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

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## ABSTRACT

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

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

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

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

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

## INTRODUCTION

PA is defined as any bodily movement produced by skeletal muscles that requires energy expenditure[1]. Leisure time physical activity (LTPA), in turn, refers to PA-related behavior that people freely engage in during their disposable time[2]. Observational studies have shown strong evidence that regular PA is associated with a reduction in numerous adverse health conditions[3,4]. High PA has been linked to a low prevalence of many non-communicable diseases (NCD) such as coronary heart disease, type 2 diabetes and breast and colorectal cancers[5]. LTPA has shown a stronger association than occupational PA with beneficial health outcomes[6,7]. Hence, it has been addressed that lifelong PA, founded in young ages, is desirable and pertains to a healthy lifestyle[4]. In research, PA is commonly divided into four dimensions: type, frequency, duration, and intensity 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, can be assessed as the Metabolic Equivalent (MET) of the activity and calculated from physical activity self-reports[8,9]. Thus, the MET value indicates the metabolic rate. For example, a MET value 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 PA[10].

It is well documented that PA tracks with a low to moderate level of significance from childhood and adolescence to adulthood[11-13]; that is, individuals tend to maintain the position of physical activity or physical inactivity they adopted earlier[12]. Investigating PA tracking has been justified by globally accepted position that PA promotion in young ages impacts the development of physically active lifestyle[14]. 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 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], Telama[12] and Malina[13] varied between 0.03 to 0.45. However, participant age at the end point has at most been 42 years. An exception is the study by Friedman et al.[18] in which it was 66 years. However, Friedman et al.[18] may 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], Telama[12] and Malina[13] 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 age at baseline varied between 8 and 80, and thus not all the inter-age correlations included data 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. The maximum age at the end point in their study was 45 years. Childhood-adulthood tracking research has shown higher correlation coefficients in males than females[12,16,17]. Correlations have also tended to increase with baseline age[12,17], as demonstrated in the Finnish 25-year follow-up[17], where the coefficients increased from 0.14/0.05 (males/females) to 0.31/0.17 at the baseline ages of 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].

The COVID-19 pandemic and the restrictions it has entailed have impacted dramatically on people's everyday lives around the world during the past two years (2020-21). Empirical research on the effects of these restrictions on PA is abundant. PA levels during the first two years of pandemic clearly decreased from pre-pandemic levels[21-25]. Variation between different age-groups has also been observed. Irrespective of country or mitigation strategies, older adults (age 45+) seem 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]. However, retrospective research on the association of previous PA engagement with PA levels during the pandemic is scarce. In their Canadian study, Lesser and Nienhuis[29] report that previously active individuals more often increased and more rarely quit their habitual PA compared with inactive peers. Most (79.3 %) of their participants were females.

Investigating the factors that have an influence on lifelong PA is essential. Despite robust evidence on the longitudinal associations of PA from childhood and adolescence to adulthood, studies including participants in their 60s are lacking. To our best knowledge, the present study is the first 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 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 COVID-19 pandemic[21-22], 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 the role of earlier PA on PA during the pandemic. Hence, there is a need for explanatory research to identify the behavioral factors behind PA adherence during exceptional situations such as the COVID-19 pandemic. This follow-up study contributes to filling this gap by utilizing 45-year retrospective data.

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

## MATERIAL AND METHODS

### Study population

This study is the third part of the three-phase LISE 45-years follow-up project designed to 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 measured fitness tests and self-reported LTPA from 56 schools in Finland. A four-phase stratified random sample (n=2 796) of children and adolescents (mean age 14.4) was drawn from different regions and from both urban and rural municipalities. In the first phase, 20 towns and rural communities were randomly selected from east, west, central, and north Finland. In the second phase, a random sample of 56 schools, matched for student numbers, was drawn proportionally from towns and rural municipalities. Classes in schools were randomly selected and the pupils drawn either in alphabetical order or by selecting every second or third in line etc. For the longitudinal analyses of the current study, the participants aged 12-19-year-old (n=2554) were extracted from the baseline sample to form the group of adolescents.

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

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

*Sample for the between-measurement path analyses*

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

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

**[Insert Table 1 here]**

**Assessment of leisure-time physical activity**

Leisure-time physical activity was assessed at each time point with a self-report questionnaire. The questionnaires differed somewhat as they had been designed by different researchers in different decades. In the 1976 baseline measurement, the self-report LTPA questionnaire was administered alongside an objective fitness test. The questions concerned the frequency, intensity, and type of LTPA and participation in organized LTPA (sports club in leisure time and extra-curricular school sports) and competitive sports. The frequency and intensity of LTPA was assessed by one question: "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 = not at all, 1 = less than once a month, 2 = once a month, 3 = 2–3 times a month, 4 = once a week, 5 = 2–6 times a week, and 6 = every day). The answers on participation in sports club training and in competitive sports were coded from 1 to 3 (1 = inactive or very low activity, 2 = moderately 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 leisure-time physical activity index for 1976 was calculated as the sum of the three PA variables with a total score ranging from 3 to 14.

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 were based on those used in two Finnish studies[30,31] but modified for the 2001 follow-up. A 7-point 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 average duration of a LTPA session were coded on a 4-point scale where 0 = “not at all”, 1 = “at most 20 min”, 2 = “20-60 min”, and 3 = “60 min or longer”. The question on participation in competitive sports events used a 3-point response scale (0 = not at all, 1 = up to club level, and 2 = regional, national or international) and the item on participation in organized LTPA a 4-point 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). An additional question on the intensity of LTPA in organized sports used a 3-point response scale (1 = “not quite breathless”, 2 = “somewhat breathless”, 3 = “heavily breathless”). The leisure-time physical activity index for 2001 comprised five variables with a total score ranging from 1 to 14.

The 45-year follow-up questionnaire for 2021 was the same as the 2001 questionnaire except for one additional question on the average intensity of a LTPA session. The question on the frequency of LTPA was answered on a 7-point scale (1 = not at all, 2 = once in a month, 3 = 2-3 times a month, 4 = 1-2 times a week, 5 = 3-4 times a week, 6 = 5-6 times a week, 7 = every day). The item on the average duration of a LTPA session was answered on a 6-point scale (1 = at most 10 min, 2 = 10-20 min, 3 = 20–40 min, 4 = 40-60 min, 5 = 60-90 min, 6 = 90 min or more). The intensity of the average LTPA session was asked with the question: ”How would you describe the intensity of your average LTPA session?” on a 4-point scale where 1 = “walking”, 2 = “combination of walking and running”, 3 = “light running or jogging”, and 4 = “brisk running”. Each question was duplicated to examine LTPA in the COVID-19 pandemic and pre-pandemic setting. The wording used was “LTPA during the current COVID-19 pandemic in Finland” and ”before the COVID-19 pandemic”. As the questionnaire was posted at the end of March 2021 and the majority of the answers received until June 2021, the answers represent the period between March and June 2021 when the COVID-19 restrictions were initially more stringent (March-May) and thereafter relaxed (June-July). In Finland, there was no total lockdown and people were allowed to move freely outside their homes. During March to May in Finland, organized sports for adults was somewhat restricted. In the 45-year follow-up, the leisure-time physical activity index was calculated separately for before and during the pandemic, with three questions on the frequency, average duration, and intensity of LTPA. Further, a MET h/day value was calculated by using a classification based on that used in the FinTwin study[32], in which walking corresponds to 4 METs, the combination of walking and running to 6 METs, light running or jogging to 10 METs, and brisk running to 13 METs.

## STATISTICAL ANALYSES

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

To investigate the associations between adolescent, early middle age, and late middle age self-reported LTPA, correlation coefficients were first calculated and tested for significance. To investigate the associations between adolescent, early middle age and late middle age self-reported LTPA and the impact of previous LTPA engagement on possible change in late middle age LTPA 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.

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

## RESULTS

### Descriptive statistics

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

**[Insert Table 2 here]**

**Correlations between the study variables**

The correlations between the LTPA index variables are presented in Table 3. A low positive 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-olds (p=.000). Positive but low correlations were also found between the 2001 LTPA index and 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 variable as an end point, the correlation coefficients and level of significance inevitably decreased. 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 2001 and 2021.

[Insert Table 3. here]

**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.

Next, main effects of gender were tested for the mean and path coefficients that had shown no interaction effects. The path from baseline to follow-up 1 differed between males and females (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 no interaction 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.

## Longitudinal associations of self-reported LTPA

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

[Insert Figure 1. here]

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

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

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

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

## DISCUSSION

The aim of this study was to investigate how self-reported leisure-time physical activity in adolescence (age 12-19 years) was associated with self-reported leisure-time physical activity 45 years later when the participants were 57-64 years old. In addition, we used the measurements obtained in early middle age (age 37-44) as a mediator between the baseline and the end measurements. Because of the COVID-19-pandemic occurred during the second follow-up, the participants assessed their LTPA before and during pandemic. This two-part question allowed us also to explore if leisure-time physical activity engagement in adolescence and early middle age was associated with change in leisure-time physical activity engagement during the COVID-19 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 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. The association, which pertained to time before COVID-19, was very low but statistically 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 physical activity during the COVID-19 pandemic. Interestingly, leisure-time physical activity in 2001 and the change in leisure-time physical activity between pre-COVID-19 and during COVID-19 were associated in males.

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 45-year period to be very low, thus confirming earlier findings indicating that the coefficients in 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 lengthens[15]. Our results suggest that leisure-time physical activity in adolescence is associated with leisure-time physical activity also in late middle age. However, the very low association supports the notion[12] that PA is substantially affected by behavioral factors, as well as life events experienced during the life-course. For example, participation in organized sports[34,35], the amount of PA[36] and the greater diversity of leisure-time sport activities[37] in youth have been contributed to higher tracking, whereas leaving the parental home, getting married and having children[38,39] later in life have been shown to decrease PA 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 lifespan[4].

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 adolescent and late middle age leisure-time physical activity irrespective of gender or age group at 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 higher among adolescents compared to children[16,17], indicating permanent physical activity habits to develop in adolescence. It has also been suggested that the widely noted decline in physical activity from childhood to adolescence[40] may affect physical activity habits in adolescence and in young adulthood, which is yet seen in tracking to adulthood. According to previous research[12,16], physical activity tracks differently from adolescence to adulthood in males and females. This has been explained by the lower physical activity engagement rate found among females and possibility that major life events such as getting married and having children may have greater impact on the life of females than males[12].

Interestingly, our results demonstrated a statistically significant but small association between early 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 throughout adulthood and from adolescence to adulthood[15,19,20]. However, it should be noted that the association between early and late middle age physical activity is less well documented, as most tracking studies have set young adulthood as the baseline age [12]. In their 21-year follow-up Norwegian study starting from age 35-44 years, Morseth et al.[20] found correlation coefficients ranging from 0.29 to 0.36, while Van der Zee et al.[15] in their 10-12-year follow-up Dutch study 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 participants (n=253), reported low to moderate tracking (0.29 to 0.60) over a 13-year follow-up between the ages 36 to 49 years. It could be speculated that the discrepancies between the self-report studies of Morseth et al.[20] and Van der Zee et al.[15] and our study may be related to differences between countries in their physical activity cultures[13]. Moreover, the moment at which the data were gathered differed significantly between our study and the other two as our last questionnaire was administered during the COVID-19 pandemic. Further, the rather small correlation coefficients found in the previous studies may indicate that the evidence remains 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 robust evidence. However, objective assessment in study samples as large as those used in self-report studies is difficult, although encouraging findings in the use of objective assessment in large-scale PA studies have recently been reported[41]. On the other hand, rather small samples, as in the study of Yang et al.[19], are more vulnerable to sample bias as that the most physically active participants are generally the most willing to take part in follow-up re-assessments[47,48].

To our knowledge the present study is the first to explore the associations between adolescent and early middle age leisure-time physical activity engagement and change in leisure-time physical 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 period. Our finding that leisure-time physical activity declined statistically significantly between before and during COVID-19, is in line with the findings of the many cross-sectional or short-term longitudinal studies on physical activity among adults during the pandemic and mitigation measures[21-25]. Previous research has demonstrated seasonal variation in adults' physical activity[42,43], with lower levels during winter than in spring or summer. Hence, it could be speculated whether seasonal variation due to the lag in the onset of spring between the southern and northern parts of Finland impacted our results despite the fact that each measurement in this project was carried out during the months of spring. The results on the association of adolescent and early middle age leisure-time physical activity with change in leisure-time physical activity during the pandemic showed a statistically significant but small association among males in the younger (12-15 years) but not older (16-19 years) baseline age-group or among females. As there is obviously no previous 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 and consequent restrictions. Such a reaction may be explained by health psychological theories such as the transtheoretical model of change[44], in which relapse in adherence to healthy behavior has been found to be common, especially among those whose behavior is not permanent. It is also notable that the younger baseline age group (12-15 years) were age 57-60 and the older baseline group (16-19 years) 61-64 at follow-up 2. The fact that the interface of the age groups in late middle age co-occurred with retirement age from work in Finland may have impacted physical activity 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 during the pandemic and related restrictions compared to younger ones.

**Limitations**

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 objective measures were not available. Thus, using the same method at the follow-ups as at baseline 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 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 results and limits the possibility to accurately compare physical activity levels between adolescence, 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 participants in such a different age is justifiable and have been implemented in other longitudinal projects in the field[49]. Finally, the participant dropout rate, a common problem in longitudinal designs, is a limitation. It is understandable that participants will be lost to follow-up over long time periods, although evidence from earlier PA follow-up studies[47,48] indicates that the dropouts are more likely to found among those who were less physically active at baseline, a factor that could further increase the risk for biased interpretations of the results. Our dropout analysis substantiated these findings. The participants present at both follow-ups 1 and 2 had a higher mean self-reported LTPA index at baseline than those not present. Nevertheless, the advantage of our structural equation modeling-based path analysis was that it could correct and unbias estimates that may have been biased by a skewed dropout profile.

## Conclusion

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


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**Ethics approval and consent to participate**

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

**Disclosure statement**

The authors report there are no competing interests to declare.


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**References**

1. World Health Organization. Physical activity fact sheet. World Health Organization. 2020. https://www.who.int/news-room/fact-sheets/detail/physical-activity Accessed January 13, 2022
2. Steinbach D. & Graf C. Leisure time physical activity and sedentariness. In: Kirch W, editor Encyclopedia of Public Health. Dordrecht: Springer; 2008. p. 99.
3. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J of Sports Med 2020;54:1451-62.
4. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. JAMA 2018;320:2020–28.
5. Lee I-M, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012;380:219–29.
6. Moore SC, Patel AV, Matthews CE, et al. Leisure time physical activity of moderate to vigorous intensity and mortality: a large pooled cohort analysis. PLoS Med. 2012;9:e1001335.
7. Holtermann A, Hansen J, Burr H, Søgaard K, Sjøgaard G. The health paradox of occupational and leisure-time physical activity. Br J Sports Med 2012;46:291-5.
8. Kriska A, Caspersen C. Introduction to a Collection of Physical Activity Questionnaires. Med Sci Sports Exerc 1997;29:5-9.
9. Ashok P, Kharche J, Raju R, Godbole G. Metabolic equivalent task assessment for physical activity in medical students. Natl J Physiol Pharm Pharmacol 2017;7:236-39.
10. Ainsworth BE, Haskell WL, Hermann SD, et al. Compendium of Physical Activities. Med Sci Sports Exerc 2011;43:1575-81.

11. Hayes G, Dowd KP, Macdonncha C, Donnelly AE. Tracking of physical activity and sedentary behavior from adolescence to young adulthood: a systematic literature review. J Adolesc Health 2019;65:446–54.
12. Telama R. Tracking of physical activity from childhood to adulthood: a review. Obes facts 2009;2:187-95.
13. Malina R. Physical activity and fitness: Pathways from childhood to adulthood. Am J of Hum Biol 2001;13:162-72.
14. Hardman K. Physical education in schools: a global perspective. Kinesiology 2008;40:5-28.
15. van der Zee MD, van der Mee D, Bartels M, et al. Tracking of voluntary exercise behaviour over the lifespan. Int J Behav Nutr Phys Act 2019;16:17.
16. Telama R, Yang X, Leskinen E, et al. Tracking of physical activity from early childhood through youth into adulthood. Med Sci Sports Exerc 2014;46:955–62.
17. Huotari P, Nupponen H, Mikkelsson L, Laakso L, Kujala U. Adolescent physical fitness and activity as predictors of adulthood activity. J Sports Sci 2011;29:1135-41.
18. Friedman HS, Martin LR, Criqui MH, Kern ML, Reynolds CA. Stability of physical activity across the lifespan. J Health Psychol 2008;13:1092–104.
19. Yang X, Kulmala J, Hakonen H, et al. Tracking and Changes in Daily Step Counts among Finnish Adults. Med Sci Sports Exerc 2021;*53*:1615–23.
20. Morseth B, Jørgensen L, Emaus N, Jacobsen BK, Wilsgaard T. Tracking of leisure time physical activity during 28 yr in adults: the Tromsø study. Med Sci Sports Exerc 2011;43:1229–34.
21. Caputo E, Reichert F. Studies of Physical Activity and COVID-19 During the Pandemic: A Scoping Review. J Phys Act Health 2020;17:1275-84.

22. Bu F, Bone J, Mitchell J, et al. Longitudinal changes in physical activity during and after the first national lockdown due to the COVID-19 pandemic in England. Sci Rep 2021;11:17723.
23. Flanagan E, Beyl R, Fearnbach S, Altazan A, Martin C, Redman L. The Impact of COVID-19 Stay-At-Home Orders on Health Behaviors in Adults. Obesity 2021;29:438-45.
24. Ammar A, Brach M, Trabelsi K, et al. Effects of COVID-19 Home Confinement on Eating Behaviour and Physical Activity: Results of the ECLB-COVID19 International Online Survey. Nutrients 2020;12:1583.
25. Stanton R, To Q, Khalesi S, et al. Depression, Anxiety and Stress during COVID-19: Associations with Changes in Physical Activity, Sleep, Tobacco and Alcohol Use in Australian Adults. Int J Environ Res Public Health 2020;17:4065.
26. McCarthy H, Potts H, Fisher A. Physical Activity Behavior Before, During, and After COVID-19 Restrictions: Longitudinal Smartphone-Tracking Study of Adults in the United Kingdom. J Med Internet Res 2021;23:e23701.
27. Faulkner J, O'Brien W, McGrane B, Wadsworth D, et al. Physical activity, mental health and well-being of adults during initial COVID-19 containment strategies: A multi-country cross-sectional analysis. J Sci Med Sport 2021;24:320-36.
28. Kantomaa M, editor. Koronapandemian vaikutukset väestön liikuntaan. Valtioneuvosto: Opetus- ja kulttuuriministeriö: Valtion liikuntaneuvoston julkaisuja 2020:2. https://www.liikuntaneuvosto.fi/wp-content/uploads/2020/10/Koronapandemian-vaikutukset-vaeston-liikuntaan-VLN-julkaisuja-2020-2.pdf Accessed January 13, 2022
29. Lesser I, Nienhuis C. The Impact of COVID-19 on Physical Activity Behavior and Well-Being of Canadians. Int J Environ Res Public Health 2020;17:3899.
30. Nupponen H. Koululaisten fyysis-motorinen kunto. Liikunnan ja kansanterveyden julkaisuja 30. Jyväskylä: Liikunnan kansanterveyden edistämissäätiö; 1981.

31. Kaprio J, Sarna S, Koskenvuo M, Rantasalo I. The Finnish Twin Registry: Baseline characteristics: Section II: History of symptoms and illnesses, use of drugs, physical characteristics, smoking, alcohol and physical activity.. Kansanterveystieteen julkaisuja M37, Helsinki: kansanterveystieteen laitos; 1978.
32. Kujala UM, Kaprio J, Sarna S, Koskenvuo M. Relationship of Leisure-Time Physical Activity and Mortality: The Finnish Twin Cohort. JAMA 1998;279:440–4.
33. Satorra A, Bentler PM. Ensuring Positiveness of the Scaled Difference Chi-square Test Statistic. Psychometrika 2010;75:243–8.
34. Palomäki S, Hirvensalo M, Smith K, et al. Does organized sport participation during youth predict healthy habits in adulthood? A 28-year longitudinal study. Scand J Med Sci Sports 2018;28:1908-15
35. Kjønniksen L, Anderssen N, Wold B. Organized youth sport as a predictor of physical activity in adulthood. Scand J Med Sci Sports 2009;19:646-54.
36. Tammelin T, Näyhä S, Hills AP, Järvelin MR.. Adolescent participation in sports and adult physical activity. American Journal of Preventive Medicine 2003;24:22-8.
37. Mäkelä S, Aaltonen S, Korhonen T, Rose R, Kaprio J. Diversity of leisure-time sport activities in adolescence as a predictor of leisure-time physical activity in adulthood. Scand J Med Sci Sports 2017;27:1902-12.
38. Corder K, Winpenny E, Love R, Brown HE, White M, Sluijs EV. Change in physical activity from adolescence to early adulthood: a systematic review and meta-analysis of longitudinal cohort studies. Br J Sports Med 2019;53:496–503.
39. Miller J, Nelson T, Barr-Anderson D, Christoph M, Winkler M, Neumark-Sztainer D. Life Events and Longitudinal Effects on Physical Activity: Adolescence to Adulthood. Med Sci Sports Exerc 2019;51:663-70.

40. Bacil ED, Mazzardo Júnior O, Rech CR, Legnani RF, de Campos W. Atividade física e maturação biológica: uma revisão sistemática [Physical activity and biological maturation: a systematic review]. Revista paulista de pediatria: orgao 25fficial da Sociedade de Pediatria de Sao Paulo 2015;33:114–21.
41. Doherty A, Jackson D, Hammerla N, et al. Large Scale Population Assessment of Physical Activity Using Wrist Worn Accelerometers: The UK Biobank Study. PLoS One 2017;12:e0169649.
42. O'Connell SE, Griffiths PL, Clemes SA. Seasonal variation in physical activity, sedentary behaviour and sleep in a sample of UK adults. Ann Hum Biol 2014;41:1-8.
43. Pivarnik JM, Reeves MJ, Rafferty AP. Seasonal variation in adult leisure-time physical activity. Med Sci Sports Exerc 2003;35:1004-8.
44. Prochaska JO, Velicer WF. The Transtheoretical Model of Health Behavior Change. Am J Health Promot 1997;12:38-48.
45. Wong SL, Leatherdale ST, Manske SR. Reliability and validity of a school-based physical activity questionnaire. Med Sci Sports Exerc 2006;38:1593-600.
46. Lee PH, Macfarlane DJ, Lam T, et al. Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. Int J Behav Nutr Phys Act 2011;8:115.
47. Aasa U, Lundell S, Barnekow BM, Jansson E, Westerståhl M. The Swedish physical activity and fitness cohort born in 1958 - dropout analysis and overview at 36-year follow-up. Scand J Med Sci Sports 2017;27:418-29.
48. Matton L, Beunen G, Duvigneaud N, et al. Methodological issues associated with longitudinal research: findings from the Leuven Longitudinal Study on Lifestyle, Fitness and Health (1969–2004). J Sports Sci 2007;25:1011–24.

49. Lounassalo I, Hirvensalo M, Kankaanpää A, et al. Associations of Leisure-Time Physical Activity Trajectories with Fruit and Vegetable Consumption from Childhood to Adulthood: The Cardiovascular Risk in Young Finns Study. Int J Environ Res Public Health 2019;16:4437.

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

| **Characteristics** | **Males 12–19 y.** n=1094 | **Males 37–44 y.** n=776 | **Males 57-64 y.** n=471 | **Females 12–19 y.** n=1236 | **Females 37–44 y.** n=924 | **Females 57-64 y.** 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 (6.5) | 177.1 (8.5) | 160.9 (8.0) | 165.8 (5.7) | 167.5 (7.1) |
| **Weight (kg)** | 54.7 (13.2) | 83.2 (12.3) | 84.5 (14.7) | 51.4 (9.2) | 66.6 (11.9) | 75.9 (16.5) |
| **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 LTPA (%)** | | | 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 |
| **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 |

**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† |
| MET h/day 2021 during COVID-19 | 867 | 2.67 | 2.80 | 1.73 | 0 - 20.66† |

† Maximum value in study population

**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* |

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

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