Adolescent Movement Behaviour Profiles are Associated with Indicators of Mental Wellbeing

*Denver M. Y. Brown[a], John Cairney[b] & Matthew Y. Kwan[ac]

[a]McMaster University, Department of Family Medicine, 100 Main St. W., Hamilton, Ontario, Canada, L8P 1H6, brownd32@mcmaster.ca

[b]University of Queensland, School of Human Movement and Nutrition Sciences, 26 Blair Dr., Brisbane, Queensland, Australia, 4067, j.cairney@uq.edu.au

[c]Brock University, Department of Child and Youth Studies, 1812 Sir Isaac Brock Way, St. Catherines, Canada, L2S 3A1, mkwan@brocku.ca

*Corresponding author

Notes:

This article has been accepted for publication in the journal *Mental Health & Physical Activity*. This manuscript is a preprint, which may differ from the final published version.

DOI: 10.1016/j.mhpa.2021.100387

Conflicts of interest: None

CRediT Author Statement. **Denver Brown**: Conceptualization, Data curation, Methodology, Writing – original draft, Formal analysis. **John Cairney**: Writing – review and editing. **Matthew Kwan**: Conceptualization, Methodology, Writing – original draft, Supervision, Funding acquistition, Investigation.

Funding: The ADAPT study is funded by an Insight Grant from the Social Sciences and Humanities Research Council of Canada.

Abstract

Recent work has demonstrated the collective impact of daily movement behaviours on mental health outcomes, however, positive aspects of mental health have received much less attention. The purpose of this study was to identify unique adolescent movement behaviour profiles and determine whether profile membership is associated with differences in mental wellbeing. This study used data from the baseline assessment of the ADAPT study. A total of 1166 Canadian adolescents enrolled in grade 11 classes (M_{age} = 15.91 ± 0.48; 54% female) self-reported their movement behaviours – moderate-to-vigorous physical activity (MVPA), recreational screen time (ST) and sleep – and completed three measures of mental wellbeing: flourishing, self-esteem and resiliency. Latent profile analysis with distal outcomes comparisons were conducted. Four distinct profiles were identified: one healthy profile (high MVPA/low ST), two mixed behavioural profiles (low MVPA/low ST and high MVPA/high ST), and one profile considered to be the least healthy (low MVPA and high ST). Sleep patterns were similar across the profiles. The healthiest profile was consistently associated with better mental wellbeing, followed by the mixed behaviour profiles, and the least healthy profile had the poorest scores for mental wellbeing. These findings highlight the additive benefits of engaging in a full complement of healthy movement behaviours. Moving forward, behavioural interventionists should consider adopting an integrated approach to promoting mental wellbeing through targeting each of the movement behaviours concurrently.

Keywords: latent profile analysis, mental health, physical activity, screen time, sleep

Introduction

Movement behaviours represent a collection of modifiable lifestyle factors consisting of light physical activity, moderate-to-vigorous physical activity (MVPA), recreational screen time (ST) (or sedentary behaviours) and sleep. Only recently have countries begun adopting 24-hour movement behaviour guidelines as an integrative approach to healthy development among children and youth (Tremblay et al., 2016). Traditionally, there were discrete recommendations for MVPA, ST and sleep, which failed to recognize the co-dependence among these behaviours over the course of a day. This monumental shift has led many researchers to move beyond investigating independent links between each movement behaviour and health outcomes to instead examine their collective impact.

Over a relatively short period, there has been an abundance of published studies demonstrating the beneficial effects of healthy combinations of movement behaviours on a variety of physical and mental health indicators (for reviews, see Chaput et al., 2017; Sampasa-Kanyinga, Colman, et al., 2020; Saunders et al., 2016). Specifically in regards to adolescent mental health, healthier combinations of movement behaviours have been associated with positive social and emotional health as well as lower anxiety and depressive symptoms (Bang et al., 2020; Carson et al., 2016, 2017; Janssen et al., 2017; Knell et al., 2019; Patte et al., 2020; Pearson et al., 2019; Sampasa-Kanyinga, Chaput, et al., 2020; Zhu et al., 2019). The majority of these studies, however, have focused solely on mental health problems. Importantly, mental health is not simply the absence of adverse symptoms or problems – rather, it exists on a continuum and measures of mental wellbeing (or mental health assets) help capture the presence of positive attributes (Keyes, 2002). Although indicators of wellbeing such as prosocial behaviour and flourishing have received some attention (Faulkner et al., 2020; Janssen et al.,

2017), there is still a paucity of research examining the relationship between collective movement behaviours and mental wellbeing.

Mental wellbeing is especially important during the developmental stages of adolescence. For example, studies have shown self-esteem and flourishing are associated with a number of positive outcomes including academic achievement (Datu, 2018; Haney & Durlak, 1998; Reschly et al., 2008) and acting as a protective psychological resource against depression and anxiety (Doré et al., 2020; Henriksen et al., 2017; Keyes, 2006; Masselink et al., 2018; Orth et al., 2008) – the latter being particularly relevant given that the peak onset of mental health problems occurs in adolescence (Merikangas et al., 2010; Paus et al., 2008). Resiliency is another facet of mental wellbeing that has been linked with lower levels of depression and other mental health problems (Hjemdal et al., 2011; Skrove et al., 2013). It has been identified as a key coping mechanism for stress (Kwok et al., 2014) and/or shown to buffer the effects of stress on depression and anxiety (Anyan & Hjemdal, 2016). Late adolescence is a potentially stressful time due to the looming transition into emerging adulthood; a period marked by increased independence and role changes as many longstanding supports are no longer available (Blakemore, 2008). The potential to feel "overwhelmed by change", while at the same time accelerated by increased independence, means adolescence is sometimes characterized as being "ridden by storm and stress" (Casey et al., 2010).

The methods by which most studies have examined movement behaviours may also be limiting in our current understanding of their impact on mental health indicators (Bang et al., 2020; Carson et al., 2017; Faulkner et al., 2020; Janssen et al., 2017; Knell et al., 2019; Patte et al., 2020; Pearson et al., 2019; Sampasa-Kanyinga, Chaput, et al., 2020; Zhu et al., 2019). Typically, these studies have classified individuals into groups based on adherence to each of the

movement behaviour recommendations. This approach fails to consider much of the variability in the data that may contribute to differences in indicators of mental health. This results in a substantial potential loss of information and can lead to misclassification problems and other methodological concerns. For example, it is reasonable to hypothesize that an individual engaging in 59 minutes of MVPA each day would experience greater benefits for their mental health than someone who does not engage in any MPVA; but these individuals are both classified as not achieving the recommended amount of 60 minutes of daily MVPA. Researchers have called for the use of more advanced analysis techniques to overcome such limitations (Chaput et al., 2017), although to date, very few studies have employed isotemporal substitution (Gilchrist et al., 2021), compositional data analysis techniques (Carson et al., 2016) or person-centered approaches (Brown et al., 2021).

Person-centered analyses (such as cluster and latent profile analyses) represent one approach that can address the shortcomings of previous studies in this area. Latent profile analysis is a technique that can use the full range of movement behaviour scores to identify mutually exclusive subgroups characterized by distinct movement behaviour patterns (Masyn, 2013). Auxiliary analysis techniques are also available for testing whether differences in mental health indicators exist between emergent profiles (Nylund-Gibson et al., 2019). But, to date, only one study has applied these methods to understand the relationship between movement behaviours and mental health during adolescence (Brown et al., 2021), and the study of Brown et al. examined depressive symptoms, thus, studies focused on indicators of mental wellbeing have yet to be undertaken.

Therefore, the purpose of the present study was twofold: (1) to identify unique movement behaviour profiles among a sample of Canadian adolescents, and (2) determine whether profile membership is associated with differences in mental wellbeing.

Methods

Study sample and data collection

Data for the present study is from the baseline assessment from the ADAPT study (Kwan et al., 2020). The ADAPT study is a four-year prospective longitudinal study tracking a sample of Canadian adolescents as they transition out of high school and into emerging adulthood in order to gain an understanding of factors underlying changes in physical activity behaviour. All grade 11 students enrolled into one of the seven secondary schools across a large school board in Southern Ontario were invited to take part in the study. Participation in the study was voluntary, and informed consent was obtained online from each participant prior to data collection at each individual school in the Fall/Autumn term. Students willing to participate completed a 20-minute online survey during class time. Parental consent collected by paper or electronically was also a requirement for their data to be included in the study. More information about the recruitment strategy and study protocol can be found in the methods paper (Kwan et al., 2020). The protocol for the ADAPT study was approved by both the Institutional Research Ethics Board and the School Board Ethics Committee.

Among the 2412 enrolled at one of the seven secondary schools within the school board, 1585 agreed and provided consent to participate (66% response rate). Of the 1585 consenting students, 146 respondents (9%) withdrew their participation (i.e., completed >5% of the survey), while 186 respondents (12%) did not have parental consent for their participation. As a result, the final baseline sample in the current study included 1253 participants. Among the total

baseline cohort, 1166 participants (93%) had full data for the variables of interest used in our analyses and were included in this study. A total of 15 participants (1%) were missing movement behaviour data and 34 (3%) were missing data for at least one mental wellbeing variable. There was no missing data for age, 26 (2%) missing values for gender and 12 (1%) for parental education. Missing data was handled using listwise deletion.

Measures

Demographics. Participants completed a demographic questionnaire assessing their age, gender, ethnicity, and highest level of parental education. For analyses purposes, ethnicity was dummy coded into White (1) and other (0), and parental education was dummy coded into college/university graduate (1) and partial completion of post-secondary education or less (0). Parental education was used as an indicator of socioeconomic status.

Movement Behaviours. As per the Canadian 24-Hour Movement Guidelines for Children and Youth (Tremblay et al., 2016), movement behaviours were operationalized as a latent construct consisting of MVPA, ST and sleep. Although a "healthy" 24 hours also includes several hours of light physical activity (despite no consensus on thresholds that should be met), we only focused on the three guideline-based components of the 24-hour cycle.

***Moderate-to-Vigorous Physical Activity*.** MVPA was measured using the International Physical Activity Questionnaire – Short Form (Booth, 2000; Craig et al., 2003). Participants responded to four items that assessed the frequency (days) and duration (hours and/or minutes on an average day) of their moderate and vigorous physical activity performed in bouts of greater than 10-minutes over the past seven days. Daily MVPA was calculated by multiplying frequency by duration for moderate and vigorous physical activity, respectively, and then summing these products and dividing by seven. The International Physical Activity Questionnaire – Short Form

has shown acceptable measurement properties when administered among adolescents (Guedes et al., 2005).

***Screen time*.** ST was assessed using a standard daily recall questionnaire that asked participants how much time (hours and/or minutes) on average they spent watching TV or using a computer, tablet or smartphone during their free time over the past seven days.

***Sleep*.** Participants responded to four items that assessed what time they typically went to sleep and woke up during weekdays and on the weekend over the past seven days. Responses were used to calculate the average number of hours participants slept on weekdays and weekends. Average daily sleep was then calculated by multiplying weekday sleep by five and weekend sleep by two, and then summing these products and dividing by seven.

Flourishing. Flourishing was measured using the Flourishing Scale (Diener et al., 2010), which provides a summary measure of the respondent's self-perceived success in important aspects of their life including relationships, purpose and optimism. This measure has demonstrated strong psychometric properties when administered to youth (Diener et al., 2010). Participants responded to eight items on a seven-point Likert scale ranging from 1 (Strongly Disagree) to 7 (Strongly Agree). Example items included: "I lead a purposeful and meaningful life", "My social relationships are supportive and rewarding", and "I am optimistic about my future". All items were summed to provide a total score ranging from 8 to 56. Internal consistency (Cronbach's α) for the eight items was 0.89.

Self-Esteem. Self-esteem was measured using a modified version of the Rosenberg Self-Esteem Scale (Rosenberg, 1965). This measure has demonstrated strong psychometric properties when administered to adolescents (Rosenberg, 1965). Participants responded to five items on a four-point scale ranging from 1 (Strongly Disagree) to 4 (Strongly Agree). Only the items associated

with positive feelings towards the self were included: "On the whole, I am satisfied with myself", "I feel that I have a number of good qualities", "I am able to do things as well as most other people", "I feel that I'm a person of worth, at least on an equal plane with others", and "I take a positive attitude towards myself". All items were summed to provide an overall score ranging from 5 to 20. Internal consistency (Cronbach's α) for the five items was 0.88.

Resiliency. Resiliency was measured using two items from the Canadian Campus Wellbeing Survey (Faulkner et al., 2019). Participants responded to each item on a five-point scale ranging from 1 (Poor) to 5 (Excellent). The items followed the stem statement: "In general, how would you rate…": (a) "your ability to handle unexpected and difficult problems (a family or performance crisis)," and (b) "your ability to handle day-to-day demands in your life (work, family responsibilities)." A mean scale score was computed. The inter-item correlation (Pearson's *r*) for the two items was 0.72.

Data Analysis

The first part of the analysis involved estimating a series of latent models for the sample. Two to six profile solutions were specified using MVPA, ST and sleep as predictors. Latent profile analysis uses a set of predictor variables to fit a model that identifies an optimal number of mutually exclusive subgroups with minimal within-group variance and maximal between-group variance (Masyn, 2013). Three quantitative model fit criteria were used to guide our decision regarding the number of profiles that best represented the data: Bayesian information criterion (Schwarz, 1978), adjusted Lo-Mendell-Rubin likelihood ratio test (Lo et al., 2001) and entropy values. Lower Bayesian information criterion values indicate better model fit. A significant *p*-value for the adjusted Lo-Mendell-Rubin likelihood ratio test indicates the *n*-profile model fit the data better than the model with *n*-1 profiles (Lo et al., 2001). Entropy values range

from 0 to 1 with higher values indicating greater precision of latent profile membership assignment. While there are no threshold values for entropy statistics, values greater than 0.6 have been shown to be acceptable (Pastor et al., 2007).

Once the final latent profile model was determined, we used the manual maximum-likelihood three-step approach for distal outcomes to examine the association between the movement behaviour profiles and indices of mental wellbeing (Nylund-Gibson et al., 2019). Benjamini-Hochberg adjustments with a false discovery rate set at 10% were performed to control for multiple comparisons (Benjamini & Hochberg, 1995). Gender, ethnicity and socioeconomic status have been shown to influence adolescent movement behaviours (Moore et al., 2011; Pate et al., 2011; Sterdt et al., 2014), and were therefore included within the distal outcomes model as covariates. Beyond the primary aims of the study, covariates were also examined as predictors of group membership using latent multinomial logistic regression. The "healthiest" movement behaviour profile was set as the reference group. Mplus Version 8.5 was used to compute all analyses (Muthén & Muthén, 2017), which took into account the nested structure of the data (i.e., participants attending different schools).

Results

Data Inspection

We observed a total of 36 extreme outliers (±2.5 SD) for sleep and 63 for ST. Outliers were replaced with the next highest or lowest value.

Demographics

Descriptive statistics for the sample demographic characteristics are presented in Table 1.

Estimating the Number of Latent Profiles

Model fit criteria for two- to six-profile solutions are presented in Table 2. Results of the latent profile analysis suggested a four-profile model was the best fit for the data. Although the Bayesian Information Criteria for the five- and six profile model suggested a slightly better fit for the data than the four-profile model, the adjusted Lo-Mendell-Rubin likelihood ratio test indicated these models were not a significant improvement over the four-class model.

Latent Profiles

The mean values for each movement behaviour are presented by profile in Table 3. Our results demonstrated similar patterns of sleep behaviour across the profiles; thus, adolescents were classified into four profiles characterized based on differences in MVPA and ST patterns:

Profile 1 (high MVPA/low ST) was the healthiest profile, consisting of 25.1% of the sample. These adolescents were defined by a high level of MVPA and low ST behaviour.

Profile 2 (low MVPA/low ST) was the largest profile, containing 61.6% of the sample. Adolescents in this profile were defined by a consistent pattern of low MVPA and ST levels.

Profile 3 (high MVPA/high ST) was the smallest profile, accounting for 6.5% of the sample. These adolescents were characterized by a consistent pattern of high MVPA and ST levels.

Profile 4 (low MVPA/high ST) represented 6.8% of the sample. These adolescents were characterized by a low amount of MVPA and high level of ST.

Variables Predicting Latent Profile Membership

Odds ratios demonstrating the likelihood of profile membership based on covariates compared to the high MVPA/low ST profile (Profile 1) are presented in Table 4. Relative to the high MVPA/low ST group, participants in the low MVPA/low ST group (Profile 2) and low MVPA/high ST group (Profile 4) were more than twice as likely to be female. No differences in the profiles emerged on the basis of parental education or ethnicity.

Comparison of Distal Outcomes by Latent Profile

The model-based profile means and mean differences between the profiles for flourishing, self-esteem and resiliency scores are presented in Table 5. These values were adjusted for gender, ethnicity and socioeconomic status. The results of our analysis estimating the effects of profile membership on mental wellbeing revealed the high MVPA/low ST profile was consistently associated with the most favourable scores for flourishing, self-esteem and resiliency. Specifically, findings revealed the high MVPA/low ST profile reported significantly greater flourishing, self-esteem and resiliency when compared to each of the other profiles (all p's < 0.05). The low MVPA/low ST profile was associated with significantly higher flourishing scores compared to both high ST profiles and a significantly higher resiliency score than the low MPVA/high ST profile (all $p's$ < .05). Finally, resiliency scores for the high MVPA/high ST profile were significantly greater than those in both of the low MVPA profiles (all $p's$ < .05).

Discussion

The current study was the first to use a person-centered approach to identify distinct movement behaviour profiles during late adolescence and to examine its relationship to mental wellbeing. Overall, a model with four profiles emerged, with profile characterization differences based on reported MVPA and ST. Average sleep time among each of the distinct profiles were found to be similar. Importantly, those within the healthiest profile (high MVPA and low ST) were found to report the highest levels of mental wellbeing. Conversely, those classified within the least healthy profile (low MVPA and high ST) were found to have the poorest mental wellbeing.

The results from our latent profile analysis identified four discrete classes: one healthy profile (high MVPA/low ST), two mixed behavioural profiles (low MVPA/low ST and high

MVPA/high ST), and one profile considered to be the least healthy (low MVPA and high ST). These profiles were consistent with those identified in a sample of over 6,000 adolescents in the United States (Brown et al., 2021). In fact, the distributions among the profiles were relatively similar across these studies in that the low MVPA/low ST and high MVPA/low ST were the largest and second largest profiles, respectively, whereas the profiles defined by high ST (regardless of MVPA) consisted of much smaller proportions of the samples. Similarities were also observed for predictors of profile membership; adolescents classified into the healthiest profile (high MVPA/low ST) were more likely to be male, whereas those in the unhealthiest profile (low MVPA/high ST) were more likely to be female. In the only other study to employ a person-centered approach, Carson et al. (2015) found three movement behaviour profiles among a sample of over 20,000 Canadian high school students: a healthy profile, a mixed profile and an unhealthy profile. It is worthwhile to note that their three-profile model did not identify a profile defined by low MVPA and ST, which was the largest profile observed in the present study and by Brown et al. (2021). Considering previous latent profile analyses of only physical activity and sedentary behaviours have also found four-profile solutions (which included a low MVPA/low ST profile) to be the best fit for their data (Kim et al., 2016; Liu et al., 2019), it is plausible that differences in the methodologies employed by Carson et al. (2015) may be the reasons for the variance in the number of profiles observed. Despite these subtle differences, findings across studies applying latent profile analysis to understand varying movement behaviour patterns within different populations highlight the ability for this statistical technique to identify groups that are in most need of intervention so that resources and efforts can be targeted appropriately.

It was positive to see that a quarter of the sample were classified into the “healthy” movement behaviour profile. In contrast to less than 10% of adolescents characterized as

engaging in a healthy cluster of movement behaviours based on adherence to all three threshold-based guidelines (e.g., Bang et al., 2020; Faulkner et al., 2020; Friel et al., 2020; Sampasa-Kanyinga, Chaput, et al., 2020), this is considerably higher. However, despite the 'healthiest' profile being characterized as low ST, it should be noted that their average reported ST was nearly four hours per day, which is double the amount of ST that is recommended within the 24-hour movement guidelines (Tremblay et al., 2016). This latter point notwithstanding, current findings also suggest that there was a clear dichotomy of ST behaviours with high ST users averaging approximately 12 hours of ST per day. Future research, particularly among those using person-centered approaches for understanding movement behaviours, will need more consistency in the operationalization, characterization and assessment of ST. More specificity within movement guidelines may help in this regard, as ST is becoming even more pervasive and ubiquitous across daily life. It has become increasingly difficult to tease out ST for leisure to that of school and work. It begs the question of how a person may be accounting for the short YouTube video that they watched during class time or doing homework on their computer while a TV program is on in the background.

Our findings of relatively consistent sleep patterns is in line with previous studies which have also observed relatively homogenous patterns across the emergent profiles (Brown et al., 2021; Carson et al., 2015). Of the three movement behaviours, previous research has shown the strongest associations between sleep with mental wellbeing (Faulkner et al., 2020) and psychosocial health (Carson et al., 2016), thus, future work exploring the patterning of sleep behaviours in greater detail is warranted. Our study only assessed average reported sleep time, accounting for both weekdays and weekends. There will likely be differing patterns of sleep that emerge that may not have been accounted for, which have important implications (Becker et al.,

2017; Tarokh et al., 2016; Zhang et al., 2017). For example, there may be adolescents with more consistent sleep patterns, while others may have more variable patterns such that they catch up on sleep on the weekend. Existing research has found that these sleep patterns may have important implications for mental health (Fuligni & Hardway, 2006; McHale et al., 2011; Telzer et al., 2015), therefore, accounting for these patterns of sleep may also be important when considering patterns of overall movement behaviours.

The current study makes a novel contribution to the literature by using a person-centered approach to examine the impact of movement patterns on indicators of mental wellbeing. Our results found the healthiest profile – adolescents who are highly active with lower reported ST – was consistently associated with greater flourishing, self-esteem, and resiliency. Comparatively, scores for mental wellbeing were the poorest among the unhealthiest profile (low MVPA/high ST). These findings align with results from previous studies regardless of whether adolescents have been grouped using latent profile analysis (Brown et al., 2021) or threshold-based guideline adherence (Bang et al., 2020; Carson et al., 2017; Janssen et al., 2017; Knell et al., 2019; Pearson et al., 2019; Sampasa-Kanyinga, Chaput, et al., 2020; Zhu et al., 2019). Closer inspection of our data suggests a potential dose-response relationship may exist between the number of healthy movement behaviours adolescents engage in and mental wellbeing – a result that is consistent with previous research using groups defined by threshold-based guideline adherence (Bang et al., 2020; Janssen et al., 2017). It was interesting that amongst the mixed behavioural profiles, individuals within the low MVPA and ST profile generally reported greater mental wellbeing than those with high engagement in ST and MVPA. Despite established benefits of MVPA for mental wellbeing (Rodriguez-Ayllon et al., 2019), high MVPA engagement did not appear to completely buffer the detrimental effects of high ST on mental wellbeing. Thus, when

considering how movement behaviours interact to influence mental wellbeing, these results suggest low ST engagement may confer greater beneficial effects than high MVPA. Overall findings suggest that more efforts are needed to get these adolescents in the low MVPA groups to be more active and to try and reduce ST among those that are high users to improve overall wellbeing. From a preventive health perspective, continued efforts to examine the collective impact of movement behaviours on not only mental health deficits, but also various facets of mental wellbeing are required.

Although this study was the first to use a person-centered approach to understand movement behaviours and their association with mental wellbeing among a large sample of adolescents, there are a number of notable limitations that are worthwhile to consider. First, this study was reliant on self-reported measures for each of the movement behaviours, which are prone to recall errors and social desirability biases (e.g., Turrisi et al., 2021). Second, these data were cross-sectional, precluding any causal inferences. Importantly, this was the baseline data of a longitudinal cohort study, and future work will be able to examine how patterns of these movement behaviours and indicators of mental wellbeing change over time. Third, movement behaviours were assessed in Fall/Autumn and may not reflect seasonal fluctuations in activity that are known to occur over the course of a year (Carson & Spence, 2010). Given the co-dependence of these behaviours, research into seasonal variations is warranted. Fourth, while the resiliency measure has been used in a national surveillance study (Faulkner et al., 2019), it is brief (i.e., two items) and has not yet been psychometrically validated. Fifth, our analysis treated units of time (hours/day) as absolute measures rather than considering time spent in each movement behaviour as relative proportions of a fixed 24-hour period where changes in any one behaviour are reflected by corresponding shifts in time use amongst the other behaviours. Future

studies should explore using person-centered approaches in combination with compositional data analysis techniques in order to overcome this issue. Finally, the sample consisted of adolescents who reported engagement in more MVPA than typical population-based estimates (e.g., Ronen & Janssen, 2019) and a slightly higher proportion living in a household with a parent who completed college or university, potentially limiting the generalizability to the broader Canadian population.

In conclusion, we found movement behaviour patterns in this sample of Canadians in late adolescence are best characterized by four unique profiles. The healthiest profile was consistently associated with better mental wellbeing, followed by profiles characterized by a mix of healthy and unhealthy movement behaviours, whereas those in the least healthy profile reported the lowest scores. These findings highlight the additive benefits of engaging in a full complement of healthy movement behaviours. Moving forward, behavioural interventionists should consider adopting an integrated approach to promoting mental wellbeing through targeting each of the movement behaviours concurrently.

References

Anyan, F., & Hjemdal, O. (2016). Adolescent stress and symptoms of anxiety and depression: Resilience explains and differentiates the relationships. *Journal of Affective Disorders, 203*, 213–220. https://doi.org/10.1016/j.jad.2016.05.031

Bang, F., Roberts, K., Chaput, J.-P., Goldfield, G., & Prince, S. (2020). Physical activity, screen time and sleep duration: Combined associations with psychosocial health among Canadian children and youth. *Health Reports / Statistics Canada, Canadian Centre for Health Information*, *31*, 9–16. https://doi.org/10.25318/82-003-x202000500002-eng

Becker, S. P., Sidol, C. A., Van Dyk, T. R., Epstein, J. N., & Beebe, D. W. (2017). Intraindividual variability of sleep/wake patterns in relation to child and adolescent functioning: A systematic review. *Sleep Medicine Reviews, 34*, 94–121. https://doi.org/10.1016/j.smrv.2016.07.004

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B (Methodological)*, *57*(1), 289–300.

Blakemore, S.-J. (2008). The social brain in adolescence. *Nature Reviews Neuroscience*, *9*(4), 267–277. https://doi.org/10.1038/nrn2353

Booth, M. (2000). Assessment of physical activity: An international perspective. *Research Quarterly for Exercise and Sport*, *71*(sup2), 114–120. https://doi.org/10.1080/02701367.2000.11082794

Brown, D. M. Y., Kwan, M. Y., Arbour-Nicitopoulos, K. P., & Cairney, J. (2021). Identifying patterns of movement behaviours in relation to depressive symptoms during adolescence:

A latent profile analysis approach. *Preventive Medicine*, *143*, 106352. https://doi.org/10.1016/j.ypmed.2020.106352

Carson, V., Chaput, J.-P., Janssen, I., & Tremblay, M. S. (2017). Health associations with meeting new 24-hour movement guidelines for Canadian children and youth. *Preventive Medicine*, *95*, 7–13. https://doi.org/10.1016/j.ypmed.2016.12.005

Carson, V., Faulkner, G., Sabiston, C. M., Tremblay, M. S., & Leatherdale, S. T. (2015). Patterns of movement behaviors and their association with overweight and obesity in youth. *International Journal of Public Health*, *60*(5), 551–559. https://doi.org/10.1007/s00038-015-0685-8

Carson, V., & Spence, J. C. (2010). Seasonal variation in physical activity among children and adolescents: A review. *Pediatric Exercise Science*, *22*(1), 81–92. https://doi.org/10.1123/pes.22.1.81

Carson, V., Tremblay, M. S., Chaput, J.-P., & Chastin, S. F. M. (2016). Associations between sleep duration, sedentary time, physical activity, and health indicators among Canadian children and youth using compositional analyses. *Applied Physiology, Nutrition, and Metabolism*, *41*(6 Suppl 3), S294-302. https://doi.org/10.1139/apnm-2016-0026

Casey, B. J., Jones, R. M., Levita, L., Libby, V., Pattwell, S. S., Ruberry, E. J., Soliman, F., & Somerville, L. H. (2010). The storm and stress of adolescence: Insights from human imaging and mouse genetics. *Developmental Psychobiology*, *52*(3), 225–235. https://doi.org/10.1002/dev.20447

Chaput, J.-P., Saunders, T. J., & Carson, V. (2017). Interactions between sleep, movement and other non-movement behaviours in the pathogenesis of childhood obesity. *Obesity Reviews*, *18*(S1), 7–14. https://doi.org/10.1111/obr.12508

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J. F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise, 35*(8), 1381–1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Datu, J. A. D. (2018). Flourishing is associated with higher academic achievement and engagement in Filipino undergraduate and high school students. *Journal of Happiness Studies, 19*(1), 27–39. https://doi.org/10.1007/s10902-016-9805-2

Diener, E., Wirtz, D., Tov, W., Kim-Prieto, C., Choi, D., Oishi, S., & Biswas-Diener, R. (2010). New well-being measures: Short scales to assess flourishing and positive and negative feelings. *Social Indicators Research, 97*(2), 143–156. https://doi.org/10.1007/s11205-009-9493-y

Doré, I., O'Loughlin, J., Sylvestre, M.-P., Sabiston, C. M., Beauchamp, G., Martineau, M., & Fournier, L. (2020). Not flourishing mental health is associated with higher risks of anxiety and depressive symptoms in college students. *Canadian Journal of Community Mental Health*, 1–16. https://doi.org/10.7870/cjcmh-2020-003

Faulkner, G., Ramanathan, S., Kwan, M., Arasaratnam, G., Bottorff, J., Burnett, A., Cornish, P., Dhaliwal, R., Dolf, M., Hawthorn, T., McElary, K., McGrath, R., Munn, C., Munro, C., Bowers, M., Pollard, B., Robb, J., Sanford, J., Szeto, A., … the CCWS Expert Panel Group. (2019). Developing a coordinated Canadian post-secondary surveillance system: A Delphi survey to identify measurement priorities for the Canadian Campus Wellbeing Survey (CCWS). *BMC Public Health, 19*(1), 935. https://doi.org/10.1186/s12889-019-7255-6

Faulkner, G., Weatherson, K., Patte, K., Qian, W., & Leatherdale, S. T. (2020). Are one-year changes in adherence to the 24-hour movement guidelines associated with flourishing among Canadian youth? *Preventive Medicine*, *139*, 106179. https://doi.org/10.1016/j.ypmed.2020.106179

Friel, C. P., Duran, A. T., Shechter, A., & Diaz, K. M. (2020). U.S. children meeting physical activity, screen time, and sleep guidelines. *American Journal of Preventive Medicine*, *59*(4), 513–521. https://doi.org/10.1016/j.amepre.2020.05.007

Fuligni, A. J., & Hardway, C. (2006). Daily variation in adolescents' sleep, activities, and psychological well-Being. *Journal of Research on Adolescence*, *16*(3), 353–378. https://doi.org/10.1111/j.1532-7795.2006.00498.x

Gilchrist, J. D., Battista, K., Patte, K. A., Faulkner, G., Carson, V., & Leatherdale, S. T. (2021). Effects of reallocating physical activity, sedentary behaviors, and sleep on mental health in adolescents. *Mental Health and Physical Activity*, *20*, 100380. https://doi.org/10.1016/j.mhpa.2020.100380

Guedes, D. P., Lopes, C. C., & Guedes, J. E. R. P. (2005). Reprodutibilidade e validade do Questionário Internacional de Atividade Física em adolescentes. *Revista Brasileira de Medicina do Esporte*, *11*(2), 151–158. https://doi.org/10.1590/S1517-86922005000200011

Haney, P., & Durlak, J. A. (1998). Changing self-esteem in children and adolescents: A meta-analytical review. *Journal of Clinical Child Psychology*, *27*(4), 423–433. https://doi.org/10.1207/s15374424jccp2704_6

Henriksen, I. O., Ranøyen, I., Indredavik, M. S., & Stenseng, F. (2017). The role of self-esteem in the development of psychiatric problems: A three-year prospective study in a clinical

sample of adolescents. *Child and Adolescent Psychiatry and Mental Health*, *11*(1), 68. https://doi.org/10.1186/s13034-017-0207-y

Hjemdal, O., Vogel, P. A., Solem, S., Hagen, K., & Stiles, T. C. (2011). The relationship between resilience and levels of anxiety, depression, and obsessive–compulsive symptoms in adolescents. *Clinical Psychology & Psychotherapy*, *18*(4), 314–321. https://doi.org/10.1002/cpp.719

Janssen, I., Roberts, K. C., & Thompson, W. (2017). Is adherence to the Canadian 24-Hour Movement Behaviour Guidelines for Children and Youth associated with improved indicators of physical, mental, and social health? *Applied Physiology, Nutrition, and Metabolism*, *42*(7), 725–731. https://doi.org/10.1139/apnm-2016-0681

Keyes, C. L. M. (2002). The mental health continuum: From languishing to flourishing in life. *Journal of Health and Social Behavior*, *43*(2), 207–222. JSTOR. https://doi.org/10.2307/3090197

Keyes, C. L. M. (2006). Mental health in adolescence: Is America's youth flourishing? *American Journal of Orthopsychiatry*, *76*(3), 395–402. https://doi.org/10.1037/0002-9432.76.3.395

Kim, Y., Umeda, M., Lochbaum, M., & Stegemeier, S. (2016). Physical activity, screen-based sedentary behavior, and sleep duration in adolescents: Youth Risk Behavior Survey, 2011–2013. *Preventing Chronic Disease*, *13*, E131. https://doi.org/10.5888/pcd13.160245

Knell, G., Durand, C. P., Kohl, H. W., Wu, I. H. C., & Gabriel, K. P. (2019). Prevalence and likelihood of meeting sleep, physical activity, and screen-time guidelines among US youth. *JAMA Pediatrics*, *173*(4), 387–389. https://doi.org/10.1001/jamapediatrics.2018.4847

Kwan, M. Y. W., Dutta, P., Bray, S. R., Brown, D. M. Y., Cairney, J., Dunton, G. F., Graham, J. D., Rebar, A. L., & Rhodes, R. E. (2020). Methods and design for the ADAPT study: Application of integrateD Approaches to understanding Physical activity during the Transition to emerging adulthood. *BMC Public Health*, *20*(1), 426. https://doi.org/10.1186/s12889-020-08484-0

Kwok, S. T., Wong, W. N., Kris, & Lee, T. Y. A. (2014). Effect of resilience on self-perceived stress and experiences on stress symptoms A surveillance report. *Universal Journal of Public Health*, *2*(2), 64–72. https://doi.org/10.13189/ujph.2014.020205

Liu, M., Zhang, J., Hu, E., Yang, H., Cheng, C., & Yao, S. (2019). Combined patterns of physical activity and screen-related sedentary behavior among chinese adolescents and their correlations with depression, anxiety and self-injurious behaviors. *Psychology Research and Behavior Management*, *12*, 1041–1050. https://doi.org/10.2147/PRBM.S220075

Lo, Y., Mendell, N. R., & Rubin, D. B. (2001). Testing the number of components in a normal mixture. *Biometrika*, *88*(3), 767–778. https://doi.org/10.1093/biomet/88.3.767

Masselink, M., Van Roekel, E., & Oldehinkel, A. J. (2018). Self-esteem in early adolescence as predictor of depressive symptoms in late adolescence and early adulthood: The mediating role of motivational and social factors. *Journal of Youth and Adolescence*, *47*(5), 932–946. https://doi.org/10.1007/s10964-017-0727-z

Masyn, K. E. (2013). Latent class analysis and finite mixture modeling. In *The Oxford handbook of quantitative methods: Statistical analysis, Vol. 2* (pp. 551–611). Oxford University Press.

McHale, S. M., Kim, J. Y., Kan, M., & Updegraff, K. A. (2011). Sleep in Mexican-American adolescents: Social ecological and well-being correlates. *Journal of Youth and Adolescence*, *40*(6), 666–679. https://doi.org/10.1007/s10964-010-9574-x

Merikangas, K. R., He, J., Burstein, M., Swanson, S. A., Avenevoli, S., Cui, L., Benjet, C., Georgiades, K., & Swendsen, J. (2010). Lifetime prevalence of mental disorders in US adolescents: Results from the National Comorbidity Study-Adolescent Supplement (NCS-A). *Journal of the American Academy of Child and Adolescent Psychiatry*, *49*(10), 980–989. https://doi.org/10.1016/j.jaac.2010.05.017

Moore, M., Kirchner, H. L., Drotar, D., Johnson, N., Rosen, C., & Redline, S. (2011). Correlates of adolescent sleep time and variability in sleep time: The role of individual and health related characteristics. *Sleep Medicine*, *12*(3), 239–245. https://doi.org/10.1016/j.sleep.2010.07.020

Muthén, L. K., & Muthén, B. O. (2017). *Mplus user's guide. Eighth edition*. Los Angeles, CA: Muthén & Muthén.

Nylund-Gibson, K., Grimm, R. P., & Masyn, K. E. (2019). Prediction from latent classes: A demonstration of different approaches to include distal outcomes in mixture models. *Structural Equation Modeling: A Multidisciplinary Journal*, *26*(6), 967–985. https://doi.org/10.1080/10705511.2019.1590146

Orth, U., Robins, R. W., & Roberts, B. W. (2008). Low self-esteem prospectively predicts depression in adolescence and young adulthood. *Journal of Personality and Social Psychology*, *95*(3), 695–708. https://doi.org/10.1037/0022-3514.95.3.695

Pastor, D. A., Barron, K. E., Miller, B. J., & Davis, S. L. (2007). A latent profile analysis of college students' achievement goal orientation. *Contemporary Educational Psychology*, *32*(1), 8–47. https://doi.org/10.1016/j.cedpsych.2006.10.003

Pate, R. R., Mitchell, J. A., Byun, W., & Dowda, M. (2011). Sedentary behaviour in youth. *British Journal of Sports Medicine*, *45*(11), 906–913. https://doi.org/10.1136/bjsports-2011-090192

Patte, K. A., Faulkner, G., Qian, W., Duncan, M., & Leatherdale, S. T. (2020). Are one-year changes in adherence to the 24-hour movement guidelines associated with depressive symptoms among youth? *BMC Public Health*, *20*(1), 793. https://doi.org/10.1186/s12889-020-08887-z

Paus, T., Keshavan, M., & Giedd, J. N. (2008). Why do many psychiatric disorders emerge during adolescence? *Nature Reviews Neuroscience*, *9*(12), 947–957. https://doi.org/10.1038/nrn2513

Pearson, N., Sherar, L. B., & Hamer, M. (2019). Prevalence and correlates of meeting sleep, screen-time, and physical activity guidelines among adolescents in the United Kingdom. *JAMA Pediatrics*, *173*(10), 993–994. https://doi.org/10.1001/jamapediatrics.2019.2822

Reschly, A. L., Huebner, E. S., Appleton, J. J., & Antaramian, S. (2008). Engagement as flourishing: The contribution of positive emotions and coping to adolescents' engagement at school and with learning. *Psychology in the Schools*, *45*(5), 419–431. https://doi.org/10.1002/pits.20306

Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J., Migueles, J. H., Molina-García, P., Henriksson, H., Mena-Molina, A., Martínez-Vizcaíno, V., Catena, A., Löf, M., Erickson, K. I., Lubans, D. R., Ortega, F. B., &

559 Esteban-Cornejo, I. (2019). Role of physical activity and sedentary behavior in the
560 mental health of preschoolers, children and adolescents: A systematic review and meta-
561 Analysis. *Sports Medicine*, *49*(9), 1383–1410. https://doi.org/10.1007/s40279-019-
562 01099-5
563 Ronen, G. M., & Janssen, I. (2019). Patterns of daily activity among young people with epilepsy.
564 *Developmental Medicine & Child Neurology*, *61*(12), 1386–1391.
565 https://doi.org/10.1111/dmcn.14223
566 Rosenberg, M. (1965). The measurement of self-esteem. In *Society and the Adolescent Self-*
567 *Image* (pp. 16–36). Princeton University Press; JSTOR.
568 https://doi.org/10.2307/j.ctt183pjjh.5
569 Sampasa-Kanyinga, H., Chaput, J.-P., Goldfield, G. S., Janssen, I., Wang, J., Hamilton, H. A.,
570 Ferro, M. A., & Colman, I. (2020). The Canadian 24-Hour movement guidelines and
571 psychological distress among adolescents: Les Directives canadiennes en matière de
572 mouvement sur 24 heures et la détresse psychologique chez les adolescents. *The*
573 *Canadian Journal of Psychiatry*, 0706743720970863.
574 https://doi.org/10.1177/0706743720970863
575 Sampasa-Kanyinga, H., Colman, I., Goldfield, G. S., Janssen, I., Wang, J., Podinic, I., Tremblay,
576 M. S., Saunders, T. J., Sampson, M., & Chaput, J.-P. (2020). Combinations of physical
577 activity, sedentary time, and sleep duration and their associations with depressive
578 symptoms and other mental health problems in children and adolescents: A systematic
579 review. *The International Journal of Behavioral Nutrition and Physical Activity*, *17*, 72.
580 https://doi.org/10.1186/s12966-020-00976-x

Saunders, T. J., Gray, C. E., Poitras, V. J., Chaput, J.-P., Janssen, I., Katzmarzyk, P. T., Olds, T., Connor Gorber, S., Kho, M. E., Sampson, M., Tremblay, M. S., & Carson, V. (2016). Combinations of physical activity, sedentary behaviour and sleep: Relationships with health indicators in school-aged children and youth. *Applied Physiology, Nutrition, and Metabolism*, *41*(6 (Suppl. 3)), S283–S293. https://doi.org/10.1139/apnm-2015-0626

Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics*, *6*(2), 461–464.

Skrove, M., Romundstad, P., & Indredavik, M. S. (2013). Resilience, lifestyle and symptoms of anxiety and depression in adolescence: The Young-HUNT study. *Social Psychiatry and Psychiatric Epidemiology*, *48*(3), 407–416. https://doi.org/10.1007/s00127-012-0561-2

Sterdt, E., Liersch, S., & Walter, U. (2014). Correlates of physical activity of children and adolescents: A systematic review of reviews. *Health Education Journal*, *73*(1), 72–89. https://doi.org/10.1177/0017896912469578

Tarokh, L., Saletin, J. M., & Carskadon, M. A. (2016). Sleep in adolescence: Physiology, cognition and mental health. *Neuroscience and Biobehavioral Reviews*, *70*, 182–188. https://doi.org/10.1016/j.neubiorev.2016.08.008

Telzer, E. H., Goldenberg, D., Fuligni, A. J., Lieberman, M. D., & Gálvan, A. (2015). Sleep variability in adolescence is associated with altered brain development. *Developmental Cognitive Neuroscience*, *14*, 16–22. https://doi.org/10.1016/j.dcn.2015.05.007

Tremblay, M. S., Carson, V., Chaput, J.-P., Connor Gorber, S., Dinh, T., Duggan, M., Faulkner, G., Gray, C. E., Gruber, R., Janson, K., Janssen, I., Katzmarzyk, P. T., Kho, M. E., Latimer-Cheung, A. E., LeBlanc, C., Okely, A. D., Olds, T., Pate, R. R., Phillips, A., … Zehr, L. (2016). Canadian 24-hour movement guidelines for children and youth: An

integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition, and Metabolism*, *41*(6), S311–S327. https://doi.org/10.1139/apnm-2016-0151

Turrisi, T. B., Bittel, K. M., West, A. B., Hojjatinia, S., Hojjatinia, S., Mama, S. K., Lagoa, C. M., & Conroy, D. E. (2021). Seasons, weather, and device-measured movement behaviors: A scoping review from 2006 to 2020. *International Journal of Behavioral Nutrition and Physical Activity*, *18*(1), 24. https://doi.org/10.1186/s12966-021-01091-1

Zhang, J., Paksarian, D., Lamers, F., Hickie, I. B., He, J., & Merikangas, K. R. (2017). Sleep patterns and mental health correlates in US adolescents. *The Journal of Pediatrics*, *182*, 137–143. https://doi.org/10.1016/j.jpeds.2016.11.007

Zhu, X., Haegele, J. A., & Healy, S. (2019). Movement and mental health: Behavioral correlates of anxiety and depression among children of 6–17 years old in the U.S. *Mental Health and Physical Activity*, *16*, 60–65. https://doi.org/10.1016/j.mhpa.2019.04.002

Table 1. *Demographic characteristics.*

	Total Sample (N = 1166) *n* (%)
Females	630 (54.0)
Age *M (SD)*	15.91 (0.48)
Ethnicity	
White	614 (52.7)
Middle Eastern/Arab	109 (9.3)
Black	93 (8.0)
Asian	68 (5.8)
Indigenous	23 (2.0)
Latin	53 (4.5)
Other	206 (17.7)
Parental Education	
Some secondary	149 (12.8)
Completed secondary	85 (7.3)
Some college/university	123 (10.6)
Completed college/university	809 (69.3)

Table 2. *Model fit indices.*

	2-Profile	3-Profile	4-Profile	5-Profile	6-Profile
Estimated Parameters	10	14	18	22	26
Total					
BIC	13138.47	13078.74	12919.03	12871.80	12821.11
Entropy	0.93	0.81	0.88	0.83	0.87
aLMR	385.26*	84.97	181.53*	72.89	76.23
Proportion in each profile (%)	13/87	12/25/63	6/7/25/62	6/7/21/30/36	4/4/5/21/30/35

Note: BIC = Bayesian Information Criteria; aLMR = adjusted Lo-Mendell-Rubin likelihood ratio test; * = $p < .05$.

621 Table 3. *Mean scores for each movement behaviour by profile and sample.*

	Profile 1 High MVPA/ Low ST	Profile 2 Low MVPA/ Low ST	Profile 3 High MVPA/ High ST	Profile 4 Low MVPA/ High ST
Total	(*n* = 293)	(*n* = 718)	(*n* = 76)	(*n* = 79)
MVPA (hours/day)	2.66 ± 0.02	0.83 ± 0.04	2.42 ± 0.07	0.51 ± 0.03
ST (hours/day)	3.64 ± 0.11	4.03 ± 0.06	11.85 ± 0.40	12.75 ± 0.19
Sleep (hours/day)	7.47 ± 0.10	7.25 ± 0.03	7.52 ± 0.17	7.23 ± 0.10

622 Values in the table represent the mean and standard error.

623 Table 4. *Associations between demographic variables and latent profile membership*

	Latent Profile					
	Low MVPA/Low ST		**High MVPA/High ST**		**Low MVPA/High ST**	
Variable	Odds Ratio	95% CI	Odds Ratio	95% CI	Odds Ratio	95% CI
Gender (female)	2.17*	1.76-2.67	0.90	0.48-1.72	2.71*	1.30-5.62
Parental Education (post-secondary graduate)	1.09	0.80-1.49	0.97	0.62-1.51	0.80	0.52-1.23
Ethnicity (White)	0.92	0.67-1.27	1.14	0.54-2.42	0.70	0.31-1.46

624 Reference class = High MVPA/Low ST. CI = Confidence interval. * = $p < .05$.

Table 5. *Differences between profiles for flourishing, self-esteem and resiliency.*

	Flourishing			
	Profile 1	Profile 2	Profile 3	Profile 4
Profile 1 (46.18 ± 0.83)	-	2.76**	5.16***	5.37***
Profile 2 (43.42 ± 0.42)		-	2.40**	2.61*
Profile 3 (41.02 ± 0.56)			-	0.21
Profile 4 (40.81 ± 0.72)				-
	Self-Esteem			
	Profile 1	Profile 2	Profile 3	Profile 4
Profile 1 (15.75 ± 0.28)	-	0.83**	1.14**	1.44**
Profile 2 (14.92 ± 0.16)		-	0.31	0.61
Profile 3 (14.61 ± 0.36)			-	0.30
Profile 4 (14.31 ± 0.37)				-
	Resiliency			
	Profile 1	Profile 2	Profile 3	Profile 4
Profile 1 (3.58 ± 0.04)	-	0.27**	0.05	0.42***
Profile 2 (3.31 ± 0.05)		-	-0.22*	0.15*
Profile 3 (3.53 ± 0.09)			-	0.37***
Profile 4 (3.16 ± 0.08)				-

Note: * = $p < .05$; ** = $p < .01$; *** = $p < .001$. Values in parentheses in the first column represent the mean and standard error for each respective profile. Values within the matrix represent the mean of the Profile in each column minus the mean of the Profile in each row. Higher values represent greater levels of flourishing, self-esteem and resiliency.