Author(s): Gråstén, Arto; Wang, John K. C.; Huhtiniemi, Mikko; Jaakkola, Timo

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8   **Accelerometer-based physical activity in need satisfaction profiles of schoolchildren – A**

9   **three-year follow-up**

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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 ($M_{age} = 11.26$
$\pm .32$ 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.

50   **Introduction**

51   For several years, experts have suggested that if children are exposed to a wide range of physical

52   education (PE) activities, they will find something they like and will continue being physically

53   active outside school hours (Aubert et al., 2018; Bailey et al., 2009). However, the declining

54   trends in regular physical activity levels in children and youth (Aubert et al., 2018) suggest that

55   the topic warrants more attention. According to the tenets of Self-Determination Theory (SDT;

56   Deci and Ryan, 2000; Ryan and Deci, 2017), knowledge of children's basic psychological need

57   satisfactions would be essential in finding ways to foster moderate-to-vigorous physical activity

58   (MVPA) participation in school PE and out-of-school (Hagger and Chatzisarantis, 2016). While

59   need satisfactions have been widely studied in the PE context (Kalajas-Tilga et al., 2020;

60   Vasconcellos et al., 2020; Warburton et al., 2020), less is known about whether need

61   satisfactions and objectively measured MVPA develop concurrently over time from childhood to

62   adolescence. This study focused on three-year trends of schoolchildren's need satisfaction

63   profiles in PE and out-of-school MVPA from childhood to early adolescence to investigate this

64   issue.

65   The SDT (Deci and Ryan, 2000; Ryan and Deci, 2017) is a dominant social-cognitive

66   theoretical approach explaining the associations between motivation and behaviour, such as

67   MVPA participation in the PE domain. Specifically, the theory postulates that basic

68   psychological needs drive autonomous motivation and human functioning in learning situations.

69   The SDT comprises the concepts of need satisfactions and frustrations, which either promote or

70   hinder the development of autonomous motivation through the basic psychological needs of

71   competence, autonomy, and social relatedness (Deci and Ryan, 2000; Ryan and Deci, 2017).

72   Suppose school PE teaching supports children in satisfying these basic needs. In that case, they

73   can experience success in each activity (competence), have an opportunity to develop a more

74   profound interest in the activity (autonomy), and enjoy safe and supportive interaction with their

75   PE teacher and peer group (relatedness). Furthermore, children with higher need satisfactions in

76   PE are likely to develop higher autonomous motivation towards PE (Ryan and Deci, 2017;

77   Vasconcellos et al., 2020). Subsequently, this motivational process has been demonstrated to be

78   associated with increased MVPA in PE classes (Vasconcellos et al., 2020) and MVPA during

79   leisure time (Wallhead, Garn, and Vidoni, 2014). In contrast, when the learning environment

80   (e.g. controlling teaching) hinders basic needs, i.e. maintains or enhances feelings of frustration

81   over satisfaction, children may experience less motivation and engagement in the target activity

82   (Bartholomew et al., 2018; De Meyer et al., 2014; Li et al., 2021).

83   Need satisfactions are influenced by teaching and interaction between teachers and

84   children (Bartholomew et al., 2018; Warburton et al., 2020). Gråstén et al. (2020) found that

85   competence and relatedness were positively associated with overall objective MVPA, whereas

86   only relatedness was associated with in-class MVPA. Similar evidence based on schoolchildren's

87   self-reported MVPA revealed correlations between competence and social relatedness need

88   satisfactions with total MVPA (Brunet et al., 2016; Cox, Smith, and Williams, 2008; Gråstén and

89   Watt, 2017). Autonomy needs satisfaction has been shown to be negatively or not correlated with

90   either objective total MVPA (Gråstén et al., 2020) or self-reported total MVPA (Brunet et al.,

91   2016; Gråstén and Watt, 2017).

92   Need profiles and self-assessed MVPA engagement have been incorporated in a few

93   previous cross-sectional studies. For instance, Li et al. (2021), who studied MVPA levels in

94   Singaporean schoolchildren, found the highest total weekly MVPA in the need profile

95   characterized by very high need satisfactions. Granero-Gallegos et al. (2012), examining need

96   satisfaction profiles in Spanish high school students, showed that the most elevated need

97   satisfactions also had the most significant weekly physical exercise frequency. Huéscar

98   Hernández et al. (2019), who also studied a sample of Spanish high school students, found that

99   the profile with the highest need satisfactions showed greater weekly self-reported physical

100   activity than other profiles with lower need satisfactions. In previous need satisfaction studies,

101   four latent profiles have typically been identified (Li et al., 2021; Warburton et al., 2020).

102   However, this finding has been strongly associated with the type of variables selected for each

103   latent profile analysis.

104   An evident shortcoming of the reviewed SDT research is the need for studies

105   incorporating longitudinal research designs for examining need satisfactions in PE and objective

106   MVPA outcomes (Kalajas-Tilga et al., 2020; Vasconcellos et al., 2020; Warburton et al., 2020).

107   It remains unclear whether higher need satisfactions in PE contribute to higher MVPA

108   behaviour over comprehensive assessments. In addition, Li et al. (2021) stated that more

109   longitudinal identification studies on psychological need profiles are required to understand

110   MVPA outcomes in children and youth better. This study addresses this gap by investigating

111   whether schoolchildren's need satisfactions in PE are longitudinally linked with their MVPA

112   engagement in PE and out-of-school MVPA. Previous theoretical models (Hagger and

113   Chatzisarantis, 2016) and empirical evidence (Gråstén et al., 2020; Wallhead, Garn, and Vidoni,

114   2014) have suggested that positive need satisfactions in one context (e.g. PE) may contribute to

115   MVPA engagement in other contexts (e.g. leisure time). However, this research question has not

116   yet been investigated using the device-based methodology to capture MVPA in PE and out-of-

117   school MVPA.

118   Considering all the above, this study examined: 1) qualitatively distinct need satisfaction

119   profiles based on competence, autonomy, and relatedness satisfaction over time and 2) whether

120   MVPA in PE and out-of-school MVPA trends differed between the need profiles identified.

121   Based on previous cross-sectional studies of need satisfactions (Granero-Gallegos et al., 2012;

122   Li et al., 2021; Warburton et al., 2020), three to four need satisfaction profiles were expected to

123   be found and need satisfactions and MVPA were expected to develop concurrently

124   (Vasconcellos et al., 2020). Specifically, the profiles with the highest need satisfactions were

125   expected to accumulate the most excellent MVPA levels in PE classes and out-of-school hours

126   (Granero-Gallegos et al., 2012; Huéscar Hernández et al., 2019; Li et al., 2021).

127

128   **Methods**

129   *Participants*

130   Participants were 445 (girls 256, boys 189) Finnish schoolchildren, with a mean age of

131   $11.26 \pm .32$ years at baseline, recruited from 17 randomly selected public schools in Southern

132   (27% of students) and Central Finland (73%). The participating schools were mainly Finnish-

133   speaking comprehensive schools with typically 300 to 500 ethnically white students and

134   following the national core curriculum. The school principals directly invited all fifth-grade

135   children to participate. Classroom teachers taught the 37 classes of children at T0 and T1,

136   whereas at T2 and T3, after the transition to middle school, all the students were instructed by

137   specialist PE teachers. All children engaged in two regular 45-minute PE classes per week (a

138   total of 90 minutes). No children with special needs or disabilities participated in the study,

139   although the opportunity was offered to all students.

140

141   *Procedure*

142   The self-report need satisfactions data were collected using equal procedures at each timepoint

143   (August to September) from 2017 to 2020 (T0 to T3). Children completed the structured

144   questionnaires in their classrooms under the researchers' supervision. Participants were informed

145   about the study protocols and their rights to terminate their participation without consequences.

146   In addition, the researchers encouraged participants to answer honestly and ask for help in cases

147   of unclear questions. At each time point, the accelerometer data were collected during the same

148   week as the self-reports. Written informed consent for their children's participation was obtained

149   from parents or guardians. The ethics committee of the local university approved the study

150   protocols before the data collection.

151

152   *Measures*

153   Participants' demographic information, including date of birth, sex, class, and school

154   information, was collected using the structured online questionnaire. Children were asked to fill

155   out the personal details section before answering the PE-related questions.

156   Need satisfactions was assessed using the Finnish version of the Basic Psychological

157   Needs in Physical Education Scale (BPN-PE; Vlachopoulos, Katartzi, and Kontou, 2011). The

158   item stem was "*In PE classes, I feel that…*" The scale consisted of 12 items divided among three

159   subscales: competence need satisfactions (e.g. *I can do well even in the lessons considered*

160   *difficult by most kids in my class*), relatedness need satisfactions (e.g. *my relationships with the*

161   *other kids in my class are friendly*), and autonomy need satisfactions (e.g. *I feel that I have the*

162   *opportunity to make choices about PE activities*). All three subscales were measured on a five-

163   point response scale from *(1) totally disagree* to *(5) totally agree*. Gråstén et al. (2019) reported

164   acceptable construct validity for the Finnish version ($\chi2(50) = 106.59$, $p < .001$, *CFI* = .97, *TLI* =

165   .96, *RMSEA* = .048, *SRMR* = .035) in a sample of Finnish elementary school students.

166   The MVPA minutes were assessed using Actigraph GT3X+ (Pensacola, FL, USA) hip-

167   worn accelerometers. The researchers distributed the accelerometers to the participants in their

168   classrooms, and the teachers collected them after each measurement period. The children were

169   instructed to wear the devices for seven consecutive days during waking hours (7 am to 11 pm),

170   excluding swimming and water-based activities. The segments of MVPA in PE and out-of-

171   school MVPA were based on the scheduled timetable of school classes. All days with ≥ 500

172   minutes of valid wear time were accepted for further analyses (Mattocks et al., 2008). The

173   MVPA data were collected using a frequency of 30-Hz and divided into 15-second epochs. Non-

174   wear time was defined as 30 minutes of consecutive zeros. The cut-off points proposed by

175   Evenson et al. (2008), which have been recently used in samples of Finnish schoolchildren (e.g.

176   Kolunsarka et al., 2021), were used to determine individual MVPA scores ($\geq$ 2296 cpm). The

177   researchers then converted the raw accelerometer data into the processing format.

178

179   *Data analysis*

180   First, diagnostic analysis, including normality of distribution, outliers, and missing values, was

181   performed. Second, the descriptive statistics and correlation coefficients between the observed

182   variables were analysed. In the case of nested groups, between-group differences in the observed

183   variables were analysed using intraclass correlations (ICC). The factor structure of the BPN-PE

184   scale at T0 to T3 was tested through a series of confirmatory factor analyses. A non-significant

185   Chi-square test demonstrated an acceptable fit (Hu and Bentler, 1999). In addition, the root mean

186   square error of approximation (RMSEA $\leq$ .06), standardised root mean square residual (SRMR $\leq$

187   .08), comparative fit index (CFI > .95), and Tucker-Lewis index (TLI > .95) were examined for

188   model fit (Hair et al., 2010; Hu and Bentler, 1999).

189   Finally, a regression auxiliary model including latent growth curves was estimated to

190   examine changes in MVPA in PE and out-of-school MVPA between the need profiles over time.

191   The regression auxiliary model was performed in two steps. In the first step, the latent need

192   satisfaction profiles were identified using observed competence, autonomy, and relatedness need

193   satisfactions variables at T0 to T3 following the procedures of Asparouhov and Muthén (2015).

194   The model fit was tested using the Akaike Information Criterion (AIC), Bayesian Information

195   Criterion (BIC), sample-size adjusted BIC (ABIC), profile sizes, Adjusted Lo-Mendell-Rubin

196   Ratio Test (LMR), and entropy values (Muthén and Muthén, 2017). Lower AIC, BIC, and ABIC

197   values and higher entropy values indicated better model fit. Profiles containing less than five

198   percent of the children were avoided. The need satisfaction profiles were then labelled based on

199   the developmental trends of need satisfactions over time.

200   The data matrix, including need profiles and MVPA in PE and out-of-school MVPA with

201   nested groups, was established in the second step. Next, the latent growth curve model was

202   computed to examine MVPA changes over time in PE and out-of-school between the need

203   profiles identified. Between-group differences in MVPA participation were tested using t-tests of

204   parameter equality. Finally, squared multiple correlations were calculated to explain the

205   variances in MVPA by the need satisfaction profiles. The diagnostic analysis and descriptive

206   statistics were performed using SPSS 26.0, and the auxiliary regression analysis using Mplus

207   version 8.8.

208

209   **Results**

210   *Preliminary analyses*

211   Before the main analysis, the graphics indicated that the measured variables were normally

212   distributed, whereas the standardized values ($\pm$ 3.0) for MVPA in PE indicated the presence of

213   significant outliers. Five unexpectedly high MVPA in PE scores at T0 (> 150 minutes) were

214   removed from the data matrix. In the final data matrix, the percentage of missing values was

215   29% (2587 out of 8900 values), as the proportion of children with incomplete MVPA data

216   increased over time (Table 1). Some participants were not willing to wear accelerometers during

217   their leisure time. Thus, the proportion of participants with sufficient out-of-school MVPA data

218   declined over time. However, the Missing Completely at Random (MCAR) test ($\chi^2 = 31.02$, $df =$

219   28, $p = .316$) showed that the data matrices with and without missing out-of-school MVPA

220   values were similar. A closer examination also revealed that the missing scores did not represent

221   any specific group. Thus, the missing out-of-school values were assumed to be missing

222   completely at random, and no further modifications were required. The construct validity of the

223   BPN-PE scale at T0 (χ^2(51) = 102.91, p < .001, *CFI* = .96, *TLI* = .95, *RMSEA* = .048, *SRMR* =

224   .043), T1 (χ^2(51) = 127.65, p < .001, *CFI* = .96, *TLI* = .94, *RMSEA* = .058, *SRMR* = .038), T2

225   (χ^2(51) = 175.99, p < .001, *CFI* = .94, *TLI* = .92, *RMSEA* = .074, *SRMR* = .051), and T3 (χ^2(51) =

226   164.77, p < .001, *CFI* = .95, *TLI* = .93, *RMSEA* = .072, *SRMR* = .044) was acceptable for the

227   latent model development.

228

229   *Descriptive statistics*

230   Descriptive statistics (Table 1) and correlation coefficients (Table 2) were examined. The

231   correlations between the observed variables varied between weak and moderate. The strongest

232   positive correlations were found between the need satisfactions of competence and relatedness at

233   T3. In contrast, the correlations of the need satisfactions variables with the MVPA and LPA

234   variables were low. Mean scores showed that the need satisfactions values were relatively high at

235   each measurement point, with higher values for competence and relatedness than autonomy

236   satisfaction. Both MVPA in PE and out-of-school MVPA showed declining trends over time,

237   reflecting the decreasing mean scores of the observed variables.

238

239   *Latent profile analysis*

240   Profile memberships derived from the competence, autonomy, and relatedness need satisfactions

241   data at T0 to T3 were determined (Table 3). The data were expected to display a hierarchical

242   structure, as the scores had been collected from classes with nested groups. The ICC p-values

243   indicated that MVPA in PE differed between the classes (Table 4). Hence, the regression

244   auxiliary model (Asparouhov and Muthén, 2015) was implemented using the complex model

245   option to adjust the parameters for the sampling weights (Asparouhov, 2005; McNeish,

246   Stapleton, and Silverman, 2016) to consider unequal MVPA variances between classes.

247   Specifically, this option with maximum likelihood and robust standard errors was obtained to fix

248   the non-independence of observed MVPA variables between the nested groups (Asparouhov,

249   2005). When the number of latent groups increased, the AIC, BIC, and ABIC indices decreased,

250   although only a little after the model with four latent groups. The indices were lower and the

251   entropy value higher in the five-group solution, but one profile contained less than five percent

252   of the participants. Thus, the indices and characteristics of the profiles pointed to the four-group

253   solution as the most reasonable. The group membership was stable between the measurement

254   points, as the probability of belonging to a specific group was 90%.

255   Profile 1 was named "*Large Decrease Profile*." The mean scores of the need satisfactions

256   in this profile showed the most significant decreases in competence, autonomy, and relatedness

257   from T0 to T3 compared to other profiles. Profile 2 was named "*Small Decrease Profile*" and

258   comprised the most considerable proportion of the children in the current sample. These children

259   showed slight decreases in their need satisfactions scores over time compared to other profiles.

260   Profile 3 was named "*Small Increase Profile*" and contained the children with small increases in

261   their need satisfactions over time. Profile 4 was named "*Large Increase Profile*" since the

262   participants showed the most significant increases in their need satisfactions over time. Means,

263   standard deviations, and the distribution of memberships between girls and boys are presented in

264   Table 5.

265

266   *Physical activity in need profiles over time*

267   A regression auxiliary model, including latent growth curves, was estimated to examine the

268   changes in MVPA in PE and out-of-school MVPA over time between the need profiles. The

269   MVPA scores were estimated using the complex option so that the hierarchical data with nested

270   groups were considered. After this, profile-specific latent growth curves were estimated. The

271   Mplus program does not produce fit indices for the random regression model but provides

272   estimates, standard errors, and p-values.

273   The model indicated that the out-of-school MVPA level was higher than the MVPA in PE

274   levels in each profile (Table 6). The levels and slopes of MVPA in PE had no significant

275   differences between the profiles. The children engaged in approximately 20 minutes of MVPA

276   per PE class over time, irrespective of their need satisfactions levels. In contrast, out-of-school

277   MVPA levels differed between profiles; the Large Decrease and Small Increase need satisfaction

278   profiles showed the highest and lowest baseline scores, respectively. Only the Large Decrease

279   profile showed a significant decline (approx. seven minutes) in out-of-school MVPA. The

280   squared multiple correlations (R^2) showed that the model significantly explained the variation

281   observed over time in MVPA in PE (.06; .01; .04; .07) and out-of-school MVPA (.44; .51; .53;

282   .45).

283

284   **Discussion**

285   This study examined the trends in MVPA in PE, and out-of-school MVPA in Finnish school-

286   aged children's SDT-based need satisfaction profiles over three years. Four latent need

287   satisfaction profiles based on need satisfactions trends over time were found: Large Decrease,

288   Small Decrease, Small Increase, and Large Increase profiles. The children in the Large Decrease

289   profile showed a significant decrease in out-of-school MVPA. Both Large Decrease and Small

290   Increase profiles had the highest out-of-school MVPA levels. All the children, irrespective of

291   their need satisfactions levels, engaged in similar MVPA per PE class over the three-year follow-

292   up.

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

294   relatedness were identified, indicating that the current PE groups were highly heterogeneous. Li

295   et al. (2021) found a similar four-profile distribution in a previous cross-sectional study. The

296   current profiling method, latent profile analysis, segregates groups with similar traits based on

297   the between-group means and variations. Multiple parameters, such as the combination of need

298   satisfactions over several follow-up measurements, could show greater variation among the

299   participants. If so, this would explain the number of profiles found here compared to previous

300   cross-sectional models with three latent profiles (e.g. Granero-Gallegos et al., 2012; Huéscar

301   Hernández et al., 2019). However, finding distinct qualities between profiles is more important

302   than the number of profiles, as in the present follow-up, which included the transition from

303   childhood to adolescence. In the present study, only one profile, the Large Decrease need

304   satisfaction profile, showed a substantial decrease in competence, autonomy, and social

305   relatedness over time. This was probably because the members of all four profiles already had

306   relatively high need satisfactions at baseline.

307   Despite the transition from elementary to middle school, the proportion of children in the

308   Large Decrease needs satisfaction profile was the smallest, comprising only 10% of the total

309   sample. Moreover, the girls and boys in this profile were almost equally distributed, despite

310   mostly being taught in gender-segregated groups in middle school. At this age, during the

311   transition from childhood to adolescence, pubertal children undergo critical maturation

312   processes. This development stage also includes changes in their physical competencies (Kohl

313   and Cook, 2013). For instance, growth spurts may influence children's motor skill performance,

314   and thus also the physical activities in which they can successfully participate (Kohl and Cook,

315   2013). From this perspective, the small number of children who reported the largest decreasing

316   need satisfactions was a positive finding, as most children received need-supportive PE classes

317   over time. This indicates that the PE experiences of participating students were relatively

318   constant. The schools in this study taught grades one to nine. This often means that children and

319   PE teachers are familiar with each other from the early school years, which could also contribute

320   to the relatively stable trends in need satisfaction. In other school systems, where students

321   typically change schools after sixth grade, this can potentially catalyse bigger changes in the PE

322   curriculum and environment. All considered, the relatively small negative changes in need

323   satisfactions trends from childhood to adolescence were a positive finding.

324   The concurrent development of contextual MVPA levels and trends in need satisfaction

325   profiles (Granero-Gallegos et al., 2012; Huéscar Hernández et al., 2019; Li et al., 2021) was only

326   partially supported. The children in the Small Increase profile had the lowest need satisfaction

327   scores and out-of-school MVPA levels at baseline. This finding supported the SDT assumptions

328   on the direct relationship between need satisfactions and actual behaviour (Ryan and Deci,

329   2017), i.e. the lower the need satisfactions, the lower the behavioural outcomes. In turn, the

330   Small Decrease profile showed the highest need satisfactions but the second lowest out-of-class

331   MVPA at baseline. However, the differences in need satisfactions reversed over the three-year

332   follow-up. Contrary to the hypothesis, out-of-school MVPA and need satisfactions decreased

333   over time only in the Large Decrease profile. For example, at baseline, the Large Decrease

334   profile had higher need satisfactions and out-of-school MVPA scores than the Small Increase

335   profile, which had the lowest need satisfactions and out-of-school MVPA. This finding that

336   higher need satisfactions at baseline was not necessarily associated with a positive change in out-

337   of-school MVPA extends the knowledge obtained from cross-sectional studies (Granero-

338   Gallegos et al., 2012; Huéscar Hernández et al., 2019; Li et al., 2021) and indicates that need-

339   supportive PE teaching could usefully focus on improving longitudinal rather than short-term

340   need satisfactions trends. Thus, regular need satisfactions follow-ups in PE teaching could be of

341   great value.

342   Our findings align with Erdvik et al. (2020), who found that adolescents who did not

343   actively participate in physical activities outside school hours reported lower basic need

344   satisfactions in PE than sports-active peers. The children who showed the most prominent

345   decreasing need satisfactions trend might feel that their psychological needs can be satisfied in a

346   less competitive environment, such as in PE classes with their peers (Deci and Ryan, 2000).

347   Because PE and out-of-school need satisfactions were not separated in this study, it is impossible

348   to evaluate the trends in segregated need satisfactions. However, based on Erdvik et al. (2020),

349   children with high need satisfactions in PE can be expected to be more physically active during

350   out-of-school hours than children with low need satisfactions. In this study, possibly also due to

351   controlling teaching (Jaakkola and Watt, 2011) or peer-related issues in PE classes

352   (Bartholomew et al., 2018; De Meyer et al., 2014; Li et al., 2021), school PE classes may not be

353   able to meet the needs of the children in the Large Decrease profile with concurrent decreasing

354   out-of-school activity levels. In addition, the PE activities in schools may be too challenging, or

355   the activities provided are outside of their interests (Deci and Ryan, 2000). These children could

356   benefit from less competitive PE classes. MacPhail (2010) concluded that positive and

357   developmentally appropriate PE experiences might support children's need satisfactions and

358   interests, increasing their positive attitudes to PE activities and their need satisfactions. For some

359   children, school PE could include more manageable tasks (e.g. a basic forward roll could be

360   performed downhill, off a gym ball, or from a small height). In contrast, for some other students,

361   more challenging tasks could be provided (e.g. a dive forward roll combined with catching a ball

362   or ending up on one foot) (Stritt, 2014). Although the proportion of children in the Large

363   Decrease profile with declining need satisfactions was the smallest, every child should be

364   provided with interesting and challenging PE activities. The key to success could be constructive

365   discussions between teachers and these children, aimed at increasing their need satisfactions,

366   especially autonomy needs, since this received the lowest scores of all three satisfactions in the

367   final measurement.

368   Finally, irrespective of their need profiles, each profile received a similar amount of

369 MVPA in PE over time. This finding was similar to previous reviews (Grao-Cruses, Velázquez-

370 Romero, and Rodríguez-Rodríguez, 2020), although the wide variation between studies with

371 different sample characteristics and measurement methods should be considered. Grao-Cruses,

372 Velázquez-Romero, and Rodríguez-Rodríguez (2020) concluded that children's MVPA levels

373 during school hours are insufficient. Hence, schools should develop more effective strategies for

374 helping children achieve the school physical activity guidelines of 30 minutes of MVPA during

375 school hours (Pate and O'Neill, 2008). The current findings, however, indicated that the need

376 satisfaction profile memberships were not associated with MVPA in PE time. Time use and

377 lesson flow may thus be relatively constant in PE classes regardless of school, level, or teacher.

378 However, MVPA in PE classes per week may be all the MVPA time some children have. If so,

379 the amount of MVPA time could be increased. Since curriculum-based PE time is unlikely to be

380 increased now or in the future, need-supportive activities during breaks (e.g. voluntary games in

381 the school gym) could be essential in increasing children's MVPA participation during school

382 days.

383   Although a stable trend of MVPA in PE was detected in each profile over three years, PE

384 teaching strategies may impact student MVPA behaviours outside the school for a considerable

385 time thereafter (Bartholomew et al., 2018; De Meyer et al., 2014; Hagger et al., 2003; Li et al.,

386 2021; Wallhead and Buckworth, 2004), especially in children with the largest declines in need

387 satisfactions. Thus, it would be essential to support children's need satisfactions in PE regardless

388 of the slow or sometimes invisible changes in current PE behaviour. To do this, past need

389 satisfactions studies have suggested several student-oriented strategies, which could concurrently

390 increase one or all the need satisfactions and MVPA engagement. For instance, competence need

391 satisfactions, and MVPA engagement could be enhanced through modifications in rules, space,

392 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

418   was not free from limitations. First, participation was entirely voluntary, so the sample size

419   decreased in Grade 8, especially in the out-of-school MVPA variable. Although it was not

420   avoidable, the fact remained that a large proportion of the participants were not willing to wear

421   accelerometers outside school hours. Second, the PE classes included in the study were not

422   standardized, and thus, class activities might vary between schools and classes. Finally, the

423   assessment of autonomous motivation could have been beneficial in addition to need

424   satisfactions measurements, as need satisfactions contribute to physical activity behaviour via

425   motivational regulation (Ryan & Deci, 2017). Future studies could assess need satisfactions in

426   other contexts. For example, it would be worth examining whether PE-related and out-of-school

427   need satisfactions are associated with physical activity participation. Furthermore, adopting a

428   more extensive range of objective measurements, such as heart rate variability, reflecting

429   autonomous motivation through need satisfactions could be of great value. Measures, especially

430   in PE classes, of the ambulatory system, including heart rate variability monitoring in a smaller

431   subsample of participants, could provide more accurate behavioural data.

432

433   **Conclusion**

434   These findings provide novel insights into decreasing MVPA trends in children by clarifying that

435   those showing the most prominent decreasing trends in need satisfactions may be at greater risk

436   of dropping out-of-school MVPA than those with higher need satisfactions levels. This is a

437   concern, as a diminishing amount of out-of-school MVPA directly affects these children's total

438   MVPA. The amount of MVPA in PE classes could be increased regardless of their need

439   satisfactions levels. Because PE time in the curriculum cannot be substantially increased, current

440   PE classes and recess activities can improve children's need satisfactions and participation in

441   MVPA. Supporting the development of need satisfactions trends and out-of-school MVPA in the

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

443   activities.

444

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447

Conflict of interest

449   The authors declare no conflicts of interest concerning the results of this study. The results are

450   presented honestly without fabrication, falsification, or inappropriate data manipulation.

451

Data availability

453   Due to the nature of this research, the participants did not consent to their data being publicly

454   shared, and supporting data are unavailable.

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