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**A one-year follow-up of basic psychological need satisfactions in physical education and associated in-class and total physical activity**

**Abstract**

26 **Abstract**  
27 This study examined basic psychological need satisfactions for competence, autonomy, and social  
28 relatedness in physical education (PE) and their contributions to accelerometer-based in-class and  
29 total moderate to vigorous physical activity (MVPA) across a one-year follow-up. Participants were  
30 523 students (girls 280, boys 243;  $M_{age} = 11.26 \pm .31$ ) and the data were collected using self-reports  
31 and waist-worn accelerometers. The key findings were 1) competence and social relatedness need  
32 satisfaction at baseline (T0) predicted total MVPA at follow-up (T1) via total MVPA at T0, 2) in-  
33 class MVPA at T0 predicted total MVPA at T1 via total MVPA at T0, 3) in-class MVPA was  
34 directly associated with total MVPA at T0 and T1, and 4) boys scored higher than girls on  
35 competence and relatedness need satisfaction at T0. These findings indicate that the need  
36 satisfactions for competence and social relatedness in PE are central components facilitating the  
37 greatest increases in total MVPA participation. To improve student outcomes, it is essential that all  
38 children receive positive and satisfying PE experiences. Enhancing the readiness and capability of  
39 pre- and in-service teachers through teacher training programmes is vital to raising awareness of the  
40 basic psychological need satisfactions behind autonomous motivation and greater MVPA  
41 engagement.

42

**Keywords**

44 competence, autonomy, social relatedness, school, cross-lagged model

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## 51 **Introduction**

52 Apart from many advantages, modern lifestyles have changed in less beneficial ways. For example,  
53 only 30% of children meet the current guidelines of 60 minutes of daily moderate to vigorous  
54 physical activity (MVPA), with boys being more physically active than girls (Tremblay et al.,  
55 2016). MVPA is defined as all physical activities, such as brisk walking, running, or active games,  
56 that increase the heart rate and cause rapid breathing (World Health Organization, 2018). It has  
57 been proposed that physical education (PE) is the most important cost-effective way of increasing  
58 regular MVPA at the population level, as it reaches the majority of school-aged children (Bassett et  
59 al., 2013). However, achieving the objectives of PE, including life-long engagement in physical  
60 activity, is challenging if children are not motivated to actively participate during their PE classes  
61 (Ntoumanis, 2001). Despite the growing body of studies on MVPA-related motivation (De Meyer et  
62 al., 2014; Haerens et al., 2013; 2015; Wang et al., 2016), understanding of the associations between  
63 psychological need satisfactions, as posited in the Self-determination Theory (SDT; Deci and Ryan,  
64 1985; 2000; Ryan and Deci, 2017), and accelerometer-based MVPA scores in PE over a prolonged  
65 period, is lacking. This study examined these associations across one year in a sample of school-  
66 aged children.

67 School PE is planned and progressive curricular learning, which is delivered to all students  
68 and involves aspects of “learning to move” (becoming more physically competent) and “moving to  
69 learn” (learning through movement) (Harris, 2015). One of the main objectives of school PE is to  
70 provide students with an exposure that will build up their interest toward in-class and out-of-school  
71 MVPA (Finnish National Agency for Education, 2014). In Finland, where this study took place,  
72 schools, taking local conditions into account, design their own curricula within the framework of  
73 the national curriculum. Typically, children in grades three to six receive 90 minutes of PE weekly  
74 (Finnish National Agency for Education, 2014). In many schools, girls and boys are taught  
75 separately in gender-specific PE groups. Based on previous studies, children’s MVPA during PE

76 classes depends on many factors, such as skill levels (Fairclough and Stratton, 2006), lesson themes  
77 (Slingerland, 2014), gender (Slingerland, 2014), the lesson venue (Mersh and Fairclough, 2010),  
78 resources available (Levin et al., 2001), teacher specialisation (Sallis et al., 1997), and class size  
79 (McKenzie et al., 2000). Since previous research has shown motivation to be an important  
80 determinant of in-class MVPA, increasing attention has been paid to the role of PE motivation in  
81 total MVPA (Ntoumanis and Standage, 2009; Vanttaja et al., 2017).

82 SDT (Deci and Ryan, 1985; 2000; Ryan and Deci, 2017) has been found advantageous as a  
83 theoretical framework for understanding behavioural processes in the PE context. According to  
84 SDT, the basis of motivational behaviour lies in the satisfaction of basic psychological needs for  
85 competence, autonomy, and social relatedness (Deci and Ryan, 1985; 2000; Ryan and Deci, 2017).  
86 Need for competence refers to the need to be successful in an activity (Ryan and Deci, 2017).  
87 Autonomy is the need to engage in activities for growth, volition, and willingness, and social  
88 relatedness the need to feel connected and interact with others. If school PE helps students to meet  
89 or satisfy these needs by increasing their perceptions of efficacy in given activities (competence),  
90 increasing their opportunities to develop interest or value in activities (autonomy), and supporting  
91 and encouraging their relationships with their teachers and peers (relatedness), students are likely to  
92 be more autonomously motivated (i.e. engage in activities for growth, stimulation, and enjoyment)  
93 to participate in PE. In the PE context, some studies have found that competence need satisfaction is  
94 the strongest predictor of higher autonomous motivation (Standage et al., 2005; Taylor et al., 2010).  
95 Despite this, the current focus in the research literature is the combination of need satisfaction with  
96 need frustration (Chen et al., 2015; Ryan et al., 2016; Warburton et al., 2020), as they have been  
97 shown to co-occur with differential effects on the outcomes experienced by young people in  
98 learning settings such as school PE (De Meyer et al., 2014; Haerens et al., 2013; 2015; Sun et al.,  
99 2017; Wang et al., 2016). In line with the objectives of the Finnish national PE curriculum (Finnish  
100 National Agency for Education, 2014), the present study focused on need satisfactions over

101 frustrations, as the satisfactions may have protective effects even when need frustration is  
102 experienced (Warburton et al., 2020). Hence, to optimise autonomous motivation in PE, positive  
103 need satisfactions could be enhanced (De Meyer et al., 2014; Haerens et al., 2013; 2015; Sun et al.,  
104 2017; Wang et al., 2016). Empirical evidence supports this assumption as the need satisfaction for  
105 competence (Cox et al., 2008; Gråstén and Watt, 2017), autonomy (Chatzisarantis and Hagger,  
106 2009; Lonsdale et al., 2009) and social relatedness (Gråstén and Watt, 2017; Taylor et al., 2010)  
107 have been shown to be associated with both total MVPA engagement and in-class MVPA. In  
108 addition, associations between in-class and total MVPA have been found in school-based PE  
109 studies (Dale et al., 2000; Gråstén et al., 2019).

110 With respect to gender, girls have been found to report less competence (Mouratidis et al.,  
111 2015; Ullrich-French and Cox, 2014) and autonomy need satisfaction (Mouratidis et al., 2015; Soini  
112 et al., 2007) but more relatedness need satisfaction in PE than boys (Gråstén and Watt, 2017). Some  
113 studies have found no gender differences in relatedness satisfaction among school students  
114 (Mouratidis et al., 2015; Xiang et al., 2017) or that boys reported higher relatedness need  
115 satisfaction than girls (Ntoumanis et al., 2009; Ullrich-French and Cox, 2014).

116 To summarise, the impact of SDT-based motivation in the PE context has been widely  
117 researched (De Meyer et al., 2014; Haerens et al., 2013; 2015; Wang et al., 2016). The most  
118 relevant application of SDT in PE pedagogy is that a teacher can motivate students to engage and  
119 learn in class through supporting need satisfactions (Chang et al., 2016). Intervention studies aimed  
120 at increasing students' self-determined motivation in PE are well-documented in the literature  
121 (Aelterman et al., 2014; Chatzisarantis and Hagger, 2009; Franco and Coterón, 2017). Of the three  
122 needs, most previous intervention studies have aimed at providing autonomy support in PE classes  
123 as a way of stimulating students' motivation (Chang et al., 2016). It has also been found that  
124 classroom experiences of autonomy and competence in PE are influenced more by teachers than  
125 peers, whereas relatedness is influenced by both peers and teachers (Vasconcellos et al., 2019).

126 Despite the large body of previous SDT-based studies on the topic of PE, several important issues  
127 remain unclear. For example, it is largely unknown how changes in all three basic psychological  
128 need satisfactions in school PE contribute to MVPA in PE and, more importantly, to total MVPA  
129 over time. A recent review by Vansteenkiste et al. (2020) and a need profile study by Warburton et  
130 al. (2020) concluded that more longitudinal work on need satisfactions over time is needed.  
131 Previous studies conducted among elementary school children (Ullrich-French and Cox, 2014),  
132 secondary school (Ntoumanis et al., 2009; Ratelle and Duchesne, 2014) and university students  
133 (Gillet et al., 2019) have revealed considerable heterogeneity in need satisfaction trajectories.

134 This follow-up study extends previous research on the topic by investigating the longitudinal  
135 relationships between the three psychological need satisfactions in PE and in-class and total MVPA.  
136 In addition to need satisfaction studies with adolescents (Ntoumanis et al., 2009; Ratelle and  
137 Duchesne, 2014), it would be also important to examine the longitudinal associations between need  
138 satisfactions and MVPA scores over time in elementary school children, as it is at this stage that the  
139 decline in physical activity usually begins (Slingerland, 2014; Telama et al., 2005; Tremblay et al.,  
140 2016). Since boys have been found to be more physically active (Tremblay et al., 2016; Yli-Piipari  
141 et al., 2012) and score higher on competence (Fairclough, 2003; Yli-Piipari et al., 2012) and  
142 autonomy needs (Mouratidis et al., 2015; Soini et al., 2007) than girls, and conflicting findings have  
143 been reported for social relatedness need satisfaction between girls and boys (Gråstén and Watt,  
144 2017; Mouratidis et al., 2015; Ntoumanis et al., 2009; Ullrich-French and Cox, 2014; Xiang et al.,  
145 2017), gender differences were also examined over time. The present findings may be utilised to  
146 develop more effective PE teaching practices to fulfil basic need satisfactions, especially in younger  
147 children, as it is crucial that children have positive physical activity experiences in PE during their  
148 elementary school years (Jaakkola et al., 2019).

149 Mindful of these considerations, the specific aims of this study were 1) to examine the  
150 associations between the need satisfaction for competence, autonomy, social relatedness, in-class

151 MVPA, and total MVPA across a period of one year (Figure 1) and 2) to analyse gender differences  
152 in these associations, means, and variances over time. Based on the current literature review, higher  
153 satisfaction of the needs for competence, autonomy, and relatedness was expected to be positively  
154 linked with higher in-class MVPA and total MVPA at baseline and also at follow-up, although  
155 these associations have not been previously investigated in a follow-up design. Positive associations  
156 between in-class and total MVPA were also expected. Girls were expected to report higher social  
157 relatedness need satisfaction, while boys were believed to score higher on competence and  
158 autonomy need satisfaction.

159

160 [Figure 1 here]

161

## 162 **Methods**

### 163 *Participants and procedure*

164 Participants were 523 (girls 280, boys 243) Finnish grade five children aged 11 to 13 with a mean  
165 age of  $11.26 \pm .31$  years at the beginning of the data collection. Children were recruited from 18  
166 randomly selected public-sector schools in Southern (26% of students) and Central (74%) Finland.  
167 The sample distribution reflects the basic characteristics of Finnish schools (i.e. Finnish-speaking,  
168 middle-size schools with approx. 500 students per school with no rankings, comparisons or  
169 competition between students, schools or regions, and every school serving the same national goals  
170 and drawing from the same pool of university-trained teachers). Through direct contact with the  
171 schools' principals, all grade five students were invited to participate. Children represented 38 study  
172 groups taught by classroom teachers, who were the same at both T0 and T1. The total number of  
173 children completing the survey was 510 (T0) and 473 (T1) and with accelerometer data 415 (T0)  
174 and 274 (T1). All students participated in regular PE classes (two x 45 minutes of PE per week), no  
175 students with special needs participated in the study, although the opportunity was given to all



176 students equally. Class sizes varied between schools, students typically being taught PE in groups  
177 of 16 to 28 students. All teachers were specialised in elementary school education, but had been  
178 trained to teach PE as well. The content of all PE classes focused primarily on developing  
179 fundamental movement skills, i.e. running, jumping, and throwing in soccer and track and field  
180 activities (Finnish National Agency for Education, 2014).

181 The first measurement phase was conducted in August-September 2017 (T0) and the second  
182 during the same months in 2018 (T1). Both measurements were implemented using the same  
183 procedures. Students answered to the questionnaires in the schools' computer labs or classrooms  
184 under the supervision of teachers and researchers. Students were encouraged to answer honestly,  
185 and they were assured that their responses were confidential. Children were advised ask for help if  
186 needed and told that their participation was optional and that they could withdraw at any time  
187 without any consequences. To implement the objective MVPA measurements, researchers entered  
188 the students' demographic details and gave them instructions on how to use the activity monitors.  
189 Teachers collected the accelerometers and the researchers downloaded the data using the  
190 manufacturer's software (Actilife 3.6.0, ActiGraph). Participation was voluntary and was not  
191 rewarded with extra credits. Students who returned signed parental consents were permitted to  
192 participate in the study. Students who had a medical condition or physical injuries reported by  
193 parents before the commencement of the study were excluded. The ethical committee of the local  
194 university approved the study.

195

### 196 *Measures*

197 Demographic information was collected during PE classes in the same weeks as the MVPA  
198 measurements. Height (130 to 172 cm,  $M = 148 \pm 7$  cm) and weight (26 to 76 kg,  $M = 41.5 \pm 8.5$   
199 kg) were measured. Body mass index (14 to 33,  $M = 19 \pm 2.9$ ) was calculated ( $\text{kg}/\text{m}^2$ ) using the cut-  
200 off points for 12 to 16 years old girls (22.14 to 24.54) and boys (21.56 to 24.19) presented by Cole

201 et al. (2000). Students were measured by the researcher in a separate space so that each student's  
202 information remained confidential and students did not see each other's results.

203 The Finnish version of the Basic Psychological Needs in Physical Education Scale (BPN-PE;  
204 Vlachopoulos et al., 2011) was used to assess the satisfaction of needs for competence, autonomy,  
205 and social relatedness in PE. The item stem was "*In PE classes I feel that...*" The scale consisted of  
206 12 items divided among three subscales: competence (e.g. *I can do well even in the lessons*  
207 *considered difficult by most kids in my class*), relatedness (e.g. *my relationships with the other kids*  
208 *in my class are friendly*), and autonomy (e.g. *we do things in class that interest me*). All three  
209 subscales were measured on five-point response scales from (1) *totally disagree* to (5) *totally agree*.  
210 Gråstén et al. (2019) reported acceptable construct validity for the Finnish version ( $\chi^2(50) = 106.59$ ,  
211  $p < .001$ ,  $CFI = .97$ ,  $TLI = .96$ ,  $RMSEA = .048$ ,  $SRMR = .035$ ) in a sample of Finnish elementary  
212 school students.

213 In-class and total MVPA (minutes per day) were measured using triaxial Actigraph GT3X+  
214 accelerometers. Total MVPA was collected across a period of seven days, and in-class MVPA was  
215 extracted from total MVPA. During the measurement period, students participated in two PE  
216 classes (two x 45 minutes) following the local curriculum. The activity monitors were light, small,  
217 easy to use, and were worn on the right waist. The devices collected the data at 15-second intervals,  
218 as longer sampling intervals might have been inaccurate with young children (Nilsson et al., 2002).  
219 Only daytime activity (7am to 11pm), excluding water-based activities as the accelerometer model  
220 used was not waterproof, was included in the analyses. Following the protocol adopted in the earlier  
221 studies of Bergh et al. (2011) and Gråstén and Watt (2016), total MVPA minutes were considered  
222 valid if a child had at least three days, including one PE class and one weekend day, with at least  
223 500 minutes of activity recorded per day. Periods of 30 minutes of consecutive zero counts were  
224 defined as non-wear time (Heil et al. 2012). The lower threshold for moderate-intensity activity was

225 2296 counts per minute (Evenson et al., 2008). The device used has previously been calibrated for  
226 young people in laboratory and free-living conditions (Martinez-Gomez et al., 2012).

227

### 228 *Statistical analyses*

229 Data were examined for normality of distributions, outliers (Tabachnick and Fidell, 2007) and  
230 missing values (Little and Rubin, 2002). Next, descriptive statistics, including correlations, means  
231 and standard deviations for the study variables, were determined. Since the data were expected to be  
232 hierarchical, intraclass correlation coefficients were calculated to detect variation in the study  
233 variables between classes and schools (Koo and Li, 2016). To examine the direct and indirect  
234 associations between the competence, autonomy, and relatedness need satisfactions, MVPA in PE,  
235 and total MVPA, a cross-lagged model using latent variables was estimated. A complex option with  
236 maximum likelihood estimation and robust standard errors was used to correct the possible non-  
237 independence of observations based on students being nested within their classes (Asparouhov,  
238 2006). Gender differences in the loadings between paths from T0 and T1, means, and variances  
239 were tested using two-group tests based on Chi-square, in which two nested models can be  
240 examined by constraining the subsequent parameters to be equal (Muthén and Muthén, 2013).  
241 Equality of means between repeated measurements at T0 and T1 were tested using the Wald's test  
242 of parameter equality (Williams, 2015).

243 The Chi-square test ( $\chi^2$ ) was used as a test of the model's overall goodness-of-fit to the data.  
244 A non-significant difference between the observed and theoretical distribution demonstrated  
245 acceptable fit (Hu and Bentler, 1999). To examine the appropriateness of the model, the root mean  
246 square error of approximation (RMSEA), standardised root mean square residual (SRMR),  
247 comparative fit index (CFI), and Tucker-Lewis index (TLI) were examined (Hu and Bentler, 1999).  
248 A value of .08 or less for SRMR indicates the reasonable magnitude of a varying quantity, a value  
249 of .06 or less for the RMSEA indicates an acceptable model fit (Hu and Bentler, 1999). CFI and

250 TLI indices greater than .95 are indicative of an excellent model fit (Hair et al., 2010). The  
251 preliminary data analyses were performed using SPSS Version 22.0 and structural equation models  
252 using Mplus Version 8.2.

253

## 254 **Results**

### 255 *Preliminary analysis*

256 Data were normally distributed, and no significant outliers were detected based on the standardized  
257 values ( $\pm 3.00$ ). The data matrix included 15.79% of missing values (826 out of 5230), owing to  
258 incomplete self-report or MVPA scores. The Missing Completely at Random (MCAR) test ( $\chi^2(245)$   
259 = 279.78,  $p = .063$ ) indicated that the data matrices with and without missing scores were similar. A  
260 closer examination of the data supported that missing values were missing completely at random, as  
261 the missing scores did not represent any particular school or group. Missing values were then  
262 estimated using the Full Information Maximum Likelihood Estimation method, which has been  
263 shown to produce unbiased parameter estimates and standard errors under MCAR conditions  
264 (Enders and Bandalos, 2001).

265

### 266 *Descriptive statistics*

267 The correlation coefficients, means, standard deviations, and Cronbach alphas for the study  
268 variables were examined (Table 1). The correlations between variables ranged from weak to strong.  
269 The strongest positive correlation was found between the autonomy and relatedness need  
270 satisfactions at T1. The mean difference tests between the T0 and T1 measurements revealed that  
271 autonomy need satisfaction, MVPA in PE and total MVPA declined in girls and that competence,  
272 autonomy, relatedness satisfactions and total MVPA declined in boys over time (Table 2). The  
273 proportions of children meeting the current MVPA guidelines varied over time (girls 38% at T0 and  
274 29% at T1; boys 54% at T0 and 49% at T1), with total MVPA minutes per day ranging from 16 to

275 128 (T0) and 17 to 114 (T1) in girls and 11 to 129 (T0) and 19 to 119 (T1) in boys. The intraclass  
276 correlation coefficients showed no variation between classes or schools in competence, autonomy  
277 or total MVPA and low to moderate variations in relatedness at T1 and in-class MVPA at T0 and  
278 T1 (Table 3). Because MVPA in PE was indicated to have a multilevel structure, the following  
279 cross-lagged model was implemented using the complex model option to adjust for sampling  
280 weights (Asparouhov, 2006).

281

282 [Table 1 here]

283 [Table 2 here]

284 [Table 3 here]

285

286 *Associations between basic psychological need satisfactions and MVPA*

287 First, to examine the appropriateness of the theorised measurement model including needs for  
288 competence, autonomy, relatedness, MVPA in PE, and total MVPA at T0 and T1, both girls and  
289 boys were combined as a single group in the same model. The theorised model revealed an  
290 acceptable model fit ( $\chi^2(329) = 666.54, p < .001, CFI = .93, TLI = .92, RMSEA = .044, 90\% CI [.04,$   
291  $.05], SRMR = .046$ ). The model showed significant direct and indirect paths between the study  
292 variables (Figure 2). Squared multiple correlations ( $R^2$ ) showed that the model explained 19% to  
293 35% of the variability of total MVPA and 9% of the variability of in-class MVPA, excluding the  
294 non-significant squared multiple correlation of in-class MVPA at T0.

295

296 [Figure 2 here]

297

298 *Gender differences in need satisfactions and MVPA*

299 To test for gender differences between the loadings from T0 to T1, a series of two-group tests was  
300 implemented by fixing the loadings between T0 and T1 to be equal. Significant gender differences  
301 emerged in the loadings between social relatedness satisfaction at T0 and T1 ( $\chi^2(1) = 4.45, p < .05$ )  
302 and social relatedness satisfaction at T1 and total MVPA at T1 ( $\chi^2(1) = 4.29, p < .05$ ), specifically  
303 between relatedness T0 and relatedness T1 (girls = .52, boys = .60) as well as relatedness T1 and  
304 total MVPA T1 (girls = -.05; boys = .18). To test the equality of means and variances to identify  
305 significant differences between girls and boys, a series of two-group tests was implemented. The  
306 results showed that boys scored higher than girls on competence at T0 ( $\chi^2(1) = 14.86, p < .001$ ) and  
307 relatedness need satisfaction at T0 ( $\chi^2(1) = 5.59, p < .05$ ) and that gender differences existed in in  
308 the variances of social relatedness satisfaction at T0 ( $\chi^2(1) = 5.60, p < .05$ ) and in-class MVPA at  
309 T1 ( $\chi^2(1) = 12.74, p < .001$ ).

310

### 311 **Discussion**

312 This study investigated the associations between the satisfaction of basic psychological needs for  
313 competence, autonomy, and social relatedness, MVPA in PE, and total MVPA. The study also  
314 examined gender differences over time. Based on the current SDT literature in the area, higher  
315 satisfaction of the needs for competence, autonomy, and relatedness was expected to be linked with  
316 higher in-class MVPA, and total MVPA at baseline. Although a few previous studies in the SDT  
317 literature have presented need satisfaction trajectories over time (Ntoumanis et al., 2009; Ratelle  
318 and Duchesne, 2014; Ullrich-French and Cox, 2014), no studies investigating need satisfactions  
319 over time have concurrently examined competence, autonomy, and relatedness in the domain of  
320 physical activity. Thus, this study contributes to the literature on the topic by examining how  
321 changes in all three basic psychological need satisfactions in PE contribute to MVPA in PE and to  
322 total MVPA over time. As expected, the positive paths from competence need satisfaction, social  
323 relatedness need satisfaction, and in-class MVPA to total MVPA as well as gender differences in

324 competence and relatedness, favouring boys were evident. It was unexpected that the association  
325 between autonomy need satisfaction and total MVPA at T0 was negative.

326 First, the results showed that the need satisfaction for competence in PE predicted later total  
327 MVPA at T1 via total MVPA at T0, thereby corroborating previous findings (Cox et al., 2008;  
328 Gråstén and Watt, 2017; Gråstén et al., 2019). In the context of the present Finnish PE curriculum  
329 (Finnish National Agency for Education, 2014), the importance of competence need satisfaction  
330 when examining engagement in MVPA is understandable. This assumption is one of the most  
331 important cornerstones of the Finnish PE curriculum and as the present results show, manifests a  
332 positive longitudinal relationship between competence and MVPA engagement. Hence, to enhance  
333 children's total MVPA engagement, it is essential that they are provided with competence  
334 supportive activities in PE classes. This is especially important for girls, who are typically less  
335 physically active than boys (Tremblay et al., 2016; Yli-Piipari et al., 2012). Following the  
336 suggestions of previous SDT-based PE programmes, the need for competence, especially among  
337 girls, could be supported by emphasizing effort and arranging activities in which students can  
338 experience optimal challenge (Standage and Ryan, 2012) and also more positive feedback (Doolittle  
339 and Rukavina, 2014; Standage and Ryan, 2012). For example, students could be instructed in how  
340 to give each other appropriate feedback from a very early age, such as through simple hand gestures  
341 or by holding up printed cards. As during the school career, students' ability to give feedback  
342 develops, they could use more versatile means of communication. Students could also be given  
343 more opportunities to comment and express respect for their experiences, thereby promoting deeper  
344 understanding and learning (Culp, 2013). For example, when teachers developed a coordinated  
345 school physical activity program for middle school students, they offered volleyball and table tennis  
346 classes because of the strong interest shown by students (Doolittle and Rukavina, 2014). As  
347 described above, competence need satisfactions could be supported in numerous different ways to  
348 lift student outcomes. Although optimal functioning driven by competence need satisfaction is

349 likely to be similar across cultures (Chen et al., 2015), strategies introduced to support competence  
350 satisfaction in PE classes may best work in Finnish or other less authoritarian school systems. In the  
351 Finnish school system, relationships between teachers and students tends towards informality,  
352 meaning that students find it easy to approach their teachers (Kauppi and Pörhölä, 2012). In school  
353 cultures with more formal teacher-student relationships, such methods may need some  
354 modification. As supporting competence need satisfaction in PE classes appears to be important in  
355 ensuring positive MVPA engagement over time, it would be crucial to identify students, whose  
356 level of competence satisfaction is low. This may be even more valuable than viewing the transition  
357 over time itself as a risk for poor student outcomes (Ullrich-French and Cox, 2014).

358         Second, in line with previously established associations (Gråstén and Watt, 2017; Taylor et  
359 al., 2010) social relatedness satisfaction at baseline was related with total MVPA at follow-up via  
360 baseline MVPA. Children who reported positive relatedness need satisfaction when engaged in PE  
361 activities were generally more physically active. This finding underlines the importance of the  
362 social aspects of PE lessons for total MVPA engagement. To support social relatedness need  
363 satisfaction across PE lessons, students could be given opportunities in their learning teams to  
364 develop their content knowledge and refine their performance through peer teaching instructional  
365 tasks (Standage and Ryan, 2012; Wallhead et al., 2013). Furthermore, students could be provided  
366 with a well-structured environment that gives clear guidelines (open teacher-student  
367 communication) and opportunities for social learning (cooperation between students), provides  
368 optimal challenges, and offers detailed feedback on how to achieve desired outcomes (Taylor and  
369 Ntoumanis, 2007). Given that some previous studies have revealed direct associations between  
370 larger class sizes and higher levels of antisocial behaviour (Reeves, 2010), class sizes should be  
371 judiciously considered, when grouping PE students. If classes are too large, the PE teacher does not  
372 have enough time to give detailed student feedback as a way of optimising learning outcomes. All  
373 such improvements rely on good cooperative working arrangements between teachers, students, and



374 other school personnel, including school principals, who play important roles in supporting clear  
375 and consistent communication via the creation of a positive school climate (Smith et al., 2014).  
376 From perspective of PE teachers, attempts to implement respectful cooperation between schools and  
377 families could support social relatedness need satisfaction and the positive development of the  
378 student-student as well as teacher-student relationship (Aldrup et al., 2018). Students in turn could  
379 make a conscious effort to be positive role models for others and demonstrate good sportsmanship  
380 within the boundaries set in cooperation by teachers and students (Smith et al., 2014).

381 An opposite and unexpected finding to the previous results in the field (Chatzisarantis and  
382 Hagger, 2009; Lonsdale et al., 2009) was the negative relationship between autonomy and total  
383 MVPA. In other words, students with higher total MVPA scores reported lower autonomy  
384 satisfaction in PE classes. Based on the current data, it is difficult to draw clear reasons behind this  
385 negative association. One possible explanation may be that PE lessons during the measurement  
386 period did not support students' autonomy need satisfaction, although students were physically  
387 active outside PE lessons, for instance when participating in leisure sports. This could be the case,  
388 for instance, when students are provided with activities that they dislike or find less interesting  
389 (Doolittle and Rukavina, 2014). It is possible that the lesson themes (Slingerland, 2014) or  
390 resources available (Levin et al., 2001) during the measurement period did not support the need for  
391 autonomy, leading students to report low autonomy scores. It should be mentioned that Finnish  
392 school PE is not an elective subject but compulsory for all grade 1 to 9 students. Hence, it cannot be  
393 assumed that students' autonomy need satisfaction is fully met in all PE lessons. The associations  
394 could have been positive if the measurement period had covered several PE lessons. For example,  
395 Chatzisarantis and Hagger (2009) collected PE data during a 5-week intervention. Reeve (2009)  
396 suggests several strategies to facilitate positive autonomy need satisfaction in PE classes. For  
397 instance, teachers could provide explanatory rationales (articulate the sometimes unmentioned use  
398 underlying a teacher's request), rely on non-controlling language (informational communication

399 often helps students to diagnose and solve their motivational problems), display patience by  
400 allowing students the time they need for self-paced learning to occur (give students time to work in  
401 their own way), and acknowledge and accept students' expressions of negative affect (treat  
402 students' complaints as valid reactions to imposed demands and structures). Although it is difficult  
403 to explain the current negative association, it might, based on previous research findings, be fruitful  
404 to promote autonomy in curriculum-based activities in PE classes. If successful, this is likely to  
405 translate into higher total MVPA scores, which is needed across the life-span (Tremblay et al.,  
406 2016).

407         The results also showed the importance of MVPA in PE classes and its contribution to total  
408 MVPA engagement. As expected, baseline MVPA in PE classes predicted total MVPA at follow-  
409 up. Specifically, in-class MVPA accounted, on average, for 37% of total MVPA in all students over  
410 the study period. This result supports previous Finnish (Gråstén et al., 2015; 2019) and international  
411 (Bailey et al., 2012) findings. The present total MVPA scores indicated that children's MVPA  
412 levels were insufficient, which is a matter of great concern. Many potential strategies can be  
413 deployed to increase the amount of MVPA time in PE classes. Schools could, for instance, review  
414 class sizes, reduce time spent in locker rooms, and implement instant activities instead of sitting and  
415 waiting for instructions at the beginning and end of the class (McKenzie et al. 2000), establish  
416 routines for the more efficient supply of equipment by letting students assist with the care and  
417 proper storage of PE teaching materials (Gråstén et al., 2017), integrate objective devices into PE  
418 classes to monitor MVPA behaviour (Strand and Reeder, 2013), and reassess MVPA time and use  
419 the results to refine and improve practice (Freedson et al., 2012; McKenzie et al. 2000). It is clear  
420 that students need more MVPA than schools alone can provide. Hence, ensuring that they have  
421 satisfying and positive PE experiences may facilitate the adoption of a more active lifestyle outside  
422 of PE.

423 Finally, in line with previous studies (Mouratidis et al., 2015; Ullrich-French and Cox, 2014),  
424 boys had higher baseline competence need satisfaction. Contrary to some previous evidence, boys  
425 also had higher baseline social relatedness need satisfaction than girls. Compared to an earlier  
426 Finnish study reporting opposite results (Gråstén and Watt, 2017), it is possible that the boys in the  
427 present sample experienced more opportunities to interact with peers in out-of-school activities. If  
428 so, they may also manifest as higher social relatedness satisfaction scores in PE classes. However,  
429 Howie et al. (2010) reported that children who participated more frequently in sports had higher  
430 social skill scores than those who participated less frequently in sports. This may also explain the  
431 differences between groups in the current study. Many previous studies have reported that  
432 interaction with peers plays a critical role in the development of children's social competence  
433 (Branchi et al., 2013; Gifford-Smith and Brownell, 2003) which, although not the same, is closely  
434 associated with SDT-based social relatedness. It is also important to remember that physical  
435 appearance, physical development, and bodily changes in early adolescent girls appear to be  
436 associated with negative perceptions of social relatedness (Craft et al., 2003). If so, this may be  
437 reflected in the present lower scores in girls. It has been suggested that perceptions of social  
438 relatedness among adolescent girls may be enhanced by emphasizing friendship and social  
439 interaction in PE classes and minimising social comparisons (Craft et al., 2003). According to  
440 Gibbons (2014), a socially supportive learning environment in PE could be created by including  
441 cooperative games and team-building activities, helping students to develop connections with  
442 teachers and peers (learn the names of your students, use icebreakers), using group rotation (by the  
443 end of the semester everyone has worked with everyone else), reinforcing positive behaviour,  
444 avoiding stereotypical language ("girls' push-ups"), asking students how to create a safer  
445 environment, and implementing a respectful process of choosing teammates (you must accept the  
446 first person who responds, if someone does not have a group invite them into your group). Thus,  
447 there are many practical ways of enhancing social interaction in PE lessons.

448

449 *Limitations and future research directions*

450 The strengths of the present study were the relatively large and nationally representative sample  
451 size, follow-up design, and the use of objective MVPA measures. The study nevertheless has its  
452 limitations. First, self-reported need satisfactions for competence, autonomy, and relatedness may  
453 vary in accuracy more than objective measurement protocols, such as observation tools. Second,  
454 school-based “real-life” follow-up studies are always vulnerable in that it is not possible to control  
455 for all the factors underlying physical activity behaviour. Finally, this study focused on need  
456 satisfactions that accorded with the objectives of the national PE curriculum, and thus need  
457 frustrations were not included in the measurements. Future studies could investigate teaching  
458 strategies that could help standardise practices in PE that support autonomy, competence, and  
459 relatedness. As this study focused on student-student relationships in respect of social relatedness  
460 need satisfaction, it would also be interesting to look more closely at student-teacher interactions. In  
461 addition, the associations between psychological need satisfactions, frustrations, and actual MVPA  
462 behaviour could be examined using follow-up designs with children and adolescents at different  
463 ages.

464

465 **Conclusion**

466 The present results showed the importance of in-class MVPA and its contribution to total MVPA  
467 engagement. To increase the amount of daily MVPA time, it would seem to be crucial to support  
468 the need satisfactions for competence and social relatedness in PE classes. This is especially  
469 important among girls, as they normally accrue fewer daily MVPA minutes than boys. An increased  
470 use of need-centred teaching strategies could promote student engagement in the PE context.  
471 Children could also be more heavily involved in the planning process and implementation of their

472 PE lessons. Such actions could enhance children's sense of autonomy, competence, social  
473 relatedness, in-class MVPA and, most importantly, total MVPA engagement over the long term  
474       Concerns arising from these findings were that total MVPA declined over time in both girls  
475 and boys, and a smaller proportion of children met the current MVPA guidelines at follow-up.  
476 Schools alone cannot provide all the MVPA children need. To help children achieve a physically  
477 active lifestyle later in their lives, it is essential to ensure that all students enjoy positive and  
478 satisfying PE experiences. To raise awareness of the basic psychological need satisfactions and  
479 improve student outcomes, it would be vital, through teacher training programmes, to enhance the  
480 readiness and capability of pre-service teachers, as they will play a crucial role in stimulating  
481 autonomous motivation and greater MVPA engagement.

482

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