A time compositional analysis of the association between movement behaviours and indicators of mental health in young adults

August 11th 2023

Ross M. Murray, PhD
University of Stirling, Stirling, United Kingdom

Isabelle Doré, PhD
Université de Montréal, Montreal, Quebec, Canada
CHUM Research Centre, Montreal, Quebec, Canada

Catherine M. Sabiston, PhD
University of Toronto, Toronto, Ontario, Canada

Fady Michael, MD
Université de Montréal, Montréal, QC, Canada;

Jennifer L. O'Loughlin, PhD
Université de Montréal, Montreal, Quebec, Canada
CHUM Research Centre, Montreal, Quebec, Canada

Corresponding author
Ross M. Murray
r.m.murray@stir.ac.uk
University of Stirling,
Stirling,
United Kingdom

Abstract

Background: Movement behaviours (i.e., physical activity (PA), sedentary behaviours (SB), sleep) relate to mental health. Although movement behaviours are often analyzed as distinct entities, they are in fact highly inter-dependent (e.g., if an individual increases sleep, then PA and/or SB must be reduced) and these dependencies should be accounted for in the analysis. We tested whether perceptions of time spent in movement behaviours (i.e., moderate-to-vigorous intensity PA (MVPA), light physical activity (LPA), SB, and sleep) related to depressive symptoms and self-report mental health in young adults using a compositional analysis. We then estimated change in depressive symptoms with reallocation of time across movement behaviours using compositional time-reallocation models.

Methods: Data were drawn from the longitudinal NDIT dataset. Complete data were available for 770 young adults (M_{age} = 20.3, 55% females).

Results: The proportion of time spent in MVPA relative to other movement behaviours related to depressive symptoms non-significantly and to mental health significantly. Reallocating 15 minutes from MVPA to SB resulted in a significant (0.46 unit) increase in depressive symptoms, and reallocating 15 minutes of MVPA to LPA was associated with a (0.57) increase in depressive symptoms.

Conclusion: These results indicate the importance of relative time spent in each movement behaviour to mental health. Further research should examine these associations over time.

Keywords: Physical activity, sedentary behaviours, sleep, depression

A time compositional analysis of the association between movement behaviours and indicators of mental health in young adults

Depressive symptoms and self-rated mental health are both well-established indicators of young adults' mental health and well-being.[1,2] Mental health disorders typically begin in adolescence and get worse in young adulthood,[3] and self-reported mental health is worse than in any other age group.[2,4] While mental health relates to a state of successful performance of mental functioning,[5] mental illness refers to all diagnosable mental disorders.[6] Depression is one of the most common mental disorders, and young adults who experience depressive symptoms are at higher risk of mental illness later in life and more than 50% who have an episode of major depression experience a recurrence.[7,8]

Physical activity (PA) is associated with a reduced risk of depression,[9–11] and individuals who are more physically active self-report better levels of mental health.[12,13] PA is a non-pharmacological strategy that may prevent mental health challenges such as experiences of depressive symptoms, and in addition, it supports good mental health. For example, longer more intense PA (e.g., moderate-to-vigorous intensity PA (MVPA)) is associated with lower levels of depressive symptoms relative to light intensity PA.[14] However, PA is only one of several movement behaviours that relates to mental health.[15] Sedentary behaviour (SB) has also been associated with depression such that individuals who spend higher amounts of time in SB are more likely to report higher levels of depressive symptoms.[16] In addition, sleep relates to depression. Compared to shorter or longer sleep durations, sleep duration between 6 to 8 hours daily is associated with better emotional regulation and fewer depressive symptoms.[17] While these movement behaviours have been studied in isolation regarding their associations with mental health, understanding how young adults spend time across these movement behaviours

may have potential in terms of informing recommendations that aim to prevent or reduce depressive symptoms and support mental health.

The current Canadian 24-hour movement guidelines recommend that adults should obtain at least 150 minutes of MVPA per week (i.e., 21.4 minutes per day), less than 8 hours of SB per day, and 7 to 9 hours of sleep per 24-hour period.[18] The guidelines also recommend several hours of light physical activity (LPA) each day. While these behaviours may often be considered distinct, considering each movement behaviour as distinct obviates that movement behaviours are inherently co-dependent. Specifically, increasing the amount of time spent in PA also affects time spent in SB, sleep, or both. As such, researchers have started to view movement behaviours as part of a "time composition".[15,19] Findings from time composition studies to date suggest that the relative time spent in each movement behaviour relates to differences in mental wellbeing (i.e., mental health assets indicative of positive attributes such as flourishing),[20] body composition,[15] mortality,[19] and depressive symptoms in children and adolescents.[21,22] However, the extent to which the time composition of movement behaviours relates to depressive symptoms and self-rated mental health in young adults is unknown.

Studies examining movement behaviours as a time composition typically use accelerometers to measure physical activity, sleep, and sedentary behaviour.[19,23] However, the amount of time that individuals perceive or self-report that they spend in these behaviours is consequential to health outcomes. For example, the amount of time individuals believe they spend doing physical activity (i.e., subjective perceptions) have tangible positive effects on the body (e.g., better affect, higher self-esteem, lower blood pressure and heart rate) regardless of objective time spent in these movement behaviours.[24–26] Thus, although self-report subjective

perceptions may be less precise than accelerometer data, there is value in understanding individuals' subjective perceptions of their time spent in movement behaviours.

The purpose of the current study was to examine whether relative time spent in LPA, MVPA, SB and sleep relates to depressive symptoms and to self-rated mental health in young adults using a compositional analysis. Specifically, we explore whether young adults who spend more time in each movement behaviour, relative to the other movement behaviours, report differences in the depressive symptoms and self-rated mental health. Further, we explore whether removing or adding 15 minutes to each behaviour, relates to changes in depressive symptoms or in self-rated mental health.

Method

Participants and procedure

Data were drawn from the Nicotine Dependence in Teens (NDIT) Study, an ongoing longitudinal investigation of 1294 grade 7 students recruited in 1999–2000 in ten Montreal-area high schools.[27] Participants were assessed in 20 data collection cycles during the five years in high school, and in four cycles post-high school (i.e., cycles 21-24) at mean ages of 20.4, 24.0, 30.6 and 33.6. Because the current study was focused on young adulthood, we used data on movement behaviours and indicators of mental health collected in cycle 21 (2007-2008), at age 20. NDIT received ethics approval from Centre de recherche du Centre Hospitalier de l'Université de Montréal (CRCHUM) (ND06.087).

Measures

Movement behaviours

LPA and **MVPA** were measured using the short version of the International Physical Activity Questionnaire: IPAQ-SF.[28] IPAQ-SF is a 6-item questionnaire that measures time spent

walking, in moderate intensity PA, and in vigorous intensity PA over the last 7 days. The IPAQ-SF has demonstrated acceptable reliability and criterion validity[28]. Participants answered items assessing how many days and minutes per day they spent walking (i.e., a proxy for LPA) doing moderate PA, and doing vigorous PA, over the last 7 days. Average minutes spent daily walking and in each of moderate and vigorous intensity PA were then calculated by multiplying the number of days by the average number of minutes each day, and then dividing this score by seven to obtain average daily minutes. As per the IPAQ-SF data processing guide (www.ipaq.ki.se, 2005), activity bouts greater than 180 minutes daily were windsorized to allow a maximum of 1260 minutes per week in each PA category (i.e., vigorous intensity, moderate intensity and walking). Average minutes in vigorous and moderate intensity PA were summed to obtain average time spent in MVPA daily. Time spent in both LPA and MVPA was treated as continuous variables.

SB was measured in cycle 21 using four items adapted from a systematic review,[29] including: "How many hours of television (including video movies) do you usually watch in a single day?"; "How many hours do you usually spend on a computer in a single day for school or at work?"; "How many hours do you usually spend on a computer in a single day during your leisure time (playing computer games, using the Internet)?; and "How many hours do you usually spend reading (books, magazines, newspapers, homework) in a single day? Participants recorded the number of hours spent in each behaviour on a usual weekday and on a usual weekend day; they were instructed to: "Write "0" if none; and Write "LT ½" if less than ½ hour". Average time spent daily in SB was then calculated using the following formula: [(sum of hours per a weekday × 5) + (sum of hours per a weekend day × 2)]/7. Time calculated in hours

was multiplied by 60 to obtain the average number of minutes spent in SB daily. In this analysis, time spent in SB daily was treated as a continuous variable.

Sleep duration was measured using two items adapted from the Pittsburgh Sleep Quality Index (PSQI)[30] : "In the past month, at what time did you usually go to sleep at night?" and "In the past month, at what time did you usually wake up in the morning?". Participants reported both go-to-sleep time and wake-up time in a 24-hour format. In this analysis, time spent in sleep daily was treated as a continuous variable.

Outcome variables

Depressive symptoms were measured using the Major Depression Inventory (MDI), a 10-item measure in which individuals self-report experiences of depressive symptoms over the previous two weeks.[31] Response options for each item were recorded on a 6-point Likert-type scale ranging from 0 (At no time) to 5 (All the time). MDI scores range between 0 and 50, with higher scores denoting a higher likelihood of a probable case of depression. The MDI has demonstrated validity and high internal consistency in an earlier study ($\alpha = 0.94$)[31] and in NDIT cycle 21 ($\alpha = 0.88$). In this analysis, the MDI score (i.e., depression symptoms) was treated as a continuous variable.

Self-rated mental health was assessed in one item "How would you rate your mental health?" Participants responded on a scale from 1 (poor) to 5 (excellent). This item was used in the Canadian Community Health Survey[32] and is commonly used in large-scale epidemiologic studies and surveillance surveys.[33,34] Further, this type of single item self-report measure predicts mortality over and above many objective indicators of health such as physician examinations and medical records.[35,36] Overall, older adults who perceive their health as excellent are six times less likely to die compared to older adults who perceive their health as poor.[37] As such, self-report

subjective perceptions of mental health are valuable tools in understanding factors related to mental health. This item was treated as continuous.

Covariates

Consistent with previous research examining movement behaviours and health outcomes,[15,19] age, sex, and highest education level attained were included in the analysis to account for known associations between those variables and health outcomes. Education level was categorized into 4 levels, (1) Did not graduate high school, (2) High school graduate, (3) Technical school (even if not graduated), (4) University (even if not graduated).

Analysis

A compositional analysis using data collected in a cross-sectional study design, was used to examine associations between movement behaviours (LPA, MVPA, SB, and sleep) and mental health. The compositional geometric mean is a measure of central tendency and was computed as the geometric mean of time spent in a movement behaviour after being normalized to the proportion of total time. All data analyses were conducted using R version 4.2.1.[38] A total of 786 of the 1294 participants who participated in the NDIT study had complete data on all study variables at Cycle 21. Of the 786, 16 participants reported more than 20 hours per day in a single movement behaviour (e.g., sleep) and were excluded because these values are highly improbable. Thus 770 participants were retained for analysis.

The predict_delta_comps function within the codaredistlm package in R[39] was used to conduct isometric log ratio (ilr) multiple linear regression models. Ratios of movement behaviours in the simplex space were transformed into equivalent isometric log-ratio (ilr) coordinates in real space that can be used in standard regression models. Log-ratios cannot be applied to zero values. Therefore, zero values in the MVPA and LPA variables were replaced by

188 0.93, which represents 65% of the detection limit in the IPAQ-SF, at 10 minutes per week, or
189 1.42 minutes per day.[40] Compositional multiple regression models that use the ilr coordinates of
190 movement behaviours were fitted to examine the association between time spent in MVPA,
191 LPA, SB and sleep, and each of the outcome variables controlling for age, sex and education.
192 Models were fit sequentially so that each behaviour played the role of the first part of the
193 composition. Specifically, we included the coefficient of the first ilr coordinate of each
194 behaviour in each model to describe the association between the proportion of time spent in this
195 behaviour, relative to other behaviours, and the outcome variables.[41] Next, a compositional
196 isotemporal reallocation model was used to estimate the effect of displacing 15 minutes of time
197 from one movement behaviour to another movement behaviour, while holding the other
198 movement behaviours constant [41]. While 30 minutes is the most common reallocation time,[42]
199 Corder and colleagues., indicate that 10 minutes should be the minimal starting point when
200 replacing SB with physical activity [43]. We examined a reallocation time of 15-minutes as this is
201 likely the maximum amount of time people could be realistically expected to increase MVPA in
202 a day.

203 **Results**

204 Descriptive statistics and correlations between study variables are available in Table 1.
205 The average age of participants was 20.4 years and 55% were female. Of the 770 participants,
206 7.4% did not graduate from high school; 11.4% graduated from high school; 61.8% attended
207 and/or graduated technical school, and 19.3% attended and/or graduated from university.
208 Participants were younger in the analytic sample (M = 20.4, SD = .71) compared to those who
209 did not participate or were not retained for analysis, (M = 20.6, SD = .93). There were 343 males
210 and 427 females in the analytic sample. Of those who did not participate or were not retained, 59

were male and 46 were female. Figure 1 details a participant flow chart outlining how the final sample was derived. Overall, the geometric means suggest that participants spent 57% of their time in sleep, 40% of their time sedentary, 2% of their time in LPA, and 1% of their time in MVPA. In accordance with MDI scoring (Bech et al., 2015), 696 individuals reported scores consistent with 'no or doubtful depression', 37 reported mild depression, 18 reported moderate depression, and 19 reported severe depression.

In multiple linear regression controlling for covariates, movement behaviours were not significantly associated with depression, $F(761, 3) = 2.49$, $p = .06$, and significantly associated with mental health, $F(760, 3) = 5.13$, $p < .01$. Controlling for covariates and holding all movement behaviours at their geometric mean, the predicted depressive symptoms score was 11.3 (95% CI = 10.5, 12.1) on a scale of 0 to 50, and the self-rated mental health score was 3.7 (95% CI = 3.6, 3.8) on a scale from 1 to 5. Table 2 reports regression coefficients and p-values for multiple regression models. Time spent in MVPA relative to other movement behaviours was not significantly associated with depressive symptoms, $\beta = -0.31$, $SE = .18$, $p = .07$, and significantly associated with self-rated mental health, $\beta = 0.09$, $SE = .02$, $p < .01$. There were no other significant associations in movement behaviours and depression or mental health.

The isotemporal substitution models exploring the effect of reallocating 15 minutes from one movement behaviour to another on the mental health indicators are presented in Table 3 and illustrated in Figure 2. The most notable changes in the mental health indicators were observed when adding to or subtracting time from MVPA. For example, subtracting 15 minutes from MVPA and adding it to sleep was associated with a .46 (95% CI = -0.02, 0.90) increase in depressive symptoms, although this was not statistically significant. Further, subtracting 15 minutes from MVPA and adding it to LPA was associated with a significant .57 (95% CI = .03,

1.08) increase in depressive symptoms. Adding 15 minutes to MVPA from SB was associated with a significant -.18 (95% CI = -.36, -.01) reduction in depressive symptoms. Similar trends in self-rated mental health were observed after adding 15 minutes from LPA, SB, or sleep to MVPA (Table 3).

Sensitivity analysis. When all movement behaviours are aggregated, on average 945 minutes within a total day was accounted for (SD = 236). This varies from the total of 1440 minutes in a day. A sensitivity analysis was conducted in which we included only individuals who reported their total time in movement behaviours ± 236 minutes (±1 SD) of the true 1440-minute day (n = 95). Overall, geometric means indicated that individuals who were within 236 minutes reported less time in sleep (40%) and more time in sedentary behaviour (57%), which is consistent with studies measuring 24-hour movements using accelerometer data (McGregor et al., 2021). Similar to the main analysis, light and moderate to vigorous physical activity represented 2% and 1% of an individual's total day respectively. In composition analyses, trends among those who were within ± 236 minutes of the 1440-minute day were similar to the overall sample. Specifically, time spent in MVPA relative to other movement behaviours was non-significantly and negatively associated with depressive symptoms, β = -0.63, SE = .53, p = .24, and significantly positively associated with self-rated mental health, β = 0.13, SE = .06, p = .04. As in the main analysis, time spent in sleep, SB, and LPA relative to other behaviours, were not significantly associated with depressive symptoms or mental health. Further, sensitivity analysis examining associations with individuals using antidepressant medication removed indicated similar results. To maximize sample size, these individuals were included in the analysis.

Discussion

This study examined whether relative time spent in LPA, MVPA, SB and sleep relates to depressive symptoms and self-rated mental health in young adults. The results suggest that young adults who spent more time in MVPA relative to other movement behaviours reported fewer depressive symptoms and better self-rated mental health. Further, reallocating 15 minutes of LPA to MVPA was associated with reductions in depressive symptoms and improvement in self-rated mental health. Similarly, reallocating 15 minutes of MVPA to LPA, SB or sleep was associated with increases in depressive symptoms and decreases in self-rated mental health. There was no change in the mental health outcomes after adding or subtracting 15 minutes between LPA, SB, and sleep. These results indicate that self-reported physical activity, relative to other self-report behaviours, relates to depressive symptoms. This novel finding extends extant 24-hour movement composition analyses, which typically use accelerometer data. Specifically, this study highlights the potential to evaluate interventions targeting 24-hour movement behaviour using self-report data. Thus, reflective of previous studies indicating positive effects of PA on both physical and mental health,[9,10] our findings support that time spent in MVPA relative to other movement behaviours is related to mental health.

Participants reported spending only 1% of their day in MVPA on average, which is near the 150 minutes of MVPA per week recommendation detailed in the Canadian public health guidelines.[18] Our data indicate that reallocating more time to MVPA from any other movement behaviour is positively associated with improvements in depression symptoms and mental health. Consistent with previous research, the strongest associations were observed when MVPA was displaced by another behaviour.[41,44] This finding may relate to the portion of time MVPA takes up in ones' day, whereby, removing 15 minutes of MVPA is a more significant change than removing 15 minutes of sedentary behaviour. This highlights that mental health not only relates

to improvements in physical activity patterns, but also relates to drop offs in MVPA. Further, compared to other behaviours, MVPA requires higher levels of energy expenditure[45] and often involves participation in the context of a social environment.[46,47] Both fitness[48] and social factors[8] are positively associated with mental health. However, the mechanisms explaining why higher levels of MVPA *compared to* other movement behaviours relate to mental health need further investigation. Overall, these findings highlight the value of including MVPA within a 24-hour timeframe, and the potential detrimental impact removing MVPA can have on mental health.

Young adults often experience changes in their living circumstances (e.g., moving out of the family home, beginning university, developing romantic partnerships, establishing careers) as they develop independent lives, which can result in reduced participation in MVPA such as sport.[49] Based on the current findings, reductions in MVPA may partly explain the heightened risk of depression in this age group. If future studies confirm that reducing MVPA in favour of other movement behaviours such as SB does indeed affect mental health negatively, public health interventions and messaging targeting mental health in young adults may need to focus on encouraging young adults to maintain or increase MVPA during these major life transitions, rather than changing LPA, SB, or sleep.

This study included subjective perceptions of movement behaviours, rather than device measured movement behaviours. Although self-report measures are susceptible to retrospective bias, self-report movement behaviours represent intentional behaviours in which individuals are consciously aware they are participating in, which are unique from device-measured PA, sleep, and SB. It is possible that the associations observed herein relate to the psychological aspects pertaining to movement behaviours [24], which may be precursors to modifiable intervention

efforts. As such, beyond encouraging individuals to be more physically active, researchers should consider how reframing relevant activities as physical activity (e.g., washing the dishes, vacuuming) to enhance potential benefits on mental health.

There were several noteworthy limitations in this study. First, the movement behaviours were categorized broadly and there are likely many contextual factors such as participation alone or with others,[50] and different modalities such as type of physical activity[51] that could influence the strength and direction of associations between movement behaviours and mental health. Likewise, there are many types of sedentary behaviour (e.g., eating, socializing, driving) that have differing impacts on mental health, but were not captured within this study. Further research on time spent in different types of movement behaviours may highlight important contextual factors and specifics of engagement. Additionally, associations in this paper are examined in a cross-sectional study design and as such, it is possible participants' mental health impacted their movement behaviours (i.e., the association is bi-directional). Further, recent research indicates that depressive symptoms relate to the time of day in which individuals engage in movement behaviours.[52] Future research will need to examine whether time of day is relevant in this domain. Also, physical activity was measures as an average across a week, sleep was measured as an average across a month, and sedentary behaviour was measured across a typical day. These different reference points may have introduced bias into individuals' self-report, however, because we examine behaviours as a daily average, it is unlikely these differences had a significant impact on the results. Finally, a possible limitation of generalizability relates to the longitudinal data that were collected over a decade ago. Advances in technology and communication, in conjunction with the pandemic, have evolved such that screen time and SB

may have increased over the past decade, suggestive that the current results may be conservative estimates.

In conclusion, our results suggest that time spent in MVPA relative to LPA, SB, and sleep is related to mental health. If replicated, public health recommendations aimed at improving or sustaining mental health in young adults may need to focus on increasing or sustaining MVPA by reallocating time spent in other behaviours.

Perspective

Young adulthood is a time of significant transition which can impact mental health.[53] Movement behaviours such as physical activity directly impacts young adult's mental health.[49] As such, there is growing attention on developing movement interventions to support mental health. However, the use of accelerometer devices to measure movement behaviour is costly and not always practical. The current study highlights the utility of using self-report measures of movement behaviours to understand the efficacy of mental health interventions. Further, this research indicates that movement behaviours, as they relate to mental health, can be understood as a composition, whereby increases in one behaviour (e.g., physical activity) comes at the expense of another (e.g., sleep). Therefore, instead of targeting one behaviour at a time, practitioners looking for behavioural strategies to support mental health should consider replacing time spent in sedentary behaviour with an increase in moderate to vigorous physical activity.

References

1. Dhillon S, Videla-Nash G, Foussias G, Segal Z v., Zakzanis KK. On the nature of objective and perceived cognitive impairments in depressive symptoms and real-world functioning in young adults. *Psychiatry Res*. 2020;287. doi:10.1016/j.psychres.2020.112932
2. Mawani FN, Gilmour H. Validation of self-rated mental health. *Health reports / Statistics Canada, Canadian Centre for Health Information = Rapports sur la santé / Statistique Canada, Centre canadien d'information sur la santé*. 2010;21(3).
3. Kessler R, Angermeyer M, Anthony J. Lifetime prevalence and age-of-onset distributions of mental disorders in the World Health Organization's World Mental Health Survey Initiative. *World Psychiatry*. 2007;6:168-176.
4. Duncan MJ, Leatherdale ST, Patte KA. Do You Really Want to Be Forever Young? Emotional Health and Psychosocial Well-being by Relative Birth Quarter in Canadian Adolescents. *Journal of Adolescent Health*. 2022;70(4). doi:10.1016/j.jadohealth.2021.10.034
5. US Department of Health and Human Services. *Mental Health: A Report of the Surgeon General*.; 1999.
6. Manderscheid RW, Ryff CD, Freeman EJ, McKnight-Eily LR, Dhingra S, Strine TW. Evolving definitions of mental illness and wellness. *Prev Chronic Dis*. 2010;7(1).
7. Lewinsohn PM, Rohde P, Klein DN, Seeley JR. Natural course of adolescent major depressive disorder: I. Continuity into young adulthood. *J Am Acad Child Adolesc Psychiatry*. 1999;38(1). doi:10.1097/00004583-199901000-00020
8. Sabiston CM, Jewett R, Ashdown-Franks G, et al. Number of years of team and individual sport participation during adolescence and depressive symptoms in early adulthood. *J Sport Exerc Psychol*. 2016;38:105-110. doi:doi.org/10.1123/jsep.2015-0175
9. Buecker S, Simacek T, Ingwersen B, Terwiel S, Simonsmeier BA. Physical activity and subjective well-being in healthy individuals: a meta-analytic review. *Health Psychol Rev*. 2021;15(4). doi:10.1080/17437199.2020.1760728
10. Rebar AL, Stanton R, Geard D, Short C, Duncan MJ, Vandelanotte C. A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health Psychol Rev*. 2015;9(3). doi:10.1080/17437199.2015.1022901
11. Pearce M, Garcia L, Abbas A, et al. Association between Physical Activity and Risk of Depression: A Systematic Review and Meta-analysis. *JAMA Psychiatry*. 2022;79(6):550-559. doi:10.1001/jamapsychiatry.2022.0609
12. Herman KM, Hopman WM, Sabiston CM. Physical activity, screen time and self-rated health and mental health in Canadian adolescents. *Prev Med (Baltim)*. 2015;73. doi:10.1016/j.ypmed.2015.01.030
13. Doré I, O'Loughlin JL, Beauchamp G, Martineau M, Fournier L. Volume and social context of physical activity in association with mental health, anxiety and depression among youth. *Prev Med (Baltim)*. 2016;91:335-350. doi:10.1016/j.ypmed.2016.09.006
14. Currier D, Lindner R, Spittal MJ, Cvetkovski S, Pirkis J, English DR. Physical activity and depression in men: Increased activity duration and intensity associated with lower likelihood of current depression. *J Affect Disord*. 2020;260. doi:10.1016/j.jad.2019.09.061

15. Rollo S, Antsygina O, Tremblay MS. The whole day matters: Understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. *J Sport Health Sci*. 2020;9(6). doi:10.1016/j.jshs.2020.07.004
16. Zhai L, Zhang Y, Zhang D. Sedentary behaviour and the risk of depression: A meta-analysis. *Br J Sports Med*. 2015;49(11). doi:10.1136/bjsports-2014-093613
17. Chaput JP, Gray CE, Poitras VJ, et al. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. *Applied Physiology, Nutrition and Metabolism*. 2016;41(6). doi:10.1139/apnm-2015-0627
18. The Canadian Society for Exercise Physiology (CSEP). Canada's First Ever 24-Hour Movement Guidelines for Adults Help Make the Whole Day Matter. csepguidelines.ca/.
19. Mcgregor DE, Palarea-Albaladejo J, Dall PM, del Pozo Cruz B, Chastin SFM. Compositional analysis of the association between mortality and 24-hour movement behaviour from NHANES. *Eur J Prev Cardiol*. 2021;28(7). doi:10.1177/2047487319867783
20. Brown DMY, Cairney J, Kwan MY. Adolescent movement behaviour profiles are associated with indicators of mental wellbeing. *Ment Health Phys Act*. 2021;20. doi:10.1016/j.mhpa.2021.100387
21. Fairclough SJ, Tyler R, Dainty JR, et al. Cross-sectional associations between 24-hour activity behaviours and mental health indicators in children and adolescents: A compositional data analysis. *J Sports Sci*. 2021;39(14). doi:10.1080/02640414.2021.1890351
22. Sampasa-Kanyinga H, Colman I, Dumuid D, et al. Longitudinal association between movement behaviours and depressive symptoms among adolescents using compositional data analysis. *PLoS One*. 2021;16(9 September). doi:10.1371/journal.pone.0256867
23. Kitano N, Kai Y, Jindo T, Tsunoda K, Arao T. Compositional data analysis of 24-hour movement behaviors and mental health in workers. *Prev Med Rep*. 2020;20. doi:10.1016/j.pmedr.2020.101213
24. Zahrt OH, Crum AJ. Effects of physical activity recommendations on mindset, behavior and perceived health. *Prev Med Rep*. 2020;17. doi:10.1016/j.pmedr.2019.101027
25. Crum AJ, Langer EJ. Mind-set matters: Exercise and the placebo effect. *Psychol Sci*. 2007;18(2). doi:10.1111/j.1467-9280.2007.01867.x
26. Zahrt OH, Evans K, Murnane E, et al. Effects of Wearable Fitness Trackers and Activity Adequacy Mindsets on Affect, Behavior, and Health: Longitudinal Randomized Controlled Trial. *J Med Internet Res*. 2023;25. doi:10.2196/40529
27. O'Loughlin JL, Dugas EN, Brunet J, et al. Cohort Profile: The Nicotine Dependence in Teens (NDIT) Study. *Int J Epidemiol*. 2015;44:1537-1546. doi:10.1093/ije/dyu135
28. Craig CL, Marshall AL, Sjostrom M, et al. International Physical Activity Questionnaire: 12-Country Reliability and Validity. *Med Sci Sports Exerc*. 2003;35:1381-1395. doi:10.1249/01.MSS.0000078924.61453.FB
29. Bryant MJ, Lucove JC, Evenson KR, Marshall S. Measurement of television viewing in children and adolescents: A systematic review. *Obesity Reviews*. 2007;8(3). doi:10.1111/j.1467-789X.2006.00295.x

30. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2). doi:10.1016/0165-1781(89)90047-4
31. Bech P, Rasmussen N, Olsen LR, Noerholm V, Abildgaard W. The sensitivity and specificity of the Major Depression Inventory, using the Present State Examination as the index of diagnostic validity. *J Affect Disord*. 2001;66:159-164. doi:10.1016/s0165-0327(00)00309-8
32. Statistics Canada. Canadian Community Health Survey. Published online 2005.
33. Diamantopoulos A, Sarstedt M, Fuchs C, Wilczynski P, Kaiser S. Guidelines for choosing between multi-item and single-item scales for construct measurement: A predictive validity perspective. *J Acad Mark Sci*. 2012;40(3):434-449. doi:10.1007/s11747-011-0300-3
34. Macias C, Gold PB, Öngür D, Cohen BM, Panch T. Are Single-Item Global Ratings Useful for Assessing Health Status? *J Clin Psychol Med Settings*. 2015;22(4):251-264. doi:10.1007/s10880-015-9436-5
35. Idler EL, Benyamini Y. Self-Rated Health and Mortality: A Review of Twenty-Seven Community Studies. *J Health Soc Behav*. 1997;38(1). doi:10.2307/2955359
36. Zahrt OH, Crum AJ. Perceived physical activity and mortality: Evidence from three nationally representative U.S. samples. *Health Psychology*. 2017;36(11). doi:10.1037/hea0000531
37. Idler EL, Kasl S. Health perceptions and survival: Do global evaluations of health status really predict mortality? *Journals of Gerontology*. 1991;46(2). doi:10.1093/geronj/46.2.S55
38. R Core Team. R core team (2022). *R: A language and environment for statistical computing R Foundation for Statistical Computing, Vienna, Austria URL http://www R-project org*. Published online 2021.
39. Stanford T, Rasmussen CL, Dumuid D. codaredistlm: Compositional Data Linear Models with Composition Redistribution. Published online December 22, 2022.
40. Palarea-Albaladejo J, Martín-Fernández JA. ZCompositions - R package for multivariate imputation of left-censored data under a compositional approach. *Chemometrics and Intelligent Laboratory Systems*. 2015;143. doi:10.1016/j.chemolab.2015.02.019
41. Chastin SFM, Palarea-Albaladejo J, Dontje ML, Skelton DA. Combined effects of time spent in physical activity, sedentary behaviors and sleep on obesity and cardio-metabolic health markers: A novel compositional data analysis approach. *PLoS One*. 2015;10(10). doi:10.1371/journal.pone.0139984
42. Grgic J, Dumuid D, Bengoechea EG, et al. Health outcomes associated with reallocations of time between sleep, sedentary behaviour, and physical activity: A systematic scoping review of isotemporal substitution studies. *International Journal of Behavioral Nutrition and Physical Activity*. 2018;15(1). doi:10.1186/s12966-018-0691-3
43. Corder K, Sharp S, Griffin S, Jones A, Ekelund U, van Sluijs E. Change in objectively measured physical activity during the transition to adolescence: Targets for intervention. *J Sci Med Sport*. 2012;15. doi:10.1016/j.jsams.2012.11.612
44. Carson V, Tremblay MS, Chaput JP, Chastin SFM. Associations between sleep duration, sedentary time, physical activity, and health indicators among Canadian children and

youth using compositional analyses. *Applied Physiology, Nutrition and Metabolism*. 2016;41(6). doi:10.1139/apnm-2016-0026

45. Lubans DR, Richards J, Hillman C, et al. Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics*. 2016;138(3). doi:10.1542/peds.2016-1642
46. Weatherson K, Gierc M, Patte K, Qian W, Leatherdale S, Faulkner G. Complete mental health status and associations with physical activity, screen time, and sleep in youth. *Ment Health Phys Act*. 2020;19. doi:10.1016/j.mhpa.2020.100354
47. Hilland TA, Costigan SA. Children's and adolescents' interpersonal-level correlates of physical activity behavior. In: *The Routledge Handbook of Youth Physical Activity*. ; 2020. doi:10.4324/9781003026426-12
48. Aan het Rot M, Collins KA, Fitterling HL. Physical Exercise and Depression. *Mount Sinai Journal of Medicine*. 2009;76:204-214. doi:10.1002/MSJ
49. Murray RM, Sabiston CM, Doré I, Bélanger M, O'Loughlin JL. Association between pattern of team sport participation from adolescence to young adulthood and mental health. *Scand J Med Sci Sports*. 2021;31(7). doi:10.1111/sms.13957
50. Jetten J, Haslam C, von Hippel C, et al. "Let's get physical" — or social: The role of physical activity versus social group memberships in predicting depression and anxiety over time. *J Affect Disord*. 2022;306. doi:10.1016/j.jad.2022.03.027
51. Ekkekakis P, Parfitt G, Petruzzello SJ. The Pleasure and Displeasure People Feel When they Exercise at Different Intensities. *Sports Medicine*. 2011;41(8). doi:10.2165/11590680-000000000-00000
52. Gianfredi V, Schaper NC, Odone A, et al. Daily patterns of physical activity, sedentary behavior, and prevalent and incident depression—The Maastricht Study. *Scand J Med Sci Sports*. 2022;32(12). doi:10.1111/sms.14235
53. Carr S, Colthurst K, Coyle M, Elliott D. Attachment dimensions as predictors of mental health and psychosocial well-being in the transition to university. *European journal of psychology of education*. 2013;28:157-172. doi:10.1007/s10212-012-0106-9

Table 1.
Means, standard deviations, and correlations with confidence intervals

Variable	*M*	*SD*	1	2	3	4	5	6
1. Age (years)	20.36	0.71						
2. MVPA (min)	36.51	49.09	.02 [-.05, .09]					
3. LPA (min)	31.64	38.93	.03 [-.04, .10]	.17** [.10, .24]				
4. SB (min)	407.06	219.66	.10** [.02, .16]	-.06 [-.13, .01]	-.04 [-.11, .03]			
5. Sleep (min)	500.27	88.09	-.06 [-.13, .01]	-.08* [-.15, -.01]	-.03 [-.10, .04]	-.05 [-.12, .02]		
6. Depressive symptoms	9.64	7.68	-.02 [-.09, .05]	-.12** [-.19, -.05]	-.01 [-.08, .06]	.03 [-.04, .10]	-.06 [-.13, .01]	
7. Self-report mental health	3.78	1.00	-.05 [-.12, .02]	.14** [.07, .21]	.06 [-.02, .13]	-.02 [-.09, .05]	-.00 [-.08, .07]	-.50** [-.55, -.45]

Note. M and *SD* are used to represent mean and standard deviation, respectively. MVPA = moderate to vigorous physical activity, LPA = light physical activity, SB = sedentary behaviour. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

Table 2. Regression coefficients and p-values associated with the first pivot coordinates for multiple regression models for the association between the proportion of time spent in movement behaviours and depressive symptoms (n = 770).

First ilr coordinate for…	Depressive symptoms	Self-rated mental health
	β (95% CI)	*β* (95% CI)
MVPA	-0.31 (.03, -.66)	**0.09 (-.04, -.13)**
LPA	0.30 (.04, -.64)	-0.01 (.04, -.06)
Sedentary behaviour	0.86 (1.87, -.15)	-0.04 (.09, -.16)
Sleep	-0.87 (.29, -1.98)	-0.04 (.10, -.19)

Note: ilr, isometric log-ratio; CI = Confidence interval, MVPA, Moderate-to-Vigorous Physical Activity; LPA, Light intensity Physical Activity; Models adjusted for age, sex, and education level

Table 3. Change in prediction matrix showing changes in depressive symptoms and mental health, with reallocation of 15 minutes from the behaviours in the columns to the behaviours in the rows (n=770), NDIT 2012.

Change in depressive symptoms with reallocation of 15 minutes…				
	To…			
From…	MVPA	LPA	SB	Sleep
MVPA	-	0.57* (.03, 1.10)	0.46 (-.02, .95)	0.43 (-.06, .92)
LPA	-0.40 (-.81, .002)	-	-0.22 (-.57, .12)	-0.26 (-61, .10)
Sedentary behaviour	-0.18* (-.35, -.002)	0.10 (-.07, 28)	-	-0.03 (-.07, .01)
Sleep	-0.15 (-.33, .35)	0.13 (-.05, .32)	0.03 (-.01, .07)	-
Change in self-report mental health with reallocation of 15 minutes…				
	To…			
From…	MVPA	LPA	SB	Sleep
MVPA	-	-0.13* (-.20, -.06)	-0.13* (-.19, -.06)	-0.13* (-.19, -.06)
LPA	0.05* (.00, .10)	-	0.01 (-.04, .05)	0.01 (-.04, .05)
Sedentary behaviour	0.05* (.02, .07)	-0.003 (-.03, .02)	-	-0.00 (-.005, .005)
Sleep	0.05* (.02, .07)	-0.003 (-.03, .02)	0.000 (-.005, .005)	-

Note: Values in brackets are 95% confidence interval; MVPA, Moderate-to-Vigorous Physical Activity; LPA, Light intensity Physical Activity; SB, Sedentary Behaviours. Negative values indicate reduction in predicted depressive symptoms values with time reallocation, while positive values indicate an increase in predicted values with time reallocation..* p-value < .05

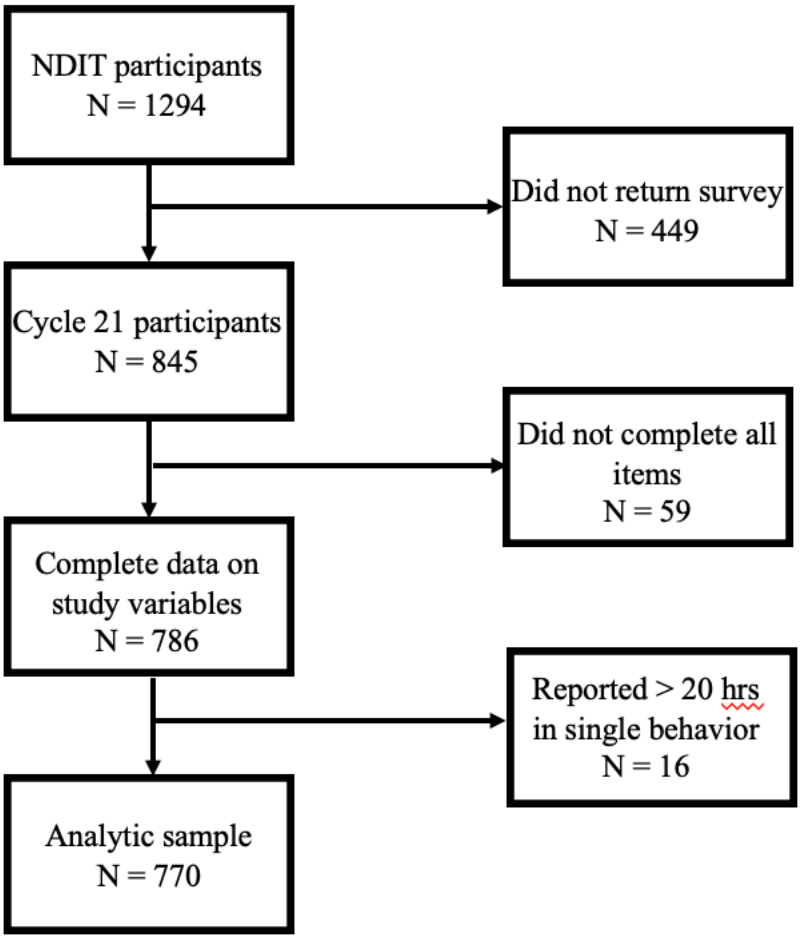
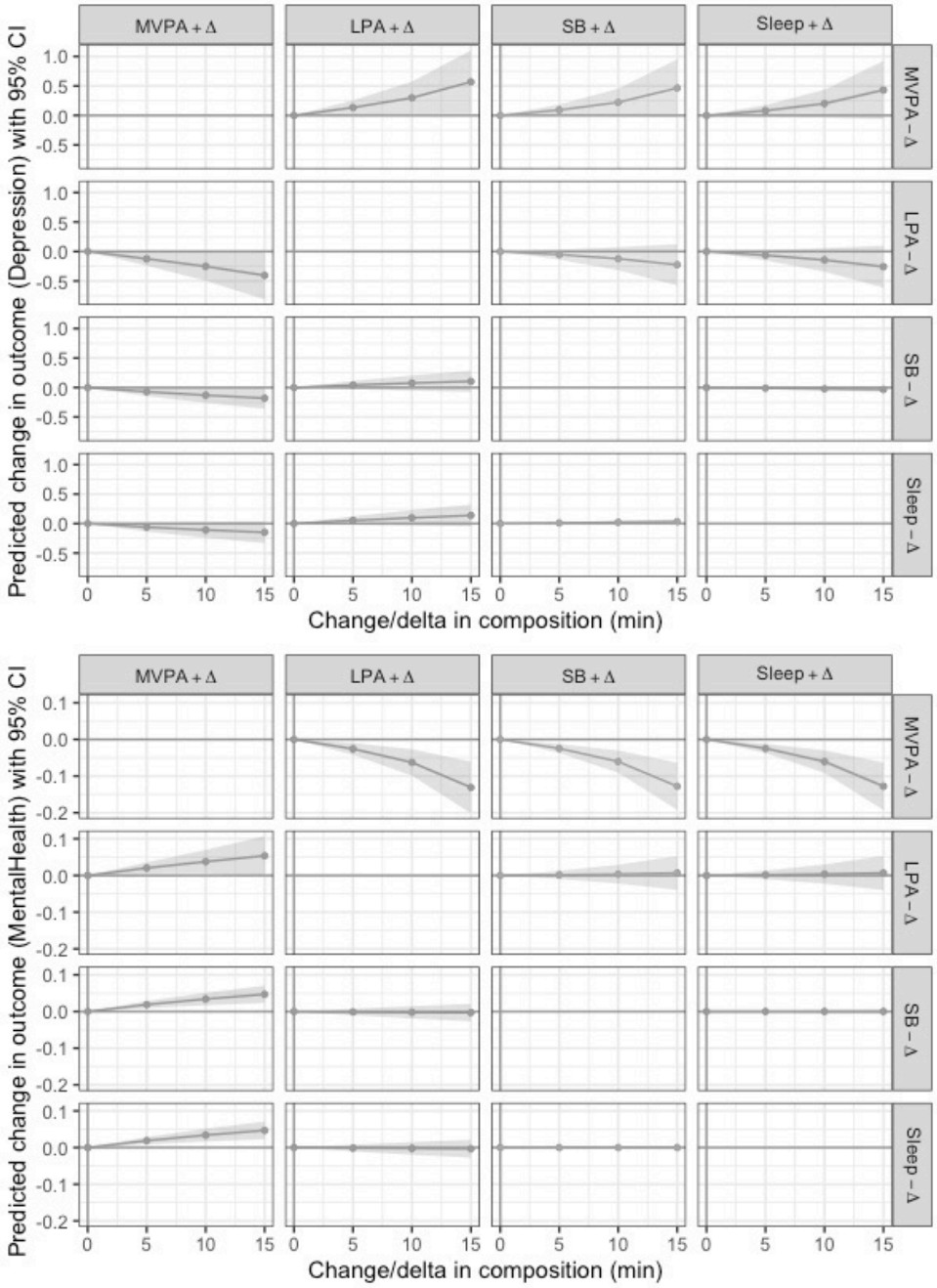


Figure 1. Participant flow chart

Figure 2



Changes in depression and mental health from adding and removing 5, 10, and 15 minutes of moderate to vigorous physical activity (MVPA), light physical activity (LPA), sedentary behaviour (SB), and sleep.