Author(s): Rovio, Suvi P.; Yang, Xiaolin; Kankaanpää, Anna; Aalto, Ville; Hirvensalo, Mirja; Telama, Risto; Pahkala, Katja; Hutri-Kähönen, Nina; Viikari, Jorma S.A.; Raitakari, Olli T.; Tammelin, Tuija H.

Title: Longitudinal physical activity trajectories from childhood to adulthood and their determinants : The Young Finns Study

Year: 2018

Version:

Please cite the original version:

Rovio, S. P., Yang, X., Kankaanpää, A., Aalto, V., Hirvensalo, M., Telama, R., Pahkala, K., Hutri-Kähönen, N., Viikari, J. S., Raitakari, O. T., & Tammelin, T. H. (2018). Longitudinal physical activity trajectories from childhood to adulthood and their determinants : The Young Finns Study. Scandinavian Journal of Medicine and Science in Sports, 28(3), 1073-1083. https://doi.org/10.1111/sms.12988

DR SUVI ROVIO (Orcid ID : 0000-0003-0911-7478)

Article type : Original Article

Longitudinal physical activity trajectories from childhood to adulthood and their determinants: The Young Finns Study

Running title: Physical activity trajectories

Suvi P. Rovio[1,2], Xiaolin Yang[2], Anna Kankaanpää[2], Ville Aalto[1], Mirja Hirvensalo[3], Risto Telama[2,3], Katja Pahkala[1,4], Nina Hutri-Kähönen[5], Jorma S.A. Viikari[6], Olli T. Raitakari[1,7], Tuija H. Tammelin[2]

[1]Research Centre of Applied and Preventive Cardiovascular Medicine, University of Turku, Turku, Finland;

[2]LIKES Research Centre for Physical Activity and Health, Jyväskylä, Finland;

[3]Department of Sport Sciences, University of Jyväskylä, Jyväskylä, Finland;

[4]Paavo Nurmi Centre, Sports & Exercise Medicine Unit, Department of Health and Physical Activity, University of Turku, Turku, Finland;

[5]Department of Pediatrics, University of Tampere and Tampere University Hospital, Tampere, Finland;

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/sms.12988

[6]Department of Medicine, University of Turku and Division of Medicine, Turku University Hospital, Turku, Finland;

[7]Department of Clinical Physiology and Nuclear Medicine, Turku University Hospital, Turku, Finland

Corresponding author:

Suvi Rovio

Research Centre of Applied and Preventive Cardiovascular Medicine

Kiinamyllynkatu 10

20520 Turku

Finland

Telephone: +358 40 5665036

Fax: +358 2 333 7270

Email: suvi.rovio@utu.fi

ABSTRACT

Background: Determining life-long trajectories and their determinants is essential to promote a physically active lifestyle throughout the life-course. We aimed to identify physical activity (PA) trajectories from childhood to midlife and their determinants in a longitudinal population-based cohort.

Methods: This study is a part of the Cardiovascular Risk in Young Finns Study. From 1980, a population-based cohort (N=3,596:1764 boys/1832 girls, age 3-18 years) has been followed-up for 31 years. PA indices were formed based on self-reported data (between age 9-49 years) on frequency, duration and intensity of leisure (during childhood) or high-intensity (at later age) PA and on sports club participation/competitions. PA trajectories were analysed using group-based trajectory modelling. Childhood (age 12 years), young adulthood (age 24 years) and early midlife (age 37 years) determinants were analysed.

Results: Five PA trajectories were identified: persistently active (6.6%), decreasingly active (13.9%), increasingly active (13.5%), persistently low active (51.4%,reference group), persistently inactive (14.6%). In childhood**,** rural residential area (OR 0.45, 95%CI 0.21-0.96) and high academic performance (OR 2.18; 95%CI 1.58-3.00) associated with persistently active group. In early midlife, smoking (OR 1.66; 95%CI 1.07-2.58) associated with persistently inactive group, regular alcohol drinking (OR 2.91; 95%CI 1.12-7.55) with persistently active group and having children (OR 2.07; 95%CI 1.27-3.38) with decreasingly active group. High adulthood education associated with both decreasingly (OR 1.87; 95%CI 1.05-3.35) and increasingly (OR 2.09; 95%CI 1.19-3.68) active groups.

Conclusions: We identified five PA trajectories from childhood into midlife. Most prominent determinants were academic achievement, education, having children and health habits (*i.e.*smoking/alcohol use).

Key words: trajectories, physical activity, behaviour, latent class growth modelling, longitudinal, population-based

BACKGROUND

The benefits of physical activity (PA)[1] and disadvantages of physical inactivity[2] are well recognised. PA typically decreases with age, particularly during adolescence.[3,4] Simultaneously, childhood PA[4,5] and inactivity[6–8] track into adulthood. However, tracking of PA, from childhood to adolescence or adulthood, tends to have low to moderate inter-age correlations[4,9] probably reflecting the existing within-individual variability in PA during the life course.[10]

Personal (*e.g.*, age, sex, previous PA), psychosocial (*e.g.*, self-efficacy, social norms), genetic, and environmental (*e.g.*, organizational practices, sport facilities) characteristics[11–14] determine PA. These determinants have their genesis partly in childhood[15,16] and adolescence.[10,17,18] Therefore, a life course perspective is needed to clarify the determinants of PA[19,20] and to point out how the changes in the determinants either in adolescence[21–23] or adulthood[24,25] affect the lifelong PA trajectories. Investigating the determinants of lifelong PA trajectories is essential for development of effective PA promotion strategies already from youth to support lifelong activity.

Only a few longitudinal studies describe a cohort approach to PA change in youth[23,26–30] and adulthood.[31,32] These studies suggest a considerable variation in timing and magnitude of decline in PA from mid to late adolescence or from adulthood to old age. Simultaneously, some studies identify subgroups of inviduals with distinct developmental PA trajectories and display heterogeneous long-term patterns in adolescence[26] and adulthood.[31] However, none of them have studied PA trajectories longitudinally from childhood to adulthood. To fill this knowledge gap, the aim of this study was to identify PA trajectories from childhood to midlife in a large population-based cohort of the Cardiovascular Risk in Young Finns Study (YFS). Additionally, we aimed at exploring descriptive characteristics and determinants of the PA trajectory groups from childhood to adulthood.

METHODS

Study population

This study is a part of the YFS, an ongoing longitudinal population-based study focusing on cardiovascular risk factors from childhood to adulthood. In 1980, the baseline study included 3,596 randomly selected boys and girls aged 3-18 years. The cohort has been followed-up in 3-9 year intervals. The latest follow-up study was in 2011 (N=2,060). The study protocol was approved by the local ethics committees. Written informed consent was obtained from all participants. Detailed information on the YFS study has been reported earlier.[33]

Physical activity

In all study phases, PA was measured among participants aged 9 years and above with a self-administered questionnaire. A complex PA index for leisure time PA was calculated using the PA data collected between the ages 9 and 49 years. Data on PA was also available for children aged 3 and 6 years based on their parents report. However, that questionnaire was not comparable to later follow-ups. Therefore, in this study the self-reported data from age 9 years was used. In 1980-1989, the questionnaire included questions concerning the frequency and intensity of leisure-time PA, participation in sports-club training, participation in sport competitions, and habitual way of spending leisure time. In the follow-ups from 1992 ahead, the PA questionnaire consisted of items on the frequency and intensity of PA, frequency of vigorous PA, hours spent on vigorous PA, average duration of a PA session, and participation in organized PA. Supplement Table 1 shows the questions assessing PA and creation of the PA index (range 5-14) in 1980-1989[7] while the Supplement Table 2 shows the questions and creation of the index (range 5-15) in 1992-2011.[34]

Determinants of physical activity trajectories

Determinants of PA trajectories were analysed at three time points: 1) childhood (age 12 years), 2) young adulthood (age 24 years) and 3) early midlife (age 36-37 years, hereafter 37). By using these age points for measuring the determinants we aimed to capture the information in three different phases of life that all represent important transition periods in terms of PA participation: from childhood to adolescence, from education to working life and settling down to midlife.[19] Residential status was queried at all age points and dichotomized into 1) urban (=cities, suburbs or centre of a town/village) and 2) rural (=outside a population centre). In all follow-ups, participant's weight and height were measured and body mass index (BMI) was calculated. In childhood, the participants were divided into: 1) normal weight and 2) overweight/obese using standard cut-off values.[35] In young adulthood and early midlife, participants were classified into: 1) normal weight (BMI <25 kg/m^2), 2) overweight (BMI 25-29.9 kg/m^2) and 3) obese (BMI ≥30 kg/m^2).

Childhood measurements

In childhood, the family's socioeconomic status was defined using parental educational level (queried from both parents) and divided into: 1) low (=primary school), 2) intermediate (=high school diploma and/or secondary level occupational education) and 3) high (=at least candidate diploma from university or an equivalent degree from university of applied sciences). Based on self-reported parental leisure-time PA participation, the participants' parents were categorized into: 1) inactive (*i.e.* mostly sedentary activities during leisure time), 2) moderately active (*i.e.* occasional physical activity or outdoor activities during leisure time), and 3) active (*i.e.* regular physical activity during leisure time). Participants' childhood academic performance was expressed as grade point average (GPA) calculated as the mean of the grades (range 4-10) in all individual school subjects

reported in the questionnaire. The participants were divided into: 1) high GPA (>8.5) and 2) low GPA (≤ 8.5).

Adulthood measurements

In young adulthood and early midlife, socioeconomical status was defined using the participants' self-reported educational level and divided into: 1) low (=primary schooling and/or high school studies or some occupational education) 2) intermediate (=high school diploma and some further occupational education) and 3) high (=at least candidate diploma from university or an equivalent degree from university of applied sciences). According to queried marital status data the participants' were divided into: 1) singles (=living alone) and 2) co-habiting (=married and/or living with someone). According to the self-reported number of children, the participants were dichotomized into: 1) childless and 2) having at least one child. Current smoking habit was queried and the participants were divided into: 1) non-smokers, 2) occasional smokers and 3) smokers. Alcohol drinking frequency was queried for different types of alcoholic beverages (beer, wine, mild alcoholic beverages, hard liquors), and the participants were classified into: 1) rarely or not at all (=less than once a month) 2) occasionally (=at least once a month, but not weekly) 3) regularly (=at least once a week). Additional information on the methods is presented in the Supplemental Material.

Statistical analyses

PA trajectories were analysed using group-based trajectory modelling performed with SAS PROC TRAJ procedure.[36] For reliability, at least two PA measurements were required, one from the years 1980-1992 and another from the years 2001-2011. Trajectory analysis gives each participant a probability of belonging to each defined PA trajectory group. Based on these probabilities, the

participants were assigned to the trajectory group where they had the highest probability of belonging to.

Model accuracy diagnostics was based on standard criteria.[37] The Bayesian Information Criteria was used as an indicator of goodness-of-fit. Average posterior probability of 0.70 for the within group membership was used to indicate internal reliability.[37] The number of trajectory groups was designated based on the model-fit criteria and average posterior probabilities.

Considering all diagnostic criteria, a five group solution was considered optimal (Table 1). Sensitivity analyses with requirement for at least three PA measurements (N=2,781; only N=55, 1.9% had two PA measurements) were performed to verify the robustness of the model. The results from the sensitivity analyses were virtually equal to the main analyses. Therefore, the main analyses including at least two measurement points were considered adequate (N=2,841) also in terms of exploiting all available data. Detailed description of the trajectory modelling is presented in the Supplemental Material.

All analyses for the descriptive characteristics and determinants were conducted at three age points (age 12, 24, and 37 years) in order to capture factors associated with PA trajectories across critical life transitions. Bivariate associations between descriptive characteristics and trajectory group membership were tested using chi-square test and ANOVA. The descriptive characteristics which associated statistically significantly with trajectory group membership in the univariate analyses were included in the multivariate multinomial logistic regression models (separately for age 12, 24 and 37 years) using the persistently low active trajectory group as the reference category in the outcome variable. After conducting these analyses similar multivariate multinomial logistic

regression models comparing the persistently and decreasingly active groups were carried out. In these analyses, the decreasingly active group was used as the reference category. All trajectory analyses were performed using SAS 9.4. Mplus statistical package (Version 7.0)[38] was used for analysing the determinants of PA. The level of statistical significance was p=0.05.

RESULTS

Attrition analyses

The representativeness of the study population was examined by comparing participants having extensive PA data (from at least six follow-ups, n=1,753) and participants having restricted PA data (from at least two but less than six follow-ups, n=1,088). Those having extensive data were more often women and normal weight in childhood and young adulthood. They had higher GPA and less often physically inactive parents in childhood as well as better educational level and less often children in young adulthood. Detailed results from the attrition analyses are presented in the Supplemental Material.

Trajectory modelling

The trajectory modelling resulted in five PA trajectory groups (Figure 1): 1) **persistently active** (n=187, 6.6%) persons were physically active in childhood and throughout life course; 2) **decreasingly active** (n=396, 13.9%) persons were physically active until young adulthood and decreased their activity during adulthood and early middle age; 3) **increasingly active** (n=384, 13.5%) persons were physically low active until young adulthood and increased their activity during adulthood and early middle age; 4) **persistently low active** (n=1459, 51.4%) persons were physically low active in childhood and remained their PA level approximately on the population mean

throughout life course; 5) **persistently inactive** (n=415, 14.6%) persons were physically low active in childhood, decreased their PA level below population mean in adolescence and remained physically inactive thereafter.

Characteristics of the trajectory groups

The characteristics of the PA trajectory groups were analysed separately for childhood, young adulthood and early midlife. The results are presented in the Supplemental Material.

Determinants of the trajectory groups

After exploring the descriptive characteristics separately for each trajectory group, we defined those determinants that significantly associate with the group membership. The persistently low active group served as the reference group as it represented the largest group and had the mean PA index value approximately at the population mean during the whole follow-up time. Additionally, we compared the persistently and decreasingly active groups to study the determinants distinguishing those groups that were active in childhood but differed from each other during the follow-up time. Results on all determinants of the trajectory groups are illustrated in the Supplemental Figure 2.

Baseline age and class membership

In all models, age at baseline was found to associate significantly with the class membership of the PA trajectories (detailed results are presented in the Supplemental Material). Therefore, all analyses for the determinants were adjusted for age.

Childhood determinants

Results for childhood determinants are presented in the Table 2. Boys were found to have increased odds of being persistently active (OR 6.67; 95% CI 4.55, 9.79), decreasingly active (OR 2.57; 95% CI 2.00, 3.32) or persistently inactive (OR 1.40; 95% CI 1.10, 1.78) compared to the persistently low active group. Additionally, boys had higher odds for being persistently active rather than decreasingly active (OR 2.59; 95% CI 1.73, 3.90).

Compared to the persistently low active group participants with higher GPA in childhood had higher odds of being persistently (OR 2.18 per grade; 95% CI 1.58, 3.00) or increasingly active (OR 1.54 per grade; 95% CI 1.25, 1.90) and lower odds of being persistently inactive (OR 0.70 per grade; 95% CI 0.55, 0.87). Additionally, participants with higher GPA at school had higher odds of belonging to the persistently active rather than decreasingly active trajectory group (OR 1.88 per grade; 95% CI 1.32, 2.66).

Lower odds of being persistently active rather than persistently low active were observed for participants living in rural surroundings in childhood (OR 0.45; 95% CI 0.21,0.96).

Young adulthood determinants

Results for young adulthood determinants are presented in the Table 3. Men were found to have increased odds of being persistently active (OR 5.17; 95% CI 3.41, 7.83), decreasingly active (OR 2.14; 95% CI 1.63, 2.81) or persistently inactive (OR 1.37; 95% CI 1.04, 1.79) rather than persistently low active. Additionally, men had higher odds of being persistently active (OR 2.41; 95% CI 1.53, 3.80) rather than decreasingly active.

In young adulthood, intermediate education level associated with higher odds of belonging to the persistently active rather than persistently low active group (OR 2.59; 95% CI 1.36, 4.93).

Compared to the persistently low active group persons who smoked had higher odds of being persistently inactive (OR 1.90; 95% CI 1.31, 2.75), and lower odds of being persistently (OR 0.36; 95% CI 0.19, 0.70) or increasingly active (OR 0.57; 95% CI 0.36, 0.89). Additionally, odds of being persistently rather than decreasingly active were lower for smokers (OR 0.45; 95% CI 0.22, 0.92). Occasional smokers had decreased odds of being either persistently inactive (OR 0.50; 95% CI 0.26, 0.95) or increasingly active (OR 0.60; 95% CI 0.36, 0.99) rather than persistently low active.

Regular alcohol consumption associated with increased odds of being persistently active (OR 2.36; 95% CI 1.20, 4.67), decreasingly active (OR 1.92; 95% CI 1.14, 3.22) and increasingly active (OR 2.06; 95% CI 1.29, 3.29) rather than persistently low active. Simultaneously, occasional alcohol consumption associated with higher odds of being decreasingly (OR 2.21; 95% CI 1.38, 3.53) or increasingly active (OR 1.82; 95% CI 1.18, 2.80) rather than persistently low active.

Obese participants were found to have lower odds of being persistently active (OR 0.16; 95% CI 0.05, 0.52) rather than persistently low active. Additionally, odds of being persistently active rather than decreasingly active were lower for obese participants (OR 0.15; 95% CI 0.04, 0.59).

Early midlife determinants

Results for early midlife determinants are presented in the Table 4. Men had higher odds of being persistently active (OR 5.06; 95% CI 3.27, 7.83), decreasingly active (OR 2.66; 95% CI 1.98, 3.56), (OR 1.61; 95% CI 1.21, 2.13) or persistently inactive (OR 1.61; 95% CI 1.21, 2.13) rather than persistently low active. Additionally, men had higher odds of being persistently active rather than decreasingly active (OR 1.90; 95% CI 1.19, 3.05).

Participants with high educational level had higher odds of being persistently active (OR 2.14; 95% CI 1.05, 4.36), decreasingly active (OR 1.87; 95% CI 1.05, 3.35) and increasingly active (OR 2.09; 95% CI 1.19, 3.68) rather than persistently low active. Simultaneously, participants having intermediate educational level had higher odds of being decreasingly rather than persistently low active (OR 2.14; 95% CI 1.15, 3.99).

Smokers had higher odds of belonging to the persistently inactive rather than persistently low active group (OR 1.66; 95% CI 1.07, 2.58). Simultaneously, smokers had lower odds of being increasingly rather than persistently low active (OR 0.51; 95% CI 0.27, 0.97).

Participants drinking alcohol either occasionally (OR 2.74; 95% CI 1.03, 7.30) or regularly (OR 2.91; 95% CI 1.12, 7.55) had higher odds of being persistently active rather than persistently low active.

Participants who had children at early midlife had higher odds of being decreasingly active (OR 2.07; 95% CI 1.27, 3.38) rather than persistently low active, and simultaneously, lower odds of being persistently rather than decreasingly active (OR 0.49; 95% CI 0.25, 0.97). Rural living surroundings

associated with lower odds of being persistently active rather than persistently low active (OR 0.44; 95% CI 0.20, 0.97)

DISCUSSION

We identified PA trajectories and their determinants from childhood to adulthood in the population-based YFS. The data on participants' PA levels from childhood to adulthood revealed five groups: 1) persistently active, 2) decreasingly active, 3) increasingly active, 4) persistently low active, and 5) persistently inactive. The most dominant trajectory group was the persistently low active group (51.4%) whereas the persistently active group (6.6%) was the most negligible. The persistently inactive, persistently low active and increasingly active groups had very similar physical activity levels in childhood until the age 12 years. At the age of 12 physical activity level of increasingly active group began to differ from the two other trajectory groups. Furthermore, at the age of 15 years physical activity level began to differ also between the persistently inactive and low active trajectory groups. Finally, our findings point out that the prevalence of persistently low (51.4%) or inactive (14.6%) participation in physical activity is high among healthy young and middle-aged population. Taken the benefits of physical activity[1] and the disadvantages of inactivity,[2] this finding is of high importance from the public health perspective.

Success at school, high educational level and non-smoking associated with persistently active and increasingly active groups, while worse academic performance at school, lower educational level and smoking associated with persistently inactive, low active and decreasingly active groups. Our results also pointed out that sex, education and smoking associate with the PA trajectory grouping more consistently than the other determinants (*e.g*. residential area or obesity) indicating that these variables might be stronger determinants of the level and change of PA from childhood to midlife. In

our study, the range of statistically significant ORs varied between 0.15 and 6.67. There exists no unambiguous definition for *e.g.* what is a high OR, but if we assume an OR of 2 to be high, we found many meaningful differences between the groups. Finally, our results pointed out that the trajectory group among which the PA promotion would be most needed (*i.e.* the persistently inactive) were older and more often men who had performed somewhat worse at school, had lower education in adulthood and were more often smokers compared to the persistently low active group.

We also observed that parental PA supports physically active lifestyle in childhood, while having children associates with decreasing PA in adulthood. Physically active parents' influence diminishes from young adulthood ahead and, simultaneously, influence of own family responsibilities increases together with age. These findings highlight the importance of PA promotion among families with children to support the adoption of physically active lifestyle already from childhood and its maintenance into adulthood.

We do not recognise previous longitudinal studies that have reported PA trajectories from childhood to midlife over a period of 30 years. However, results from a previous study with PA data from adolescence to midlife found three PA trajectory groups using measurement points at the ages of 14, 31 and 46 years.[39] We used several PA measurement points in 3-6 year intervals, which further strengthens our analyses. Supporting our findings, two previous longitudinal studies with two decades' follow-up time during adulthood found four PA trajectory groups.[31,40] Importantly, instead of one inactive trajectory group we succeeded to distinguish two trajectory groups at the lower extreme of the PA continuum. Furthermore, men have been suggested to more likely follow the consistently active or increasingly active trajectories compared to women.[31] However, sex differences were not observed in another study.[39] Supporting our findings, higher socio-economic

status[31] and education[40] have been previously associated rather with physically active than inactive longitudinal trajectories. Additionally, lower education and income groups have been associated with decreasing PA trajectories.[31] In addition to age, sex and education *e.g.* aspects related to health status and to physical and social environment have been linked to PA.[11] Finally, life transitions or changes such as change in health, employment status, relationships or family structure may affect PA level during the life-course.[19,41]

Our population-based study with exceptionally long follow-up and extensive data on PA offers a unique possibility to analyse the longitudinal development of PA from childhood to adulthood. In all YFS follow-ups, the data on PA has been carefully collected with standardized methods. Furthermore, as an indicator of PA level, we have used a complex PA index taking into account the frequency, intensity and duration of leisure time PA. Compared to using a single question, the index considerably better indicates the overall PA level, which increases the reliability of the measurement and strengthens our results. Additionally, the short intervals between the follow-up studies and the fact that a vast majority of the population has several PA measurements are strengths in our study. In this study, we focused on describing the natural course of leisure time PA behaviour, and on studying the main determinants associated with the PA trajectories. However, there are also other aspects of movement behavior that are of importance regarding health (*e.g*. sedentary behavior), entities associating with PA trajectories (*e.g*. diet, health status, social capital, environmental aspects), methods assessing PA (*e.g*. objective PA measurements) and statistical methods (*e.g*. random effect modelling) that merit focusing in future studies on PA trajectories and their determinants. Taking these additional aspects into account in the future studies will offer an important addition to the public health implications of our current findings.

In our extensive data, latent class growth analysis offers a data driven method to model longitudinal PA. As the method bases merely on the data and applies no a priori hypothesis for the groups, it allows analysing the life-long natural history of PA. Due to the very lack of a priori hypothesis, the criticisms may point out that latent class growth analyses results in groups that do not exist. However, taken that the diagnostic criteria related to the analyses are amply followed, as in our study, latent class growth analysis comprises an adequate method to model life-course PA behaviour and to classify appropriate groups showing different behavioural patterns. In a recent study exploring obesogenic behaviour from childhood to adulthood, latent class growth analysis was applied to an objective PA data.[42] Even with different study design, shorter follow-up time and smaller sample size, that study supports our findings and indicate that latent class growth analysis is a useful tool to model PA behaviour in longitudinal data.

Limitations of the study include, that the PA questionnaire was marginally modified between the follow-ups in 1989 and 1992. Minor modification was necessary because of differences in PA phenomenon between school-aged children and adults. The minor questionnaire modification was done to focus precisely on the specific PA properties at each age and study phase. In YFS, the original focus of the PA index was not to measure the absolute amount/exposure of PA but rather to arrange the participants into order concerning their PA level. Therefore, the effect of the questionnaire modification is marginal in the current analyses. Nevertheless, questionnaire modification offered a challenge for the latent class growth analyses as identical questionnaire was not used for all participants at same age. We handled this challenge by excluding the overlapping age points from our analyses. Consequently, in the final analyses, the questionnaire was identical for all participants until the age of 21 years, and again identical for all participants from the age 24 years. This procedure minimized the possibility that the results were altered by the questionnaire modification. Furthermore, assessing PA with a self-administered questionnaire may introduce bias due to *e.g.*

inaccurate recall and overestimation of the PA level. Also, the use of the PA index categorises the PA data leading to reduced sensitivity. Additionally, the interpretation of the PA index might be found challenging. Originally, the PA index was created to serve as a classification tool for the level of PA aiming to place the participants into order according to their level of PA. The index was not meant to take a stand on the superiority of different qualities of PA. Therefore, participants with different PA profiles may end up with identical PA index values. Moreover, information on the validity of the PA index has been provided in two previous studies[43,44] by comparing the PA index to objective PA and fitness data. These studies indicate good validity for the PA index. Furthermore, our study population consists of Finnish citizens. Therefore, our results are generalisable in Finnish/Scandinavian population, but not necessarily in other populations with different schooling, education, and employment structures or different lifestyle habits. Furthermore, with respect to the establishment of causality, all observational studies are prone to bias caused by reverse causation. Nevertheless, the use of existing population cohorts with follow-up data from childhood to adulthood is the only realistic approach to study the life-course PA trajectories and their determinants.

This study elucidates the trajectories of PA behaviour from childhood to adulthood and their determinants in a population-based Finnish cohort. Our results form a scientific background for appropriate planning and execution of tailored PA promotion in order to maintain active lifestyle among those already active and to effectively affect the PA level also among the low/inactive persons.

PERSPECTIVE

There are no previous studies determining the life-long trajectories from childhood to adulthood/midlife and their determinants in a large population-based cohort. Therefore, the aim of this study was to fill this knowledge gap leveraging the unique YFS data with a follow-up time over 30 years. Using data-driven analyses, we identified five physical activity trajectories: persistently active (6.6%), decreasingly active (13.9%), increasingly active (13.5%), persistently low active (51.4%), persistently inactive (14.6%). In childhood**,** rural residential area and high academic performance at school associated with persistently active group. In midlife, smoking associated with persistently inactive group, regular alcohol drinking with persistently active group and having children with decreasingly active group. High adulthood education associated with both decreasingly and increasingly active groups. Concluding, the most prevailing determinants for the physical activity trajectories were academic achievement, education, having children and smoking/alcohol use. Importantly, our findings point out the high prevalence of physically low/inactive persons in a healthy young population and the determinants associated with these activity profiles. Our study serve as a platform for tailored physical activity promotion focusing to support adoption of physically active lifestyle among low/inactive persons as well as maintenance of physically active lifestyle among those already active.

Acknowledgements

Expert technical assistance in data management and statistical analyses by Harto Hakonen is gratefully acknowledged. The Young Finns Study has been financially supported by the Academy of Finland: grants 273971, 134309 (Eye), 126925, 121584, 124282, 129378 (Salve), 77841, 210283, 117797 (Gendi), and 41071 (Skidi), The Social Insurance Institution of Finland, Finnish Ministry of Education and Culture, Kuopio, Tampere and Turku University Hospital Medical Funds, Juho Vainio

Foundation, Sigrid Juselius Foundation, Yrjö Jahnsson Foundation, Paavo Nurmi Foundation, Finnish Foundation of Cardiovascular Research, Finnish Cultural Foundation, Finnish Medical Foundation, Turku University Foundation, Tampere Tuberculosis Foundation and Emil Aaltonen Foundation.

REFERENCES

1. WHO. *World Health Organization: Global Recommendations on Physical Activity for Health. Geneva: WHO*. 2010.

2. 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(9838):219–29.

3. Kwan MY, Cairney J, Faulkner GE, Pullenayegum EE. Physical activity and other health-risk behaviors during the transition into early adulthood: a longitudinal cohort study. *Am J Prev Med*. 2012;42(1):14–20.

4. 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(5):955–62.

5. Malina RM. Physical activity and fitness: pathways from childhood to adulthood. *Am J Hum Bio*. 2001;13(2):162–72.

6. Raitakari OT, Juonala M, Rönnemaa T, et al. Cohort profile: the cardiovascular risk in Young Finns Study. *Int J Epidemiol*. 2008;37(6):1220–6.

7. Telama R. Tracking of physical activity from childhood to adulthood: a review. *Obe Facts*. 2009;2(3):187–95.

8. Van Mechelen W, Twisk JWR, Post BG, Snel J, Kemper HCG. Physical activity of young people : the Amsterdam longitudinal growth and health study. *Med Sci Sports Exerc*. 2000;32(9):1610–1616.

9. Jones RA, Hinkley T, Okely AD, Salmon J. Tracking physical activity and sedentary behavior in childhood: a systematic review. *Am J Prev Med*. 2013;44(6):651–8.

10. Erlandson MC, Sherar LB, Mosewich AD, Kowalski KC, Bailey DA, Baxter-Jones ADG. Does controlling for biological maturity improve physical activity tracking? *Med Sci Sports Exerc*. 2011;43(5):800–807.

11. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet*. 2012;380:258–71.

12. Hirvensalo M, Telama R, Schmidt MD, et al. Daily steps among Finnish adults: variation by age, sex, and socioeconomic position. *Scand J Public Health*. 2011;39(7):669–77.

13. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc*. 2002;34(12):1996–2001.

14. Kern ML, Reynolds CA, Friedman HS. Predictors of physical activity patterns across adulthood: a growth curve analysis. *Pers Soc Psychol Bull*. 2010;36(8):1058–72.

15. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc*. 2000;32(5):963–975.

16. Seefeldt V, Malina RM, Clark MA. Factors affecting levels of physical activity in adults. *Sports Med (Auckland, N.Z.)*. 2002;32(3):143–68.

17. Biddle SJ, Whitehead S, O'Donovan TM, Nevill ME. Correlates of participation in physical activity for adolescent girls: A systematic review of recent literature. *J Phys Act Health*. 2005;2(4):421–432.

18. Van Der Horst K, Paw MJCA, Twisk JWR, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. *Med Sci Sports Exerc*. 2007;39(8):1241–50.

19. Hirvensalo M, Lintunen T. Life-course perspective for physical activity and sports participation. *Eur Rev Aging Phys Act*. 2011;8(1):13–22.

20. Li K, Cardinal BJ, Settersten RA. A life-course perspective on physical activity promotion : applications and implications toward a life-Course perspective on physical. *Quest*. 2009;61:336–352.

21. Craggs C, Corder K, van Sluijs EMF, Griffin SJ. Determinants of change in physical activity in children and adolescents: a systematic review. *Am J Prev Med*. 2011;40(6):645–58.

22. Dumith SC, Gigante DP, Domingues MR, Kohl HW. Physical activity change during adolescence: a systematic review and a pooled analysis. *Int J Epidemiol*. 2011;40(3):685–98.

23. Kahn J a, Huang B, Gillman MW, et al. Patterns and determinants of physical activity in U.S. adolescents. *J Adolesc Health*. 2008;42(4):369–77.

24. Picavet HSJ, Wendel-vos GCW, Vreeken HL, Schuit a J, Verschuren WMM. How stable are physical activity habits among adults? The Doetinchem Cohort Study. *Med Sci Sports Exerc*. 2011;43(1):74–9.

25. Seiluri T, Lahti J, Rahkonen O, Lahelma E, Lallukka T. Changes in occupational class differences in leisure-time physical activity: a follow-up study. *Int J Behav Nutr Phys Act*. 2011;8(1):14.

26. Audrain-McGovern J, Rodriguez D, Rodgers K, Cuevas J, Sass J. Longitudinal variation in adolescent physical activity patterns and the emergence of tobacco use. *J Pediatr Psychol*. 2012;37(6):622–33.

27. Duncan SC, Duncan TE, Strycker LA, Chaumeton NR. A cohort-sequential latent growth model of physical activity from ages 12-17 years. *Ann Behav Med*. 2007;33(1):80–89.

28. Langlois KA, Birkett N, Garner R, O'Loughlin J. Trajectories of physical activity in Montreal adolescents from age 12 to 17 years. *J Phys Act Health*. 2012;9(8):1146–54.

29. Raudsepp L, Neissaar I, Kull M. Longitudinal stability of sedentary behaviors and physical activity during early adolescence. *Pediatr Exerc Sci*. 2008;20:251–262.

30. Zook KR, Saksvig BI, Wu TT, Young DR. Physical activity trajectories and multilevel factors among adolescent girls. *J Adolesc Health*. 2014;54(1):74–80.

31. Barnett TA, Gauvin L, Craig CL, Katzmarzyk PT. Distinct trajectories of leisure time physical activity and predictors of trajectory class membership: a 22 year cohort study. *Int J Behav Nutr Phys Act*. 2008;5:57.

32. Shaw BA, Liang J, Krause N, Gallant M, Mcgeever K. Age differences and social stratification in the long-term trajectories of leisure-time physical activity. *J Gerontol B Psychol Sci Soc Sci*. 2010;65(6):756–766.

33. Raitakari OT, Porkka KVK, Taimela S, Telama R, Räsänen L, Vllkari JS. Effects of persistent physical activity and inactivity on coronary risk factors in children and young adults. The Cardiovascular Risk in Young Finns Study. *Am J Epidemiol* 1994;140(3):195–205.

34. Telama R, Yang X, Hirvensalo M, Raitakari O. Participation in organized youth sport as a predictor of adult physical activity : a 21-year longitudinal study. *Pediatr Exerc Sci*. 2006;17:76–88.

35. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Estabilishing a standard definition for child overweight and obesity worldwide : international survey. *BMJ*. 2000;320(1240):1–6.

36. Jones BL, Nagin DS. Advances in group-based trajectory modeling and an SAS procedure for estimating them. *Sociol Methods Res*. 2007;35(4):542–571.

37. Nagin DS. *Group-based modeling of development. Cambridge Massachusetts: Harvard University Press.*; 2005.

38. Muthén B, Muthén L. *Mplus user's guide and Mplus (1998-2015). Available at: http://www.stamodel.com.*; 2015:1–55.

39. Oura P, Paananen M, Niinimäki J, Tammelin T, Herrala S. Effects of leisure-time hysical activity on vertebral dimensions in the northern Finland birth cohort. *Sci Rep*. 2016;6:27844.

40. Artaud F, Sabia S, Dugravot A, Kivimaki M, Singh- A, Elbaz A. Trajectories of unhealthy behaviors in midlife and risk of disability at older ages in the Whitehall II cohort study. *J Gerontol A Biol Sci Med Sci*. 2016;71(11):1500–1506.

41. Allender S, Hutchinson L, Foster C. Life-change events and participation in physical activity: a systematic review. *Health Promot Int*. 2008;23(2):160–72.

42. Kwon S, Janz KF, Letuchy EM, Burns TL, Levy SM. Developmental trajectories of physical activity, sports, and television viewing during childhood to young adulthood. *JAMA Pediatr*. 2015:1–7.

43. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. *Am J Prev Med*. 2005;28(3):267–73.

44. Mansikkaniemi K, Juonala M, Taimela S, et al. Cross-sectional associations between physical activity and selected coronary heart disease risk factors in young adults. The Cardiovascular Risk in Young Finns Study. *Ann Med.* 2012;44(7):733–44.

Table 1. Physical activity trajectory group distributions, posterior probabilities and classification.

PHYSICAL ACTIVITY TRAJECTORY GROUP	DISTRIBUTION % (N)	POSTERIOR PROBABILITY Mean (Range)
Group 1: Persistently active	6.6 (187)	0.87 (0.33-1.00)
Group 2: Decreasingly active	13.9 (396)	0.75 (0.35-1.00)
Group 3: Increasingly active	13.5 (384)	0.75 (0.35-1.00)
Group 4: Persistently low active	51.4 (1459)	0.76 (0.36-0.98)
Group 5: Persistently inactive	14.6 (415)	0.79 (0.43-1.00)

Figure 1. The mean physical activity level described as physical activity index (PAI) in five trajectory groups at different age.

Table 2. Determinants of the physical activity trajectory groups at the age of 12 years.

	Persistently active vs. Persistently low active*		**Decreasingly active vs. Persistently low active***		**Persistently inactive vs. Persistently low active***		**Increasingly active vs. Persistently low active***		**Persistently active vs. Decreasingly active +**	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sex										
Female	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Male	**6.67**	**(4.55, 9.79)**	**2.57**	**(2.00, 3.32)**	**1.40**	**(1.10, 1.78)**	1.25	(0.97, 1.61)	**2.59**	**(1.71, 3.92)**
Residential area										
Urban	1.00	-	1.00	-	1.00	-	1.00	-		
Rural	**0.45**	**(0.21, 0.96)**	0.64	(0.38, 1.06)	1.05	(0.69, 1.62)	0.97	(0.62, 1.51)	0.71	(0.31, 1.61)
Parental physical activity										
Inactive	1.00	-	1.00	-	1.00	-	1.00	-		
Moderately active	1.35	(0.59, 3.09)	1.23	(0.68, 2.23)	0.76	(0.48, 1.20)	0.85	(0.50, 1.46)	1.09	(0.42, 2.83)
Active	2.02	(0.86, 4.73)	**2.75**	**(1.50, 5.05)**	0.64	(0.36, 1.12)	1.27	(0.71, 2.28)	0.73	(0.28, 1.92)
High grade point average	**2.18**	**(1.58, 3.00)**	1.16	(0.93, 1.44)	**0.70**	**(0.55, 0.87)**	**1.54**	**(1.25, 1.90)**	**1.88**	**(1.32, 2.66)**
Obesity level										
Normal weight	1.00	-	1.00	-	1.00	-	1.00	-		
Overweight/obese	0.61	(0.26, 1.42)	0.65	(0.38, 1.11)	1.29	(0.81, 2.05)	1.39	(0.87, 2.22)	0.94	(0.38, 2.32)

The values are odds ratios (OR) and 95% confidence intervals (95% CI) from a multivariate multinomial logistic regression model. All determinants are entered simultaneously in the age adjusted model . *Persistenly low active group was used as the reference category. +Decreasingly active group was used as the reference category.

Table 3. Determinants of the physical activity trajectory groups at the age of 24 years.

	Persistently active vs. Persistently low active*		**Decreasingly active vs. Persistently low active***		**Persistently inactive vs. Persistently low active***		**Increasingly active vs. Persistently low active***		**Persistently active vs. Decreasingly active +**	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sex										
Female	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Male	**5.17**	**(3.41, 7.83)**	**2.14**	**(1.63, 2.81)**	**1.37**	**(1.04, 1.79)**	1.01	(0.77, 1.34)	**2.41**	**(1.53, 3.80)**
Residential area										
Urban	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Rural	0.68	(0.29, 1.59)	0.85	(0.49, 1.49)	1.22	(0.80, 1.88)	0.90	(0.53, 1.53)	0.80	(0.31, 2.05)
Having children										
No	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Yes	0.74	(0.32, 1.71)	0.83	(0.49, 1.41)	0.87	(0.57, 1.33)	1.52	(0.97, 2.38)	0.89	(0.35, 2.27)
Education										
Low	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Intermediate	**2.59**	**(1.36, 4.93)**	1.34	(0.86, 2.09)	0.92	(0.61, 1.38)	1.48	(0.94, 2.33)	1.93	(0.94, 3.97)

High	1.77	(0.89, 3.54)	1.3	(0.81, 2.07)	0.57	(0.32, 1.01)	1.32	(0.80, 2.19)	1.37	(0.64, 2.92)
Obesity level										
Normal weight	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Overweight	0.79	(0.39, 1.59)	1.58	(0.95, 2.63)	1.39	(0.77, 2.52)	1.56	(0.92, 2.65)	0.50	(0.23, 1.07)
Obese	**0.16**	**(0.05, 0.52)**	1.06	(0.37, 3.08)	1.98	(0.80, 4.92)	0.47	(0.11, 1.98)	**0.15**	**(0.04, 0.59)**
Current smoking status										
Non-smoker	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Occasional smoker	0.59	(0.31, 1.13)	0.82	(0.51, 1.33)	**0.50**	**(0.26, 0.95)**	**0.60**	**(0.36, 0.99)**	0.72	(0.35, 1.49)
Smoker	**0.36**	**(0.19, 0.70)**	0.80	(0.53, 1.22)	**1.90**	**(1.31, 2.75)**	**0.57**	**(0.36, 0.89)**	**0.45**	**(0.22, 0.92)**
Alcohol use										
Rarely or not at all	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Occasionally	1.17	(0.59, 2.34)	**2.21**	**(1.38, 3.53)**	0.89	(0.59, 1.35)	**1.82**	**(1.18, 2.80)**	0.53	(0.25, 1.15)
Regularly	**2.36**	**(1.20, 4.67)**	**1.92**	**(1.14, 3.22)**	1.17	(0.76, 1.80)	**2.06**	**(1.29, 3.29)**	1.23	(0.57, 2.68)

Values are odds ratios (OR) and 95% confidence intervals (95% CI) from a multivariate multinomial logistic regression model. All determinants are entered simultaneously in the age adjusted model. *Persistenly low active group was used as the reference category. +Decreasingly active group was used as the reference category.

Table 4. Determinants of the physical activity groups at the age of 37 years.

	Persistently active vs. Persistently low active*		**Decreasingly active vs. Persistently low active***		**Persistently inactive vs. Persistently low active***		**Increasingly active vs. Persistently low active***		**Persistently active vs. Decreasingly active +**	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Sex										
Female	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Male	**5.06**	**(3.27, 7.83)**	**2.66**	**(1.98, 3.56)**	**1.61**	**(1.21, 2.13)**	1.27	(0.95, 1.69)	**1.90**	**(1.19, 3.05)**
Residential area										
Urban	1.00	-	1.00							
Rural	**0.44**	**(0.20, 0.97)**	0.70	(0.42, 1.15)	1.19	(0.78, 1.83)	0.70	(0.41, 1.2)	0.63	(0.27, 1.47)
Having children										
No	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Yes	1.01	(0.56, 1.83)	**2.07**	**(1.27, 3.38)**	1.55	(0.98, 2.46)	0.89	(0.59, 1.34)	**0.49**	**(0.25, 0.97)**
Education										
Low	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Intermediate	2.10	(0.94, 4.71)	**2.14**	**(1.15, 3.99)**	0.74	(0.43, 1.29)	1.69	(0.89, 3.21)	0.98	(0.39, 2.46)
High	**2.14**	**(1.05, 4.36)**	**1.87**	**(1.05, 3.35)**	0.58	(0.31, 1.07)	**2.09**	**(1.19, 3.68)**	1.14	(0.50, 2.61)
Obesity level										
Normal	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Overweight	1.03	(0.60, 1.75)	0.94	(0.63, 1.40)	0.97	(0.63, 1.49)	0.86	(0.56, 1.32)	1.09	(0.61, 1.95)
Obese	0.44	(0.19, 1.01)	0.82	(0.46, 1.44)	0.98	(0.57, 1.68)	0.63	(0.35, 1.14)	0.53	(0.21, 1.37)
Current smoking status										
Non-smoker	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Occasional smoker	1.05	(0.49, 2.22)	0.86	(0.43, 1.71)	1.21	(0.60, 2.42)	1.64	(0.92, 2.91)	1.22	(0.50, 2.99)
Smoker	0.67	(0.34, 1.33)	1.16	(0.70, 1.92)	**1.66**	**(1.07, 2.58)**	**0.51**	**(0.27, 0.97)**	0.58	(0.27, 1.25)

Alcohol use											
Rarely or not at all		1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
Occasionally		**2.74**	**(1.03, 7.30)**	1.86	(0.88, 3.91)	1.17	(0.68, 2.01)	1.12	(0.64, 1.96)	1.48	(0.47, 4.68)
Regularly		**2.91**	**(1.12, 7.55)**	1.79	(0.88, 3.66)	0.83	(0.50, 1.38)	0.79	(0.46, 1.34)	1.62	(0.53, 5.00)

Values are odds ratios (OR) and 95% confidence intervals (95% CI) from a multivariate multinomial logistic regression model. All determinants are entered simultaneously in the age adjusted model. *Persistenly low active group was used as the reference category. +Decreasingly active group was used as the reference category.