Accelerometer-based physical activity in need satisfaction profiles of schoolchildren – A three-year follow-up

Abstract

This study examined moderate-to-vigorous physical activity (MVPA) trends in physical education (PE) classes and beyond school hours in children's need satisfaction profiles over three years. Participants were 445 (girls 256, boys 189) Finnish schoolchildren (M_{age} = 11.26 ± .32 years). Need satisfaction self-reports and accelerometer-based MVPA data were collected in 17 comprehensive schools over four assessment phases. Four latent profiles based on the need satisfaction trends over time were found: Profiles with Large Decrease, Small Decrease, Small Increase, and Large Increase. The children with the most prominent need satisfaction decreases showed a significant decline in out-of-school MVPA. All the children, irrespective of their need satisfaction profile, exhibited similar patterns of MVPA in PE over the three-year follow-up. Developing need satisfactions and out-of-school MVPA of the children with the greatest need satisfaction decreases may require enhancements in need-supportive PE activities.

Keywords

Competence, autonomy, relatedness, accelerometer, regression auxiliary model

Introduction

For several years, experts have suggested that if children are exposed to a wide range of physical education (PE) activities, they will find something they like and will continue being physically active outside school hours (Aubert et al., 2018; Bailey et al., 2009). However, the declining trends in regular physical activity levels in children and youth (Aubert et al., 2018) suggest that the topic warrants more attention. According to the tenets of Self-Determination Theory (SDT; Deci and Ryan, 2000; Ryan and Deci, 2017), knowledge of children's basic psychological need satisfactions would be essential in finding ways to foster moderate-to-vigorous physical activity (MVPA) participation in school PE and out-of-school (Hagger and Chatzisarantis, 2016). While need satisfactions have been widely studied in the PE context (Kalajas-Tilga et al., 2020; Vasconcellos et al., 2020; Warburton et al., 2020), less is known about whether need satisfactions and objectively measured MVPA develop concurrently over time from childhood to adolescence. This study focused on three-year trends of schoolchildren's need satisfaction profiles in PE and out-of-school MVPA from childhood to early adolescence to investigate this issue.

The SDT (Deci and Ryan, 2000; Ryan and Deci, 2017) is a dominant social-cognitive theoretical approach explaining the associations between motivation and behaviour, such as MVPA participation in the PE domain. Specifically, the theory postulates that basic psychological needs drive autonomous motivation and human functioning in learning situations. The SDT comprises the concepts of need satisfactions and frustrations, which either promote or hinder the development of autonomous motivation through the basic psychological needs of competence, autonomy, and social relatedness (Deci and Ryan, 2000; Ryan and Deci, 2017). Suppose school PE teaching supports children in satisfying these basic needs. In that case, they can experience success in each activity (competence), have an opportunity to develop a more profound interest in the activity (autonomy), and enjoy safe and supportive interaction with their

PE teacher and peer group (relatedness). Furthermore, children with higher need satisfactions in PE are likely to develop higher autonomous motivation towards PE (Ryan and Deci, 2017; Vasconcellos et al., 2020). Subsequently, this motivational process has been demonstrated to be associated with increased MVPA in PE classes (Vasconcellos et al., 2020) and MVPA during leisure time (Wallhead, Garn, and Vidoni, 2014). In contrast, when the learning environment (e.g. controlling teaching) hinders basic needs, i.e. maintains or enhances feelings of frustration over satisfaction, children may experience less motivation and engagement in the target activity (Bartholomew et al., 2018; De Meyer et al., 2014; Li et al., 2021).

Need satisfactions are influenced by teaching and interaction between teachers and children (Bartholomew et al., 2018; Warburton et al., 2020). Gråstén et al. (2020) found that competence and relatedness were positively associated with overall objective MVPA, whereas only relatedness was associated with in-class MVPA. Similar evidence based on schoolchildren's self-reported MVPA revealed correlations between competence and social relatedness need satisfactions with total MVPA (Brunet et al., 2016; Cox, Smith, and Williams, 2008; Gråstén and Watt, 2017). Autonomy needs satisfaction has been shown to be negatively or not correlated with either objective total MVPA (Gråstén et al., 2020) or self-reported total MVPA (Brunet et al., 2016; Gråstén and Watt, 2017).

Need profiles and self-assessed MVPA engagement have been incorporated in a few previous cross-sectional studies. For instance, Li et al. (2021), who studied MVPA levels in Singaporean schoolchildren, found the highest total weekly MVPA in the need profile characterized by very high need satisfactions. Granero-Gallegos et al. (2012), examining need satisfaction profiles in Spanish high school students, showed that the most elevated need satisfactions also had the most significant weekly physical exercise frequency. Huéscar Hernández et al. (2019), who also studied a sample of Spanish high school students, found that the profile with the highest need satisfactions showed greater weekly self-reported physical

activity than other profiles with lower need satisfactions. In previous need satisfaction studies, four latent profiles have typically been identified (Li et al., 2021; Warburton et al., 2020). However, this finding has been strongly associated with the type of variables selected for each latent profile analysis.

An evident shortcoming of the reviewed SDT research is the need for studies incorporating longitudinal research designs for examining need satisfactions in PE and objective MVPA outcomes (Kalajas-Tilga et al., 2020; Vasconcellos et al., 2020; Warburton et al., 2020). It remains unclear whether higher need satisfactions in PE contribute to higher MVPA behaviour over comprehensive assessments. In addition, Li et al. (2021) stated that more longitudinal identification studies on psychological need profiles are required to understand MVPA outcomes in children and youth better. This study addresses this gap by investigating whether schoolchildren's need satisfactions in PE are longitudinally linked with their MVPA engagement in PE and out-of-school MVPA. Previous theoretical models (Hagger and Chatzisarantis, 2016) and empirical evidence (Gråstén et al., 2020; Wallhead, Garn, and Vidoni, 2014) have suggested that positive need satisfactions in one context (e.g. PE) may contribute to MVPA engagement in other contexts (e.g. leisure time). However, this research question has not yet been investigated using the device-based methodology to capture MVPA in PE and out-of-school MVPA.

Considering all the above, this study examined: 1) qualitatively distinct need satisfaction profiles based on competence, autonomy, and relatedness satisfaction over time and 2) whether MVPA in PE and out-of-school MVPA trends differed between the need profiles identified. Based on previous cross-sectional studies of need satisfactions (Granero-Gallegos et al., 2012; Li et al., 2021; Warburton et al., 2020), three to four need satisfaction profiles were expected to be found and need satisfactions and MVPA were expected to develop concurrently (Vasconcellos et al., 2020). Specifically, the profiles with the highest need satisfactions were

expected to accumulate the most excellent MVPA levels in PE classes and out-of-school hours (Granero-Gallegos et al., 2012; Huéscar Hernández et al., 2019; Li et al., 2021).

Methods

Participants

Participants were 445 (girls 256, boys 189) Finnish schoolchildren, with a mean age of 11.26 ± .32 years at baseline, recruited from 17 randomly selected public schools in Southern (27% of students) and Central Finland (73%). The participating schools were mainly Finnish-speaking comprehensive schools with typically 300 to 500 ethnically white students and following the national core curriculum. The school principals directly invited all fifth-grade children to participate. Classroom teachers taught the 37 classes of children at T0 and T1, whereas at T2 and T3, after the transition to middle school, all the students were instructed by specialist PE teachers. All children engaged in two regular 45-minute PE classes per week (a total of 90 minutes). No children with special needs or disabilities participated in the study, although the opportunity was offered to all students.

Procedure

The self-report need satisfactions data were collected using equal procedures at each timepoint (August to September) from 2017 to 2020 (T0 to T3). Children completed the structured questionnaires in their classrooms under the researchers' supervision. Participants were informed about the study protocols and their rights to terminate their participation without consequences. In addition, the researchers encouraged participants to answer honestly and ask for help in cases of unclear questions. At each time point, the accelerometer data were collected during the same week as the self-reports. Written informed consent for their children's participation was obtained

from parents or guardians. The ethics committee of the local university approved the study protocols before the data collection.

Measures

Participants' demographic information, including date of birth, sex, class, and school information, was collected using the structured online questionnaire. Children were asked to fill out the personal details section before answering the PE-related questions.

Need satisfactions was assessed using the Finnish version of the Basic Psychological Needs in Physical Education Scale (BPN-PE; Vlachopoulos, Katartzi, and Kontou, 2011). The item stem was "*In PE classes, I feel that…*" The scale consisted of 12 items divided among three subscales: competence need satisfactions (e.g. *I can do well even in the lessons considered difficult by most kids in my class*), relatedness need satisfactions (e.g. *my relationships with the other kids in my class are friendly*), and autonomy need satisfactions (e.g. *I feel that I have the opportunity to make choices about PE activities*). All three subscales were measured on a five-point response scale from *(1) totally disagree* to *(5) totally agree*. Gråstén et al. (2019) reported acceptable construct validity for the Finnish version ($\chi 2(50) = 106.59$, $p < .001$, *CFI* = .97, *TLI* = .96, *RMSEA* = .048, *SRMR* = .035) in a sample of Finnish elementary school students.

The MVPA minutes were assessed using Actigraph GT3X+ (Pensacola, FL, USA) hip-worn accelerometers. The researchers distributed the accelerometers to the participants in their classrooms, and the teachers collected them after each measurement period. The children were instructed to wear the devices for seven consecutive days during waking hours (7 am to 11 pm), excluding swimming and water-based activities. The segments of MVPA in PE and out-of-school MVPA were based on the scheduled timetable of school classes. All days with ≥ 500 minutes of valid wear time were accepted for further analyses (Mattocks et al., 2008). The MVPA data were collected using a frequency of 30-Hz and divided into 15-second epochs. Non-

wear time was defined as 30 minutes of consecutive zeros. The cut-off points proposed by Evenson et al. (2008), which have been recently used in samples of Finnish schoolchildren (e.g. Kolunsarka et al., 2021), were used to determine individual MVPA scores (≥ 2296 cpm). The researchers then converted the raw accelerometer data into the processing format.

Data analysis

First, diagnostic analysis, including normality of distribution, outliers, and missing values, was performed. Second, the descriptive statistics and correlation coefficients between the observed variables were analysed. In the case of nested groups, between-group differences in the observed variables were analysed using intraclass correlations (ICC). The factor structure of the BPN-PE scale at T0 to T3 was tested through a series of confirmatory factor analyses. A non-significant Chi-square test demonstrated an acceptable fit (Hu and Bentler, 1999). In addition, the root mean square error of approximation (RMSEA ≤ .06), standardised root mean square residual (SRMR ≤ .08), comparative fit index (CFI > .95), and Tucker-Lewis index (TLI > .95) were examined for model fit (Hair et al., 2010; Hu and Bentler, 1999).

Finally, a regression auxiliary model including latent growth curves was estimated to examine changes in MVPA in PE and out-of-school MVPA between the need profiles over time. The regression auxiliary model was performed in two steps. In the first step, the latent need satisfaction profiles were identified using observed competence, autonomy, and relatedness need satisfactions variables at T0 to T3 following the procedures of Asparouhov and Muthén (2015). The model fit was tested using the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample-size adjusted BIC (ABIC), profile sizes, Adjusted Lo-Mendell-Rubin Ratio Test (LMR), and entropy values (Muthén and Muthén, 2017). Lower AIC, BIC, and ABIC values and higher entropy values indicated better model fit. Profiles containing less than five

percent of the children were avoided. The need satisfaction profiles were then labelled based on the developmental trends of need satisfactions over time.

The data matrix, including need profiles and MVPA in PE and out-of-school MVPA with nested groups, was established in the second step. Next, the latent growth curve model was computed to examine MVPA changes over time in PE and out-of-school between the need profiles identified. Between-group differences in MVPA participation were tested using t-tests of parameter equality. Finally, squared multiple correlations were calculated to explain the variances in MVPA by the need satisfaction profiles. The diagnostic analysis and descriptive statistics were performed using SPSS 26.0, and the auxiliary regression analysis using Mplus version 8.8.

Results

Preliminary analyses

Before the main analysis, the graphics indicated that the measured variables were normally distributed, whereas the standardized values (± 3.0) for MVPA in PE indicated the presence of significant outliers. Five unexpectedly high MVPA in PE scores at T0 (> 150 minutes) were removed from the data matrix. In the final data matrix, the percentage of missing values was 29% (2587 out of 8900 values), as the proportion of children with incomplete MVPA data increased over time (Table 1). Some participants were not willing to wear accelerometers during their leisure time. Thus, the proportion of participants with sufficient out-of-school MVPA data declined over time. However, the Missing Completely at Random (MCAR) test ($\chi^2 = 31.02$, $df = 28$, $p = .316$) showed that the data matrices with and without missing out-of-school MVPA values were similar. A closer examination also revealed that the missing scores did not represent any specific group. Thus, the missing out-of-school values were assumed to be missing

completely at random, and no further modifications were required. The construct validity of the BPN-PE scale at T0 ($\chi^2(51) = 102.91$, $p < .001$, *CFI* = .96, *TLI* = .95, *RMSEA* = .048, *SRMR* = .043), T1 ($\chi^2(51) = 127.65$, $p < .001$, *CFI* = .96, *TLI* = .94, *RMSEA* = .058, *SRMR* = .038), T2 ($\chi^2(51) = 175.99$, $p < .001$, *CFI* = .94, *TLI* = .92, *RMSEA* = .074, *SRMR* = .051), and T3 ($\chi^2(51) = 164.77$, $p < .001$, *CFI* = .95, *TLI* = .93, *RMSEA* = .072, *SRMR* = .044) was acceptable for the latent model development.

Descriptive statistics

Descriptive statistics (Table 1) and correlation coefficients (Table 2) were examined. The correlations between the observed variables varied between weak and moderate. The strongest positive correlations were found between the need satisfactions of competence and relatedness at T3. In contrast, the correlations of the need satisfactions variables with the MVPA and LPA variables were low. Mean scores showed that the need satisfactions values were relatively high at each measurement point, with higher values for competence and relatedness than autonomy satisfaction. Both MVPA in PE and out-of-school MVPA showed declining trends over time, reflecting the decreasing mean scores of the observed variables.

Latent profile analysis

Profile memberships derived from the competence, autonomy, and relatedness need satisfactions data at T0 to T3 were determined (Table 3). The data were expected to display a hierarchical structure, as the scores had been collected from classes with nested groups. The ICC p-values indicated that MVPA in PE differed between the classes (Table 4). Hence, the regression auxiliary model (Asparouhov and Muthén, 2015) was implemented using the complex model option to adjust the parameters for the sampling weights (Asparouhov, 2005; McNeish,

Stapleton, and Silverman, 2016) to consider unequal MVPA variances between classes. Specifically, this option with maximum likelihood and robust standard errors was obtained to fix the non-independence of observed MVPA variables between the nested groups (Asparouhov, 2005). When the number of latent groups increased, the AIC, BIC, and ABIC indices decreased, although only a little after the model with four latent groups. The indices were lower and the entropy value higher in the five-group solution, but one profile contained less than five percent of the participants. Thus, the indices and characteristics of the profiles pointed to the four-group solution as the most reasonable. The group membership was stable between the measurement points, as the probability of belonging to a specific group was 90%.

Profile 1 was named "*Large Decrease Profile*." The mean scores of the need satisfactions in this profile showed the most significant decreases in competence, autonomy, and relatedness from T0 to T3 compared to other profiles. Profile 2 was named "*Small Decrease Profile*" and comprised the most considerable proportion of the children in the current sample. These children showed slight decreases in their need satisfactions scores over time compared to other profiles. Profile 3 was named "*Small Increase Profile*" and contained the children with small increases in their need satisfactions over time. Profile 4 was named "*Large Increase Profile"* since the participants showed the most significant increases in their need satisfactions over time. Means, standard deviations, and the distribution of memberships between girls and boys are presented in Table 5.

Physical activity in need profiles over time

A regression auxiliary model, including latent growth curves, was estimated to examine the changes in MVPA in PE and out-of-school MVPA over time between the need profiles. The MVPA scores were estimated using the complex option so that the hierarchical data with nested

groups were considered. After this, profile-specific latent growth curves were estimated. The Mplus program does not produce fit indices for the random regression model but provides estimates, standard errors, and p-values.

The model indicated that the out-of-school MVPA level was higher than the MVPA in PE levels in each profile (Table 6). The levels and slopes of MVPA in PE had no significant differences between the profiles. The children engaged in approximately 20 minutes of MVPA per PE class over time, irrespective of their need satisfactions levels. In contrast, out-of-school MVPA levels differed between profiles; the Large Decrease and Small Increase need satisfaction profiles showed the highest and lowest baseline scores, respectively. Only the Large Decrease profile showed a significant decline (approx. seven minutes) in out-of-school MVPA. The squared multiple correlations (R^2) showed that the model significantly explained the variation observed over time in MVPA in PE (.06; .01; .04; .07) and out-of-school MVPA (.44; .51; .53; .45).

Discussion

This study examined the trends in MVPA in PE, and out-of-school MVPA in Finnish school-aged children's SDT-based need satisfaction profiles over three years. Four latent need satisfaction profiles based on need satisfactions trends over time were found: Large Decrease, Small Decrease, Small Increase, and Large Increase profiles. The children in the Large Decrease profile showed a significant decrease in out-of-school MVPA. Both Large Decrease and Small Increase profiles had the highest out-of-school MVPA levels. All the children, irrespective of their need satisfactions levels, engaged in similar MVPA per PE class over the three-year follow-up.

Four latent profiles based on the need satisfactions of competence, autonomy, and

relatedness were identified, indicating that the current PE groups were highly heterogeneous. Li et al. (2021) found a similar four-profile distribution in a previous cross-sectional study. The current profiling method, latent profile analysis, segregates groups with similar traits based on the between-group means and variations. Multiple parameters, such as the combination of need satisfactions over several follow-up measurements, could show greater variation among the participants. If so, this would explain the number of profiles found here compared to previous cross-sectional models with three latent profiles (e.g. Granero-Gallegos et al., 2012; Huéscar Hernández et al., 2019). However, finding distinct qualities between profiles is more important than the number of profiles, as in the present follow-up, which included the transition from childhood to adolescence. In the present study, only one profile, the Large Decrease need satisfaction profile, showed a substantial decrease in competence, autonomy, and social relatedness over time. This was probably because the members of all four profiles already had relatively high need satisfactions at baseline.

Despite the transition from elementary to middle school, the proportion of children in the Large Decrease needs satisfaction profile was the smallest, comprising only 10% of the total sample. Moreover, the girls and boys in this profile were almost equally distributed, despite mostly being taught in gender-segregated groups in middle school. At this age, during the transition from childhood to adolescence, pubertal children undergo critical maturation processes. This development stage also includes changes in their physical competencies (Kohl and Cook, 2013). For instance, growth spurts may influence children's motor skill performance, and thus also the physical activities in which they can successfully participate (Kohl and Cook, 2013). From this perspective, the small number of children who reported the largest decreasing need satisfactions was a positive finding, as most children received need-supportive PE classes over time. This indicates that the PE experiences of participating students were relatively constant. The schools in this study taught grades one to nine. This often means that children and

PE teachers are familiar with each other from the early school years, which could also contribute to the relatively stable trends in need satisfaction. In other school systems, where students typically change schools after sixth grade, this can potentially catalyse bigger changes in the PE curriculum and environment. All considered, the relatively small negative changes in need satisfactions trends from childhood to adolescence were a positive finding.

The concurrent development of contextual MVPA levels and trends in need satisfaction profiles (Granero-Gallegos et al., 2012; Huéscar Hernández et al., 2019; Li et al., 2021) was only partially supported. The children in the Small Increase profile had the lowest need satisfaction scores and out-of-school MVPA levels at baseline. This finding supported the SDT assumptions on the direct relationship between need satisfactions and actual behaviour (Ryan and Deci, 2017), i.e. the lower the need satisfactions, the lower the behavioural outcomes. In turn, the Small Decrease profile showed the highest need satisfactions but the second lowest out-of-class MVPA at baseline. However, the differences in need satisfactions reversed over the three-year follow-up. Contrary to the hypothesis, out-of-school MVPA and need satisfactions decreased over time only in the Large Decrease profile. For example, at baseline, the Large Decrease profile had higher need satisfactions and out-of-school MVPA scores than the Small Increase profile, which had the lowest need satisfactions and out-of-school MVPA. This finding that higher need satisfactions at baseline was not necessarily associated with a positive change in out-of-school MVPA extends the knowledge obtained from cross-sectional studies (Granero-Gallegos et al., 2012; Huéscar Hernández et al., 2019; Li et al., 2021) and indicates that need-supportive PE teaching could usefully focus on improving longitudinal rather than short-term need satisfactions trends. Thus, regular need satisfactions follow-ups in PE teaching could be of great value.

Our findings align with Erdvik et al. (2020), who found that adolescents who did not actively participate in physical activities outside school hours reported lower basic need

satisfactions in PE than sports-active peers. The children who showed the most prominent decreasing need satisfactions trend might feel that their psychological needs can be satisfied in a less competitive environment, such as in PE classes with their peers (Deci and Ryan, 2000). Because PE and out-of-school need satisfactions were not separated in this study, it is impossible to evaluate the trends in segregated need satisfactions. However, based on Erdvik et al. (2020), children with high need satisfactions in PE can be expected to be more physically active during out-of-school hours than children with low need satisfactions. In this study, possibly also due to controlling teaching (Jaakkola and Watt, 2011) or peer-related issues in PE classes (Bartholomew et al., 2018; De Meyer et al., 2014; Li et al., 2021), school PE classes may not be able to meet the needs of the children in the Large Decrease profile with concurrent decreasing out-of-school activity levels. In addition, the PE activities in schools may be too challenging, or the activities provided are outside of their interests (Deci and Ryan, 2000). These children could benefit from less competitive PE classes. MacPhail (2010) concluded that positive and developmentally appropriate PE experiences might support children's need satisfactions and interests, increasing their positive attitudes to PE activities and their need satisfactions. For some children, school PE could include more manageable tasks (e.g. a basic forward roll could be performed downhill, off a gym ball, or from a small height). In contrast, for some other students, more challenging tasks could be provided (e.g. a dive forward roll combined with catching a ball or ending up on one foot) (Stritt, 2014). Although the proportion of children in the Large Decrease profile with declining need satisfactions was the smallest, every child should be provided with interesting and challenging PE activities. The key to success could be constructive discussions between teachers and these children, aimed at increasing their need satisfactions, especially autonomy needs, since this received the lowest scores of all three satisfactions in the final measurement.

Finally, irrespective of their need profiles, each profile received a similar amount of MVPA in PE over time. This finding was similar to previous reviews (Grao-Cruses, Velázquez-Romero, and Rodríguez-Rodríguez, 2020), although the wide variation between studies with different sample characteristics and measurement methods should be considered. Grao-Cruses, Velázquez-Romero, and Rodríguez-Rodríguez (2020) concluded that children's MVPA levels during school hours are insufficient. Hence, schools should develop more effective strategies for helping children achieve the school physical activity guidelines of 30 minutes of MVPA during school hours (Pate and O'Neill, 2008). The current findings, however, indicated that the need satisfaction profile memberships were not associated with MVPA in PE time. Time use and lesson flow may thus be relatively constant in PE classes regardless of school, level, or teacher. However, MVPA in PE classes per week may be all the MVPA time some children have. If so, the amount of MVPA time could be increased. Since curriculum-based PE time is unlikely to be increased now or in the future, need-supportive activities during breaks (e.g. voluntary games in the school gym) could be essential in increasing children's MVPA participation during school days.

Although a stable trend of MVPA in PE was detected in each profile over three years, PE teaching strategies may impact student MVPA behaviours outside the school for a considerable time thereafter (Bartholomew et al., 2018; De Meyer et al., 2014; Hagger et al., 2003; Li et al., 2021; Wallhead and Buckworth, 2004), especially in children with the largest declines in need satisfactions. Thus, it would be essential to support children's need satisfactions in PE regardless of the slow or sometimes invisible changes in current PE behaviour. To do this, past need satisfactions studies have suggested several student-oriented strategies, which could concurrently increase one or all the need satisfactions and MVPA engagement. For instance, competence need satisfactions, and MVPA engagement could be enhanced through modifications in rules, space, or equipment so that movements support children's individual needs (Rudd et al., 2020). PE

393 teachers themselves could participate in these activities with students and, as competence
394 building requires constant new experiences (Escalié et al., 2019), provide novel activities that
395 develop new skills (White et al., 2020). Children could also be given opportunities to design
396 practice sessions in pairs or small groups (Gråstén et al., 2019) and offered additional activities,
397 such as a morning jump rope program (Ennis, 2013). To enhance autonomy needs, PE teachers
398 could, for example, explain essential fundamentals, use non-controlling language, demonstrate
399 patience by providing children with enough time to learn at their own pace (Reeve, 2009), and
400 offer choices of tasks varying in their skill requirements (White et al., 2020). Small group
401 activities may support competence, autonomy, and relatedness need satisfactions if children feel
402 they are valued and their opinions matter (Barney and Christenson, 2018). Concerning social
403 relatedness need satisfactions, PE teachers could assist students in developing familiarity with
404 classmates (by the end of the semester, everyone has worked with everyone else or must accept
405 the first person who asks to work with them), including an expectation of social responsibility
406 (help with equipment, be on time, help others), provide opportunities for peer tutoring, and
407 finally, encourage students to share their interests with their peer group (student-led warm-ups,
408 cool-down routines) (Gibbons, 2014). All the strategies mentioned above are cost-effective and
409 could be applied in most PE situations. In schools, PE teachers could, together with students,
410 discuss and plan the most reasonable ways to promote motivation through need satisfaction
411 enhancement considering the local facilities and conditions. Although need-supportive PE
412 teaching is important (Vasconcellos et al., 2020) and need satisfactions could be widely
413 promoted in schools, including in recess activities, it cannot be the entire responsibility of PE
414 teachers.

415 This was the first study to track the need satisfaction profiles and MVPA student outcomes
416 over a longer period. Strengths were the long follow-up period and the use of objective MVPA
417 measures to monitor behavioural MVPA in PE and outside school hours. However, this study

was not free from limitations. First, participation was entirely voluntary, so the sample size decreased in Grade 8, especially in the out-of-school MVPA variable. Although it was not avoidable, the fact remained that a large proportion of the participants were not willing to wear accelerometers outside school hours. Second, the PE classes included in the study were not standardized, and thus, class activities might vary between schools and classes. Finally, the assessment of autonomous motivation could have been beneficial in addition to need satisfactions measurements, as need satisfactions contribute to physical activity behaviour via motivational regulation (Ryan & Deci, 2017). Future studies could assess need satisfactions in other contexts. For example, it would be worth examining whether PE-related and out-of-school need satisfactions are associated with physical activity participation. Furthermore, adopting a more extensive range of objective measurements, such as heart rate variability, reflecting autonomous motivation through need satisfactions could be of great value. Measures, especially in PE classes, of the ambulatory system, including heart rate variability monitoring in a smaller subsample of participants, could provide more accurate behavioural data.

Conclusion

These findings provide novel insights into decreasing MVPA trends in children by clarifying that those showing the most prominent decreasing trends in need satisfactions may be at greater risk of dropping out-of-school MVPA than those with higher need satisfactions levels. This is a concern, as a diminishing amount of out-of-school MVPA directly affects these children's total MVPA. The amount of MVPA in PE classes could be increased regardless of their need satisfactions levels. Because PE time in the curriculum cannot be substantially increased, current PE classes and recess activities can improve children's need satisfactions and participation in MVPA. Supporting the development of need satisfactions trends and out-of-school MVPA in the

children with the most prominent decreasing trends may require more need-supportive PE activities.

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Conflict of interest

The authors declare no conflicts of interest concerning the results of this study. The results are presented honestly without fabrication, falsification, or inappropriate data manipulation.

Data availability

Due to the nature of this research, the participants did not consent to their data being publicly shared, and supporting data are unavailable.

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