

Exploring social and physical contextual factors on adolescent's physical activity: An ecological momentary assessment study

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Abstract

Physical activity (PA) peaks during early adolescence followed by sharp declines. Understanding factors related to PA during adolescence will help inform strategies to attenuate such declines. We explored effects of social and physical contexts on moderate-to-vigorous intensity PA (MVPA) among adolescents using ecological momentary assessment (EMA). In Fall 2019, participants ($N=190$ adolescents; $M_{\text{age}} = 15.8 \pm 0.5$ years; 83 female; 64% White) from Southern Ontario, Canada received four EMA surveys daily after-school while wearing an accelerometer for one week. Time spent in MVPA 60-mins following each EMA prompt was calculated. A mixed-effects location scale model estimated each person's mean MVPA and MVPA variance at between-person and within-person levels. Results showed a statistically significant within-person interaction between social and physical context such that the fewest MVPA minutes occurred after participants reported being alone and at home, whereas the highest amount of MVPA occurred after reports of being away from home and alone. There was a statistically significant within-person effect of physical context on within-person variance suggesting more consistent patterns of activity when participants reported being at home relative to when they were away from home. Gender was a statistically significant covariate in the mean and within-person models. This study aligns with prior literature examining socio-environmental factors related to PA during adolescence and is among the first to examine associations between contextual factors and variability in MVPA.

Keywords: exercise, experience sampling methods; youth; MixWILD; variability.

Introduction

Current guidelines recommend children and adolescents between the ages of 5 and 17 engage in at least 60 minutes of moderate to vigorous physical activity (MVPA) each day in addition to several hours of light physical activity (PA) daily for disease prevention and health promotion (Bull et al., 2020; Tremblay et al., 2016). Despite strong associations between physical inactivity and increased risk of several chronic diseases and mortality from multiple causes (Warburton et al., 2006), global estimates suggest 81% of adolescents aged 11-17 years are insufficiently physically active (Guthold et al., 2018). Furthermore, despite already low levels of PA among adolescence, evidence suggests PA declines during the adolescent years by an average rate of 7% per year (Dumith et al., 2011). It has been argued that interventions aiming to stave off these declines in PA during the adolescent years have the potential for a “*triple benefit*” (van Sluijs et al., 2021) by promoting overall health and wellbeing in the present, into adulthood, and for future generations. Thus, identifying factors that influence MVPA within the natural day-to-day lives of adolescents is necessary to promote greater engagement in PA for sustained health and well-being across their lifespan.

Longitudinal studies have consistently shown decreases in energy expenditure and weekly sessions of MVPA across the youth period (Gordon-Larsen et al., 2004; Kwan et al., 2012; Stearns et al., 2022); however, these results are often based on self-reported surveys administered at different timepoints estimating cross-sectional changes in MVPA, and do not account for dynamic changes in MVPA on a smaller time scale such as the within-day level. Understanding within-day changes in MVPA will help refine existing behavioral theories and inform the development of dynamic interventions that can adapt to an individual’s changing context and needs throughout a day. In addition, cross-sectional designs cannot provide insight

into the contextual factors (i.e., where a person is currently located and who they are currently with) that are related to adolescents' engagement in MVPA. Ecological momentary assessment (EMA) represents a data capture methodology that addresses these limitations, measuring people's experiences and behaviours in real-time and in their natural environments through repeated assessments (Reis, 2012; Shiffman et al., 2008). By administering brief surveys to people's personal electronic devices requesting immediate responses, EMA allows for the evaluation of associations between psychological and contextual experiences with behaviour in people's natural environments.

While EMA offers a method to capture real-time determinants of PA, socioecological frameworks provide a structured approach to categorizing these predictors across multiple levels ranging from the individual level to public policy (Bronfenbrenner, 1979; McLeroy et al., 1988; Sallis et al., 2006). For example, the ecological model suggests human development is shaped by influences and interactions between the individual and their environment over time (Bronfenbrenner, 1979, 1994). Specifically, levels of influences include one's immediate environment including family and peers (i.e., microsystem), connections between microsystems such as one's home and school (i.e., mesosystem), processes between two or more environments external to the individual such as one's extended family (i.e., exosystems), social and cultural influences (i.e., macrosystems), and changes or consistencies over time to the person and their environment (i.e., chronosystems).

The model proposed by Sallis and colleagues (2006) hypothesizes that influences from various environments and policies uniquely affect behaviour within the active living domains of recreation, occupation, household, and transport. This includes influences from the perceived environment (e.g., safety, accessibility), natural environment (e.g., weather), social cultural

environment (e.g., social support, social norms), information environment (news, mass media), and policy environment (e.g., the built environment, incentives). More broadly, socioecological models can be classified based on influences at intrapersonal (e.g., personal characteristics, attitudes), interpersonal (e.g., formal and informal social networks), environmental (e.g., natural environment and sociocultural environment), institutional/organizational (e.g., social institutions with shared characteristics), and policy (e.g., local, national) levels. Previous research examining intrapersonal-level factors and PA using EMA shows factors such as affect and motivation predict within-day PA among adolescents. For example, Cushing and colleagues (2018) found that during moments in the day when adolescents reported greater negative affect, they engaged in fewer minutes of MVPA in the subsequent 30 minutes. In addition, reporting higher motivation than one's average level was associated with engaging in more MVPA in the subsequent 60 minutes (Harris et al., 2024).

In addition to examining dynamic fluctuations at the intrapersonal level predicting PA in real time, EMA is also ideal to assess the constantly changing socio-environmental contexts for which a person is situated on a day-to-day basis consistent with socioecological frameworks. Specifically, contextual factors may include both social context referring to the people that are around a person at a given moment in time (e.g., by themselves, with family, with friends, etc.) and physical context which refers to the physical location of a person (e.g., at home, at school, at a restaurant, etc.). Prior work investigating the role of physical and social context and PA behaviors using EMA demonstrates greater engagement in PA when children and youth report being outdoors and in the company of others such as family and friends (Bourke et al., 2022; Dunton et al., 2007; Dunton et al., 2011; Dunton et al., 2012), while being at home has been shown to be associated with greater sedentary behavior (Bejarano et al., 2019). Furthermore, a

recent review exploring the role of contextual factors on PA in various age groups found being in the presence of others and being outdoors are associated with increased PA (Papini et al., 2023). In addition to EMA methodologies, studies have leveraged Global Positioning System (GPS) data for device-assessed physical location and showed positive associations between time spent outdoors and MVPA (Klinker et al., 2014; Pearce et al., 2014). Furthermore, Pearce and colleagues (2014) found that time spent outdoors with friends was associated with MVPA among children and time spent outdoors with siblings was also associated with MVPA in girls. These studies provide evidence of associations between both social and physical contexts with PA.

An additional opportunity with EMA methods is the examination of intraindividual variability within the context of MVPA. The study of intraindividual variability has been a growing area of interest within psychological research, recognizing the importance of understanding dynamic patterns of behaviour beyond static averages (Bolger et al., 2003; Nesselroade, 2004). Notably, it has been argued that between-person differences in variability have been neglected in psychology research and analyses examining within-person variability are required for a comprehensive understanding intensive longitudinal data (Bolger et al., 2003). Typically, data analysis methods have treated the within- and between-person variability as homogeneous across participants (Hedeker et al., 2008), despite EMA data being able to capture important differences in variability, yielding potentially new insights.

For example, research examining intraindividual variability in the context of PA has shown variability in affective states are associated with same-day levels of PA such that beyond one's mean affect, greater variability in positive-activated affect and lower variability in negative-deactivated affect were associated with engaging in greater same-day PA (Do et al., 2024). Thus, as an extension of traditional approaches modelling mean levels of an outcome,

repeated assessments from intensive longitudinal data further allow for the examination of between-person and within-person variances to identify unique correlates of behavior (Hedeker et al., 2008; Dzubur et al., 2020).

As described above, previous studies have examined the effects of socio-environmental contexts on subsequent MVPA, however, little research has explored the impact of these factors as it relates to between-person and within-person variance in acute PA behaviours. Specifically, it remains unclear how physical or social contexts not only affect overall levels of PA, but also the heterogeneity/homogeneity at the between-person level and consistency/erraticism of adolescents' MVPA at the within-person level. Between-person variance assesses how adolescents differ in their mean MVPA based on contexts (e.g., whether adolescents engage in similar mean MVPA when alone relative to when they are with others). Within-person variance assesses whether an adolescent's MVPA is more consistent in certain contexts relative to their own behaviour in other contexts (e.g., whether an adolescent is consistently inactive at home relative to occasions when they are away from home). Thus, in addition to examining real-time predictors of mean PA levels, further examination of between- and within-person variances may offer important insights on PA promotion and intervention development. Specifically, patterns of variability may help identify contextual influences on behaviour as meaningful targets for both population-level as well as individual-level interventions.

For example, between-person differences in variance may show adolescents are more similar to each other with their PA engagement in certain contexts but more dissimilar or heterogeneous in other contexts. In contexts with high between-person variance where some adolescents are highly active while others are minimally active, this may highlight the need for intervention approaches targeting the less active subgroups to reduce between-person variance.

In contrast, understanding within-person variance may help identify contexts in which individuals are consistently active versus contexts in which MVPA is less stable. For adolescents with high overall MVPA but high within-person variance, interventions may focus on extending patterns from more active contexts to less active ones to reduce within-person variance and promote more consistency in MVPA.

Therefore, the purpose of the present study is to examine the role of social (i.e., alone vs. with others) and physical (i.e., home vs. not home) context on mean MVPA, between-person variance in MVPA and within-person variance in MVPA among adolescents using EMA. Consistent with a systematic review of empirical EMA studies in populations across the lifespan (Papini et al., 2023), it was hypothesized that being with others (i.e., not alone) and being away from home would be associated with greater MVPA. As no literature to date has been reported on associations between context variables and between- or within-person variance in MVPA, these analyses were exploratory and no specific hypotheses were specified.

Methods

Transparency and Openness

We provide full transparency regarding our sample size rationale, inclusion criteria, and study procedures. The design and data collection protocol for this study align with a previously published protocol paper (citation to be added post-peer review). Additionally, the study team has a publication with some data from this research (MVPA) as part of a previous project (citation to be added post-peer review). The research aims differ as the previous publications examined psychosocial factors as it relates to acute MVPA and the contextual variables utilized for this study have not been previously examined. Data, code, and study instruments are available upon reasonable request.

Overview

This study draws on baseline data from a subsample of the *Application of integrated Approaches to understanding Physical activity during the Transition to emerging adulthood* (ADAPT) study, a four-year longitudinal cohort study following youth through their final two years of high school and the initial years of emerging adulthood (citation to be added post-peer review). The current study provides a novel contribution by focusing specifically on contextual predictors of daily life MVPA.

Participants

Participants included a subset of 190 adolescents ($M_{\text{age}} = 15.76$, $SD = 0.47$) from a larger cohort participating in baseline assessment of an intensive sub-study, involving device-assessed physical activity measurement and EMA. Recruitment was conducted in partnership with a publicly funded school board in Southern Ontario, whereby students enrolled in a select grade 11 English classes (mandatory for all students) were invited to participate in this data intensive sub-study. This a priori recruitment strategy was guided by pragmatic considerations, including the typical class size and the limited number of accelerometers available during the rolling recruitment period. The design aimed to ensure adequate statistical power for multilevel modeling by targeting repeated assessments within individuals as participants were expected to receive 28 after-school EMA prompts over a 7-day period, and power calculations assumed a 50% response rate. Due to resource constraints, the same sample was used for the mixed-effects location-scale analyses. However, simulation studies indicate that approximately 80% power ($\alpha = .05$) to detect small-to-moderate effects in intra-individual variability have been observed with level 2 sample sizes around 80 and moderate numbers of repeated observations per person (Walters et al., 2018). This level of data density was anticipated to provide sufficient

within- and between-person variability to reliably estimate effects in intensive longitudinal models.

Study Procedures

In brief, students within the select classes agreeing to participate in the study were provided with a study package that included a wrist-worn accelerometer (ActiGraph GT9X) and a personalized login for a custom-built EMA smartphone app (Lumedi EMA; Webility Solutions Inc., 2019). The one-week data collection period took place between the months of September and November. Participants were instructed to wear the device for one week, excluding periods involving water-based activities, and to respond to EMA prompts throughout the day. Prompts were delivered at randomized times within predefined time windows – including one sent in the morning prior to school times, and four across the after-school afternoon (i.e., 3:30pm – 4:30pm and 5:00pm – 6:00pm) and evening (i.e., 6:30pm – 7:30pm and 8:00pm – 9:00pm) periods. Only data from the after-school EMA prompts were used in the current analysis due to poor compliance in the before-school EMA prompt. Each EMA survey contained brief questionnaires designed to be completed within two minutes, and participants could respond for up to 30 minutes following each initial prompt sent. To compensate for high participant burden, students received a \$100 gift card for participating. This study was approved by both the university and the school board’s ethics committees.

Measures

Socio-demographic factors. Participants provided sociodemographic information including age, gender, ethnicity, and highest level of parental/caregiver education when completing questionnaires during class time.

Contextual factors. Social context and physical context were assessed using a single item each. Participants were asked who they were currently with at the time of the prompt. Response options included: by themselves, with friend(s), with family, with classmate(s), with boyfriend/girlfriend. Participants were also asked where they currently were at the time of the prompt. Response options included: home, school, outside, café/restaurant, in transportation, other.

Moderate-to-vigorous physical activity. Moderate-to-vigorous physical activity was assessed using the ActiGraph GT9X Link accelerometer. Participants were given the accelerometer to wear on their non-dominant wrist for seven consecutive days and asked to wear the accelerometer as much as possible (including during their sleep). Participants were instructed to remove the accelerometer during water-based activities including showering. Wear time was calculated through CentrePoint (V3) using the Troiano et al. (2008) wear time validation parameters. Using validated wrist cut points for the GT9X device, vector-magnitude counts per minute > 5858 were categorized as MVPA (Rhudy et al., 2020). Accelerometer data were analyzed in 60s epochs, and only observations with non-zero wear time data for the 60 minutes immediately after the EMA prompt were analyzed (i.e., observations with 0 minutes of wear time were considered non-valid and excluded from analysis).

Data Preparation and Analysis

Descriptive statistics and preliminary analyses were conducted using STATA version 18.0. To aid interpretation, participant age was mean-centered. Analyses were restricted to after-school EMA responses with non-zero accelerometer wear time in the 60-minutes post-EMA survey. Observations from participants with less than five valid EMA entries were excluded due to insufficient variability for modeling. After removing observations with accelerometer non-

wear, the distribution of MVPA in the 60-minute window post-survey prompt was positively skewed (skewness = 1.61; kurtosis = 5.66; see Supplemental Material 1 for distribution of MVPA). A square-root transformation ($\sqrt{[MVPA + 1]}$) was applied (skewness = .69; kurtosis = 2.89). Frequencies were computed for both social and physical contexts reported at the EMA prompts.

To examine both the average levels and the within-person fluctuations in MVPA, we applied a Mixed-Effects Location Scale (MELS) model using MixWILD software (Dzubur et al., 2020). This modeling strategy allows for simultaneous estimation of fixed effects and variance components at the between-person and within-person levels. Contextual EMA predictors were decomposed into their respective between-person (BP) and within-person (WP) components, following established multilevel centering techniques (Curran & Bauer, 2011). Specifically, individual-level means were calculated to represent BP differences, while WP scores were derived by subtracting these means from each prompt-level score. R^2 measures for the MELS model were estimated using the R package, *r2mels* (Shaw et al., 2023; Zang & Hedeker, 2022). Age, gender, and time of day were included as covariates, and all statistical significance tests used an alpha threshold of 0.05.

Results

Descriptive Statistics

Descriptive statistics using Year 1 of the ADAPT dataset are previously reported (citation to be added post-peer review). One hundred and ninety youth had valid accelerometry data and answered a minimum of one EMA prompt during the study period. The majority of participants identified as White (63.64%) and resided with a parent who completed college or university (73.54%). There were a few more boys (53.72%) than there were girls (44.15%) in the study

sample. Fifty-two percent of participants indicated engaging in organized sport. Full demographic characteristics are reported in Table 1 (citation to be added post-peer review). Overall, this was an active sample based on the accelerometer cut-points used (MVPA = 593.9, SD = 394.9 minutes within the week). The mean compliance to afternoon prompts was 49.9%. Seventeen percent of participants responded to at least 75% of EMA prompts and 54% responded to at least 50% of EMA prompts.

Participants most frequently reported being by themselves ($M = 48\%$; $SD = 27\%$, min = 0%, max = 100%), followed by with family (32%) and with friends (15%). Regarding physical context, participants most frequently reported being at home ($M = 79\%$; $SD = 19\%$, min = 14%, max = 100%) and the remaining categories were reported in < 7% of observations each. On average, participants engaged in 9 minutes (SD = 5, min = .1, max = 23) of MVPA within the 60-minutes following EMA prompts. Given challenges with interpreting results from unbalanced proportions (Yaremych et al., 2023), social context was re-coded as not alone and alone (coded as 0 and 1, respectively). Similarly, physical context was re-coded as not home and home (coded as 0 and 1, respectively). On average, participants were at home 79% of the time (SD = 19%, min = 14%, max = 100%) and alone 48% of the time (SD = 27%, min = 0%, max = 100%).

Data Availability

Of the 190 participants, there were a total of 2,655 completed EMA prompts during the after-school period (50% of all prompts). On average, accelerometer wear time was 46.12 minutes (SD = 25.18 minutes) in the 60-minute epoch following EMA surveys. Five hundred and five surveys were removed for accelerometer non-wear, and an additional 5 observations were excluded as wear-time was not available. Seventy-seven observations were removed from

participants with valid data for less than five EMA prompts and thus, limited variability to model. Twenty-five observations from two participant were excluded from analyses as age was missing (See Supplemental Material 2 for sensitivity analysis excluding age and gender). Four observations were excluded for missing physical and/or social context leaving a final sample including 2,039 observations from 152 participants who responded to at least five prompts with non-zero wear-time in the 60-minute epoch following the prompt.

Primary Analyses

Model coefficients are presented in Table 2. Results from the mean model revealed a significant WP effect of physical context on acute MVPA levels (estimate = -0.82, $p < .001$) which was superseded by a significant interaction between social and physical contexts at the WP level (estimate = -0.75, $p < .001$). To decompose this interaction, we conducted simple effects analyses using the *margins* command in Stata to examine WP associations between social and physical contexts and MVPA. Estimates suggest that within adolescents, being at home was associated with fewer MVPA minutes relative to being away from home for the same individual when they were with others (estimate = -0.83, SE = .08, $p < .001$). This negative effect of being at home was stronger when adolescents reported being alone (estimate = -1.72, SE = 0.23, $p < .001$). The effect of social context showed that within individuals, being alone versus with others was not significantly associated with MVPA when adolescents reported being away from home (estimate = -0.09, SE = 0.07, $p = .20$). In contrast, when adolescents were at home, being alone was associated with engaging in fewer minutes of MVPA (estimate = -0.97, SE = 0.19, $p < .001$).

Together, these results indicate that the reduction in MVPA associated with being at home is amplified within individuals when they are alone, and being alone predicts lower MVPA only when adolescents are at home. To aid in interpretation of square-root transformed MVPA data,

predicted values in each category were squared to estimate minutes. Based on model-predicted values from the simple effects analysis, at the within-person level, the least amount of MVPA was estimated in the 60-min epoch after adolescents reported being at home and alone (around 1 minute), whereas the greatest amount of MVPA was estimated after reports of being away from home and with others (around 8 minutes).

Social context was unrelated to the mean levels of MVPA at the WP and BP levels ($ps > .19$). There was a significant effect of gender (estimate = 0.39, $p < .001$), suggesting that girls had higher mean levels of MVPA compared to boys, and a significant effect of time of day (estimate = -0.12, $p < .001$), suggesting that MVPA was lower following prompts later in the day. Age was not a significant covariate ($p = .43$).

Results from the submodel examining the association between physical and social context on between-person variance in acute MVPA found no significant differences based on physical context ($ps > .06$), social context ($ps > .24$), or their interactions ($ps > .36$). Age, gender, and time of day were not significant ($ps > .59$).

Results from the submodel assessing within-person variability in acute MVPA revealed a significant WP effect of physical location (estimate = -0.57, $p < .001$), suggesting lower within-person variance of MVPA during observations when participants reported being at home, compared to observations when they reported being away from home. Exponentiating this coefficient indicates that within-person variance was approximately 43% lower when participants reported being home relative to not at home (variance ratio = 0.57, 95% C.I. = 0.46, 0.70). In other words, adolescents were more consistent with their MVPA behavior. There was a significant effect of gender (estimate = 0.22, $p = .01$, variance ratio = 1.24, 95% C.I. = 1.04, 1.48), suggesting that girls had greater WP variability in MVPA (i.e., less consistent MVPA)

compared to boys. There was a significant effect of time of day (estimate = -0.08, $p = .008$, variance ratio = 0.92, 95% C.I. = 0.86, 0.98) indicating that for a given individual, within-person variance decreased following prompts later in the day relative to earlier prompts. The BP effect of physical location ($p = .49$), BP and WP effects of social context ($ps > .36$), and the interactions between physical and social context ($ps > .06$) and age ($p = .64$) on within-person variance were non-significant.

Results from *r2mels* indicated that the MELS location (mean) submodel explained 11.4% of the total variance in mean MVPA. Variance decomposition revealed 5.6% of the total variance in mean MVPA is explained by within-person fixed effects (e.g., physical and social contexts), 1.5% of the variance in mean MVPA is explained by between-person fixed effects (e.g., gender), and 4.3% of the variance in mean MVPA is explained by between-person differences at baseline. The scale submodel explained 8.7% of the within-person variance in MVPA.

Discussion

The present study investigated the role of physical and social context on acute MVPA in real-time. Results from the mean model showed a statistically significant WP interaction between physical and social context on mean MVPA suggesting that the combination of social and physical context jointly influence momentary physical activity. Results suggest that within-person variability was lower when a person was at home relative to when they were not at home, such that adolescents were found to have more consistent patterns of MVPA when at home compared to other contexts. Neither social context, nor the interaction between social and physical contexts were statistically significantly associated with variability at the between-person or within-person levels.

Overall, study results are in partial alignment with previous work demonstrating external factors such as physical location are associated with acute PA behaviours among adolescents. The statistically significant WP interaction effect of physical and social context on MVPA suggest a combined influence of both environmental factors on subsequent MVPA among adolescents. Specifically, adolescents engaged in the fewest minutes of MVPA in the 60 minutes following the survey prompts when they reported being both alone and at home, whereas MVPA was greatest when they were alone and away from home. Findings are consistent with prior work showing that adolescents engage in greater sedentary behaviour when indoors at home (Bejarano et al., 2019; Kracht et al., 2021). It is worth noting that although investigations into physical contexts most frequently compare outside vs. inside contexts (Papini et al., 2023), only 3% of observations in the present study were reported as being outside, preventing us from making similar comparisons. Since indoor contexts may include a combination of home, libraries, and recreational facilities among other settings, this study provides a valuable contribution to the literature by demonstrating the independent influence of the home context, specifically, on MVPA. Results from variance decomposition of effect sizes suggest that physical and social contexts explained substantially more within-person variability in MVPA than between-person differences, highlighting the importance of one's context in shaping adolescents' MVPA.

While no main effect of social context on mean MVPA was observed, the statistically significant WP interaction shows a combined influence of social and physical context on mean MVPA. Consistent with prior studies demonstrating greater engagement in PA when people are in the presence of others such as friends and family (Papini et al., 2023), results from the present study suggest that the greatest engagement in MVPA occurred within the 60-minutes after participants reported being away from home and with others. The absence of a main effect of

social context on mean MVPA may be due to differences in PA intensity between studies such that the present study examined MVPA whereas associations previously reported are often with lower-intensity PA. For example, Bohnert and colleagues (2013) found that adolescents that spent a greater percentage of non-school hours with siblings were more likely to engage in light intensity PA. Similarly, Dunton and colleagues (2012) found that being in the presence of others rather than alone was associated with greater steps, however, no association was observed between social context and MVPA. Furthermore, in the present study, the most frequently reported social context after being alone was with family (32%) with prior work demonstrating adolescents were more likely to have engaged in sedentary activity in the time following a prompt when with parents (Bohnert et al., 2013) which may further explain the non-significant main-effect of social context on mean MVPA.

Results from the between-person variance submodel showed no significant main or interactive effects of physical or social context on MVPA. In other words, differences in how often adolescents were at home, away from home, alone, or with others did not explain variability in acute MVPA between adolescents. The within-person variance submodel, however, suggests that there was statistically significantly less variability in acute MVPA behaviours when adolescents reported being at home. Combined with results from the mean submodel, these results indicate a pattern of consistent inactivity when adolescents report being at home, indicating that the home environment may not afford children as many opportunities to engage in MVPA as external environments.

The statistically significant and negative WP effect of physical context on within-person variance demonstrates that within-person variance decreased when an adolescent reported being at home, relative to when they are away from home. In other words, relative to when they are

away from home, adolescents are more consistent in their MVPA when at home and showed greater moment-to-moment variability in MVPA after reporting being away from home. This result is not unexpected given the many different contexts that they could have been in away from home (e.g., at a café/restaurant, library, outdoors). In some of these settings (e.g., outdoors), adolescents may be more likely to be active such as during active play or transport, or engaging in organized sports, while in other settings they are more likely to be engaged in sedentary activities such as studying or socializing at a café or library. These contextual patterns appear to be similar among our broader adolescent population. Notably, results from the scale model indicated that contextual factors explained approximately 9% of the within-person variability in MVPA. This suggests that beyond mean-level effects, contextual factors help explain differences in the consistency of adolescents' MVPA within a week. This finding is practically relevant considering the cumulative benefits of physical activity on health and well-being over time. Results suggest adolescents' social and physical environments influence not only how active adolescents are but how much their MVPA fluctuates within a week.

Several strengths and limitations of the study are worthwhile to note to help inform future directions. First, the use of location scale modelling should be viewed as a strength as it allows for the examination of new research questions by modeling the variability of data beyond the mean levels to advance the field. For example, results from the present study hold important practical importance for potential targets of interventions aimed to increase MVPA in adolescents. Specifically, the home context was found to be a context of consistently low levels of activity in adolescence, which requires further investigation to understand barriers and facilitators to engaging in home-based MVPA. Use of real-time data capture methods including EMA and device-assessed MVPA should also be considered a strength of the present study.

However, there are several limitations to consider. First, examining associations between contextual factors and MVPA in isolation of light-intensity PA and sedentary behaviour may be considered a limitation as it may not fully represent the complex interactions between different movement behaviours. Using compositional data analysis, Bourke and colleagues (2022) found adolescents replaced sedentary behaviors with MVPA when in outdoor contexts and replaced sedentary behavior with light-intensity PA when with others. Thus, it is possible that examining MVPA in isolation may not adequately capture the complexities of movement behaviours within a day. Considering the interdependence of movement behaviours, future research should explore trade-offs between one movement behaviour for another. Second, the quality of social and physical contexts was not assessed. Regarding quality of social environments, Arigo and colleagues (2023) showed that at times when participants experienced more pleasant interactions, their motivation to engage in PA was higher, whereas when they experienced more unpleasant interactions than usual, their motivation to engage in PA was lower. Additional features of the quality of social contexts may include one's familiarity with and perceived importance of the people they are interacting with (Vogel et al., 2017). Despite physical context being associated with MVPA, we did not assess factors such as the current weather, neighbourhood safety, or built environment, which may help better understand the impact of external contextual factors on behaviour. Future work should consider assessing the impact of perceived quality of various contexts on MVPA in an adolescent population. Finally, compliance of EMA was modest in the current study, which poses a threat to validity. Ambulatory assessment literature has demonstrated that compliance is influenced by both person-level (e.g., individual motivation, competing demands) and contextual factors (e.g., time of day, social environment), meaning that missingness is unlikely to be missing completely at random, but instead may be missing

conditionally at random (Baldwin et al., 2016; Estabrook et al., 2012; Lin et al., 2018; Wang & Grimm, 2012). This has important implications for interpreting results, as patterns of nonresponse could systematically bias estimates of within- and between-person variance. Future research that aims to improve compliance among participants recruited is needed.

The present study aligns with theorizing that behaviour is influenced by independent and interactive influences across multiple levels as outlined by socioecological frameworks (Bronfenbrenner, 1979; McLeroy et al., 1988). Specifically, the main effect of physical context on within-person variability in MVPA suggests independent influences from the organizational level, encompassing one's physical environment. In addition, the interactive effect between physical and social context on average MVPA highlights the combined influence of factors at interpersonal and organizational levels on adolescents' behavior. Future research should continue to examine interactions between levels of socioecological frameworks to provide a more comprehensive understanding of behavior in real-time by leveraging real-time data capture methods such as EMA to assess interactive effects between current psychological states and physical or social environments.

Overall, this study examined associations between physical and social contexts with MVPA in adolescents. Results showed participants engaged in the fewest minutes of MVPA after reports of being alone and at home, and the highest amounts of MVPA occurred following reports of being away from home and alone. At the within-person level, findings show that MVPA among adolescents was more consistent after adolescents reported being at home relative to after times when they were not-at home which may reflect consistent patterns of physical inactivity/low activity when home. Findings demonstrate the utility of novel statistical

496 approaches to model variability and suggest the home context may be a valuable opportunity to
497 target MVPA among adolescents.

498

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662

663 *Table 1. Descriptive statistics for study participants (N = 190).*

	Mean (SD)
Age	15.76 (.47)
Weekly moderate-to-vigorous intensity physical activity	593.92 (394.92)
	n (%)
Grade	
10	1 (.53%)
11	186 (98.94%)
12	1 (.53%)
Gender	
Male	101 (53.72%)
Female	83 (44.15%)
Prefer not to answer	4 (2.13%)
Ethnicity	
Aboriginal People of Canada	5 (3.03%)
Indigenous (Outside of Canada)	1 (0.61%)
Arab	7 (4.24%)
Black	5 (3.03%)
Chinese	1 (0.61%)
Filipino	7 (4.24%)
Korean	1 (0.61%)
Latin, Central, or South American	4 (2.42%)
South Asian	4 (2.42%)

Southeast Asian	1 (0.61%)
West Asian	1 (0.61%)
White	105 (63.64%)
None of the above	23 (13.94%)
Parental education	
Some Secondary	18 (11.04%)
Completed Secondary	11 (6.75%)
Some College	6 (3.68%)
College	55 (33.74%)
Some University	8 (4.91%)
Completed University	65 (39.88%)
Participation in organized sport	
Yes	83 (51.88%)
No	76 (47.50%)
Prefer not to answer	1 (0.62%)

Note. Reprinted from [details to be added post-peer review], licensed under CC BY-NC 4.0 (<https://creativecommons.org/licenses/by-nc/4.0/>). *M* = mean, *SD* = standard deviation. Age was missing for 4 participants. Grade was missing for 2 participants. Gender was missing for 2 participants. Ethnicity was missing from 25 participants. Ethnicity was dichotomized as White and Non-White in analyses. Parental education was missing from 27 participants. Participation in organized sport was missing from 30 participants.

671 *Table 2. Physical and social context predicting acute moderate-to-vigorous physical activity*
 672 *(MVPA).*

		Estimate (Standard Error)	<i>p</i>
<hr/>			
Predictors of Mean Level of Acute PA (beta)			
Alone	BP effect	-0.53 (1.59)	.74
	WP effect	-0.09 (0.07)	.20
Home	BP effect	-1.62 (0.96)	.09
	WP effect	-0.82 (0.10)	< .001
BP alone * BP home		0.69 (1.77)	.70
WP alone * WP home		-0.75 (0.21)	< .001
Age		-0.09 (0.11)	.43
Gender		0.39 (0.10)	< .001
Time of day		-0.12 (0.02)	< .001
Intercept		4.13 (0.84)	< .001
Predictors of BP Variability in Acute PA (alpha)			
Alone	BP effect	-2.29 (2.73)	.40
<hr/>			

	WP effect	-0.41 (0.35)	.25
	BP effect	-3.12 (1.75)	.07
Home	WP effect	-0.19 (0.56)	.73
	BP alone * BP home	2.58 (3.33)	.44
	WP alone * WP home	-0.91 (1.00)	.36
Age		.20 (0.37)	.59
Gender		-0.05 (0.36)	.90
Time of day		-0.05 (0.12)	.68
Intercept		1.40 (1.35)	.30
Predictors of WP Variability in Acute PA (tau)			
	BP effect	0.68 (0.85)	.43
Alone	WP effect	0.08 (0.09)	.36
	BP effect	-0.34 (0.49)	.49
Home	WP effect	-0.57 (0.11)	< .001
	BP alone * BP home	-0.70 (0.98)	.47
	WP alone * WP home	-0.39 (0.21)	.07
Age		-0.05 (0.10)	.64

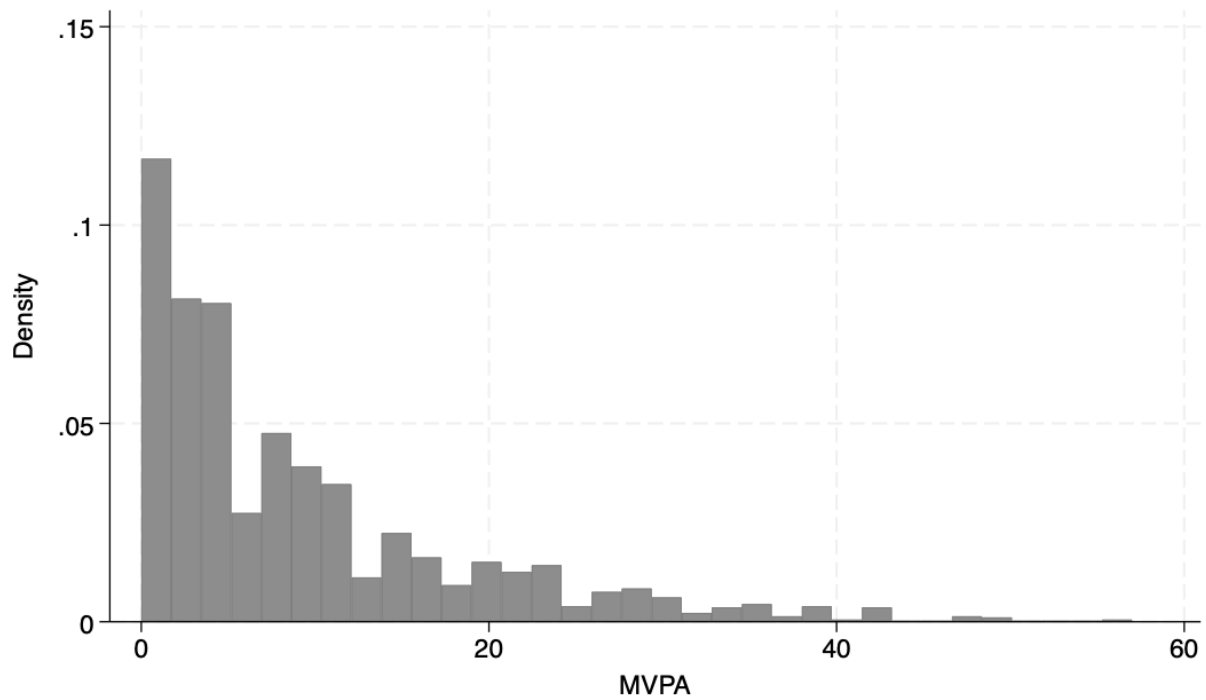
Gender	0.22 (0.09)	.01
Time of day	-0.08 (0.03)	.008
Intercept	0.59 (0.41)	.15

673 Note: BP = between-person. WP = within-person. Level 2 N = 152, Level 1 N = 2039.

674

675 **Figure S1.**

676 *Distribution of Physical Activity Minutes Within 60-Minute Epochs*



677

678

679

680 *Table S1. Physical and social context predicting acute moderate-to-vigorous physical activity*
 681 *(MVPA).*

		Estimate (Standard Error)	<i>p</i>
<hr/>			
Predictors of Mean Level of Acute PA (beta)			
Alone	BP effect	-0.90 (1.64)	.58
	WP effect	-0.10 (0.07)	.16
Home	BP effect	-1.71 (1.02)	.09
	WP effect	-0.80 (0.10)	< .001
BP alone * BP home		1.06 (1.85)	.57
WP alone * WP home		-0.73 (0.21)	< .001
Time of day		-0.12 (0.02)	<.001
Intercept		4.42 (0.88)	<.001
Predictors of BP Variability in Acute PA (alpha)			
Alone	BP effect	-2.64 (2.60)	.31
	WP effect	-0.40 (0.30)	.18
Home	BP effect	-2.36 (1.59)	.14
<hr/>			

	WP effect	0.05 (0.54)	.92
BP alone * BP home		2.72 (3.16)	.39
WP alone * WP home		-0.64 (0.93)	.49
Time of day		-0.02 (0.10)	.87
Intercept		1.03 (1.25)	.41
Predictors of WP Variability in Acute PA (tau)			
Alone	BP effect	0.49 (0.89)	.58
	WP effect	0.08 (0.09)	.36
Home	BP effect	-0.46 (0.52)	.37
	WP effect	-0.58 (0.10)	< .001
BP alone * BP home		-0.48 (1.02)	.64
WP alone * WP home		-0.40 (0.21)	.05
Time of day		-0.08 (0.03)	.008
Intercept		0.80 (0.43)	.06

682 Note: BP = between-person. WP = within-person. Level 2 N = 154, Level 1 N = 2064.