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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 ¹ . Leisure time physical activity (LTPA), in turn, refers to PA-related behavior that
38	people freely engage in during their disposable time ² . Observational studies have shown strong
39	evidence that regular PA is associated with a reduction in numerous adverse health conditions ^{3,4} .
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 ⁵ . LTPA has shown a
42	stronger association than occupational PA with beneficial health outcomes ^{6,7} . Hence, it has been
43	addressed that lifelong PA, founded in young ages, is desirable and pertains to a healthy lifestyle ⁴ .
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 ⁸ .

The increased energy expenditure induced by PA, which is directly linked to the intensity of PA, 46

can be assessed as the Metabolic Equivalent (MET) of the activity and calculated from physical 47

activity self-reports^{8,9}. Thus, the MET value indicates the metabolic rate. For example, a MET value 48

of one represents the resting metabolic rate, a value of 3-5.9 indicates moderate-intensity PA and a
 value of 6 indicates vigorous-intensity PA¹⁰.

51

52 It is well documented that PA tracks with a low to moderate level of significance from childhood and adolescence to adulthood¹¹⁻¹³; that is, individuals tend to maintain the position of physical 53 activity or physical inactivity they adopted earlier¹². Investigating PA tracking has been justified by 54 globally accepted position that PA promotion in young ages impacts the development of physically 55 56 active lifestyle¹⁴. Tracking studies using self-reported PA from childhood and adolescence to adulthood^{11-13,15-17} have mostly revealed a low or at least moderate correlation between PA in 57 58 childhood and adolescence with PA in adulthood. The correlation coefficients reported in the vast majority of studies in the extensive reviews by Hayes et al.¹¹, Telama¹² and Malina¹³ varied 59 between 0.03 to 0.45. However, participant age at the end point has at most been 42 years. An 60 exception is the study by Friedman et al.¹⁸ in which it was 66 years. However, Friedman et al.¹⁸ may 61 62 not meet the validity criteria of current PA research, as the baseline data, collected in the year 1922, was obtained from teacher or parent reports. The findings of Hayes et al.¹¹, Telama¹² and Malina¹³ 63 64 were confirmed in a population-based study (n=43 889) by Van der Zee et al.¹⁵, who reported correlation coefficients lower than 0.30. However, their maximum follow-up time was 20 years and 65 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.¹⁶ similarly reported coefficients varying between 0.07-0.32, depending on gender and age at baseline. 68 The maximum age at the end point in their study was 45 years. Childhood-adulthood tracking 69 research has shown higher correlation coefficients in males than females^{12,16,17}. Correlations have 70 also tended to increase with baseline age^{12,17}, as demonstrated in the Finnish 25-year follow-up¹⁷, 71 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

has been limited to adults aged 30 to 45-years^{12,13,15}. PA tracking studies from early middle age to
late middle age, while scarce, have shown results comparable to those from a young age to
adulthood^{15,19,20}.

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 levels²¹⁻²⁵. 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 people and have returned sooner to their habitual PA level when restrictions have been eased^{22,26-28}. 84 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 Nienhuis²⁹ 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 later years of working life is justifiable, as it is known that insufficient PA, especially when 94 95 combined with older age, increases the risk for many health impairments and reduced physical function^{5,7}. Despite the rapid accumulation of evidence showing a decline in PA levels due to the 96 97 COVID-19 pandemic²¹⁻²², empirical research on PA habits during the pandemic has been wholly cross-sectional and descriptive, and only sporadic findings^{22,26-29} have been presented on concerning 98

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 April-May 1976, a trained measurement team collected the baseline data, including objectively 115 116 measured fitness tests and self-reported LTPA from 56 schools in Finland. A four-phase stratified 117 random sample (n=2796) 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 ¹⁷ .
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	
138 139	Sample for the between-measurement path analyses
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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 duration so that you feel breathless?" This question was coded on a 6-point response scale (0 = not167 at all, 1 = less than once a month, 2 = once a month, 3 = 2-3 times a month, 4 = once a week, 168 169 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 school sports (school sports club) was coded dichotomously with 1 = "no" and 2 = "yes". The 172

173 leisure-time physical activity index for 1976 was calculated as the sum of the three PA variables174 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 duration of a LTPA session and participation in organized and competitive sports. The questions 177 were based on those used in two Finnish studies^{30,31} but modified for the 2001 follow-up. A 7-point 178 179 response scale was used to assess the frequency of LTPA, which was subsequently recoded from 1 to 3 (1 = at most 3 times a month, 2 = 1-4 times a week, 3 = 5-7 times a week). Answers on the 180 average duration of a LTPA session were coded on a 4-point scale where 0 = "not at all", 1 = "at 181 182 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 amonth, 4 = 1-2 times a week, 5 = 3-4 times a week, 6 = 5-6 times a week, 7 = every day). The item 193 194 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 ³² , 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

equation modeling was used (Figure 1). A multigroup path model with four groups (male, females,
and two age groups) was used to test for interaction between gender and age at baseline. The
younger age group contained participants aged 12 to 15 years, and the older group participants aged
16 to 19. If the gender-age interaction effect was statistically significant, the path coefficient was
tested separately in each age and gender group. Possible mean differences in LTPA before and
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^{33} .

- 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 2021 across the entire study population and in the subgroups of males (p=.007) and 16- to 19-year-265 olds (p=.000). Positive but low correlations were also found between the 2001 LTPA index and 266 267 MET h/day before COVID-19 in 2021 across the entire study population (p=.002) and in the subgroups of males (p=.003) and 12- to 15-year-olds (p=.003). When used during COVID-19 268 269 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

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

273

274 [Insert Table 3. here]

275

276 Estimation of the path model

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

283 Next, main effects of gender were tested for the mean and path coefficients that had shown no284 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.

Further, main effects of age were tested for the mean and path coefficients that had shown nointeraction effects. None of the paths between the age groups differed statistically significantly.

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

293 Longitudinal associations of self-reported LTPA

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 study is the first to follow the same individuals' leisure-time physical activity systematically from a 343 344 young age up to age 57-64. The main finding was that adolescent leisure-time physical activity was positively associated with late middle-age leisure-time physical activity over the 45-year time span. 345 346 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 age groups (ages 12-15 and 16-19). Our results showed a significant decrease in leisure-time 348 physical activity during the COVID-19 pandemic. Interestingly, leisure-time physical activity in 349 350 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 our data accords with previous findings^{12,15,16}. We found the magnitude of the association across the 354 355 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^{12,15,16} and tend to decrease as the time between the baseline and the follow-up lengthens¹⁵. Our results suggest that 357 358 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 notion¹² that PA is substantially affected by behavioral factors, as well as life events experienced during the life-course. For 360 example, participation in organized sports^{34,35}, the amount of PA³⁶ and the greater diversity of 361 leisure-time sport activities³⁷ in youth have been contributed to higher tracking, whereas leaving the 362 parental home, getting married and having children^{38,39} later in life have been shown to decrease PA 363 364 levels and thus impact tracking. The present association found across the 45-year period is

nevertheless important given the indisputable immediate and long-term health benefits for
 individuals of physical activity engagement throughout the lifespan⁴.

367

368 In our path analysis, we tested whether gender had a different effect between the two age groups of 12-15 and 16-19 years. Our results showed similar statistically significant associations between 369 370 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 physical activity later in life. The literature shows that correlation coefficients have tended to be 372 higher among adolescents compared to children^{16,17}, indicating permanent physical activity habits to 373 374 develop in adolescence. It has also been suggested that the widely noted decline in physical activity from childhood to adolescence⁴⁰ may affect physical activity habits in adolescence and in young 375 adulthood, which is yet seen in tracking to adulthood. According to previous research^{12,16}, physical 376 377 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 males¹².

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. These results were inconsistent with previous findings demonstrating similar tracking coefficients 384 throughout adulthood and from adolescence to adulthood^{15,19,20}. However, it should be noted that 385 the association between early and late middle age physical activity is less well documented, as most 386 tracking studies have set young adulthood as the baseline age ¹². In their 21-year follow-up 387 Norwegian study starting from age 35-44 years, Morseth et al.²⁰ found correlation coefficients 388 ranging from 0.29 to 0.36, while Van der Zee et al.¹⁵ in their 10-12-year follow-up Dutch study 389

390 starting from age 38-40 years found coefficients ranging from 0.20 to 0.30. A Finnish study by Yang et al.¹⁹, conducted with objective physical activity assessment and smaller number of 391 392 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 selfreport studies of Morseth et al.²⁰ and Van der Zee et al.¹⁵ and our study may be related to 394 395 differences between countries in their physical activity cultures¹³. Moreover, the moment at which the data were gathered differed significantly between our study and the other two as our last 396 397 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 Yang et al.¹⁹, to investigate the stability of physical activity throughout middle age could yield more 400 401 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 largescale PA studies have recently been reported⁴¹. On the other hand, rather small samples, as in the 403 study of Yang et al.¹⁹, are more vulnerable to sample bias as that the most physically active 404 405 participants are generally the most willing to take part in follow-up re-assessments^{47,48}.

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 restrictions, voluntary exercising and recreational activity was freely allowed in Finland during this 410 411 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 measures²¹⁻²⁵. Previous research has demonstrated seasonal variation in adults' physical activity^{42,43}, 414

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 physical activity in the unusual circumstances triggered by the onset of the COVID-19 pandemic 423 424 and consequent restrictions. Such a reaction may be explained by health psychological theories such as the transtheoretical model of change⁴⁴, in which relapse in adherence to healthy behavior has 425 been found to be common, especially among those whose behavior is not permanent. It is also 426 427 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^{22,26-28} on physical activity during the pandemic, demonstrating that older people have more often remained physically active 431 432 during the pandemic and related restrictions compared to younger ones.

433

434 Limitations

435

A limitation of this study is its reliance on self-reports, as validation studies have confirmed that this method overestimates PA levels in both adolescents and adults ^{45,46}. To yield more valid and reliable results on physical activity, a combination of objective and self-report methods should be 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 physical activity questionnaire was carefully designed and developed throughout the project to 442 443 measure different dimensions of PA. Another limitation related to the self-reports is that the physical activity questions differed slightly between the study phases. This might have impacted the 444 445 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, modifications and improvements in questionnaire sheet in such a long project investigating 447 448 participants in such a different age is justifiable and have been implemented in other longitudinal projects in the field⁴⁹. Finally, the participant dropout rate, a common problem in longitudinal 449 designs, is a limitation. It is understandable that participants will be lost to follow-up over long time 450 periods, although evidence from earlier PA follow-up studies^{47,48} indicates that the dropouts are 451 452 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 unbias estimates that may have 457 been biased by a skewed dropout profile.

458

459 Conclusion

460

The results of this study extend previously gained knowledge on the predictive value of adolescent physical activity for PA in later life. The findings support the view that the promotion of physical activity in childhood and adolescence has an important impact on adult physical activity. However, 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

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475

476 Ethics approval and consent to participate

477 The Human Sciences Ethics Committee of the University of Jyväskylä approved the study. A

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479

480 **Disclosure statement**

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

482

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

Characteristics	Males 12–19	Males 37–	Males 57-	Females	Females	Females 57-
	у.	44 y.	64 y.	12–19 y.	37–44 y.	64 y.
	n=1094	n=776	n=471	n=1236	n=924	n=508
Age (years)	14.6 (2.0)	39.6 (2.0)	59.6 (2.0)	14.5 (2.0)	39.5 (2.0)	59.5 (2.0)
Height (cm)	166.4 (12.8)	179.6	177.1 (8.5)	160.9	165.8	167.5 (7.1)
		(6.5)		(8.0)	(5.7)	
Weight (kg)	54.7 (13.2)	83.2	84.5 (14.7)	51.4 (9.2)	66.6	75.9 (16.5)
		(12.3)			(11.9)	
BMI (kg/m2)	19.4 (2.8)	25.8 (3.4)	26.9 (4.0)	19.8 (2.7)	24.2 (4.0)	27.1 (5.4)
Participation in			pre-COVID			pre-COVID /
LTPA (%)			/ COVID			COVID
<once a="" th="" week<=""><th>14.6</th><th>281</th><th>12.2 / 15.7</th><th>12.4</th><th>16.8</th><th>8.5 / 11.6</th></once>	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
Participation in						
sports club						
training (%)						
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
				1		

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

Measurement	Ν	Mean	Standard	Median	Scale
			deviation		
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
MET h/day 2021 during COVID-19	867	2.67	2.80	1.73	0 -
					20.66†

620 † Maximum value in study population

Sample	1976–2001	2001-2021 pre-	1976–2021 pre-	
		COVID / during	COVID / during	
		COVID	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*	

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

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

625

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



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