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Associations of parental physical activity trajectories with offspring's physical activity patterns from childhood to middle adulthood: The Young Finns Study

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A R T I C L E I N F O

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A B S T R A C T

We investigated the association of parental physical activity (PA) trajectories with offspring's youth and adult PA. Self-reported PA data were extracted from the Young Finns Study with three follow-ups for parents between 1980 and 1986 and nine follow-ups for their offspring in youth between 1980 and 2011 (aged 9–39 years, n = 2402) and in adulthood in 2018. Accelerometer-derived PA was quantified in 2018–2020 (aged 43–58 years, n = 1134). Data were analyzed using mixture models and conducted in 2022. We identified three trajectories for fathers and mothers (high-stable activity, 20.2%/16.6%; moderate-stable activity, 50.5%/49.6%; and low-stable activity, 29.4%/33.7%) and four for youth male and female offspring (persistently active, 13.4%/5.1%; increasingly active, 32.1%/43.1%; decreasingly active, 14.4%/12.6%; and persistently low-active, 40.1%/39.1%). Compared to low-stable active parents, high-stable active fathers had a higher probability of having their sons and daughters classified as persistently active, increasingly active, and decreasingly active in youth (B_{range} = 0.50–1.79, all $p < 0.008$), while high- and moderate-stable active mothers had significantly increased likelihood of having their daughters classified as persistently active and decreasingly active in youth (B_{range} = 0.63–1.16, all $p < 0.009$). Fathers' and mothers' high-stable activity was associated with higher self-reported PA of adult offspring than parental low-stable activity. Persistently active and increasingly active offspring in youth accumulated more adult total PA, moderate-to-vigorous PA, step counts, and self-reported PA than persistently low-active ones (all $p < 0.036$). Parental persistent PA, particularly paternal persistent PA, predicts offspring's PA concurrently and prospectively. Increasing and maintaining PA in youth predicts higher PA levels in midlife.

1. Introduction

Regular physical activity (PA) has shown to contribute to various aspects of wellbeing and public health during the past few decades (Bull et al., 2020). In Finland, only 1 in 5 children and adolescents who are physically active maintain or increase their PA throughout adulthood (Rovio et al., 2018). More recently, longitudinal research has convincingly shown that being persistently active in youth achieves a more favorable cardiometabolic and mental health profile in young adulthood (Howie et al., 2020). It is important, therefore, to detect early age factors that contribute to the initiation and maintenance of PA across the life course.

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Along with a variety of psychological, social and environmental correlates, the influence of parents has been shown to play an important role in determining children's PA using devise-based and self-reported assessments in cross-sectional studies (Stearns et al., 2016; Christofaro et al., 2018). Some studies have detected the relationships between parent and child PA (Christofaro et al., 2018; Craig et al., 2013), whereas other studies have found no such relationships (Jago et al., 2010; Trost and Loprinzi, 2011). There are also sex pairing effects in parent–child PA interactions, such as father–son, father–daughter, and mother–son pairs (Craig et al., 2013). In longitudinal studies, some evidence has shown that parental PA predict children's PA through the transition from childhood to adolescence (Jacobi et al., 2011) and adulthood (Kaseva et al., 2017). A recent systematic review has denoted that there seems to exist a positive association between parent and child PA regardless of the age of the child, the sex of the parent-child dyad, and type of PA (Petersen et al., 2020a).

Of the 27 studies included in a recent systematic review (Lounassalo et al., 2019), 11 identify distinct trajectories of youth sports participation and PA, seven of which are related to health profiles in young adulthood. These findings suggest that persistent participation in youth sports and PA are associated positively with bone strength and physical health, and negatively with smoking, TV viewing, obesity, and cardiometabolic and mental health in young adulthood. However, to our knowledge, none has identified distinct trajectories of PA from childhood to young adulthood with self-reported and accelerometer-derived PA in midlife. The aims of this study are to (i) identify developmental trajectories of PA between parents over 6 years and youth offspring (9–39 years) through eight successive phases, (ii) examine the linkages between PA trajectory classes of parents and youth offspring and sex differences in such associations, and (iii) estimate the associations of PA trajectories of parents and youth offspring with self-reported and accelerometer-derived PA in adult offspring (43–58 years). We hypothesized that the interaction between PA trajectory classes of parents and youth offspring could modulate offspring's adult PA. Specifically, we expected that parental stable activity (i.e., parents with high- and moderate-stable PA over time) would be independently associated with higher levels of offspring's youth and adult PA compared to parental low-stable activity (i.e., parents maintaining low PA levels). We also expected that PA trajectories of youth offspring would be associated with their PA later in life.

2. Methods

2.1. The Young Finns Study (YFS)

Data were from the YFS of children and adolescents 3–18 years in 1980, representing six age-cohorts born between 1962 and 1977 (Raitakari et al., 2008). 3596 individuals have been studied triennially from baseline to 1992, and then followed up in 4–9 year intervals from 1992 to 2018–2020 (Telama et al., 2014; Yang et al., 2021). The individuals were randomly selected from the five Finnish university cities with medical schools (Helsinki, Kuopio, Oulu, Tampere and Turku) and their surrounding rural communities. For the present study, parental PA data were available in 1980–1986. Youth offspring ($n = 2402$) and their parents who had at least one non-missing measure of PA across time were included in trajectory analyses. Adult offspring ($n = 1134$) who wore an accelerometer were included in multinomial logistic regression analyses. The study protocol was approved by the local ethics committees. Written informed consent was obtained from all participants in accordance with the Helsinki Declaration. Details of the YFS have been reported elsewhere (Raitakari et al., 2008).

2.2. Self-reported physical activity

2.2.1. Offspring measures

Self-reported PA data were available for offspring from childhood to adulthood (1980–2018). To avoid age ranges overlapping during middle adulthood, the number of youth offspring aged 42–49 years in 2007 and 2011 were excluded from the analysis (Yang et al., 2022). In 1980–1989, the PA questionnaires comprised the frequency and intensity of PA, participation in sports club training, participation in competitions, and habitual way of spending leisure time. Each item was coded from 1 = low to 3 = high, except for participation in sport competitions (1 = no and 2 = yes). By summing the variables, a PA index was formed with scores ranging from 5 to 14. In 1992–2018, the questions consisted of the intensity of PA, frequency of vigorous PA, hours spent on vigorous PA, average duration of a PA session, and participation in organized PA. The items were based on the average number of hours/times per week. Each item was coded from 1 = low to 3 = high and summed to create a PA index ranging from 5 to 15 (Yang et al., 2022). All PA indices were categorized into tertiles (low [< 8], moderate [8–10], and high [>10]) in line with a widely used procedure (Haskell et al., 2007). The PA index has been found to be reliable and valid to measure PA across the lifespan (Rovio et al., 2018; Telama et al., 2014; Telama et al., 2005).

2.2.2. Parental measures

Parental PA was assessed separately for fathers and mothers with a simple question in 1980, 1983, and 1986: “How much do you engage in leisure-time physical activity?” The response alternatives were a little bit, somewhat and regular.

2.3. Accelerometer protocol

In 2018–2020, the offspring were instructed to wear a triaxial accelerometer (ActiGraph GT3X+ and wGT3X+, FL, USA) on the right hip for seven consecutive days and nights, but to remove it for bathing and water activities. Data were collected at a 60-Hz sample rate using normal filter and later averaged to 60-s epochs. The valid amount of data was set to include at least four days, 600 min/d or more and non-wear time was defined as 60 min of consecutive zero counts (Migueles et al., 2017). For this study, the outcome variables included average daily vector magnitude counts per minute (cpm) as an index of total PA, steps per day, and moderate-to-vigorous PA (MVPA as $\geq$2690 cpm) (Sasaki et al., 2011).

2.4. Covariates

Age and residential place (urban vs. rural) were queried at baseline and follow-up questionnaires. Offspring's height and weight were measured at the baseline and follow-up study visits. BMI was calculated as weight (kg)/height (m^2). Parental and adult offspring's educational level were self-reported and applied as completed school years. Self-reported information on parental occupation were classified into three categories based on the criteria of the Central Statistical Office of Finland: manual (builders, metal workers, nannies, etc.), lower non-manual (civil servants, specialized and skilled workers, etc.), and upper non-manual (administrators, managers, academics, etc.). Number of children with adult offspring was queried, and two categories were presented as no child and at least one child. Adult offspring's income level was grouped as <€25,000, €25,000 − 45,000, and > €45,000. Accelerometer wear time was fitted as a covariate when the recorded number of certain behaviors might depend on the daily measuring effort in regression models.

2.5. Statistical analyses

Data were analyzed using R environment (R core team, 2020) and Mplus Version 7.0[22] via R software package MplusAutomation (Hallquist and Wiley, 2018). Descriptive characteristics are expressed as mean (standard deviation) for continuous variables and as percentages for categorical variables. Sex and group (included and excluded offspring) differences were analyzed using independent *t*-tests or χ^2

tests. To identify PA trajectories, latent classification analysis with 2 to 5 classes was fitted on paternal and maternal PA at three phases, while latent profile analysis with 2 to 6 classes was fitted on youth PA scores of male and female offspring at eight phases which were synchronized by at least one PA observation at successive ages 9–21 and 24–39. The flexibility of latent profile analysis approach enables the classification of incompletely observed indicators. Classification of parental PA and offspring's youth PA was conducted by adjusting for baseline age, BMI (for youth offspring), residential place, and parental education and occupation. Several measures of model fit were calculated and evaluated to determine the optimal number of classes, including Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), Sample-size Adjusted Bayesian Information Criterion, Vuong-Lo-Mendell-Rubin likelihood ratio test (VLMR), Lo-Mendell-Rubin adjusted likelihood ratio test (LMR), Parametric bootstrapped likelihood ratio test, entropy values, and average posterior probabilities describing the classification uncertainty (Tein et al., 2013). The decision of number of classes was made based on the lowest AIC and BIC values with minimum class sizes of 5% and both VLMR and LMR tests ($p < 0.0001$).

Associations between PA trajectories of parents and youth offspring were evaluated using multinomial logistic regression analysis (Muthén and Asparouhov, 2011), indicating that the latent class variables of paternal and maternal PA were regressed separately on the latent class variables of male and female offspring's youth PA. Regression models were also used separately for accelerometer-derived and self-reported PA outcomes representing unstandardized regression coefficients (B) and SE, when controlling for adult offspring's age and BMI, having children, offspring's own education and income, accelerometer wear time, and parental PA trajectory subgroups. All analyses were conducted in 2022. Missing data were assumed to be missing at random (MAR) and were considered missing as a function of observed covariates and observed outcomes (Muthén and Muthén, 2017). Full information maximum likelihood estimation with robust standard errors was used to handle the MAR assumption to reduce potential bias in the parameter estimates and statistical power to detect statistically significant effects.

3. Results

3.1. Attrition analyses

Of the 2402 offspring, 1134 were included from the sample used in the trajectory analyses with valid accelerometer data in adult offspring. The excluded offspring were slightly younger (48.0 vs. 48.6 years, $p = 0.001$) and male (50.8% vs. 39.5%, $p < 0.001$), had lower physically active (8.8 vs. 9.1, $p = 0.002$), and were less educated (30.3% vs. 21.1%, $p < 0.001$) and had lower annual income (20.3% vs. 15.2%, $p = 0.002$) than the included offspring. There were no differences in residential place, follow-up BMI, and having children between the included and excluded offspring.

3.2. Preliminary analyses

The complete data were obtained from 1079 (44.9%) male and 1323 (55.1%) female offspring (Table 1). In youth offspring, males engaged more in PA from 1980 to 1992 and 2011 than females. In adult offspring, males engaged more in total PA and MVPA, had higher income, and were less educated than female. Fathers had higher PA (1980 and 1983) and lower education and occupation than mothers. No other sex differences were observed. Additionally, the result showed significant but low correlations of self-reported PA with accelerometer-derived MVPA ($r = 0.17$, $p < 0.001$), step counts ($r = 0.18$, $p < 0.001$), and total PA ($r = 0.12$, $p < 0.001$).

3.3. Physical activity trajectories

Three trajectory groups were identified for fathers: high-stable activity (20.2%), moderate-stable activity (50.5%) and low-stable activity (29.4%), and the corresponding proportions for mothers were 16.6%, 49.6% and 33.7%, respectively (Fig. 1 A-B). Four trajectory groups were identified for youth male and female offspring: *persistently active* (13.4% and 5.1%) subjects were physically active in childhood and throughout life course; *increasingly active* (32.1% and 43.1%) subjects were physically low active until late adolescence, increased their

Table 1
Comparison of participant characteristics by sex.

	Overall (n = 2402)	Males (n = 1079)	Females (n = 1323)	
Variable	Mean (SD)	Mean (SD)	Mean (SD)	p[‡]
Baseline age (years)	10.3 (4.9)	10.2 (5.0)	10.3 (4.9)	0.567
Follow-up age (years)	48.3 (4.9)	48.2 (5.0)	48.3 (4.9)	0.567
Offspring's baseline BMI (kg/m^2)	17.7 (3.0)	17.7 (2.9)	17.7 (3.0)	0.754
Residential place (%)				
Urban	55.0	55.2	54.8	0.863
Rural	45.0	44.8	45.2	
Offspring's PA (index)				
1980	9.1 (1.8)	9.6 (1.9)	8.7 (1.6)	<0.001
1983	9.0 (1.8)	9.5 (2.0)	8.6 (1.6)	<0.001
1986	8.9 (2.0)	9.3 (2.1)	8.6 (1.8)	<0.001
1989	8.7 (2.1)	9.0 (2.3)	8.5 (1.9)	<0.001
1992	9.1 (1.9)	9.5 (2.2)	8.9 (1.7)	<0.001
2001	8.9 (2.0)	9.0 (2.1)	8.8 (1.8)	0.085
2007	8.8 (1.8)	8.8 (1.9)	8.9 (1.7)	0.346
2011	9.0 (1.9)	8.9 (1.9)	9.1 (1.9)	0.026
2018	9.0 (1.9)	9.0 (1.9)	9.0 (1.9)	0.792
Adult offspring's BMI (kg/m^2)	27.3 (5.2)	27.5 (4.5)	27.1 (5.8)	0.059
Adult offspring's education (year) (%)				
Low (≤13 years)	25.3	33.7	18.7	<0.001
High (>13 years)	74.7	66.3	81.3	
Adult offspring's income (annual) (%)				
<€25,000	16.8	13.4	19.4	<0.001
€25,000–45,000	42.7	32.5	50.6	
>€45,000	40.5	54.1	30.0	
Having children (in the household) (%)	50.4	53.1	48.4	0.064
Accelerometry data 2018–2020	(n = 1134)	(n = 441)	(n = 693)	
Total PA (cpm)	55.2 (31.7)	63.8 (35.6)	49.7 (27.6)	<0.001
MVPA (min/day)	1037 (397)	1080 (440)	1010 (365)	0.004
Total steps (step/day)	8588 (2967)	8584 (3036)	8590 (2924)	0.972
Wear time (min/day)	1018 (75)	1017 (80)	1018 (72)	0.791
Parental variables				
PA (%)	Overall	Fathers	Mothers	
1980 low	24.6	21.4	27.8	<0.001
Moderate	56.2	56.7	55.6	
High	19.2	21.8	16.6	
1983 low	25.1	23.0	27.1	0.004
Moderate	54.9	55.6	54.3	
High	20.0	21.4	18.6	
1986 low	24.7	24.4	25.1	0.244
Moderate	52.5	51.3	53.6	
High	22.8	24.4	21.4	
Education (years, %)				
Low (≤9 years)	50.8	54.8	46.8	<0.001
Moderate (10–12 years)	26.5	22.9	30.1	
High (>12 years)	22.7	22.2	23.1	
Occupation (%)				
Manual	34.9	39.3	30.6	<0.001
Lower non-manual	29.0	19.2	38.9	
Upper non-manual	36.0	41.5	30.5	

Abbreviations: SD, standard deviation; cpm, counts per minute, BMI, body mass index; PA, physical activity; MVPA, moderate-to-vigorous PA.
[‡] The p value for sex difference, independent t-tests or χ^2 tests.

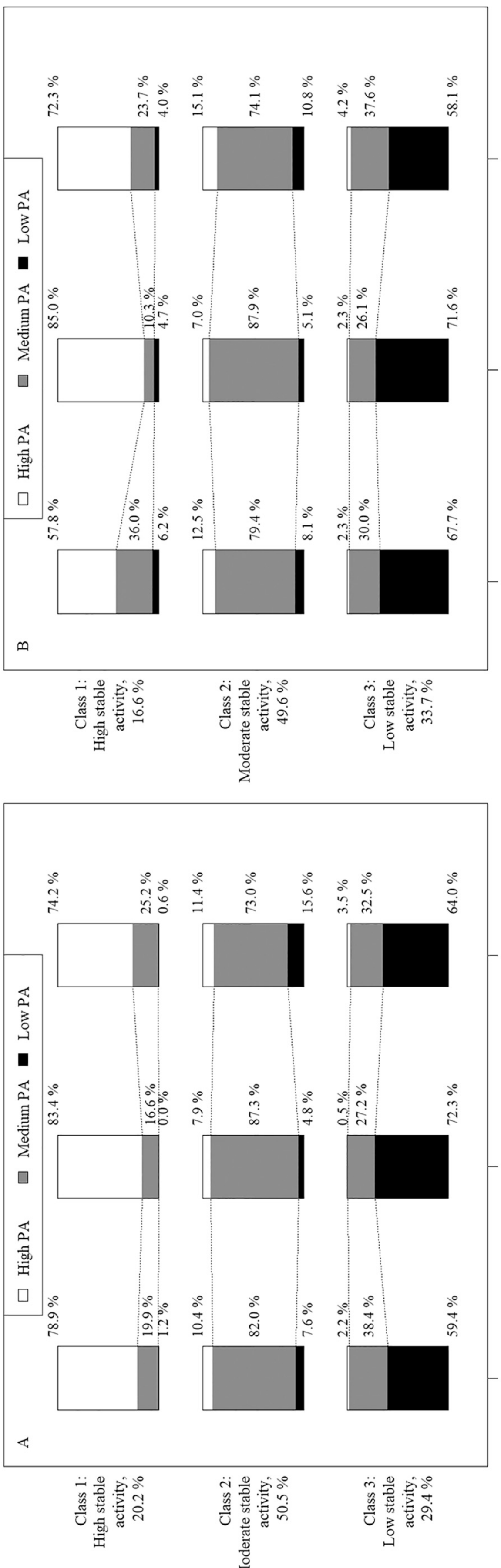

Fig. 1. Proportions of observed intensities of physical activity within latent classification analysis (C = 3) of fathers (A) and mothers (B).

activity during young adulthood, with relatively high stable thereafter; *decreasingly active* (14.4% and 12.6%) subjects were physically active until adolescence, decreased their activity during young adulthood, with relatively low stable thereafter; and *persistently low-active* (40.1% and 39.1%) subjects were physically active in childhood, decreased their activity during adolescence and young adulthood, with relatively low stable thereafter (Fig. 2 A-B). Quality of the classification for PA in both parents and youth offspring was acceptable.

3.4. Interaction between parental and offspring's PA trajectories

Compared to low-stable active fathers, high-stable active fathers had a higher probability of capturing their sons and daughters who were persistently active (B = 1.79, $p < 0.001$; B = 1.02, p = 0.007), increasingly active (B = 1.06, $p < 0.001$; B = 0.50, p = 0.008), and decreasingly active (B = 1.46 and 1.05, $p < 0.001$ for both)(Table 2). Moderate-stable active fathers had increased likelihood of having their sons classified as decreasingly active (B = 0.57, p = 0.037) than low-stable active fathers. High- and moderate-stable active mothers had a higher probability of capturing their daughters who were persistently active (B = 1.16, p = 0.008; B = 1.14, p = 0.003) and decreasingly active (B = 0.88, p = 0.029; B = 0.63, p = 0.009) than their low-stable active counterparts. Compared to low-stable active mothers, high-stable active mothers had increased likelihood of having their sons classified as persistently active (B = 0.61, p = 0.048).

3.5. Midlife physical activity differences between PA trajectories

Paternal and maternal high-stable activity were associated with higher levels of self-reported PA of adult offspring than their low-stable activity (B = 0.56, $p < 0.001$; B = 0.31, p = 0.028) after adjusting for adult offspring's age, sex, BMI, having children, and own education and income (Table 3). In the models, none of the parental PA classes were associated with accelerometer-derived PA of adult offspring. Youth offspring who were persistently PA, increasingly PA, and decreasingly PA had higher levels of self-reported PA of adult offspring than those who were persistently low-active (B = 1.91, 1.40, and 0.83 for males; B = 2.13, 1.14, and 0.93 for females, all $p < 0.001$, respectively) after adjusting for follow-up covariates and parental PA trajectory subgroups. Male and female offspring who were persistently active accumulated more MVPA (B = 15.43, p = 0.008; B = 39.9, $p < 0.001$), step counts (B = 954.6, p = 0.036; B = 2987.9, $p < 0.001$), and total PA (B = 152.4, p = 0.025; B = 323.4, $p < 0.001$) in midlife than persistently low-active ones. Compared to the persistently low-active group, being increasingly active in female offspring was associated with higher adult MVPA (B = 7.59, p = 0.001) and step counts (B = 797.3, p = 0.001); and being decreasingly active in male offspring was associated with more step counts (B = 938, p = 0.049) in midlife. All associations remained significant after adjusting for follow-up covariates, accelerometer wear time, and parental PA trajectory subgroups.

4. Discussion

This is the first long-term prospective study to identify distinct trajectories of PA in parents and youth offspring for the prediction of self-reported and accelerometer-derived PA patterns in adult offspring. Three parental PA (high stable activity, moderate stable activity, and low stable activity) and four offspring's youth PA (persistently active, increasingly active, decreasingly active, and persistently low-active) trajectory groups were identified. We found that parental PA trajectories over 6 years were differentially associated with offspring's PA concurrently and 40-years later. Changes in offspring's youth PA displayed significant relationships with PA patterns in midlife.

Consistent with our hypotheses, paternal and maternal high-stable activities were associated with being persistently active in youth offspring of both sexes. Further, parental high-stable activity was

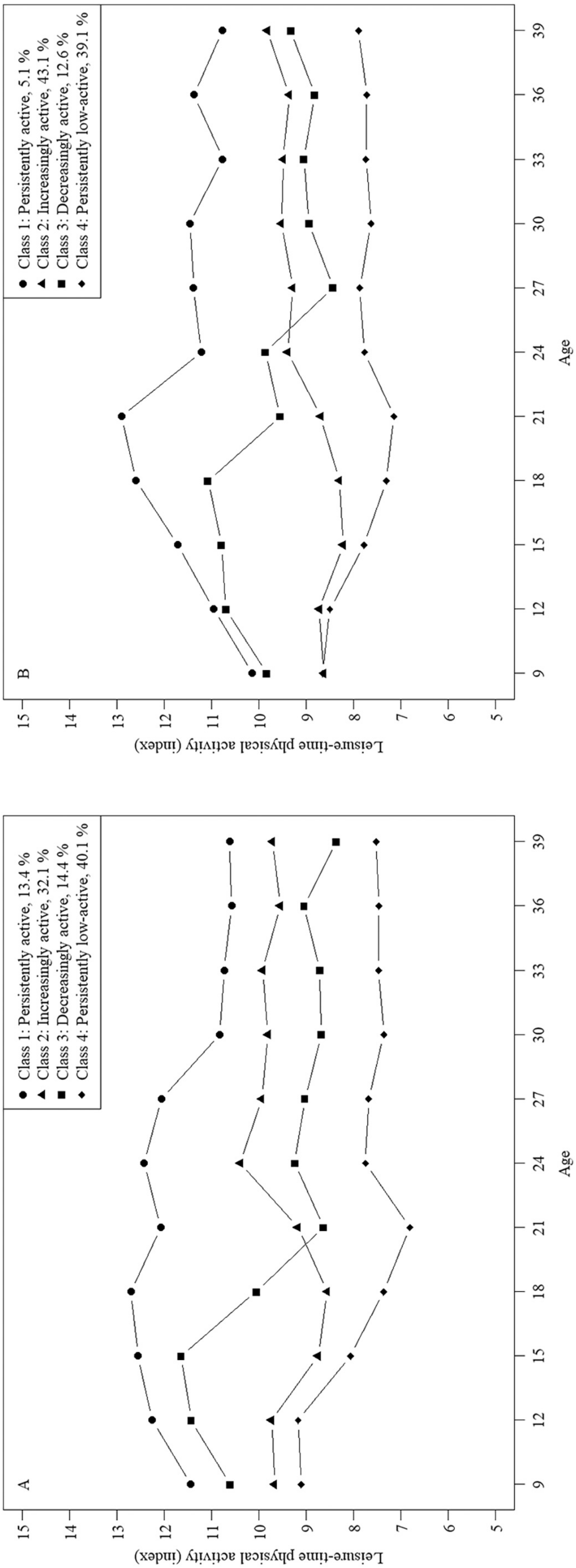

Fig. 2. Mean profile lines for latent physical activity classes (C = 4) of male offspring (A) and female offspring (B).

associated with high levels of self-reported PA in adult offspring of both sexes. These findings are similar to those found in previous studies indicating that parental PA at baseline is independently associated with more favorable children's PA later in life (Kaseva et al., 2017). Our results extend the previous findings (Craig et al., 2013) by showing the long-lasting effects of paternal and maternal PA on the maintenance of male and female offspring's PA concurrently and at a 40-year follow-up. The literature in general implies that PA in childhood and adolescence are associated with later PA through genetic and environment factors (Bauman et al., 2012; Huppertz et al., 2016). Especially parental modeling and social support have previously been found to be related to children's PA (Tandon et al., 2014; Petersen et al., 2020b; Keyes and Wilson, 2021). There is also evidence that parental PA predicts children's PA from childhood through adolescence (Jacobi et al., 2011) and in adulthood (Kaseva et al., 2017). The present study suggests that parental persistent PA may still have a beneficial effect on adult offspring's PA, mainly due to retaining parental influences during childhood and adolescence and the transition to adulthood. Our results also extend the previous research indicating that fathers' persistent high PA was more strongly associated with offspring's youth and adult PA than that of mothers (Kaseva et al., 2017). Moreover, the results showed that paternal high-stable activity was associated with being increasingly active in youth offspring of both sexes, while maternal moderate-stable activity was associated with being persistently active in youth female offspring. It is possible that there are sex-related differences in the different levels of intensity of long-term PA from fathers or mothers which may be attributed to the differences in sustaining PA participation among male and female offspring. However, it appears unlikely that parental high- or moderate-stable activity was associated with being decreasingly active in either male or female offspring in youth, but these findings did not rule out the possibility that non-differential misclassification bias might lead to an underestimation of the true association between exposure and outcome. Theoretically, this study contributes to and extends the literature by examining how longitudinal parental PA enhance the development of strategies to increase each active PA trajectory for offspring across the life course.

We also tested whether distinct trajectories of offspring's PA from childhood to young adulthood predict their later PA using both accelerometer and self-reported measures. The results indicated that being persistently active and increasingly active were associated with higher self-reported PA in adult offspring of both sexes. Compared to persistently low-active offspring, persistently active offspring accumulated more adult MVPA, step counts, and total PA. Increasingly active female offspring also accumulated higher adult MVPA and step counts. These findings are in line with previous research demonstrating that those being persistently active in youth achieve a more favorable PA in young adulthood (Howie et al., 2020; Howie et al., 2016). Our results emphasize the importance of engaging children and adolescents in long-lasting PA to influence the adoption and maintenance of an active lifestyle in midlife. On the other hand, the present study showed that being decreasingly active was associated with higher self-reported PA in adult offspring of both sexes and more step counts in adult male offspring compared with being persistently low active. For youth offspring to get the most beneficial effects from PA, the long-term prevalence of high-to-moderate PA was also considered enough to be an effective for increasing PA later in life. Future studies considering the impact of change in PA on the development of healthy behavior (e.g., PA) are warranted when the follow-up period has been longer in male and female offspring. These results further suggest that the distinct trajectories of offspring's PA may prove to be useful for identifying offspring's behaviors as potential targets of intervention to sustain active lifestyles, such as improved PA for the long-term.

4.1. Strengths and limitations

A major strength of this study is its use of a large population-based

Table 2
Parameter estimates for the association between parental and youth offspring's physical activity trajectories.

	Paternal PA group[†]						Maternal PA group[†]					
	High-stable activity			Moderate-stable activity			High-stable activity			Moderate-stable activity		
Group	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Male offspring's PA in youth (n = 1079)												
Persistently low-active (as ref.)												
Persistently active	1.79	0.31	<0.001	0.19	0.26	0.480	0.61	0.31	0.048	0.25	0.25	0.325
Increasingly active	1.06	0.25	<0.001	0.12	0.18	0.498	0.13	0.25	0.598	0.10	0.18	0.563
Decreasingly active	1.46	0.34	<0.001	0.57	0.27	0.037	0.22	0.34	0.507	0.12	0.25	0.628
Female offspring's PA in youth (n = 1323)												
Persistently low-active (as ref.)												
Persistently active	1.02	0.38	0.007	−0.31	0.37	0.411	1.16	0.44	0.008	1.14	0.38	0.003
Increasingly active	0.50	0.19	0.008	0.05	0.15	0.720	0.11	0.20	0.596	0.19	0.14	0.192
Decreasingly active	1.05	0.29	<0.001	0.36	0.26	0.162	0.88	0.29	0.002	0.63	0.24	0.009

Abbreviations: B, regression coefficient; SE, standard error; PA, physical activity.
[†] Parental low-stable activity serves as the reference group for each.

Table 3
Parameter estimates for the associations of parental and youth offspring's physical activity trajectories with offspring's accelerometer-derived and self-reported physical activity in midlife.

	Accelerometer-derived PA									Self-reported PA		
	MVPA (min/day)			Daily steps			Total PA (cpm)			Index values		
Trajectory group	B	SE	p	B	SE	p	B	SE	p	B	SE	p
Paternal PA[†]												
Low-stable activity (as ref.)												
Moderate-stable activity	−1.03	2.15	0.635	−212.6	200.3	0.289	−42.5	27.3	0.120	0.14	0.11	0.195
High-stable activity	1.72	2.65	0.517	222.3	246.8	0.368	−14.8	33.6	0.660	0.56	0.14	<0.001
Maternal PA[†]												
Low-stable activity (as ref.)												
Moderate-stable activity	2.70	2.05	0.189	141.7	191.0	0.458	14.7	26.0	0.573	0.14	0.11	0.183
High-stable activity	2.80	2.83	0.322	361.7	263.4	0.170	40.9	35.9	0.255	0.31	0.14	0.028
Male offspring's PA[†,§]												
Persistently low-active (as ref.)												
Decreasingly active	5.95	5.69	0.296	938.0	474.1	0.049	99.9	70.7	0.158	0.83	0.22	<0.001
Increasingly active	4.51	4.03	0.263	247.2	335.9	0.462	15.0	50.1	0.765	1.40	0.16	<0.001
Persistently active	15.43	5.45	0.005	954.6	454.2	0.036	152.4	67.7	0.025	1.91	0.21	<0.001
Female offspring's PA[†,§]												
Persistently low-active (as ref.)												
Decreasingly active	5.24	3.39	0.122	489.3	358.2	0.173	34.2	46.0	0.458	0.93	0.19	<0.001
Increasingly active	7.59	2.31	0.001	797.3	244.3	0.001	38.4	31.4	0.222	1.14	0.13	<0.001
Persistently active	39.90	4.38	<0.001	2987.9	463.6	<0.001	323.4	59.6	<0.001	2.13	0.26	<0.001

Abbreviations: B, regression coefficients; SE, standard error; PA, physical activity; MVPA, moderate-to-vigorous PA.
[†] Adjusted for adult offspring's age, sex, BMI, having children, and own education and income as well as accelerometer wear time (special for the device).
[§] Stratified by sex and additionally adjusted for parental physical activity trajectory subgroups.

nationally representative sample of Finnish children and adolescents and their parents, the use of prospective cohort design over a 40-year follow-up period, repeated measures of self-reported PA, accurate measurement of PA using an accelerometer, and the inclusion of potential covariates. Several potential covariates that could affect the associations of PA trajectories of parents and youth offspring with PA patterns in adult offspring were controlled for in the analysis.

However, there are also limitations. First, we could not assess trajectories of parental PA using the latent profile analysis because their PA levels were self-reported with a single question from baseline to follow-up, and we were not able to estimate a random measurement error. Further YFS examinations including parental PA would enable us to explore the multiple PA questions or wearable devices for parents. Second, although the PA questions had no seasonal variation, the accelerometer-derived PA measurement was completed from June 2018 to June 2020 that would underestimate seasonal differences in adult offspring's PA. Third, some offspring were excluded from the analysis because of missing accelerometer measures. Since the excluded offspring were more likely to have lower PA in adult years, there was an unavoidable potential bias that was prone to the underestimation of included participants in each trajectory group. Nevertheless, we estimated offspring's PA in each measurement year in the sensitivity analysis and found similar results. Fourth, our analyses relied on self-reported PA in earlier years which was subject to recall and social desirability bias. Accelerometers in the most recent follow-up provided more accurate estimates of volumes and intensities of PA than self-reported measures, even though they did not capture some types of PA (e.g., weight training, swimming, and cycling). Due to these methodological deficiencies, self-reported PA was poorly correlated with accelerometer-derived PA in middle adulthood. Moreover, self-reported PA measurement in parents also likely led to underestimating the true association with offspring's youth and adult PA, especially in paternal moderate-stable activity class. Finally, although there were a wide variety of cut-points to choose from when translating accelerometer data, we opted to derive the vector magnitude cut-points of ≥2690 cpm for MVPA. These cut-points would influence the amount of MVPA in adult participants, which in turn could potentially affect the outcomes of the statistical approaches.

5. Conclusion

This study identified longitudinal trajectories of PA in parents and youth offspring over time. Persistent physically active parents may be associated with offspring's PA both concurrently and prospectively. Paternal high-stable PA is a stronger predictor for offspring's youth and adult PA in both sexes than that of mothers. Increasing and maintaining PA in youth offspring are likely to be beneficial for their PA in midlife. These findings highlight the importance of sharing persistently physically active lifestyle in parents and youth offspring to promote the development of offspring's PA levels later in life.

CRediT authorship contribution statement

Xiaolin Yang: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Tuomas Kukko:** Data curation, Formal analysis, Software, Writing – review & editing. **Kaisa Kaseva:** Writing – original draft, Writing – review & editing. **Stuart J.H. Biddle:** Writing – review & editing. **Suvi P. Rovio:** Investigation, Resources, Data curation, Writing – review & editing, Project administration. **Katja Pahkala:** Investigation, Resources, Writing – review & editing. **Janne Kulmala:** Data curation, Investigation, Software, Writing – review & editing. **Harto Hakonen:** Data curation, Investigation, Software. **Mirja Hirvensalo:** Data curation, Writing – review & editing, Project administration. **Nina Hutri-Kähönen:** Investigation, Resources. **Olli T. Raitakari:** Funding acquisition, Writing – review & editing, Project administration, Supervision. **Tuija H. Tammelin:** Funding acquisition, Writing – review & editing, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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