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**Title:** Leisure-time physical activity from adolescence to late middle age and its associations with the COVID-19 pandemic : A 45-year follow-up

**Year:** 2022

**Version:** Accepted version (Final draft)

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**Please cite the original version:**

Laakso, P. T., Huotari, P., Tolvanen, A. J., Kujala, U. M., Laakso, L. H., & Jaakkola, T. T. (2022). Leisure-time physical activity from adolescence to late middle age and its associations with the COVID-19 pandemic : A 45-year follow-up. *Journal of Sports Sciences*, 40(17), 1931-1939. <https://doi.org/10.1080/02640414.2022.2122318>

1 **Leisure-time physical activity from adolescence to late middle-age and its associations with**  
2 **the COVID pandemic: A 45-year follow-up**

3

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9

10 **ABSTRACT**

11

12 We aimed to investigate the association of self-reported leisure-time physical activity (LTPA) over  
13 a 45-years from adolescence to late middle age mediated by LTPA in early middle age. We also  
14 explored whether LTPA in adolescence and early middle age was associated with change in LTPA  
15 during the COVID-19 pandemic.

16

17 We constructed a path model employing questionnaire data from three LTPA measurements (1976,  
18 2001, 2021) including duplicated assessment for pre- and during COVID-19 in 2021. The direct and  
19 indirect associations between LTPA in adolescence, early middle and late middle age were  
20 investigated, as well as the impact of previous LTPA on change in late middle age LTPA due to the  
21 pandemic. The number of participants per assessment was: n=2083; n=1468 (71% of the original);  
22 n=878 (42%) and n=867 (42%), respectively. However, the number varied depending on the path  
23 examined.

24

25 LTPA in adolescence was associated with LTPA in late middle age, although the association was  
26 not strong. LTPA decreased significantly during the pandemic. Earlier LTPA was associated with  
27 change in LTPA between before and during COVID-19 among males.

28

29 This study is the first to demonstrate an association between adolescent and late middle age LTPA.  
30 However, the association across the 45-years was low.

31

32 **Keywords:** Physical activity, longitudinal, follow-up, adolescence, middle age, COVID-19

33

## 34 **INTRODUCTION**

35

36 PA is defined as any bodily movement produced by skeletal muscles that requires energy  
37 expenditure<sup>1</sup>. Leisure time physical activity (LTPA), in turn, refers to PA-related behavior that  
38 people freely engage in during their disposable time<sup>2</sup>. Observational studies have shown strong  
39 evidence that regular PA is associated with a reduction in numerous adverse health conditions<sup>3,4</sup>.  
40 High PA has been linked to a low prevalence of many non-communicable diseases (NCD) such as  
41 coronary heart disease, type 2 diabetes and breast and colorectal cancers<sup>5</sup>. LTPA has shown a  
42 stronger association than occupational PA with beneficial health outcomes<sup>6,7</sup>. Hence, it has been  
43 addressed that lifelong PA, founded in young ages, is desirable and pertains to a healthy lifestyle<sup>4</sup>.  
44 In research, PA is commonly divided into four dimensions: type, frequency, duration, and intensity  
45 of activity. These dimensions are typically mapped in physical activity self-report questionnaires<sup>8</sup>.  
46 The increased energy expenditure induced by PA, which is directly linked to the intensity of PA,  
47 can be assessed as the Metabolic Equivalent (MET) of the activity and calculated from physical  
48 activity self-reports<sup>8,9</sup>. Thus, the MET value indicates the metabolic rate. For example, a MET value

49 of one represents the resting metabolic rate, a value of 3-5.9 indicates moderate-intensity PA and a  
50 value of 6 indicates vigorous-intensity PA<sup>10</sup>.

51

52 It is well documented that PA tracks with a low to moderate level of significance from childhood  
53 and adolescence to adulthood<sup>11-13</sup>; that is, individuals tend to maintain the position of physical  
54 activity or physical inactivity they adopted earlier<sup>12</sup>. Investigating PA tracking has been justified by  
55 globally accepted position that PA promotion in young ages impacts the development of physically  
56 active lifestyle<sup>14</sup>. Tracking studies using self-reported PA from childhood and adolescence to  
57 adulthood<sup>11-13,15-17</sup> have mostly revealed a low or at least moderate correlation between PA in  
58 childhood and adolescence with PA in adulthood. The correlation coefficients reported in the vast  
59 majority of studies in the extensive reviews by Hayes et al.<sup>11</sup>, Telama<sup>12</sup> and Malina<sup>13</sup> varied  
60 between 0.03 to 0.45. However, participant age at the end point has at most been 42 years. An  
61 exception is the study by Friedman et al.<sup>18</sup> in which it was 66 years. However, Friedman et al.<sup>18</sup> may  
62 not meet the validity criteria of current PA research, as the baseline data, collected in the year 1922,  
63 was obtained from teacher or parent reports. The findings of Hayes et al.<sup>11</sup>, Telama<sup>12</sup> and Malina<sup>13</sup>  
64 were confirmed in a population-based study (n=43 889) by Van der Zee et al.<sup>15</sup>, who reported  
65 correlation coefficients lower than 0.30. However, their maximum follow-up time was 20 years and  
66 age at baseline varied between 8 and 80, and thus not all the inter-age correlations included data  
67 from childhood/adolescence. The Finnish population-based study (n=3596) by Telama et al.<sup>16</sup>  
68 similarly reported coefficients varying between 0.07-0.32, depending on gender and age at baseline.  
69 The maximum age at the end point in their study was 45 years. Childhood-adulthood tracking  
70 research has shown higher correlation coefficients in males than females<sup>12,16,17</sup>. Correlations have  
71 also tended to increase with baseline age<sup>12,17</sup>, as demonstrated in the Finnish 25-year follow-up<sup>17</sup>,  
72 where the coefficients increased from 0.14/0.05 (males/females) to 0.31/0.17 at the baseline ages of  
73 12-15 and 16-18 years. Follow-up age in the vast majority of childhood-adulthood tracking studies

74 has been limited to adults aged 30 to 45-years<sup>12,13,15</sup>. PA tracking studies from early middle age to  
75 late middle age, while scarce, have shown results comparable to those from a young age to  
76 adulthood<sup>15,19,20</sup>.

77

78 The COVID-19 pandemic and the restrictions it has entailed have impacted dramatically on  
79 people's everyday lives around the world during the past two years (2020-21). Empirical research  
80 on the effects of these restrictions on PA is abundant. PA levels during the first two years of  
81 pandemic clearly decreased from pre-pandemic levels<sup>21-25</sup>. Variation between different age-groups  
82 has also been observed. Irrespective of country or mitigation strategies, older adults (age 45+) seem  
83 to have maintained their PA level during periods of restrictions more often compared to younger  
84 people and have returned sooner to their habitual PA level when restrictions have been eased<sup>22,26-28</sup>.  
85 However, retrospective research on the association of previous PA engagement with PA levels  
86 during the pandemic is scarce. In their Canadian study, Lesser and Nienhuis<sup>29</sup> report that previously  
87 active individuals more often increased and more rarely quit their habitual PA compared with  
88 inactive peers. Most (79.3 %) of their participants were females.

89

90 Investigating the factors that have an influence on lifelong PA is essential. Despite robust evidence  
91 on the longitudinal associations of PA from childhood and adolescence to adulthood, studies  
92 including participants in their 60s are lacking. To our best knowledge, the present study is the first  
93 to track PA from a young age up to age 57-64 years. Extending longitudinal investigation to the  
94 later years of working life is justifiable, as it is known that insufficient PA, especially when  
95 combined with older age, increases the risk for many health impairments and reduced physical  
96 function<sup>5,7</sup>. Despite the rapid accumulation of evidence showing a decline in PA levels due to the  
97 COVID-19 pandemic<sup>21-22</sup>, empirical research on PA habits during the pandemic has been wholly  
98 cross-sectional and descriptive, and only sporadic findings<sup>22,26-29</sup> have been presented on concerning

99 the role of earlier PA on PA during the pandemic. Hence, there is a need for explanatory research to  
100 identify the behavioral factors behind PA adherence during exceptional situations such as the  
101 COVID-19 pandemic. This follow-up study contributes to filling this gap by utilizing 45-year  
102 retrospective data.

103

104 The aim of this study was to investigate how self-reported LTPA in adolescence and in early middle  
105 age predicted self-reported LTPA in late middle age 45 years later on. Because of pandemic-driven  
106 exceptional times we also explored whether LTPA engagement in adolescence and early middle age  
107 was associated with change in LTPA engagement during the COVID-19 pandemic.

108

## 109 **MATERIAL AND METHODS**

110

### 111 **Study population**

112

113 This study is the third part of the three-phase LISE 45-years follow-up project designed to  
114 investigate LTPA and physical fitness (PF) engagement and adherence over a 45-year period. In  
115 April-May 1976, a trained measurement team collected the baseline data, including objectively  
116 measured fitness tests and self-reported LTPA from 56 schools in Finland. A four-phase stratified  
117 random sample (n=2 796) of children and adolescents (mean age 14.4) was drawn from different  
118 regions and from both urban and rural municipalities. In the first phase, 20 towns and rural  
119 communities were randomly selected from east, west, central, and north Finland. In the second  
120 phase, a random sample of 56 schools, matched for student numbers, was drawn proportionally  
121 from towns and rural municipalities. Classes in schools were randomly selected and the pupils  
122 drawn either in alphabetical order or by selecting every second or third in line etc. For the

123 longitudinal analyses of the current study, the participants aged 12-19-year-old (n=2554) were  
124 extracted from the baseline sample to form the group of adolescents.

125

126 In April-May 2001, 25 years post-baseline, the first follow-up questionnaire on self-reported LTPA,  
127 PF and health was sent to the same participants who had taken part in the fitness tests and/or  
128 answered the LTPA questionnaire in 1976. In total, 2 396 questionnaires were mailed, and 1 820  
129 responses (65 % of the original sample) returned<sup>17</sup>.

130

131 In the third phase, the current street addresses of the original 2 352 participants were extracted from  
132 the Finnish Population Information System. Those living abroad (n=66) were removed due to  
133 difficulties in implementing third phase measurement protocol. Moreover, 137 participants had died  
134 since the baseline measurements. In March 2021, a postal questionnaire, including separate  
135 questions for LTPA engagement before and during the COVID-19, was sent to all the 2 286 eligible  
136 participants who could be reached. A total of 1042 questionnaires (57 % of the follow-up 1 sample)  
137 were returned.

138

139 *Sample for the between-measurement path analyses*

140

141 To provide sufficient data for the between-measurement analyses, only the participants who  
142 answered all the questions on which the LTPA index of 1976 and 2001 and the MET-h/day of 2021  
143 were based were included. For calculating the LTPA index and MET-h/day, 2083 participants had  
144 eligible baseline (1976) data, 1468 had eligible data for follow-up 1 (2001), and 878 and 867,  
145 respectively, had eligible data for follow-up 2 (2021), i.e., for the before and during COVID-19  
146 measurements.

147

148 Because not all the participants attending the third measurement had participated in the second  
149 measurement, the number of participants included in the between-measurement analyses differed.  
150 The sample for the in between-measurement path analysis comprised 2309 participants, of whom  
151 55% (n=1270) had baseline + follow-up 1 data, 33% (n=762) baseline + follow-up 2 data, and 28%  
152 (n=647) for follow-up 1 + follow-up 2 data. The number of participants providing data from all the  
153 measurements (baseline + follow-up 1 + follow-up 2 including before and during COVID-19) was  
154 555.

155

156 **[Insert Table 1 here]**

157

### 158 **Assessment of leisure-time physical activity**

159

160 Leisure-time physical activity was assessed at each time point with a self-report questionnaire. The  
161 questionnaires differed somewhat as they had been designed by different researchers in different  
162 decades. In the 1976 baseline measurement, the self-report LTPA questionnaire was administered  
163 alongside an objective fitness test. The questions concerned the frequency, intensity, and type of  
164 LTPA and participation in organized LTPA (sports club in leisure time and extra-curricular school  
165 sports) and competitive sports. The frequency and intensity of LTPA was assessed by one question:  
166 "How many times a week do you participate in leisure-time physical activity of at least 30 min  
167 duration so that you feel breathless?" This question was coded on a 6-point response scale (0 = not  
168 at all, 1 = less than once a month, 2 = once a month, 3 = 2–3 times a month, 4 = once a week,  
169 5 = 2–6 times a week, and 6 = every day). The answers on participation in sports club training and  
170 in competitive sports were coded from 1 to 3 (1 = inactive or very low activity, 2 = moderately  
171 intensive or frequent activity, 3 = frequent or vigorous activity). Participation in extra-curricular  
172 school sports (school sports club) was coded dichotomously with 1 = "no" and 2 = "yes". The



173 leisure-time physical activity index for 1976 was calculated as the sum of the three PA variables  
174 with a total score ranging from 3 to 14.

175

176 The 25-year follow-up questionnaire in 2001 examined the frequency of LTPA, the average  
177 duration of a LTPA session and participation in organized and competitive sports. The questions  
178 were based on those used in two Finnish studies<sup>30,31</sup> but modified for the 2001 follow-up. A 7-point  
179 response scale was used to assess the frequency of LTPA, which was subsequently recoded from 1  
180 to 3 (1 = at most 3 times a month, 2 = 1-4 times a week, 3 = 5-7 times a week). Answers on the  
181 average duration of a LTPA session were coded on a 4-point scale where 0 = “not at all”, 1 = “at  
182 most 20 min”, 2 = “20-60 min”, and 3 = “60 min or longer”. The question on participation in  
183 competitive sports events used a 3-point response scale (0 = not at all, 1 = up to club level, and  
184 2 = regional, national or international) and the item on participation in organized LTPA a 4-point  
185 scale (0 = not at all, 1 = at most 3 times a month, 2 = 1-2 times a week, and 3 = 3-7 times a week).  
186 An additional question on the intensity of LTPA in organized sports used a 3-point response scale  
187 (1 = “not quite breathless”, 2 = “somewhat breathless”, 3 = “heavily breathless”). The leisure-time  
188 physical activity index for 2001 comprised five variables with a total score ranging from 1 to 14.

189

190 The 45-year follow-up questionnaire for 2021 was the same as the 2001 questionnaire except for  
191 one additional question on the average intensity of a LTPA session. The question on the frequency  
192 of LTPA was answered on a 7-point scale (1 = not at all, 2 = once in a month, 3 = 2-3 times a  
193 month, 4 = 1-2 times a week, 5 = 3-4 times a week, 6 = 5-6 times a week, 7 = every day). The item  
194 on the average duration of a LTPA session was answered on a 6-point scale (1 = at most 10 min,  
195 2 = 10-20 min, 3 = 20–40 min, 4 = 40-60 min, 5 = 60-90 min, 6 = 90 min or more). The intensity of  
196 the average LTPA session was asked with the question: “How would you describe the intensity of  
197 your average LTPA session?” on a 4-point scale where 1 = “walking”, 2 = “combination of walking

198 and running”, 3 = “light running or jogging”, and 4 = “brisk running”. Each question was  
199 duplicated to examine LTPA in the COVID-19 pandemic and pre-pandemic setting. The wording  
200 used was “LTPA during the current COVID-19 pandemic in Finland” and “before the COVID-19  
201 pandemic”. As the questionnaire was posted at the end of March 2021 and the majority of the  
202 answers received until June 2021, the answers represent the period between March and June 2021  
203 when the COVID-19 restrictions were initially more stringent (March-May) and thereafter relaxed  
204 (June-July). In Finland, there was no total lockdown and people were allowed to move freely  
205 outside their homes. During March to May in Finland, organized sports for adults was somewhat  
206 restricted. In the 45-year follow-up, the leisure-time physical activity index was calculated  
207 separately for before and during the pandemic, with three questions on the frequency, average  
208 duration, and intensity of LTPA. Further, a MET h/day value was calculated by using a  
209 classification based on that used in the FinTwin study<sup>32</sup>, in which walking corresponds to 4 METs,  
210 the combination of walking and running to 6 METs, light running or jogging to 10 METs, and brisk  
211 running to 13 METs.

212

213

## 214 **STATISTICAL ANALYSES**

215

216 Preliminary data handling and missing data analyses were carried out using IBM SPSS.

217

218 To investigate the associations between adolescent, early middle age, and late middle age self-  
219 reported LTPA, correlation coefficients were first calculated and tested for significance. To  
220 investigate the associations between adolescent, early middle age and late middle age self-reported  
221 LTPA and the impact of previous LTPA engagement on possible change in late middle age LTPA  
222 due to the COVID-19 pandemic, a path analysis conducted within the framework of structural

223 equation modeling was used (Figure 1). A multigroup path model with four groups (male, females,  
224 and two age groups) was used to test for interaction between gender and age at baseline. The  
225 younger age group contained participants aged 12 to 15 years, and the older group participants aged  
226 16 to 19. If the gender-age interaction effect was statistically significant, the path coefficient was  
227 tested separately in each age and gender group. Possible mean differences in LTPA before and  
228 during COVID-19 was investigated in the whole sample using the multigroup method.

229

230 The correlations between the study variables, the path analysis and the mean difference analysis  
231 were conducted using Mplus version 7.4 (Muthen & Muthen, Los-Angeles, CA). Correlation  
232 coefficients were calculated with the full information maximum likelihood (FIML) estimator.  
233 Missing values were assumed to be missing at random (MAR). The estimator MLR in Mplus  
234 produces full information maximum likelihood estimation with robust standard errors. Model fit  
235 was evaluated using a chi-square test, RMSEA (Root mean square error of approximation), CFI  
236 (comparative fit index), TLI (Tucker-Lewis index) and SRMR (standardized root mean square  
237 residuals). The model fit is good if the chi-square test value is nonsignificant, RMSEA is lower than  
238 .06, CFI and TLI are greater than .95 and SRMR is lower than .08. Equality of the parameter  
239 estimates was tested for each parameter separately using the new definition of parameters in the  
240 multigroup analysis. This gives information on which parameters should be estimated freely. The  
241 Satorra-Bentler scale-corrected chi-square difference test was used to evaluate if parameters found  
242 to differ in a specific analysis improved the overall model fit<sup>33</sup>.

243

## 244 **RESULTS**

245

### 246 **Descriptive statistics**

247

248 Descriptive statistics of the participants involved in path analysis, including LTPA frequencies and  
249 participation in sports club training in adolescence, early middle age, and late middle age, are  
250 presented in Table 1. Values of LTPA indexes and MET-h/day variables are presented in Table 2.  
251 The LTPA index value at baseline between the follow-up and non-follow-up participants was  
252 examined using Little's MCAR test. The test showed that missing values were not completely  
253 missing at random ( $\chi^2(27) = 43.18, p = .026$ ). The participants present at follow-up 2 had a higher  
254 mean self-reported LTPA index at baseline compared to those not present (Cohen's  $d=0.13, p <$   
255  $.01$ ). Moreover, the participants present at follow-up 1 had a higher mean LTPA index at baseline  
256 than those not present (Cohen's  $d=0.16, p < .001$ ). Missing values were assumed to be missing at  
257 random (MAR) and estimates were corrected and unbiased using full information maximum  
258 likelihood estimation.

259 **[Insert Table 2 here]**

260

### 261 **Correlations between the study variables**

262

263 The correlations between the LTPA index variables are presented in Table 3. A low positive  
264 correlation ( $p=.002$ ) was observed between LTPA index 1976 and MET h/day before COVID-19 in  
265 2021 across the entire study population and in the subgroups of males ( $p=.007$ ) and 16- to 19-year-  
266 olds ( $p=.000$ ). Positive but low correlations were also found between the 2001 LTPA index and  
267 MET h/day before COVID-19 in 2021 across the entire study population ( $p=.002$ ) and in the  
268 subgroups of males ( $p=.003$ ) and 12- to 15-year-olds ( $p=.003$ ). When used during COVID-19  
269 variable as an end point, the correlation coefficients and level of significance inevitably decreased.  
270 The correlations between the 1976 and 2001 measurements across the entire study population and

271 in all subgroups were positive and higher compared to correlations between 1976 and 2021, or 2001  
272 and 2021.

273

274 [Insert Table 3. here]

275

## 276 **Estimation of the path model**

277 The first step in the analysis was to estimate a multigroup method path model with gender and two  
278 age groups to test for gender and age interaction in means and path coefficients. Two statistically  
279 significant interaction effects were found, one in the path from follow-up 1 to follow-up 2 ( $p=.043$ )  
280 before COVID-19 and the other in the path from follow-up 1 to the change before and during  
281 COVID-19 at follow-up 2 ( $p=.043$ ). These two path coefficients were freely estimated for gender  
282 and age groups in the final model.

283 Next, main effects of gender were tested for the mean and path coefficients that had shown no  
284 interaction effects. The path from baseline to follow-up 1 differed between males and females  
285 ( $p=.008$ ). This path coefficient was freely estimated for males and females in the final model.

286 Further, main effects of age were tested for the mean and path coefficients that had shown no  
287 interaction effects. None of the paths between the age groups differed statistically significantly.

288 In the final model, all the parameters between gender and age groups were set equal except for two:  
289 one showing an interaction effect for gender and age and the other a main effect for gender. These  
290 freely estimated parameters increased model fit ( $\chi^2(7) = 22.67, p = .002$ ) and the model fitted  
291 well to the data  $\chi^2(35) = 13.23, p = .99, RMSEA=0, CFI=1.0, TLI=1.0, SRMR=.03$ .

292

293 **Longitudinal associations of self-reported LTPA**

294

295 The results from the path model (Figure 1) showed that LTPA in adolescence was associated with  
296 LTPA in late middle age. LTPA in 1976 had very low direct effect (Est = 0.08, SE = 0.03) on  
297 LTPA in late middle age (2021) before COVID-19. The effect was detected for both baseline age  
298 groups (12- to 15-year-olds and 16- to 19-year-olds) and in both males and females. The  
299 associations in adulthood showed that LTPA in early middle age (2001) had a low direct effect (Est  
300 = 0.17, SE = 0.07) on LTPA (before COVID-19) in late middle age (2021) among the 12- to 15-  
301 year-old females. This effect was not found for the other baseline age groups. The association  
302 between LTPA in adolescence and LTPA in early middle age (2001) was significant only among  
303 males. A low direct effect with a regression coefficient of 0.22 (SE = 0.04) was detected for males  
304 in both the 12- to 15-year-olds and 16- to 19-year-olds at baseline but not for either of the  
305 corresponding female groups. With respect to the two measures in late middle age (2021), LTPA  
306 before COVID-19 had a large direct effect on LTPA during COVID-19 (Est = 1.00, SE = 0.04)  
307 across the entire sample.

308

309

310 [Insert Figure 1. here]

311

312

313 **Change in self-reported leisure-time physical activity in late middle age between before and**  
314 **during COVID-19**

315

316 Compared to the time before COVID-19, self-reported LTPA decreased during the COVID-19  
317 pandemic. Mean MET h/day for LTPA at follow-up 2 was 3.17 before and 2.67 during COVID-19.  
318 The 0.50 difference between the means was statistically significant ( $p < .001$ ).

319

320

321 **The effect of self-reported leisure-time physical activity in 1976 and 2001 on change in self-**  
322 **reported physical activity in 2021 between before and during COVID-19**

323

324 The results showed that LTPA earlier in life was associated with change in LTPA in late middle age  
325 between before and during-COVID-19 among males. Figure 1 shows the low effect (Est = 0.20, SE  
326 = 0.06) between self-reported LTPA in early middle age (2001) and change in LTPA in late middle  
327 age between the time before and the time during COVID-19. The effect was found for the 12-15-  
328 year-old males at baseline but not for the other groups. LTPA in adolescence was not directly  
329 associated with change in LTPA in late middle age ( $p = .986$ ).

330

331

332 **DISCUSSION**

333

334 The aim of this study was to investigate how self-reported leisure-time physical activity in  
335 adolescence (age 12-19 years) was associated with self-reported leisure-time physical activity 45  
336 years later when the participants were 57-64 years old. In addition, we used the measurements  
337 obtained in early middle age (age 37-44) as a mediator between the baseline and the end  
338 measurements. Because of the COVID-19-pandemic occurred during the second follow-up, the  
339 participants assessed their LTPA before and during pandemic. This two-part question allowed us  
340 also to explore if leisure-time physical activity engagement in adolescence and early middle age

341 was associated with change in leisure-time physical activity engagement during the COVID-19  
342 pandemic and the strategies implemented to mitigate its effects. To our knowledge, the present  
343 study is the first to follow the same individuals' leisure-time physical activity systematically from a  
344 young age up to age 57-64. The main finding was that adolescent leisure-time physical activity was  
345 positively associated with late middle-age leisure-time physical activity over the 45-year time span.  
346 The association, which pertained to time before COVID-19, was very low but statistically  
347 significant and in accordance with the baseline results for both gender groups and both adolescent  
348 age groups (ages 12-15 and 16-19). Our results showed a significant decrease in leisure-time  
349 physical activity during the COVID-19 pandemic. Interestingly, leisure-time physical activity in  
350 2001 and the change in leisure-time physical activity between pre-COVID-19 and during COVID-  
351 19 were associated in males.

352  
353 The association between adolescence and late middle age leisure-time physical activity observed in  
354 our data accords with previous findings<sup>12,15,16</sup>. We found the magnitude of the association across the  
355 45-year period to be very low, thus confirming earlier findings indicating that the coefficients in  
356 adolescence-adulthood tracking typically remain at a low or at most moderate level<sup>12,15,16</sup> and tend  
357 to decrease as the time between the baseline and the follow-up lengthens<sup>15</sup>. Our results suggest that  
358 leisure-time physical activity in adolescence is associated with leisure-time physical activity also in  
359 late middle age. However, the very low association supports the notion<sup>12</sup> that PA is substantially  
360 affected by behavioral factors, as well as life events experienced during the life-course. For  
361 example, participation in organized sports<sup>34,35</sup>, the amount of PA<sup>36</sup> and the greater diversity of  
362 leisure-time sport activities<sup>37</sup> in youth have been contributed to higher tracking, whereas leaving the  
363 parental home, getting married and having children<sup>38,39</sup> later in life have been shown to decrease PA  
364 levels and thus impact tracking. The present association found across the 45-year period is



365 nevertheless important given the indisputable immediate and long-term health benefits for  
366 individuals of physical activity engagement throughout the lifespan<sup>4</sup>.

367

368 In our path analysis, we tested whether gender had a different effect between the two age groups of  
369 12-15 and 16-19 years. Our results showed similar statistically significant associations between  
370 adolescent and late middle age leisure-time physical activity irrespective of gender or age group at  
371 baseline. This finding may highlight the role of adolescent physical activity behavior in predicting  
372 physical activity later in life. The literature shows that correlation coefficients have tended to be  
373 higher among adolescents compared to children<sup>16,17</sup>, indicating permanent physical activity habits to  
374 develop in adolescence. It has also been suggested that the widely noted decline in physical activity  
375 from childhood to adolescence<sup>40</sup> may affect physical activity habits in adolescence and in young  
376 adulthood, which is yet seen in tracking to adulthood. According to previous research<sup>12,16</sup>, physical  
377 activity tracks differently from adolescence to adulthood in males and females. This has been  
378 explained by the lower physical activity engagement rate found among females and possibility that  
379 major life events such as getting married and having children may have greater impact on the life of  
380 females than males<sup>12</sup>.

381

382 Interestingly, our results demonstrated a statistically significant but small association between early  
383 and late middle age leisure-time physical activity in females who were aged 12-15 at baseline.  
384 These results were inconsistent with previous findings demonstrating similar tracking coefficients  
385 throughout adulthood and from adolescence to adulthood<sup>15,19,20</sup>. However, it should be noted that  
386 the association between early and late middle age physical activity is less well documented, as most  
387 tracking studies have set young adulthood as the baseline age<sup>12</sup>. In their 21-year follow-up  
388 Norwegian study starting from age 35-44 years, Morseth et al.<sup>20</sup> found correlation coefficients  
389 ranging from 0.29 to 0.36, while Van der Zee et al.<sup>15</sup> in their 10-12-year follow-up Dutch study

390 starting from age 38-40 years found coefficients ranging from 0.20 to 0.30. A Finnish study by  
391 Yang et al.<sup>19</sup>, conducted with objective physical activity assessment and smaller number of  
392 participants (n=253), reported low to moderate tracking (0.29 to 0.60) over a 13-year follow-up  
393 between the ages 36 to 49 years. It could be speculated that the discrepancies between the self-  
394 report studies of Morseth et al.<sup>20</sup> and Van der Zee et al.<sup>15</sup> and our study may be related to  
395 differences between countries in their physical activity cultures<sup>13</sup>. Moreover, the moment at which  
396 the data were gathered differed significantly between our study and the other two as our last  
397 questionnaire was administered during the COVID-19 pandemic. Further, the rather small  
398 correlation coefficients found in the previous studies may indicate that the evidence remains  
399 unclear, and thus more investigation is needed. Employing objective assessment methods, as in  
400 Yang et al.<sup>19</sup>, to investigate the stability of physical activity throughout middle age could yield more  
401 robust evidence. However, objective assessment in study samples as large as those used in self-  
402 report studies is difficult, although encouraging findings in the use of objective assessment in large-  
403 scale PA studies have recently been reported<sup>41</sup>. On the other hand, rather small samples, as in the  
404 study of Yang et al.<sup>19</sup>, are more vulnerable to sample bias as that the most physically active  
405 participants are generally the most willing to take part in follow-up re-assessments<sup>47,48</sup>.

406

407 To our knowledge the present study is the first to explore the associations between adolescent and  
408 early middle age leisure-time physical activity engagement and change in leisure-time physical  
409 activity engagement during the COVID-19 pandemic. Although the data were collected during  
410 restrictions, voluntary exercising and recreational activity was freely allowed in Finland during this  
411 period. Our finding that leisure-time physical activity declined statistically significantly between  
412 before and during COVID-19, is in line with the findings of the many cross-sectional or short-term  
413 longitudinal studies on physical activity among adults during the pandemic and mitigation  
414 measures<sup>21-25</sup>. Previous research has demonstrated seasonal variation in adults' physical activity<sup>42,43</sup>,

415 with lower levels during winter than in spring or summer. Hence, it could be speculated whether  
416 seasonal variation due to the lag in the onset of spring between the southern and northern parts of  
417 Finland impacted our results despite the fact that each measurement in this project was carried out  
418 during the months of spring. The results on the association of adolescent and early middle age  
419 leisure-time physical activity with change in leisure-time physical activity during the pandemic  
420 showed a statistically significant but small association among males in the younger (12-15 years)  
421 but not older (16-19 years) baseline age-group or among females. As there is obviously no previous  
422 research on such an effect, interpreting this finding is not easy. It may be related to a relapse in  
423 physical activity in the unusual circumstances triggered by the onset of the COVID-19 pandemic  
424 and consequent restrictions. Such a reaction may be explained by health psychological theories such  
425 as the transtheoretical model of change<sup>44</sup>, in which relapse in adherence to healthy behavior has  
426 been found to be common, especially among those whose behavior is not permanent. It is also  
427 notable that the younger baseline age group (12-15 years) were age 57-60 and the older baseline  
428 group (16-19 years) 61-64 at follow-up 2. The fact that the interface of the age groups in late middle  
429 age co-occurred with retirement age from work in Finland may have impacted physical activity  
430 behavior in males. This hypothesis has been supported by several studies<sup>22,26-28</sup> on physical activity  
431 during the pandemic, demonstrating that older people have more often remained physically active  
432 during the pandemic and related restrictions compared to younger ones.

433

#### 434 **Limitations**

435

436 A limitation of this study is its reliance on self-reports, as validation studies have confirmed that  
437 this method overestimates PA levels in both adolescents and adults<sup>45,46</sup>. To yield more valid and  
438 reliable results on physical activity, a combination of objective and self-report methods should be  
439 used. The baseline measurement in this longitudinal project dates from the year 1976, when

440 objective measures were not available. Thus, using the same method at the follow-ups as at baseline  
441 can be justified. Moreover, although lacking an objective method, the self-report leisure-time  
442 physical activity questionnaire was carefully designed and developed throughout the project to  
443 measure different dimensions of PA. Another limitation related to the self-reports is that the  
444 physical activity questions differed slightly between the study phases. This might have impacted the  
445 results and limits the possibility to accurately compare physical activity levels between adolescence,  
446 early and late middle age, even though this was not the aim of this study. Nevertheless,  
447 modifications and improvements in questionnaire sheet in such a long project investigating  
448 participants in such a different age is justifiable and have been implemented in other longitudinal  
449 projects in the field<sup>49</sup>. Finally, the participant dropout rate, a common problem in longitudinal  
450 designs, is a limitation. It is understandable that participants will be lost to follow-up over long time  
451 periods, although evidence from earlier PA follow-up studies<sup>47,48</sup> indicates that the dropouts are  
452 more likely to found among those who were less physically active at baseline, a factor that could  
453 further increase the risk for biased interpretations of the results. Our dropout analysis substantiated  
454 these findings. The participants present at both follow-ups 1 and 2 had a higher mean self-reported  
455 LTPA index at baseline than those not present. Nevertheless, the advantage of our structural  
456 equation modeling-based path analysis was that it could correct and unbiased estimates that may have  
457 been biased by a skewed dropout profile.

458

## 459 Conclusion

460

461 The results of this study extend previously gained knowledge on the predictive value of adolescent  
462 physical activity for PA in later life. The findings support the view that the promotion of physical  
463 activity in childhood and adolescence has an important impact on adult physical activity. However,  
464 the effect sizes of the longitudinal associations found in this study were low, indicating that further

465 research on physical activity engagement should focus not only the younger years of life but also on  
466 adult physical activity-enhancing strategies such as adult physical activity counseling. The results  
467 also indicate that earlier engagement in physically active lifestyle may help people to stay active  
468 during unexpected life events such as pandemic.

469

#### 470 **Acknowledgements**

471 The authors wish to thank Michael Freeman for his contribution in language review and Heimo  
472 Nupponen for launching the longitudinal study project and allowing the research data for further  
473 investigation. This study was financially supported by Emil Aaltonen foundation and Yrjö Jahnsson  
474 foundation.

475

#### 476 **Ethics approval and consent to participate**

477 The Human Sciences Ethics Committee of the University of Jyväskylä approved the study. A  
478 written informed consent was obtained before study entry.

479

#### 480 **Disclosure statement**

481 The authors report there are no competing interests to declare.

482

#### 483 **Funding**

484 This work was supported by Yrjö Jahnsson Foundation under Grant 20207295 and Emil Aaltonen  
485 Foundation under Grant 210097 O.

486

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615 **Table 1. Characteristics of participants in between-measurement analyses (at least two**  
 616 **measurements). Values are mean values and (standard deviations).**

<b>Characteristics</b>	<b>Males 12–19 y.</b> n=1094	<b>Males 37–44 y.</b> n=776	<b>Males 57–64 y.</b> n=471	<b>Females 12–19 y.</b> n=1236	<b>Females 37–44 y.</b> n=924	<b>Females 57–64 y.</b> n=508
<b>Age (years)</b>	14.6 (2.0)	39.6 (2.0)	59.6 (2.0)	14.5 (2.0)	39.5 (2.0)	59.5 (2.0)
<b>Height (cm)</b>	166.4 (12.8)	179.6 (6.5)	177.1 (8.5)	160.9 (8.0)	165.8 (5.7)	167.5 (7.1)
<b>Weight (kg)</b>	54.7 (13.2)	83.2 (12.3)	84.5 (14.7)	51.4 (9.2)	66.6 (11.9)	75.9 (16.5)
<b>BMI (kg/m<sup>2</sup>)</b>	19.4 (2.8)	25.8 (3.4)	26.9 (4.0)	19.8 (2.7)	24.2 (4.0)	27.1 (5.4)
<b>Participation in LTPA (%)</b>			pre-COVID / COVID			pre-COVID / COVID
<once a week	14.6	281	12.2 / 15.7	12.4	16.8	8.5 / 11.6
1–6 time/week	58.3	68.2	77.4 / 72.7	58.3	75.4	74.5 / 69.8

Every day	27.1	3.7	10.4 / 11.6	29.3	7.8	17.0 / 18.6
<b>Participation in sports club training (%)</b>						
not at all	64.0	77.0	84.3 / 92.9	82.3	60.3	86.6 / 96.8
occasionally	14.9	6.7	2.7 / 1.2	8.7	7.4	2.5 / 0.9
regularly	21.1	16.3	13.0 / 5.9	9.0	32.3	10.9 / 2.3

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618

619 **Table 2. Descriptive statistics of LTPA indexes in different measurements.**

Measurement	N	Mean	Standard deviation	Median	Scale
LTPA index 1976	2083	8.59	2.11	9.00	3 - 14
LTPA index 2001	1468	5.74	2.56	5.00	1 - 14
MET-h/day 2021 before COVID-19	878	3.17	3.04	2.33	0 - 20.66 <sup>†</sup>
MET h/day 2021 during COVID-19	867	2.67	2.80	1.73	0 - 20.66 <sup>†</sup>

620 † Maximum value in study population

621

622

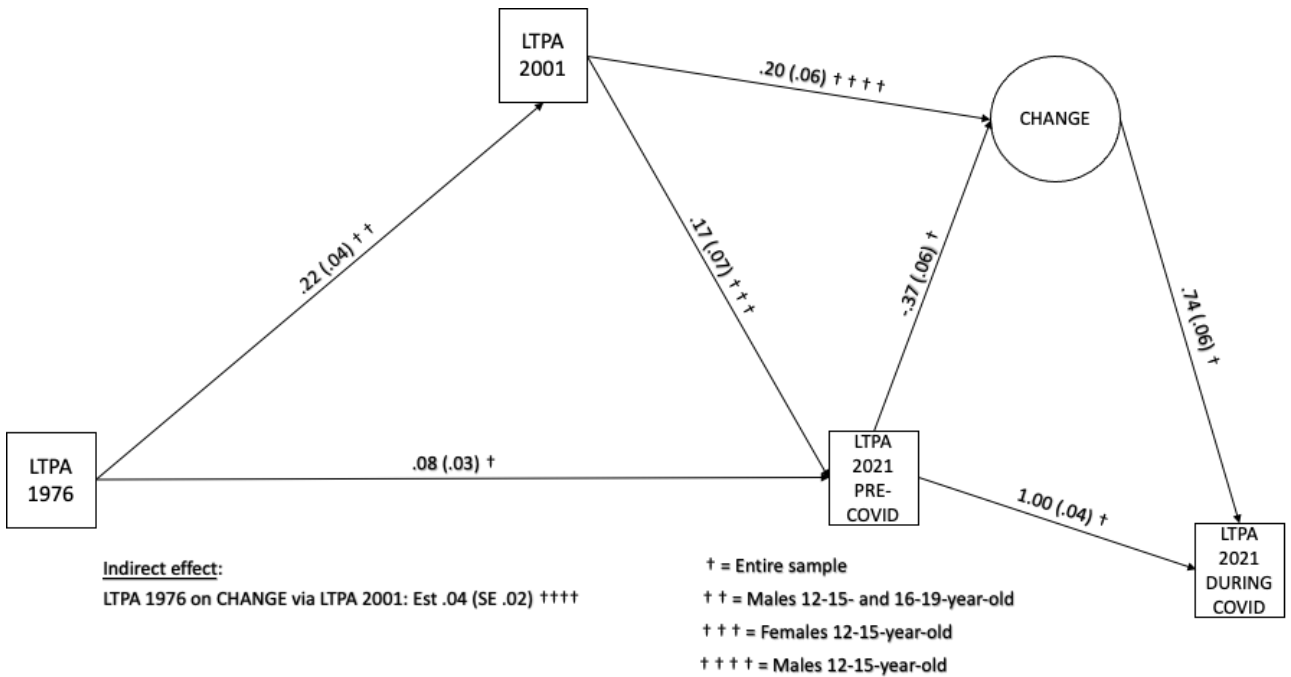
623 **Table 3. Correlations (FIML) of LTPA indexes.**

Sample	1976–2001	2001–2021 pre- COVID / during COVID	1976–2021 pre- COVID / during COVID
All	.127**	.113**/.093*	.110**/.087*
Males	.233**	.155**/.175**	.124**/.091
Females	.070*	.086/.050	.061/.058
Age 12-15 years	.082*	.149**/.134*	.066/.061
Age 16-19 years	.204**	.028/.040	.196**/.135*

624 \* P<.05, \*\* P<.01

625

626 **Figure 1. Path analysis with statistically significant (p<.05) standardized coefficients.**



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628