issue in studies of physical activity during COVID-19 is the limited use of comparable data collected pre-pandemically (i.e., before March 2020). Most extant studies in this realm were conducted during the pandemic and ask participants to retrospectively recall physical activity behavior before COVID-19 (Husain and Ashkanani, 2020; Robinson et al., 2021). Recall error could introduce bias into estimates of change. Longitudinal studies with pre-pandemic data are needed to establish whether concerns about physical activity declines are warranted and if so, in which sub-groups and/or whether physical activity levels remain stable or even increase in some sub-groups. However, such studies to date are challenged by small sample sizes (Gallo et al., 2020; Savage et al., 2020), few data points and/or short follow-ups (Yang and Koenigstorfer, 2020), a focus on specific subgroups such as clinical populations with consequent lack of generalizability (Savage et al., 2020; Vetrovsky et al., 2020), selection bias because of low response proportions (Gallo et al., 2020; Yang and Koenigstorfer, 2020), and use of a single rather than multiple physical activity indicators (Savage et al., 2020). Further, few studies identify factors related to change in physical activity, whether declines or increases, during COVID-19 (Rhodes et al., 2020; Yang and Koenigstorfer, 2020).

The objectives of this study were, using data from an ongoing study of a population-based sample of young people in which comparable self-report physical activity data were available both before and during the COVID-19 pandemic: (i) to describe change in three physical activity indicators (i.e., walking, moderate-to-vigorous physical activity (MVPA), met MVPA guidelines for adults (i.e., ≥150 min MVPA per week) (Ross et al., 2020) from before to during the pandemic; and (ii) to identify sociodemographic, psychosocial, and physical activity- and COVID-19-related factors associated with both newly meeting MVPA guidelines among participants who were inactive pre-pandemically, and no longer meeting MVPA guidelines during the pandemic among participants who were active pre-pandemically.

2. Methods

Data were drawn from the Nicotine Dependence in Teens (NDIT) study (O'Loughlin et al., 2015), which recruited 1294 grade 7 students age 12–13 in 1999–2000 in a purposive sample of 10 high schools in Montreal, Quebec, Canada (i.e., the sample was designed to include schools in urban, suburban and rural neighbourhoods, schools serving advantaged and disadvantaged students, and schools serving French- and English-speaking students). The main source of data in NDIT was self-report questionnaires administered in-class at school every 3 months from grade 7 to grade 11 (1999–2005), for a total of 20 cycles during high school (O'Loughlin et al., 2015). Post-high school data were collected in cycle 21 (2007–08; mean (SD) age 20.4 (0.8)), cycle 22 (2010–12; age 24.0 (0.7)), and cycle 23 (2017–20; age 30.6 (1.0)). In Québec, a state of sanitary emergency was implemented on March 13, 2020, leading to closures of schools and post-secondary institutions, daycares, non-essential businesses as well as bans on private gatherings (Gouvernement du Québec, 2021; Institut national de santé publique du Québec, 2021). In cycle 23, 99.3% of participants completed data collection before implementation of the state of sanitary emergency. Data for cycle 24 were collected online from December 2020 to June 2021 (mean (SD) age 33.6 (0.6) years) during the COVID-19 lockdown in Canada. In this study, we used data collected between 2010 and 2021. At inception, the characteristics of NDIT participants were comparable to those reported for same-age adolescents in the 1999 provincially representative Québec Child and Adolescent Health and Social Survey (Paradis et al., 2003). NDIT was approved by ethics committees at the Montreal Department of Public Health, McGill University and the University of Montréal (2007–2384, 2017–6895, ND06.087). Parents/guardians provided written consent at inception. Participants provided consent post-high school.

In this current analysis, we compared number of minutes walking per week, number of minutes MVPA per week and met MVPA guidelines from before the COVID-19 pandemic (i.e., cycles 22 and 23) to during the COVID-19 pandemic (i.e., cycle 24) among 614 participants (i.e., 71.6% of the 858 participants who provided data at "baseline" (i.e., which was considered to be cycle 22 in this current study) with complete data across these three cycles. In the absence of a "control group" not exposed to the COVID-19 pandemic, we compared change in physical activity during the pandemic with the change in physical activity for the same participants between cycles 22 and 23 before the pandemic.

2.1. Measures

Participants reported number of days and average number of minutes per day that they engaged in each of walking, moderate physical activity and vigorous physical activity in the past 7 days using the International Physical Activity Questionnaire-Short Form (IPAQ-SF) (Craig et al., 2003). Based on the IPAQ truncation protocol (Forde, 2018; IPAQ Research Committee, 2005), number of minutes reported for each physical activity type was truncated at 180 before computing minutes weekly. IPAQ-SF items demonstrate adequate reliability and validity against accelerometer (Dyrstad et al., 2014).

Number of minutes walking per week was computed as number of days per week that the participant reported walking multiplied by the average number of minutes walking per bout. We also computed a *change in walking* score between cycle 22 and 23 and between cycles 23 and 24, by subtracting the number of minutes walking per week in the earlier cycle from number of minutes walking per week in the later cycle.

To compute *number of minutes of MVPA per week*, we summed the number of minutes of moderate physical activity per week (i.e., number of days per week that the participant reported moderate physical activity multiplied by the average number of minutes per bout) and number of minutes of vigorous physical activity per week (i.e., number of days per week that the participant reported vigorous physical activity multiplied by the average number of minutes per bout). A *change in MVPA* score was also computed between cycle 22 and 23 and between cycle 23 and 24.

Participants were categorized as *met MPVA guidelines* (yes, no) in each cycle if they engaged in MVPA for ≥ 150 min per week (Ross et al., 2020). Because preliminary analyses plotting change in individual participants from cycle 22 to 24 suggested heterogeneity in MVPA patterns over time (i.e., consistently low, consistently high , increasing , decreasing) (data not shown)), and to avoid not detecting important changes in MVPA due to averaging across all participants, we stratified participants into four sub-groups according to consistency in meeting MVPA guidelines between cycle 23 (i.e., the data collection cycle immediately pre-COVID-19) and 24 (i.e., during the COVID-19 pandemic). We focused on change in meeting MVPA guidelines (rather

than change in minutes walking or MVPA) because *met MVPA guidelines* is a standardized and well-accepted metric of attaining health-enhancing levels of MVPA (Ross et al., 2020) that has been used in previous Canadian studies assessing physical activity in adults (Clarke et al., 2019; Colley et al., 2011; Weatherson et al., 2021). The four sub-groups included: did not meet MVPA guidelines in either cycle 23 or 24 (i.e., labelled *stable inactive*), met MVPA guidelines in cycle 24 but not cycle 23 (i.e., labelled *newly met MVPA guidelines* during the pandemic), met MVPA guidelines in cycle 23 but not cycle 24 (i.e., labelled *no longer met MVPA guidelines* during the pandemic), and met MVPA guidelines in both cycle 23 and 24 (i.e., labelled *stable active*).

We examined 19 variables as potentially associated with *newly met MVPA guidelines*, and with *no longer met MVPA guidelines* during the pandemic. These variables were selected based on well-established associations with physical activity, theoretical interest in regard to the pandemic, and/or their availability in NDIT (Caputo and Reichert, 2020; Dowda et al., 2003; Polero et al., 2020; Stockwell et al., 2021; Trost et al., 2002). Unless otherwise indicated, data for all factors potentially associated with the outcomes were drawn from cycle 24. Sociodemographic characteristics included *sex* (male, female), *age, university-educated* (yes, no), *employed* (yes, no), *annual household income* (<$50,000, ≥$50,000 CAD), *works-from-home during pandemic* (no, yes/unemployed), *lives alone* (yes, no), *lives with children* (yes, no), *single-parent* (yes, no), and *lives in rural area* (yes, no). Psychosocial variables included *amotivated to engage in physical activity pre-pandemic* (yes, no) which was measured in cycle 23 using the Behavioral Regulation in Exercise Questionnaire (BREQ), three indicators of coping style (i.e., *problem-focused coping, emotion-focused coping, avoidant coping*) measured in cycle 22, and *endorsed* physical activity *as a COVID-19 coping strategy* (yes, no). Variables related to how participants cope were of particular interest since some coping styles (e.g., problem-focused coping) are believed to be more adaptive than others, which are thought to be more maladaptive (e.g., emotion-focused coping). Physical activity-related variables investigated included past-year *exergaming* (yes, no), past year regular use of *physical activity trackers* (yes, no), and *participated in organized team sports* (yes, no) measured in cycle 23. Finally, we measured level of *adherence to pandemic public health measures* (moderate/high, low). Additional sociodemographic variables used in descriptive analyses only include *born in Canada* (yes, no) and *French-speaking* (yes, no). Supplementary Table S1 provides details on all study variables including references (if applicable), cycle(s) in which data on the variable were collected, questionnaire items, response choices, and re-coding for analysis.

2.2. Statistical analysis

Descriptive statistics (i.e., means and standard deviations (SD) for variables that were normally distributed, medians and interquartile range (IQR) for variables that were not normally distributed, percents and 95% confidence intervals (CI) for categorical variables) were calculated for all study variables including *number of minutes walking per week, number of minutes MVPA per week* and prevalence of *met MVPA guidelines* in cycles 22, 23 and 24 in the sample overall.

Because physical activity is affected by seasonality (Chan and Ryan, 2009) and because most cycle 24 data were collected from December 2020 to March 2021, sensitivity analysis restricting the data to the winter months for cycles 22 and 23 (i.e., the data collection cycles prior to the pandemic) were conducted. The results (Table S2) were similar to results using all data, and the findings for all months are reported in the main paper.

We also estimated change in each physical activity indicator at the individual level between cycle 22 and 23 and between cycles 23 and 24. We repeated these analyses in each of the four sub-groups defined by consistency in *met MVPA guidelines* between cycle 23 and 24.

Odds ratios (OR) and 95%CI for potential correlates were estimated for the contrast between: (i) participants who *newly met MVPA guidelines* during the pandemic and those who were *stable inactive*; and (ii) participants who *no longer met MVPA guidelines* and those who were *stable active,* using multivariable logistic regression adjusting for age, sex and education. Each of age and the three variables measuring general coping styles (i.e., problem-focused coping, emotion-focused coping, and avoidant coping) were categorized for descriptive purposes, but were considered as continuous variables in the logistic regression models.

Data were analyzed using SPSS version 26 (released 2019, SPSS Statistics for Mac; IBM Corp., Armonk, NY).

3. Results

Of 858 participants with data in cycle 22 (i.e., "baseline" for this analysis), 614 (71.6%) also provided data in cycle 23 and 24. Compared to participants retained for analysis, higher proportions of those lost-to-follow-up were male, reported high school education only and lived alone (Table 1). Other characteristics investigated were comparable across groups.

3.1. Overall trends in physical activity

There was little change in walking pre-pandemically between cycle 22 and 23 (Table 2). However, walking declined between cycle 23 and 24 during the COVID-19 pandemic. Specifically, the median change in number of minutes walking per week was 7 between cycle 22 and 23, compared to −30 between cycle 23 and 24.

Median *number of minutes MVPA per week* declined slightly from 150 in cycle 22 to 135 in cycle 23, although the median change in minutes per week was 0. *Median number of minutes MVPA per week* declined from 135 in cycle 23 to 80 min per week in cycle 24, with a median change in number of minutes per week of −30.

Finally, the proportion of participants that met recommended MVPA guidelines was stable across cycle 22 and 23 (i.e., 50.8% and 48.9%, respectively) but declined to 35.0% during the pandemic.

Table 1
Characteristics of participants retained and not retained for analysis, Nicotine Dependence in Teens Study, Montreal, Canada, 2010–2021.

Characteristic[a]	Retained[b] (n = 614)	Not retained[c] (n = 244)
Age, y, mean (SD)	24.0 (0.7)	24.3 (0.8)
Male. % (95% CI)	41.7 (37.8, 45.7)	53.7 (47.2, 60.1)
High school education only, % (95% CI)	8.6 (6.5, 11.1)	20.1 (15.2, 25.7)
Born in Canada, % (95% CI)	94.6 (92.5, 96.3)	90.9 (86.6, 94.2)
French-speaking, % (95% CI)	29.5 (25.9, 33.3)	32.9 (27.0, 39.2)
Annual household income <$50,000 CAD, % (95% CI)	55.8 (51.6, 60.0)	57.7 (50.9, 64.3)
Lives alone, % (95% CI)	9.1 (7.0, 11.7)	19.6 (14.8, 25.2)
Employed, % (95% CI)	80.4 (77.1, 83.5)	76.5 (70.7, 81.7)
No. minutes walking/wk, median (IQR)	140 (220)	140 (260)
No. minutes MVPA/wk, median (IQR)	150 (303)	180 (478)
Met MVPA guidelines, % (95% CI)	50.8 (47.0, 55.1)	54.9 (48.9, 61.7)

SD: Standard Deviation; IQR: InterQuartile Range; MVPA: Moderate-to-Vigorous Physical Activity: No.; Number of: Y; Number of Years: WK; Week

[a] Data were drawn from cycle 22 (collected in 2010–12 (mean age 24.0)).

[b] Includes participants with complete data in cycle 22, 23 and 24.

[c] Includes participants with data in cycle 22 only.

Table 2
Change in number of minutes walking and MVPA per week and in the percent of participants that met MVPA guidelines from before to during the COVID-19 pandemic in the sample overall, Nicotine Dependence in Teens Study, Montreal, Canada, 2010–2021 (n = 614).

	Before COVID-19		During COVID-19	Change between cycle…	
	Cycle 22[a]	Cycle 23[b]	Cycle 24[c]	22 and 23	23 to 24
No. minutes walking/wk, median (IQR)	140 (50, 273)	150 (60, 315)	120 (45, 225)	7 (-82, 140)	−30 (-140, 60)
No. minutes MVPA/wk, median (IQR)	150 (30, 333)	135 (0, 300)	80 (0, 228)	0 (-160, 120)	−30 (-170, 45)
Met MVPA guidelines, % (95% CI)	50.8 (46.9, 54.8)	48.9 (44.9, 52.8)	35.0 (31.1, 38.9)	−1.8 (-6.7, 2.8)	−13.8 (-18.5, −9.2)

MVPA: Moderate-to-Vigorous Physical Activity; CI: confidence interval; IQR: InterQuartile Range.
[a] Data were collected in 2010–12 (mean age 24.0).
[b] Data were collected in 2017–20 (mean age 30.6).
[c] Data were collected from December 2020 to June 2021 during the COVID-19 pandemic (mean age 33.6).

3.2. Met MVPA guidelines over time

Overall, 63.3% of the 614 participants reported no change in *met MVPA guidelines* between cycle 23 and 24; 244 participants (39.7% of 614) were *stable inactive* and 145 (23.6%) were *stable active.* Among the 36.7% of participants whose guideline status changed, 70 (11.4% of 614) *newly met MVPA guidelines* during the pandemic; and 155 (25.2% of 614) *no longer met MVPA guidelines*.

The median change in number of minutes walking per week was relatively small across all four sub-groups between cycles 22 and 23, ranging from 0 to 50 min per week (Table 3). However, between cycle 23 and 24, walking decreased by (a median) 25–38 min per week in three of the four sub-groups (i.e., *stable inactive, no longer met MVPA guidelines*, *stable active)*. In contrast, participants who *newly met MVPA guidelines* increased walking by a median of 8 min per week.

The pattern of change in MVPA between cycle 22 and 23 compared to cycle 23 and 24 was heterogeneous across the four sub-groups (Table 3). Change in minutes MVPA per week was −40 among *stable inactive* participants between cycle 22 and 23, but 0 between cycle 23 and 24. Those who *newly met MVPA guidelines* also declined between cycle 22 and 23 (i.e., by 60 min per week), but they then increased by 260 min per week between cycle 23 and 24. Both *stable active* participants and participants who *no longer met MVPA guidelines* increased MVPA between cycle 22 and 23 (i.e., MVPA per week increased by 90 and 130 min per week, respectively) and both declined between cycle 23 and 24. However *stable active* participants declined by 45 min per week while those who *no longer met MVPA guidelines* declined by 230 min per week.

3.3. Factors associated with meeting MVPA guidelines

Table 4 identifies factors associated with *newly met MVPA guidelines* during the pandemic among 314 participants who did not meet guidelines pre-pandemic. Male sex and not being university-educated were associated with two-fold increases in the odds of *newly met guidelines.* Both amotivated to engage in physical activity pre-pandemic and endorsed physical activity as a COVID-19 coping strategy were also associated with an increased odds of *newly met MVPA guidelines.* None of the physical activity-related variables or adherence to pandemic public health measures were associated with *newly met MVPA guidelines*.

Table 5 identifies factors associated with *no longer met MVPA guidelines* during the pandemic among the 300 participants who met guidelines pre-pandemic. Male sex, not being university-educated, higher levels of problem-focused coping style and endorsed physical activity as a coping strategy during COVID-19 were protective. Emotion-focused coping style was associated with a 24% increase in the odds of no longer *met MVPA guidelines*, although the 95% CI encompassed the null value. None of the physical activity-related factors or adherence to pandemic public health measures were associated with *no longer met MVPA guidelines.*

Table 3
Change in number of minutes walking and MVPA per week from before to during the COVID-19 pandemic in four sub-groups defined by consistency in meeting MVPA guidelines over time, Nicotine Dependence in Teens Study, Montreal, Canada, 2010–2021.

	n	Before COVID-19		During COVID-19	Change between cycle…	
		Cycle 22[a]	Cycle 23[b]	Cycle 24[c]	22 and 23	23 to 24
Walking, no. minutes/wk, median (IQR)						
Stable inactive	244	120 (37, 210)	120 (58, 210)	80 (30, 179)	0 (-105, 85)	−25 (-120, 50)
Newly met MVPA guidelines	70	145 (40, 254)	150 (40, 420)	180 (58, 420)	15 (-115, 180)	8 (-106, 210)
No longer met MVPA guidelines	155	140 (50, 225)	210 (79, 350)	120 (40, 210)	13 (-77, 165)	−38 (-183, 30)
Stable active	145	150 (78, 390)	210 (105, 630)	210 (90, 420)	50 (-75, 315)	−30 (-210, 60)
MVPA, no. minutes/wk, median (IQR)						
Stable inactive	244	80 (0, 210)	0 (0, 64)	0 (0, 60)	−40 (-180, 0)	0 (-40, 15)
Newly met MVPA guidelines	70	120 (0, 304)	0 (0, 81)	300 (210, 555)	−60 (-240, 0)	260 (180,546)
No longer met MVPA guidelines	155	160 (75, 330)	270 (191, 363)	50 (0, 90)	90 (-20, 240)	−230 (-330, −150)
Stable active	145	300 (145, 540)	380 (240, 720)	330 (220, 515)	130 (-150, 390)	−45 (-240, 90)

MVPA: Moderate-to-Vigorous Physical Activity; IQR: InterQuartile Range : No.; Number of: WK; Week
[a] Data were collected in 2010–12 (mean age 24.0).
[b] Data were collected in 2017–20 (mean age 30.6).
[c] Data were collected from December 2020 to June 2021 during the COVID-19 pandemic (mean age 33.6).

4. Discussion

This current analysis investigated changes in physical activity in a sample of young adults from before the COVID-19 pandemic to 9–15 months after the declaration of the state of emergency in March 2020. Although our findings generally align with numerous extant studies, direct comparison with specific studies is challenged because of high heterogeneity in sociodemographic characteristics across samples, differences in the timing of data collection, and variability in lockdown severity. Because NDIT data collection occurred 9–15 months into the pandemic, physical activity levels may have stabilized after early sharp declines, as people adjusted to lockdowns. Di Sebastiano et al. (Di Sebastiano et al., 2020) found that among 2,338 Canadians (26.6% age 35–44; 90.2% female), mean MVPA measured with fitness trackers declined immediately after declaration of the pandemic (from 194 ± 5.2 to 177 ± 5.0 min per week) but returned to pre-pandemic levels 6 weeks later. Gallo et al. (2020), reported that 30% fewer medical students in

Table 4
Odds ratios and 95% confidence intervals for factors potentially associated with newly meeting MVPA guidelines during the COVID-19 pandemic, Nicotine Dependence in Teens Study, Montreal, Canada, 2010–2021 (n = 314).

	n	Newly met MVPA guidelines during the COVID-19 pandemic[a]		
		%	OR_{crude} (95% CI)[a]	OR_{adj} (95% CI)[a]
Sex				
Female	216	18.5	**ref**	**ref**
Male	98	30.6	**1.94 (1.12, 3.36)**	**1.92 1.09, 3.37)**
Age, y[b]			1.30 (0.76, 2.22)	1.00 (0.62, 1.62)
≤33.61	155	20.0		
>33.61	159	24.5		
University-educated				
Yes	207	17.9	**ref**	**ref**
No	106	30.2	**1.99 (1.15, 3.43)**	**2.03 (1.15, 3.60)**
Employed				
Yes	255	21.6	ref	ref
No	59	25.4	1.24 (0.64, 2.39)	1.30 (0.63, 2.55)
Annual household income, $CAD				
≥50 000	226	18.6	**ref**	ref
<50 000	73	30.1	**1.89 (1.04, 3.45)**	1.68 (0.88, 3.16)
Works-from-home during pandemic				
No	150	24.7	ref	ref
Yes/unemployed	158	19.0	0.72 (0.42, 1.23)	0.75 (0.43, 1.30)
Lives alone				
No	273	23.1	ref	ref
Yes	41	17.1	0.69 (0.29, 1.62)	0.58 (0.22, 1.34)
Lives with children				
No	170	21.8	ref	ref
Yes	144	22.9	1.07 (0.63, 1.82)	1.19 (0.67, 2.10)
Single-parent				
No	132	21.2	ref	ref
Yes	12	41.7	2.65 (0.78, 9.00)	2.45 (0.66, 8.57)
Lives in rural setting				
No	272	23.2	ref	ref
Yes	41	17.1	0.68 (0.29, 1.62)	0.58 (0.22, 1.36)
Exergames				
No	272	22.4	ref	ref
Yes	42	21.4	0.94 (0.43, 2.08)	0.91 (0.38, 1.98)
Regular physical activity tracker				
No	257	23.0	ref	ref
Yes	57	19.3	0.80 (0.39, 1.65)	0.98 (0.45, 2.00)
Amotivated to engage in physical activity pre-pandemically[c]				
No (motivated)	230	17.4	**ref**	**ref**
Yes (not motivated)	83	36.1	**2.69 (1.53, 4.72)**	**2.27 (1.26, 4.06)**
Participated in organized team sports[c]				
No	264	22.0	ref	ref
Yes	49	22.4	1.03 (0.50, 2.14)	1.06 (0.48, 2.22)
Endorsed physical activity as COVID-19 coping strategy				
No	244	17.6	**ref**	**ref**
Yes	70	38.6	**2.94 (1.64, 5.26)**	**3.38 (1.83, 6.23)**
Problem-focused coping[b,d]			1.19 (0.85, 1.68)	1.19 (0.85, 1.68)
<3.43	165	19.4		
≥3.43	149	25.5		
Emotion-focused coping[b,d]			0.96 (0.70, 1.32)	1.04 (0.74, 1.44)
<2.29	149	22.8		
≥2.29	165	21.8		
Avoidant coping[b,d]			0.98 (0.69, 1.38)	1.09 (0.75, 1.57)
<2.57	152	22.4		
≥2.57	162	22.2		
Adherence to pandemic public health measures				
Moderate/high	285	22.1	ref	ref
Low	29	24.1	1.12 (0.46, 2.75)	0.88 (0.30, 2.19)

[a] Contrasts participants who *newly met MVPA guidelines* during the pandemic (n = 75) with *stable inactive* (n = 258). Unless otherwise indicated, factors potentially associated with the outcome were measured in cycle 24 during the COVID-19 pandemic. Adjusted models controlled for age, sex and education except for the models for age, sex and education which controlled for sex and education, age and education, and age and sex, respectively.
[b] Variable was categorized for descriptive purposes, but considered as continuous in the logistic regression models.
[c] Measured in cycle 23 (before COVID-19 pandemic, 2017–20).
[d] Measured in cycle 22 (before COVID-19 pandemic, 2010–12).

Australia achieved "sufficient" levels of physical activity in 2020 compared to 2018–19. However, there were no differences in physical activity levels 6–8 weeks after containment restrictions began to ease. NDIT data could therefore reflect a new "normal."

Our study strengthens this literature because, in contrast to online, volunteer and convenience samples, NDIT used a population-based sample which resembled same-age young adults in Canada in terms of meeting MVPA guidelines (i.e., 50% in NDIT vs. 52–61% in Canada) (Weatherson et al., 2021). Further, NDIT's longitudinal design incorporated physical activity data collection before and during COVID-19. Finally, we examined physical activity changes in four sub-groups defined by patterns of meeting MVPA guidelines, permitting detection of important variation across these sub-groups over time. Rhodes et al. (2020) also created profiles representing whether participants met MVPA guidelines pre- and/or during COVID-19, with similar findings. However, the Rhodes et al. study (Rhodes et al., 2020) was a cross-sectional survey of 1055 Canadian adults of all ages conducted during the pandemic, which asked participants to recall physical activity levels pre-pandemically. Both the Rhodes et al. and NDIT studies however, underscore that analytic strategies in studies investigating physical activity change during pandemics should anticipate that many people will not change their physical activity patterns and among those that do, some will increase and others will decrease.

4.1. Physical activity change in sub-groups

Similar to Ernstein et al. (2021), two-thirds of NDIT participants reported stable MVPA patterns from pre- to during the pandemic. *Stable inactive* participants may simply be steadfastly amotivated to participate in physical activity regardless of external influences such as a pandemic, which could have affected motivation to become more active. *Stable active* participants on the other hand may have strongly entrenched physical activity habits with high levels of motivation to maintain their usual physical activity behaviors despite containment. More specifically, they may possess the "physical literacy" to reduce reliance on gyms or recreational facilities and switch to home workouts and/or transport their workouts outdoors. Rhodes et al. (2020) reported that availability of home equipment and strategic planning (i.e., preparing a plan,

Table 5
Odds ratios and 95% confidence intervals for factors potentially associated with no longer meeting MVPA guidelines during the COVID-19 pandemic, Nicotine Dependence in Teens Study, Montreal, Canada, 2010–2021 (n = 300).

	n	No longer met MVPA guidelines during the COVID-19 pandemic[a]		
		%	OR_{crude} (95% CI)[a]	OR_{adj} (95% CI)[a]
Sex				
Female	142	59.9	**ref**	**ref**
Male	158	44.3	**0.53 (0.34, 0.85)**	**0.54 (0.34, 0.87)**
Age, y[b]			1.00 (0.64, 1.57)	0.87 (0.55, 1.35)
≤33.61	151	51.7		
>33.61	149	51.7		
University-educated				
Yes	185	57.3	**ref**	**ref**
No	115	42.6	**0.55 (0.35, 0.89)**	**0.57 (0.35, 0.92)**
Employed				
Yes	255	53.3	ref	ref
No	45	42.2	0.64 (0.34, 1.21)	0.63 (0.32, 1.24)
Annual household income, $CAD				
≥50 000	231	52.8	ref	ref
<50 000	54	46.3	0.77 (0.43, 1.40)	0.84 (0.45, 1.56)
Works-from-home during pandemic				
No	166	47.6	ref	ref
Yes/unemployed	131	56.5	1.43 (0.90, 2.27)	1.31 (0.81, 2.10)
Lives alone				
No	250	51.6	ref	ref
Yes	50	52.0	1.02 (0.55, 1.87)	1.01 (0.54, 1.90)
Lives with children				
No	179	48.6	ref	ref
Yes	121	56.2	1.36 (0.85, 2.16)	1.43 (0.88, 2.33)
Single-parent				
No	113	58.4	ref	ref
Yes	8	25.0	0.24 (0.05, 1.23)	0.26 (0.03, 1.31)
Lives in rural setting				
No	60	51.7	ref	ref
Yes	238	51.7	1.00 (0.57, 1.76)	0.90 (0.49, 1.61)
Exergames				
No	252	51.2	ref	ref
Yes	48	54.2	1.13 (0.61, 2.09)	1.28 (0.67, 2.44)
Regular physical activity tracker				
No	212	51.9	ref	ref
Yes	88	51.1	0.97 (0.59, 1.60)	0.80 (0.47, 1.35)
Amotivated to engage in physical activity pre-pandemically[c]				
No (motivated)	251	52.6	ref	ref
Yes (not motivated)	49	46.9	0.80 (0.43, 1.47)	1.10 (0.57, 2.11)
Participated in organized team sports[c]				
No	204	52.9	ref	ref
Yes	93	50.5	0.91 (0.56, 1.48)	0.99 (0.59, 1.68)
Endorsed physical activity as COVID-19 coping strategy				
No	167	67.7	**ref**	**ref**
Yes	133	31.6	**0.22 (0.14, 0.36)**	**0.18 (0.11, 0.31)**
Problem-focused coping[b,d]			**0.73 (0.55, 0.98)**	**0.60 (0.43, 0.82)**
<3.43	143	58.0		
≥3.43	155	45.8		
Emotion-focused copingb[b,d]			**1.33 (1.02, 1.74)**	1.24 (0.94, 1.65)
<2.29	178	47.8		
≥ 2.29	120	57.5		
Avoidant coping[b,d]			0.96 (0.72, 1.28)	0.91 (0.67, 1.23)
<2.57	154	51.9		
≥2.57	144	51.4		
Adherence to pandemic public health measures				
Moderate/high	264	53.8	ref	ref
Low	36	36.1	0.49 (0.24, 1.00)	0.59 (0.28, 1.23)

[a] Contrasts participants who no longer met MVPA guidelines during the pandemic (n = 162) with *stable active* participants (n = 161). Unless otherwise indicated, factors potentially associated with the outcome were measured in cycle 24 during the COVID-19 pandemic. Adjusted models controlled for age, sex and education except for the models for age, sex and education which controlled for sex and education, age and education, and age and sex, respectively.
[b] Variable was categorized for descriptive purposes, but considered as continuous in the logistic regression models.
[c] Measured in cycle 23 (before COVID-19 pandemic, 2017–20).
[d] Measured in cycle 22 (before COVID-19 pandemic, 2010–12).

anticipating consequences, using strategies to execute the plan (Spinella, 2005)) were key to optimizing physical activity levels. Others have also reported that people who met guidelines pre-COVID-19, also did so during the lockdowns (López-Valenciano et al., 2021).

Eleven percent of participants *newly met MVPA guidelines*. Relative to stable inactive participants, higher proportion of those newly meeting MVPA guidelines were male and reported lower education. Interestingly they were more likely to be amotivated to engage in physical activity pre-pandemically but endorsed physical activity as a COVID-19 coping strategy. For this sub-group, the pandemic may have provided an opportunity, motivation or impetus to improve previously neglected aspects of their lives such as physical activity, especially if they were attuned to public health messaging that physical activity is helpful in coping with pandemic-related stress. Faulkner et al. (2021) reported that in a sample of 1500 Canadians, 56% of young adults vs. 43% of older adults used physical activity to cope with stress and anxiety during COVID-19. Alternate explanations include attempts to offset higher levels of sedentary behaviour during the pandemic and having more time, opportunities or incentives to walk or exercise outdoors (Stables, 2020).

The 25% of participants that *no longer met MVPA guidelines* represent an important at-risk sub-group. Female sex, university-educated, endorsing emotion- but not problem-focused coping, and not endorsing using physical activity to cope during COVID-19 characterized this sub-group. The physical activity decline among previously

active women is not surprising - women are responsible for 75% of the world's unpaid care and domestic work, and 57% of mothers (vs. 32% of fathers) reported worse mental health during the pandemic (Moreira da Silva, 2019). In addition to challenges working from home, women in this age group may have taken on the brunt of at-home childcare in addition to household tasks (Power, 2020). They may not have viewed physical activity as a priority or viable mechanism to deal with pandemic-related stress, and/or they may have been more challenged to formulate or implement a plan to compensate for reductions in physical activity. Targeted initiatives may be needed during and beyond containment to support sustained physical activity in this sub-group.

5. Implications

Because pandemic-related containment is likely into the future, evidence-based intervention is critical to ensure that physical activity declines during containment are minimized, do not become entrenched, and are targeted to sub-groups particularly vulnerable to physical activity declines. Our data suggest that in addition to using physical activity as a mechanism to cope, pandemic-related containment may represent an opportunity to revisit personal physical activity objectives. Capitalizing on pandemic-related change in physical activity motivation may be key in conceptualizing effective physical activity-related messaging and intervention during pandemics.

Future research in this realm should take advantage of existing longitudinal studies with pre-COVID-19 physical activity data, include longer and more frequent follow-ups, incorporate device-based measures of physical activity and assess whether physical activity changes during COVID-19 translate into changes in morbidity or mortality. Although the focus on young adults was a strength in this study, future studies should examine a wider age range with adequate samples of possibly vulnerable sub-groups. Finally, future studies should investigate whether change in physical activity motivation during pandemics relate to long-term positive physical activity change.

Limitations of this study include that self-report IPAQ-SF data are subject to over-reporting (Lee et al., 2011), although Lee et al. suggest that because of its adequate reliability, the IPAQ-SF can be used with care in repeated measures studies. Loss-to-follow-up could have resulted in selection bias, although there were few important differences between those retained and not retained for analysis. Use of a purposive sample as well as (non-differential and differential) loss-to-follow-up since NDIT inception may limit generalizability of the findings. We could not discern whether changes in physical activity during COVID-19 were caused by pandemic-related phenomena or whether they simply reflect secular or seasonal changes in physical activity. Finally, we acknowledge that the estimated associations between factors investigated as associated with the outcomes and the outcomes could be affected by residual confounding.

6. Conclusion

MVPA remained stable in two-thirds of participants during the COVID-19 pandemic and 11.4% of participants actually increased MVPA to newly meet MVPA guidelines. More worrisome, MVPA declined in 25.2% of (previously active) participants so that they no longer attained MVPA guidelines.

7. Availability of data and materials

NDIT data are available upon request. Access to NDIT data is open to any university-appointed or affiliated investigator upon successful completion of the application process. Masters, doctoral and post-doctoral students may apply through their primary supervisor. To gain access, applicants must complete a data access form available on our NDIT website (https://www.CELPHIE.ca) and return it to the principal investigator (jennifer.oloughlin@umontreal.ca). The procedure to obtain access to NDIT data is described in O'Loughlin, J., Dugas, E. N., Brunet, J., DiFranza, J., Engert, J. C., Gervais, A., Gray-Donald, K., Karp, I., Low, N. C., Sabiston, C., Sylvestre, M. P., Tyndale, R. F., Auger, N., Belanger, M., Barnett, T., Chaiton, M., Chenoweth, M. J., Constantin, E., Contreras, G., Kakinami, L., Labbe, A., Maximova, K., McMillan, E., O'Loughlin, E. K., Pabayo, R., Roy-Gagnon, M. H., Tremblay, M., Wellman, R. J., Hulst, A., Paradis, G., 2015. Cohort Profile: The Nicotine Dependence in Teens (NDIT) Study. Int J Epidemiol. 44(5), 1537–1546. https://doi.org/10.1093/ije/dyu135.

Authors contribution

EKO and TR are co-first authors on the manuscript. EKO, TR, and AP conducted all analyses and data verifications. JOL, TR, and EKO drafted and revised the manuscript. JOL designed and acquired the funding for the NDIT study, and JOL, MPS and MB acquired the funding for the COVID-19 data collection. All authors contributed to the interpretation of results and read and approved the final manuscript.

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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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Appendix A. Supplementary data

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