Parental physical activity associates with offspring's physical activity until middle age – a 30-year study

Kaisa Kaseva[1], Taina Hintsa[1], Jari Lipsanen[1], Laura Pulkki-Råback[2,1], Mirka Hintsanen[3,1], Xiaolin Yang[4], Mirja Hirvensalo[5], Nina Hutri-Kähönen[6], Olli Raitakari[7,8], Liisa Keltikangas-Järvinen[1], Tuija Tammelin[4]

[1]Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Helsinki, Finland

[2]Helsinki Collegium for Advanced Studies, University of Helsinki, Helsinki, Finland

[3]Unit of Psychology, University of Oulu, Oulu, Finland

[4]LIKES –Research Centre for Physical Activity and Health, Jyväskylä, Finland

[5]Department of Sport Sciences, University of Jyväskylä, Jyväskylä, Finland

[6]Department of Pediatrics, University of Tampere and Tampere University Hospital, Tampere, Finland

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

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

Corresponding Author:

Kaisa Kaseva, Unit of Personality, Work and Health Psychology,

Institute of Behavioral Sciences, P.O. Box 9, 00014 University of Helsinki,

Finland. E-mail: kaisa.kaseva@helsinki.fi

tel: +358443077737

Abstract

Background Parents' physical activity associates with their children's physical activity. Prospective designs assessing this association are rare. This study examined how parents' physical activity was associated with their children's physical activity from childhood to middle adulthood in a 30-year prospective, population-based setting.

Methods Participants (n=3596) were from the ongoing Cardiovascular Risk in Young Finns study started in 1980. Participants' physical activity was self-reported at eight phases from 1980 to 2011, and their parents' physical activity at 1980. Analyses were adjusted for a set of health-related covariates assessed from 1980 to 2007.

Results High levels of mothers' and fathers' physical activity were systematically associated with increased levels of their children's physical activity until offspring's age of 24. Longitudinal analyses conducted from 1980 to 2011 showed that higher levels of parents' physical activity were associated with increased levels of physical activity within their offspring until midlife, but the association between parents' and their children's physical activity weakened when participants aged ($p<0.05$). Covariate adjustment did not attenuate the association.

Conclusions This study suggests that parents' physical activity assessed in their offspring's childhood contributes favorably to offspring's physical activity from childhood to middle age.

Keywords: community-based research, health behavior, physical activity, sport psychology

Introduction

Physical activity is one of the most influential lifestyle factors contributing to global health and mortality.[1,2] Annually, approximately 3.2 million deaths and 32.1 million disability-adjusted life years are attributable to insufficient levels of physical activity.[2] Despite the widely known benefits of physical activity, inactivity has increased, and many age groups are not achieving the recommended levels of physical activity.[3] Physical inactivity, which has been defined as an activity level insufficient to meet these recommendations,[4] has been estimated to cause 6% of the burden of illness from coronary heart disease, 7% of type 2 diabetes, and 10% of breast and colonial cancers worldwide.[4] Due to its' public health impact, it is important to examine factors contributing to the initiation and maintenance of physical activity.

Literature has designated that relatively vigorous and regular physical activity leads to better health outcomes than infrequent physical activity,[5] although some evidence for health benefits from lower doses of physical activity has also been documented.[6] Physical activity has a tendency to track from childhood into adulthood in both sexes,[7-9] and childhood physical activity also contributes to health outcomes in later life.[10] To engender lifelong patterns of physical activity, attention should be paid to childhood and adolescence as critical periods of life.[11,12]

Parents' health behaviors associate with the development of those of their offspring's.[11,13,14] It has been suggested that daughters identify especially with their mothers' behaviors, and sons with those of their fathers.[15,16] More recent studies concerning the associations between parents' and children's physical activity habits have supported these views,[17,18] but there are also differing findings. Some studies have also indicated that mothers' physical activity associates with children's physical

activity in both sexes.[19, 20] Fathers' physical activity has shown to be a stronger predictor for late childhood and adolescent physical activity in both sexes compared to that of mothers'.[21,22] In addition, research has shown that sport participation is highest among boys and girls whose both parents were physically active,[23] and both parents' physical inactivity predicts their children's physical inactivity.[24] There are also a few studies that have not found parent-child associations in physical activity.[25]

The mechanisms between parents' and their children's physical activity are likely to be biological and psychosocial. Twin and family studies have demonstrated that genetic factors contribute in varying degrees to child's physical activity[26-28] indicating that physical activity levels may be partly regulated by biological processes.[29] Parents have also been regarded as socialization agents.[11,13,14] Their explicit training efforts, and shared physical activities with children are likely to influence offspring's behaviors.[13,18] Furthermore, parents may influence offspring's physical activities by providing distinct forms of social support, including stimulation, encouragement, and positive reinforcement.[18] The given support can also exert an indirect influence on children by developing individual qualities, such as sense of self-efficacy.[18] Furthermore, parents may give instrumental assistance for their children, i.e., facilitate the access to activities, and acquire sports equipment.[18,23] Studies have also demonstrated parents' role as referents and role models whose attitudes, values and behaviors children observe and model.[11,13,29] Finally, a child's developmental level, as well as cultural factors are likely to affect the mechanisms between parents' and their children's physical activity.[29,30]

To date, many of the previous studies have examined the associations between parents' and their children's physical activity either in offspring's childhood or adolescence.[19-21,23] Different samples,

including school-based and community-based ones, as well as groups of population with health concerns (i.e., overweight) are well represented in these studies.[11,20,21] Previous studies have been mostly cross-sectional, experimental, or prospective ones that cover quite short follow-up phases.[17,19,21,22] Researchers have recognized a deficiency in knowledge of how far-reaching the parents' influence on their children potentially is,[13] and the need for longitudinal studies has been acknowledged.[29] To date, population-based, prospective cohort studies assessing the potential effects of parents' physical activity on children's physical activity from childhood to middle adulthood over 30 years do not exist. As the etiology of physical activity has been regarded as a complex process, the use of advanced methods has been recommended.[23,29] Multilevel or mixed models have been used in assessing development and changes in phenomena within clustered and/ or repeated-measures data.[31,32] Mixed models have become a standard analyzing technique for longitudinal data within health and behavioral sciences.[31,32]

Early life factors, such as birth cohort,[33] living area,[29] as well as parents' marital and socioeconomic statuses[29,34,35] have been taken account in previous studies concerning health-related factors[33] and physical activity in youth.[29,34,35] Physical characteristics (age, body mass index), socioeconomic, and health behavioral factors (i.e., diet, level of alcohol consumption, and smoking status) have shown to be associated with physical activity in adulthood.[29] Furthermore, social support, whether gained along with doing physical activities or outside those contexts, has been regarded as an important contributor to leisure-time physical activity.[36,37] It has also been denoted that the support gained from variety of sources is essential for health-related behaviors.[36-38] More studies assessing how these factors affect the development of physical activity habits are needed,[10,29,39,40] and there exists no evidence of these factors' potential role regarding the association between parents' and children's physical activity over a 30 year-period.

This study was conducted within a population-based, prospective cohort design, using linear mixed models. We examined 1) whether parents' physical activity was associated with their children's physical activity from childhood to middle adulthood, and 2) whether the associations were independent of participants' birth cohort effects, living area, and familial factors (1980), as well as participants' body mass index, socioeconomic factors, diet, level of alcohol consumption, smoking status and social support (2007).

Methods

Study design and participants

The study participants were from the ongoing community-based Cardiovascular Risk in Young Finns study that began in 1980.[41] The original sample consisted of 3596 children and adolescents (83.20% of those invited, 1832 females and 1764 males) from six birth cohorts (aged 3, 6, 9, 12, 15 and 18). To acquire a representative sample, Finland was divided into five areas based on the locations of universities with medical schools (Helsinki, Kuopio, Oulu, Tampere, and Turku), and the subjects were randomly selected based on their social security numbers from nearby urban and rural areas. The sampling frame was the Social Institution's population register, which covers the whole Finnish population and is continuously updated. In practice, each age cohort's females and males within each community were separately placed in random order based on their personal identification number. Every k^{th} female and every k^{th} male in each community was selected so that the sample contained the required number of females and males. The varying k factors were determined on the basis of sample size and the total number of females and males within different

age cohorts in each community. Based on this randomization procedure, no siblings were selected to the sample. Eight (0.30%) participants in the Cardiovascular Risk in Young Finns Study were adopted. Informed consent was requested from each participant or from the small children's parents, and the study was approved by the local ethics committees. The study was conducted in accordance with the Declaration of Helsinki (revised in 1983), and the treatment of the sample complied with American Psychological Association's ethical guidelines.

After 1980, the sample has been followed in 8 waves, 1983, 1986, 1989, 1992, 1997, 2001, 2007, and 2011, in which medical, psychological and physical activity studies were performed. Some measurement periods extended for two years (e.g., 2011-2012). Participation rate in the medical examinations varied between 60% and 80%. In the current study, participants' parents' physical activity was measured in 1980 [(for females' mothers, n=1781 (97.20%), and females' fathers, n=1601 (87.40%), for males' mothers, n=1700 (96.40%), and males' fathers, n=1519 (86.11%)] (Table 1). Participants' physical activity from childhood to adulthood was assessed in 1980, 1983, 1986, 1989, 1992, 2001, 2007 and 2011 (for females n=1064-1443, for males n=846-1176) (Table 1). Physical activity information from 3 and 6-year-old children (born in 1974 and 1977) was not included to the measurements performed in 1980, because the children were not able to fulfill the physical activity questionnaires themselves. These children were included to the present study from the age 9 on. Participants, who were 3-year olds in 1980, were included to the study from 1986 on, and the ones who were 6-year olds in 1980 were included to the study from 1983 on. Thus, the participants of this study were 9-18-year-olds in 1980, and 34-49-year-olds in 2011. Based on the previous analyses of sample attrition, there has not been systematic selection bias in study participants' medical profiles[41] or in physical activity.[7]

Measures

Parents' physical activity

Parents' physical activity was determined by surveying the regularity of their physical activity during leisure-time in 1980.[21,22] Parents self-reported their physical activity using a 3-point scale, and higher scores reflected higher levels of physical activity. The information was collected separately from participants' fathers and mothers. Parents were requested to select one of the alternatives which best describes their way of spending their leisure-time: 1 = No physical activity: In my leisure-time I mostly read, watch TV, listen to radio, go to movies, go to restaurant, meet my friends or do activities that do not physically strain me; 2 = Some physical activity: I participate in sports/ physical activities every now and then, or I am physically active in other hobbies such as fishing, hunting, gardening or outdoor recreation; 3 = Regular physical activity: I participate regularly or quite regularly in sports/ physical activities such as running, cross-country skiing, cycling, ball games, swimming, gymnastics or strength training.

Parents' physical activity has been examined with single questions in previous substudies conducted within Cardiovascular Risk in Young Finns study.[21,22] Short instruments have long been used in population surveys to measure health-related factors due their brevity.[42] Literature has also demonstrated high levels of reliability, as well as construct and predictive validity of single-item instruments.[42]

Participants' physical activity

Participants' leisure-time physical activity was self-reported from childhood to adulthood (from 9 to 49 years). Participants' physical activity from 1980 to 1989 was measured with 5 questions assessing the frequency and intensity of leisure-time physical activity, participation in sports-club training and sports competitions, and the usual way the participants spent their leisure time.[43] From 1980 to 1989, the answers for the questions were coded into 3 categories (ranging from 1 to 3) except the item assessing participation in sports competitions, with which a 2-point scale was used. The specific questions were as follows: 1) How often do you engage in leisure-time physical activity for at least half an hour per session? 2) How much breathlessness and sweating do you experience when you engage in physical activity and sport? 3) How many times a week do you usually engage in training sessions organized by a sport club? 4) Do you participate in sports competitions? 5) What do you usually do in your leisure time?.

From year 1992 on, the questionnaire items were adjusted to reflect participants' physical activity in adulthood. The question regarding participation of sports competitions was excluded from the questionnaire, as it was not regarded as a suitable indicator for adulthood physical activity. The sentence structures of other questions and response options were also slightly modified. From year 1992 on, the intensity of physical activity, frequency of vigorous physical activity, hours spent in vigorous physical activity, average duration of a physical activity session, and participation in organized physical activity were assessed via 5 questions.[7,44] In 1992, the answers for the questions were coded into 3 categories (ranging from 1 to 3) except the item assessing participation in organized sports, with which a 2-point scale was used. From 2001 to 2011, all question responses were rated via a 3-point scale (ranging from 1 to 3). The specific questions from 1992 to 2011 were

as follows: 1) How much breathlessness and sweating do you experience when you engage in physical activity and sport? 2) How often do you engage in rigorous physical activity? 3) How many hours per week do you engage in rigorous physical activity? 4) How much time do you usually spend in a physical activity session? 5) Do you participate in organized physical activity?.

A sum score (physical activity index) of question responses was created for each participant each study year (1980-2011) (Table 1), and higher scores reflected higher levels of physical activity (Table 1). Previous reports have denoted that the test-retest estimates for physical activity have good reliability in both sexes over time (ICC's >0.70).[7,45] The predictive validity tests conducted within 3-year intervals from 1980 to 1992 have demonstrated tracking (stability) of physical activity over time.[7] Recent study has also given support for these results by indicating that the stability of physical activity is moderate or high from youth to adulthood.[46] Construct validity of physical activity indices has been demonstrated in a study assessing physical activity and indicators of exercise capacity.[7] These findings are in agreement with previous literature demonstrating that self-reports of physical activity are correlated with objective measurements of physical activity.[47,48] Based on the evidence, physical activity measure has been regarded reliable and valid (1980-2011).[7,46]

Covariates

As different birth cohorts were followed over the same time period of time, the analyses were adjusted for the possible cohort effects.[33] Participants' childhood living area (1=city center, 2=suburb, 3=rural community, 4=dispersed settlement area) was also adjusted for in the analyses,[29] as well as parents' cohabiting through offspring's youth (1=cohabiting, 2=living separately).[49]

Previous research found no difference between being married or cohabiting on physical activity.[49] These constructs may also overlap to some degree as people usually cohabit prior getting married.[49] Participants' parents' education and income levels (1980) were used as indicators of socioeconomic status in participants' childhood.[35] Parents' educational information was collected from mothers' and fathers' [(1= less than 9 years (low), 2= 9-12 years (average), 3=over 12 years (high)]. If parents' educational information differed, we used information from the parent with the higher educational level. If educational information was available for only one parent, family's educational status was determined using his/her educational information. Family's income level was assessed via an 8-point scale [(1=<15 000 marks (2755 dollars), 8=>100 000 marks (18370 dollars)].

In addition, the analyses were adjusted for participants' age and body mass index.[29] Weight and height were measured, and body mass index was thereafter calculated (kg/m^2). Participants' socioeconomic status[35] (2007) was also determined via two indices; education was assessed via a 3-category scale [1=comprehensive school (low), 2=secondary school (average), 3=academic level (high)], and income level with an 8-point scale [1=<10 000 euros (10 924 dollars), 8=>70 000 euros (76467 dollars)]. Participants' food consumption was determined using a 131-item food frequency questionnaire, and intakes of favorable (whole grains, fish, fruits, vegetables and nuts/ seeds) and unfavorable (red and processed meat, sweets, sugar-sweetened beverages and fried potatoes) foods were assessed to generate a diet score, with higher scores representing healthier diets.[50] Participants' alcohol use was determined by asking them to report their consumption of 1/3 liter cans or bottles of beer, glasses (12 cl) of wine, and 4 cl shots of liquor or strong alcohol during the last week.[51] Participants' smoking status[29] was determined via a 5-category scale (1=smokes a cigarette per day or more, 2=smokes once in a week, 3=smokes less than once in a week, 4=has quitted smoking, 5=has never smoked).

Furthermore, social support (2007) was assessed via a 12-question inventory using a 5-point scale,[38] and a mean score of the items was calculated for each participant. The items reflected participants' experiences of social support gained from family members, friends and from a significant other.[38] The scale demonstrated excellent reliability (Cronbach's α=0.95). Previous tests have shown that the scale has an adequate internal and test-retest reliability, as well as factorial validity and construct validity.[38] The instrument has shown to be applicable in variety of study designs, including community-based ones.[52]

Statistical analyses

Physical activity questionnaires for children and adolescents (1980-1989), and adults (1992-2011), differed slightly regarding their content. To ensure that the findings of this study were based on changes in physical activity, and not due a measurement error, a confirmatory factor model was used to examine whether the physical activity indices comprising of five indicator variables had measurement and structural invariance across time.[53,54] Weighted least squares means and variance adjusted (WLSMV) estimation was used for all analyses.[54-55] The goodness of fit for scalar invariance was determined with comparative fit index (CFI), Tucker-Lewis index (TLI), and root-mean square error of approximation index (RMSEA).[56] The analyses were performed via Mplus (version 7.1). The standardized factor scores derived from the confirmatory model are estimated values for the true latent scores, and likely to provide more accurate information than the original indices. Therefore, the factor scores were applied in subsequent analyses. Prior this, correlations between the estimated factor scores and the (original) physical activity indices were examined.

The cross-sectional and longitudinal associations between parents' physical activity and their children's activity were first studied with linear regression analyses. The potential birth cohort effects were adjusted for in these, as well as in subsequent analyses. Due to the potential multiple testing problem, Bonferroni-adjusted p-values ($p<0.003$) were used in designating significant associations. Thereafter, the associations between parents' physical activity and the potential changes in their children's physical activity levels from childhood to adulthood were examined using linear mixed models. Linear mixed models provide the possibility of studying repeated measures data, and have several benefits over more traditional methods (i.e., repeated measures ANOVA).[31,32] First, they allow for studying both fixed and random factors. The models deal efficiently with missing cases, as each subject does not need to be measured on the same number of occasions.[31] Mixed models allow for the inclusion of time-varying covariates, and the change over time can be modeled flexibly using polynomial functions or segmented regression.[31] The method applies to this study, as the participants were clustered regarding repeated measurements, data contains missing values, extensive set of covariates is controlled for, and the potential change in behaviors is in focus. Maximum likelihood method (ML) was used as an estimation technique for the models. The main effects of fathers' and mothers' physical activity, children's age, as well as their interactions (father's / mother's physical activity x child's age) on children's physical activity were first assessed. In the case of significant interactions, we studied whether the associations differed by child's sex by examining the 3-way interactions (father's/ mother's physical activity x child's age x child's sex). In the case of significant interactions, we examined whether parents' physical activity (father's/ mother's physical activity x child's age) associated differently with females' and males' physical activity. Thereafter, the associations were further tested via adjusting the models for covariates. As a supplementary analysis, the main effects of fathers' and mothers' physical activity, children's age, as well as their interactions (father's / mother's physical activity x

child's age) on children's physical activity were assessed within different birth cohorts (participants aged 9, 12, 15 and 18). The analyses were performed via IBM SPSS (version 21). P-values <0.05 were considered significant.

Results

Descriptive characteristics of the sample are summarized in the Table 1. Although the scalar invariance model for physical activity did not demonstrate strong factorial invariance across time, the fit for partial scalar invariance model was adequate (CFI=0.90, TLI=0.90, RMSEA=0.047), given partial invariance of the thresholds. For RMSEA, values <0.05 indicate a close model fit, and CFI and TLI values close to 0.90 denote an adequate fit.[56] The deviance from full measurement invariance was due to a one question, which considered the participation in organized sports (assessed from 1980 to 2011). In this question, the measurements were invariant through childhood and adolescence, but a minor deviation (although significant, p<0.05) from full invariance was found in adulthood. Since the partial scalar invariance model was considered acceptable, factor scores were predicted for each subject to be used in subsequent analyses (see Tables 1 and 2). The estimated factor scores correlated highly with physical activity indices from participants' childhood to adulthood (1980-2011), coefficients ranging from 0.95 to 0.97.

The linear regression analyses indicated that mothers' and fathers' physical activity was systematically and favorably associated with both males' and females' physical activity in childhood, adolescence and young adulthood until the age of 24 (Table 3). In addition, few associations were detected in participants' middle adulthood (Table 3). Fathers' physical activity

had relatively far-reaching effects on males' physical activity until their age of 37, and mothers' physical activity on females' activity until their age of 33 (Table 3).

The results from the linear mixed models indicated significant main effects for parents' physical activity and participants' age on participants' physical activity from childhood to adulthood. Higher levels of parents' physical activity were associated with higher physical activity levels in their offspring ($p<0.001$) (Table 4, footnote). Participants' physical activity levels decreased with age ($p<0.001$) (Table 4, footnote).

After examining the main effects, interaction terms were included to the linear mixed models. The results from the first 2-way interaction analysis (mother's physical activity x child's age) indicated that the favorable impact of mothers' physical activity on children's activity decreased with time ($B=-0.00$, $p<0.001$, $R^2= 0.06$) (Table 4). When the 3-way interactions (mother's physical activity x age x sex) were studied, mothers' physical activity had different effects on females' and males' physical activity ($B=0.00$, $p=0.002$, $R^2=0.07$) (Table 4). When the 2-way interactions (mother's physical activity x child's age) were studied separately in females and males, mothers' activity associated favorably with physical activity in both groups, and the effect decreased with time (in females, $B=-0.00$, $p<0.001$, $R^2=0.04$; in males, $B=-0.00$, $p=0.025$, $R^2=0.10$) (Table 4).

After adjustment for covariates, mothers' physical activity's effect on females' activity remained significant ($B=-0.01$, $p=0.002$, $R^2=0.04$), as well as mothers' physical activity and males' activity ($B=0.01$, $p<0.001$, $R^2=0.18$) (Table 5). Mothers' and females' physical activity's positive association decreased along with time. Mothers' physical activity was positively associated with with males' physical activity, and the association seemed not to change over time.

When the interaction of fathers' physical activity and participants' age on participants' physical activity was examined, the favorable effect of fathers' physical activity on children's activity decreased with time (B=-0.00, p<0.001, R^2=0.18) (Table 4). When the 3-way interactions (father's physical activity x age x sex) were studied, fathers' physical activity associated similarly with both sexes' physical activity (B=0.00, p=0.339, R^2=0.19) (Table 4). The association between fathers' activity and children's physical activity was independent of covariate controls (B=-0.00, p=0.009, R^2=0.12) (Table 5). The non-adjusted 2-way interaction analyses (mother's/ father's physical activity x child's age) within different birth cohorts demonstrated approximately similar results as the analyses conducted in all participants, regression estimates ranging from 0.00
to -0.01. A positive, although non-significant interaction effect between father's physical activity and child's age (B=0.00, p=0.990) was found in the cohort born 1965 (participants' aged 15).

Discussion

This study examined whether parents' physical activity assessed in their offspring's childhood and adolescence (1980) associated with offspring's physical activity from childhood to midlife. Mothers' and fathers' physical activity was systematically associated with children's activity until the age of 24. The main findings indicated that higher levels of parents' physical activity were related to higher physical activity levels in offspring up to midlife, although these effects decreased with time. The associations between parents' and their offspring's physical activity were independent of health-related covariates (birth cohort, parents' living area, parents' cohabiting, parents' socioeconomic status, participants' body mass index, socioeconomic status, diet, level of alcohol consumption, smoking status and social support).

The cross-sectional and longitudinal examinations showed that high levels of both parents' physical activity were associated with their children's increased physical activity in childhood and adolescence, which is in accord with previous studies.[23] Some associations between parents' and children's physical activity were also detected in offspring's middle adulthood, indicating that both parents' physical activity had relatively far-reaching effects on both males and females. Our longitudinal analyses (1980-2011) showed that higher levels of parents' physical activity were associated with higher physical activity levels in offspring, and covariate adjustment did not attenuate these associations. After covariate adjustments, mothers' physical activity explained 18% of males' physical activity, and this model had the highest explanatory power comparing to the other adjusted ones. Overall, the present study accentuated the importance of both parents' physical activity for children's physical activity up to middle age.

It has been suggested that health beliefs and behaviors learned from a family during childhood tend to remain relatively stable throughout life.[13] Behavioral modeling could partly explain the associations between parents' and their children's physical activity in different phases of life. The strength of the association between parents' and their children's physical activity could be related to the effectiveness of parental roles. Previous studies have also demonstrated the importance of parental social support in the formation adolescents' physical activity.[18] There exists some evidence indicating that fathers invest more time on playing with their children than mothers,[30] but mothers may also be active playmates or sporting activity organizers for their children. Parents might have thus stimulated their children's interest to physical activities, and potentially also facilitated children's access and engagement to these activities. The associations between parents' and their children's physical activity may also be culturally mediated.[29,30]

Along with interpersonal and environmental correlates, heritable factors may predispose a person to physical activity or inactivity.[29] Thus, physical activity is likely to be determined by the interplay of many contributors.[29] Therefore, the interpretations concerning the associations between parents' and their offspring's physical activity need to be considered with caution. More research is needed to gain insights to the factors that relate with variation in physical activity, and mediate the association between exposure variables and physical activity.[29] Causal mechanisms between parents' and their children's activity could not be assessed in this study. Intervention studies are needed in addressing the mechanisms.

Limitations and strengths

The following limitations require consideration. Participants' and their parents' physical activity were assessed via self-reports. Thus, the possibility of subjective bias cannot be perfectly ruled out. However, self-administered physical activity questionnaires are commonly used in epidemiological studies due their applicability for assessing large populations.[57] Previous studies have also demonstrated the correlations between self-reports and objective physical activity measurements.[47,48] Furthermore, although the variable reflecting participants' parents' cohabiting status was adjusted for in this study, we cannot make inferences of whether the parents' potential divorce could have affected the associations. Future studies are needed to examine the question.

It has been stated that measurement non-invariance may affect the comparability of results from different studies.[53] In this study, a minor deviation from full invariance occurred in adulthood within one question. The fit indices for measurement invariance demonstrated acceptable model.[56]

Previous studies have allowed for partial measurement invariance within longitudinal models,[58] and there exists research demonstrating that partial invariance is not likely to cause concerns (e.g., biased estimates or risks for errors in hypothesis testing) when the models are correctly specified.[59] Furthermore, the factor scores derived from this study's analyses correlated highly with the physical activity indices.

It has been shown that the direction of the association between predictor and outcome variables may sometimes be affected by third variables.[60] Theoretical background plays an important role in the interpretation.[60] Furthermore, complexity of linear mixed models (i.e., addition of covariates), may lead to challenges in interpreting R^2 values.[31,32] Literature encourages considering the research designs when evaluating the applicability of different R^2 statistics,[31,32] and suggests evaluating them in conjuction with statistical testing.[31] Although the recommendations were followed in this study,[31,32,61] the predictive ability of the models should be considered with caution.

Strengths of this study included the population-based sample, the prospective cohort design that has continued over 30 years, and the possibility to control a set of relevant covariates. Our study also gave us the opportunity to study the development of physical activity over several age-related transitions from childhood to middle adulthood.

Conclusions

This prospective, population-based cohort study showed that higher levels of parents' physical activity were associated with higher levels of physical activity in offspring from childhood to middle age. The association between parents' and their offspring's physical activity weakened when

participants aged. The results indicated also that parents' physical activity predicted children’s physical activity after adjusting for an extensive set of health-related covariates. This study suggests that parents' physical activity assessed in their offspring's childhood contributes favorably to offspring's physical activity from childhood to middle age.

Acknowledgements: Irina Lisinen and Mauri Niiniaho are gratefully acknowledged for data management

Funding: Academy of Finland [grants no. 258711, 265869, 258578, 286284, 134309 (Eye), 126925, 121584, 124282, 129378 (Salve), 117787 (Gendi), and 41071 (Skidi)]; the Social Insurance Institution of Finland; Kuopio, Tampere and Turku University Hospital Medical Funds; Paavo Nurmi Foundation; Finnish Foundation of Cardiovascular Research; Finnish Cultural Foundation; Tampere Tuberculosis Foundation; Emil Aaltonen Foundation; Yrjö Jahnsson Foundation; Ministry of Education and Culture; Juho Vainio Foundation; Urheiluopistosäätiö

Conflict of interest: None declared

References

1. Penedo F, Dahn J. Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Curr Opin Psychiatry.* 2005;18:189-193.

2. World Health Organization. *Global health risks: mortality and burden of disease attributable to selected major risks*. Geneva: World Health Organization; 2009.

3. Hallal P, Andersen L, Bull F, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. *The Lancet.* 2012;380:247-257.

4. Lee I, Shiroma E, Lobelo F, Puska P, Blair S, Katzmarzyk P. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *The Lancet.* 2012;380:219-229.

5. Wen C, Wai J, Tsai M, Yang Y, Cheng T, Lee M, et al. Minimum amount of physical activity for reduced mortality and extended life-expectancy: a prospective cohort study. *The Lancet.* 2011;378:1244-1253.

6. Teychenne M, Ball K, Salmon J. Physical activity and likelihood of depression in adults: a review. *Prev Med.* 2008;46:397-411.

7. 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;28:267-273.

8. Friedman H, Martin L, Tucker J, Criqui M, Kern M, Reynolds C. Stability of physical activity across the lifespan. *J Health Psychol.* 2008;13:1092-1104.

9. Telama R, Yang X, Leskinen E, Kankaanpää A, Hirvensalo M, Tammelin T, et al. Tracking of physical activity from early childhood into young adulthood. *Med Sci Sports Exerc.* 2014;46:955-962.

10. Malina R. Physical activity and fitness: pathways from childhood to adulthood. *Am J Hum Biol,* 2001;13:162-172.

11. Steinbeck K. The importance of physical activity in the prevention of overweight and obesity in childhood: a review and opinion. *Obes Rev.* 2001;2:117-130.

12. Hallal P, Victora C, Azevedo M, Wells J. Adolescent physical activity and health: a systematic review. *Sports Med.* 2006;36:1019-1030.

13. Lau R, Quadrel M, Hartman K. Development and change of young adults' preventive health beliefs and behavior: influence from parents and peers. *J Health Soc Behav.* 1990;31:240-259.

14. Abbott G, Hnatiuk J, Timperio A, Salmon J, Best K, Hesketh K. Cross-sectional and longitudinal associations between parents' and preschoolers' physical activity and TV viewing: the HAPPY Study. *Journal of Phys Act Health.* 2016;13:269-274.

15. Hill J, Lynch E. *The intensification of gender-related role expectations during adolescence. Girls at Puberty*. In: Brooks-Gunn J et al, eds. New York, NY: Springer US; 1983:201-228.

16. Grusec J. Social learning theory and developmental psychology: the legacies of Robert Sears and Albert Bandura. *Dev Psychol.* 1992;28:776-786.

17. DiLorenzo T, Stucky-Ropp R, Vander Wal J, Gotham H. Determinants of exercise among children. II. A longitudinal analysis. *Prev Med.* 1998;27:470-477.

18. Cheng L, Mendonça G, Júnior F. Physical activity in adolescents: analysis of the social influence of parents and friends. *J Pediatr.* 2014;90:35-41.

19. Pahkala K, Heinonen O, Lagström H, Hakala P, Sillanmäki L, Simell O. Leisure-time physical activity of 13-year adolescents. *Scand J Med Sci Sports.* 2007;17:324-330.

20. Karppanen A, Ahonen S, Tammelin T, Vanhala M, Korpelainen R. Physical activity and fitness in 8-year-old overweight and normal weight children and their parents. *Int J Circumpolar Health.* 2012;71:17621.

21. Yang X, Telama R, Laakso L. Parents' physical activity, socioeconomic status and education as predictors of physical activity and sport among children and youths – a 12 year follow-up study. *Int Rev Soc Sport.* 1996;31:273-291.

22. Yang X, Telama R, Leskinen E. Testing a multidisciplinary model of socialization into physical activity: a 6-year follow-up study. *Eur J Phys Educ.* 2000;5:67-87.

23. Dollman J. Changing associations of Autralian parents' physical activity with their children's sport participation: 1985 to 2004. *Aust N Z J Public Health.* 2010;34:578-582.

24. Fogelhom M, Nuutinen O, Pasanen M, Myöhänen E, Säätelä T. Parent-child relationship of physical activity patterns and obesity. *Int J Obes Relat Metab Disord.* 1999;23:1262-1268.

25. Nichols-English G, Lemmon C, Litaker M, Cartee S, Yin Z, Gutin B, et al. Relations of black mothers' and daughters' body fatness, physical activity beliefs and behavior. *Ethn Dis.* 2006;16:172-179.

26. Simonen R, Pérusse L, Rankinen T, Rice T, Rao D, Bouchard C. Familial aggregation of physical activity levels in the Québec Family Study. *Med Sci Sports Exerc.* 2002;34: 1137–42.

27. Kaprio J, Koskenvuo M, Sarna S. Cigarette smoking, use of alcohol, and leisure-time physical activity among same-sexed adult male twins. *Prog Clin Biol Res.* 1981;69:37–46.

28. Joosen A, Gielen M, Vlietinck R, Westerterp K. Genetic analysis of physical activity in twins. *Am J Clin Nutr.* 2005;82:1253–59.

29. Bauman A, Reis R, Sallis J, Wells J, Loos R, Martin, B. Correlates of physical activity: why are some people physically active and others not? *The Lancet*. 2012;380:258-271.

30. Lamb E. *The role of father in child development.* 4th Ed. New Jersey, NJ: John Wiley & Sons Inc; 2004.

31. Hox J, Roberts J. *Handbook of advanced multilevel analysis*. New York, NY: Psychology Press; 2011.

32. Lott J, James S. *Multilevel modeling techniques and applications in institutional research: New Directions in Institutional Research, Number 154*. San Fransisco, CA: John Wiley & Sons Inc; 2013.

33. Hakulinen C, Jokela M, Hintsanen M, Pulkki-Råback L, Hintsa T, Merjonen P, et al. Childhood family factors predict developmental trajectories of hostility and anger: A prospective study from childhood into middle adulthood. *Psychol Med.* 2013;43:2417-2426.

34. Zecevik C, Tremblay L, Lovsin T, Lariviere M. Parental Influence on Young Children's Physical Activity. *Int J Pediatrics*. 2010, http://dx.doi.org/10.1155/2010/468526

35. Galobardes B, Shaw M, Lawlor D, Lynch J, Smith D. Indicators of socioeconomic position (part 1). *J Epidemiol Community Health.* 2006;60:7-12.

36. Chograha M, Cousins S, Wankel L. Social influences on physical activity in older adults: A review. *J Aging Phys Act*. 1998;6:1-17.

37. Beets M, Cardinal B, Alderman, B. Parental social support and the physical activity–related behaviors of youth: A review. *Health Education & Behavior*. 2010;37:621-644

38. Zimet G, Dahlem N, Zimet S, Farley G. The Multidimensional Scale of Perceived Social Support. *J Pers Asses.* 1988;52:30-41.

39. Trost S, Owen N, Bauman A, Sallis J, Brown, W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc.* 2002;34:1996-2001.

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

41. Raitakari O, Juonala M, Rönnemaa T, Keltikangas-Järvinen L, Räsänen L, Pietikäinen M, et al. Cohort profile: the cardiovascular risk in Young Finns Study. *Int J Epidemiol.*

2008;37:1220-1226.

42. Bowling A. Just one question: If one question works, why ask several?. *J Epidemiol Community Health.* 2005;59:342-345.

43. Telama R, Viikari J, Välimäki I, Siren-Tiusanen H, Åkerblom H, Uhari M, et al. Atherosclerosis precursors in Finnish children and adolescents. X. Leisure time physical activity. *Acta Paediatr Scand Suppl*. 1985;74:169-180.

44. Yang X, Telama R, Hirvensalo M, Hintsa T, Pulkki-Råback L, Hintsanen M, et al. Leadership component of type A behavior predicts physical activity in early midlife. *Int J Behav Med.* 2012;19:48-55.

45. Yang X, Kaseva K, Keltikangas-Järvinen L, Pulkki-Råback L, Hirvensalo M, Jokela M, et al. Does Childhood Temperamental Activity Predict Physical Activity and Sedentary Behavior over a 30-Year Period? Evidence from the Young Finns Study. *Int J Behav Med*, 2016:1-9.

46. Telama R, Yang X, Leskinen E, Kankaanpää A, Hirvensalo M., et al. Tracking of physical activity from early childhood through youth into adulthood. *Med Sci Sports Exerc*. 2014;46:955-962.

47. Mansikkaniemi K, Juonala M, Taimela S, Hirvensalo M, Telama, R, Huupponen R, 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;44:733-744.

48. Tudor-Locke C, Williams J, Reis J, Pluto D. Utility of pedometers for assessing physical activity: construct validity. *Sports Med.* 2004;34:281-291.

49. Hull E, Rofey D, Robertson R, Nagle E, Otto A, Aaron D. Influence of marriage and

parenthood on physical activity: a 2-year prospective analysis. *J Phys Act Health.* 2010;7:577.

50. Nettleton J, Hivert M, Lemaitre R, McKeown N, Mozaffarian D, Tanaka T, et al. Meta-Analysis Investigating Associations Between Healthy Diet and Fasting Glucose and Insulin Levels and Modification by Loci Associated With Glucose Homeostasis in Data From 15 Cohorts. *Am J Epidemiol.* 2013;177:103-115.
51. Juonala M, Viikari J, Kähönen M, Laitinen T, Taittonen L, Loo B, et al. Alcohol consumption is directly associated with carotid intima–media thickness in Finnish young adults: The Cardiovascular Risk in Young Finns Study. *Atherosclerosis.* 2009;204:e93-e98.
52. Josefsson K, Cloninger C, Hintsanen M, Jokela M, Pulkki-Råback L, Keltikangas-Järvinen L. Associations of personality profiles with various aspects of well-being: a population - based study. *J Aff Dis.* 2011;133:265-273.
53. Vandenberg R, Lance C. A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Org Res Methods.* 2000;3:4-70.
54. Beauducel A, Herzberg P. On the performance of maximum likelihood versus means and variance adjusted weighted least squares estimation in CFA. *Struct Equ Modeling.* 2006;13:186-203.
55. Muthén L, Muthén B. *Mplus User's Guide*. 6th Ed. Los Angeles, CA: Muthén & Muthén; 1998-2010.
56. Cheung G, Rensvold R. Evaluating goodness-of-fit indexes for testing measurement invariance. *Struct Equ Modeling.* 2002;9:233-255.
57. Pols M, Peeters P, Kemper H, Grobbee D. Methodological aspects of physical activity assess- ment in epidemiological studies. *Eur J Epidemiol.* 1998;14:63-70.

58. Muthén, B. Beyond SEM: General latent variable modeling. *Behaviormetrika.* 2002;29:81-117.

59. Kim E, Willson V. Measurement invariance across groups in latent growth modeling. *Struct Equ Modeling*. 2014;21:408-424.

60. Onyebuchi A. The role of causal reasoning in understanding Simpson's paradox, Lord's paradox, and the suppression effect: covariate selection in the analysis of observational studies. *Emerg Themes Epidemiol.* 2008;5:1.

61. Nagelkerke N. A note on a general definition of the coefficient of determination. *Biometrika*. 1991;78:691-692.

Table 1. Descriptive statistics of the sample (for females, n=461-1832; for males, n=438-1764)

Variable	Females			Males		
	n	Mean ± SD/ (% of total n)	Range	n	Mean ± SD/ (% of total n)	Range
Covariates						
Birth cohort (1980)	1832	10.53±4.99	3-18	1764	10.36±4.99	3-18
Family's living area (1980)	1828			1756		
City center	180	9.80%		187	10.60%	
Suburb	672	36.80%		654	37.20%	
Rural community	533	29.20%		486	27.70%	
Dispersed settlement area	443	24.20%		429	24.40%	
Parents' cohabiting status (1980)	1829			1760		
Cohabiting	1571	85.90%		1487	84.50%	
Living separately	258	14.10%		273	15.50%	
Parents' cohabiting status (1983)	1451			1375		
Cohabiting	1298	89.50%		1198	87.10%	
Living separately	153	10.50%		177	12.90%	
Parents' cohabiting status (1986)	756			733		
Cohabiting	669	88.50%		636	86.80%	
Living separately	87	11.50%		97	13.20%	
Parents' cohabiting status (1989)	461			438		
Cohabiting	397	86.10%		376	85.80%	
Living separately	64	13.90%		62	14.20%	
Parents' education (1980)	1801			1739		
Low	638	35.40%		590	33.90%	
Average	721	40.00%		707	40.70%	
High	442	24.50%		442	25.40%	
Parents' income (1980)	1752	4.78±1.96	1-8	1701	4.81±1.92	1-8
Participants' age	1832	31.58±11.83	9-49	1764	31.58±11.83	9-49
Participants' body mass index (2007)	1183	25.38±5.06	16.56-58.82	987	26.75±4.24	17.54-49.35
Participants' education (2007)	1076			946		
Low	306	28.40%		407	43.00%	
Average	246	22.90%		130	13.70%	
High	524	48.70%		409	43.20%	
Participants' income (2007)	1173	3.05±1.35	1-8	973	4.03±1.62	1-8
Participants' diet (2007)	1105	15.01±3.73	3-26	867	11.87±3.74	2-21
Participants' alcohol use (2007)	1212	0.55±0.72	0-5.43	993	1.40±1.84	0-28.57
Participants' smoking status	1225	4.00±1.44	1-5	999	3.57±1.60	1-5
Participants' social support (2007)	1211	4.33±0.71	1.42-5.00	844	3.89±0.85	1.08-5.00
Independent variables (1980)						
Mothers' physical activity	1781			1700		
No physical activity	550	30.90%		508	29.90%	
Some physical activity	939	52.70%		913	53.70%	
Regular physical activity	292	16.40%		279	16.40%	
Fathers' physical activity (1980)	1601			1519		
No physical activity	361	22.50%		351	23.10%	
Some physical activity	899	56.20%		861	56.70%	
Regular physical activity	341	21.30%		307	20.20%	

Dependent variables[a,b]

Physical activity 1980	1133	8.60±1.63 (61.80%)[c]	5-14	1091	9.52 ±1.91 (61.80%)	5-14
Physical activity 1983	1093	8.60±1.65 (59.70%)	5-14	1023	9.49±2.00 (58.00%)	5-14
Physical activity 1986	1223	8.54±1.79 (66.80%)	5-14	1097	9.31±2.16 (62.20%)	5-14
Physical activity 1989	1443	8.43±1.88 (78.80%)	5-14	1176	8.88±2.33 (66.70%)	5-14
Physical activity 1992	1210	8.83±1.70 (66.00%)	5-14	982	9.40±2.13 (55.70%)	5-14
Physical activity 2001	1345	8.79±1.79 (73.40%)	5-15	1097	8.94±2.15 (62.20%)	5-15
Physical activity 2007	1200	8.86±1.71 (65.50%)	5-15	966	8.76±1.93 (54.80%)	5-15
Physical activity 2011	1064	9.11±1.87 (58.10%)	5-15	846	8.91±1.89 (48.00%)	5-15

[a]Physical activity indices ≤ 7 indicate low, >7 to 10< moderate, and ≥10 high levels of physical activity

[b]Factor scores, which were predicted from physical activity indices (1980-2011), were used in all analyses (see Table 2). In 1980, participants were aged 9-18; in 1983, 9-21; in 1986, 9-24; in 1989, 12-27; in 1992, 15-30; in 2001, 24-39; in 2007, 30-45; in 2011, 34-49. Participants, who were not able to self-report their physical activity levels in 1980 (3 and 6 year-olds) were included to the study at their age of 9 (during the years 1983 and 1986)

[c]Proportion of participants who were included to the Cardiovascular Risk in Young Finns Study (females n=1832, males n=1764) in 1980

Table 2. Descriptive statistics[a] of the physical activity factor scores by age (for females, n=275-1544; for males, n=257-1488)

Participants' age	Females			Males		
	n	Mean ± SD	Range	n	Mean ± SD	Range
9	896	0.10±0.40	-1.09 to 1.50	879	0.36±0.46	-1.27 to 1.67
12	1225	0.11±0.47	-1.30 to 1.74	1201	0.37±0.52	-1.61 to 1.83
15	1539	-0.01±0.54	-1.56 to 1.88	1488	0.20±0.60	-1.79 to 1.95
18	1544	-0.13±0.55	-1.63 to 1.84	1463	0.04±0.62	-1.61 to 2.04
21	1246	-0.15±0.52	-1.67 to 1.87	1189	-0.05±0.63	-1.73 to 1.91
24	1198	-0.10±0.53	-1.76 to 1.96	1148	-0.03±0.64	-1.75 to 1.65
27	892	-0.11±0.54	-1.84 to 1.60	818	-0.04±0.61	-1.69 to 1.86
30	878	-0.06±0.54	-2.00 to 1.63	862	-0.01±0.64	-1.74 to 1.66
33	627	-0.02±0.52	-1.68 to 2.08	596	-0.03±0.56	-1.76 to 1.49
34	275	0.07±0.50	-1.61 to 1.42	282	0.11±0.61	-1.74 to 1.50
36	637	-0.08±0.52	-1.90 to 1.75	610	-0.04±0.58	-1.80 to 1.63
37	298	-0.00±0.54	-1.76 to 2.00	274	0.01±0.55	-1.57 to 1.25
39	609	-0.07±0.54	-1.66 to 1.45	579	-0.11±0.58	-1.87 to 1.53
40	323	-0.03±0.56	-1.89 to 1.58	323	0.01±0.59	-1.77 to 1.41
42	314	-0.08±0.52	-1.92 to 1.87	287	-0.07±0.61	-1.87 to 1.79
43	329	-0.01±0.55	-1.67 to 1.71	322	-0.12±0.58	-1.91 to 1.39
45	280	-0.10±0.56	-1.75 to 1.82	257	-0.09±0.64	-1.88 to 2.25
46	314	-0.08±0.53	-1.91 to 1.78	287	-0.06±0.59	-1.86 to 1.34
49	280	-0.07±0.59	-1.83 to 1.51	257	-0.09±0.64	-1.96 to 2.13

[a]The values are standardized factor scores, with a mean of 0 and a standard deviation of 1

Table 3. Mothers' and fathers' physical activity (1980) as predictors for females' and males' physical activity at different ages (1980-2011)[a]

	Mothers' physical activity				Fathers' physical activity			
	Females (n=266-1503)		Males (n=245-1437)		Females (n=230-1358)		Males (n=203-1299)	
Partici-pants' age	b	p-value[b]	b	p-value	b	p-value	b	p-value
9	0.10	<0.001	0.10	<0.001	0.11	<0.001	0.14	<0.001
12	0.12	<0.001	0.08	0.001	0.14	<0.001	0.17	<0.001
15	0.13	<0.001	0.08	0.001	0.12	<0.001	0.19	<0.001
18	0.13	<0.001	0.06	0.009	0.11	<0.001	0.20	<0.001
21	0.12	<0.001	0.08	0.005	0.10	<0.001	0.20	<0.001
24	0.10	<0.001	0.10	<0.001	0.07	0.005	0.16	<0.001
27	0.08	0.002	0.08	0.014	0.05	0.093	0.15	<0.001
30	0.07	0.007	0.10	0.002	0.08	0.003	0.20	<0.001
33	0.09	0.005	0.05	0.128	0.04	0.293	0.13	0.001
34	-0.02	0.642	0.13	0.016	-0.00	0.935	0.17	0.004
36	0.08	0.007	0.04	0.245	0.10	0.004	0.17	<0.001
37	0.10	0.036	0.05	0.310	0.05	0.360	0.11	0.041
39	0.09	0.007	0.05	0.183	0.07	0.064	0.08	0.055
40	0.06	0.204	0.04	0.482	0.13	0.007	0.15	0.005
42	0.05	0.247	0.03	0.537	0.05	0.354	0.18	0.002
43	0.09	0.053	0.05	0.366	0.09	0.074	0.06	0.279
45	0.07	0.148	0.09	0.123	0.07	0.226	0.13	0.057
46	0.01	0.808	0.08	0.120	0.01	0.902	0.21	<0.001
49	0.03	0.529	0.08	0.174	0.05	0.356	0.11	0.118

[a]The analyses were adjusted for birth cohort effects (assessed in 1980)
[b]Bonferroni-corrected p-values (α=0.05/19, p<0.003) were used in determining significant associations

Table 4. Mothers' and fathers' physical activity (1980), participants' age and sex as predictors for participants' physical activity from childhood to midlife (from 1980 to 2011)

Independent variables	B	SE	p-value[c]	95%CI	R^2
Model 1[a]					
Mothers' physical activity (1980)	0.14	0.01	<0.001	0.11 to 0.17	
Participants' age	0.00	0.00	0.573	-0.00 to 0.00	
Mothers' physical activity x age	-0.00	0.00	<0.001	-0.00 to -0.00	0.06
Model 2[b]					
Fathers' physical activity (1980)	0.17	0.02	<0.001	0.14 to 0.20	
Participants' age	-0.00	0.00	0.906	-0.00 to 0.00	
Fathers' physical activity x age	-0.00	0.00	<0.001	-0.00 to -0.00	0.18
Model 3					
Mothers' physical activity (1980)	0.17	0.02	<0.001	0.14 to 0.21	
Participants' age	0.01	0.00	<0.001	0.00 to 0.01	
Participants' sex (female vs. male)	0.45	0.05	<0.001	0.35 to 0.56	
Age x sex	-0.01	0.00	<0.001	-0.01 to -0.01	
Mothers' physical activity x age	-0.00	0.00	<0.001	-0.00 to -0.00	
Mothers' physical activity x sex	-0.07	0.03	0.012	-0.12 to -0.02	
Mothers' physical activity x age x sex	0.00	0.00	0.002	0.00 to 0.00	0.07
Model 4					
Fathers' physical activity (1980)	0.15	0.02	<0.001	0.11 to 0.19	
Participants' age	0.01	0.00	<0.001	0.00 to 0.01	
Participants' sex	0.20	0.06	0.001	0.08 to 0.32	
Age x sex	-0.01	0.00	<0.001	-0.01 to -0.01	
Fathers' physical activity x age	-0.00	0.00	<0.001	-0.00 to -0.00	
Fathers' physical activity x sex	0.06	0.03	0.043	0.00 to 0.12	
Fathers' physical activity x age x sex	0.00	0.00	0.339	-0.00 to 0.00	0.19
Model 5 (females)					
Mothers' physical activity (1980)	0.17	0.02	<0.001	0.14 to 0.21	
Participants' age	0.01	0.00	<0.001	0.00 to 0.01	
Mothers' physical activity x age	-0.00	0.00	<0.001	-0.00 to -0.00	0.04
Model 6 (males)					
Mothers' physical activity (1980)	0.10	0.02	<0.001	0.06 to 0.15	
Participants' age	-0.01	0.00	<0.001	-0.01 to -0.00	
Mothers' physical activity x age	-0.00	0.00	0.025	-0.00 to -0.00	0.10

[a]When the main effects were studied without the inclusion of the interaction term, mothers' physical activity (B=0.09, SE=0.01, p<0.001, 95%CI: 0.07 to 0.11) and participants' age predicted the outcome significantly (B=-0.00, SE=0.00, p<0.001, 95%CI: -0.00 to -0.00)
[b]When the main effects were studied without the inclusion of the interaction term, fathers' physical activity (B=0.12, SE= 0.01, p<0.001, 95%CI: 0.10 to 0.15) and participants' age predicted the outcome significantly (B=-0.00, SE=0.00, p<0.001, 95%CI: -0.00 to -0.00)
[c]All the analyses were adjusted for the birth cohort effects (assessed in 1980)

Table 5. Mothers' and fathers' physical activity (1980) and participants age as predictors for participants' physical activity from childhood to midlife (from 1980 to 2011) adjusting for covariates

Predictors	B	SE	P-value	95%CI	R^2
Model 1					
Covariates					
Birth cohort (1980)	-0.05	0.02	0.001	-0.09 to -0.02	
Living area (1980)	-0.02	0.03	0.515	-0.08 to 0.04	
Parents' cohabiting (1983)[a]	0.05	0.21	0.812	-0.36 to 0.46	
Parents' cohabiting (1986)	-0.03	0.21	0.884	-0.45 to 0.39	
Parents' cohabiting (1989)	-0.09	0.14	0.531	-0.37 to 0.19	
Parents' education (1980)	-0.04	0.04	0.301	-0.12 to 0.04	
Parents' income (1980)	0.01	0.02	0.432	-0.02 to 0.05	
Participants' body mass index (2007)	0.00	0.01	0.720	-0.01 to 0.01	
Participants' education (2007)	0.00	0.03	0.945	-0.06 to 0.07	
Participants' income (2007)	0.07	0.02	<0.001	0.03 to 0.11	
Participants' diet (2007)	0.01	0.01	0.200	-0.00 to 0.02	
Participants' alcohol use (2007)	0.05	0.03	0.074	-0.01 to 0.11	
Participants' smoking status (2007)	0.03	0.02	0.109	-0.01 to 0.07	
Participants' social support (2007)	0.03	0.04	0.408	-0.04 to 0.11	
Independent variables					
Fathers' physical activity (1980)	0.21	0.05	<0.001	0.11 to 0.32	
Participants' age	0.00	0.00	0.956	-0.01 to 0.01	
Fathers' physical activity x age	-0.00	0.00	0.009	-0.01 to -0.00	0.12
Model 2 (females)					
Covariates					
Birth cohort (1980)	-0.05	0.02	0.013	-0.08 to -0.01	
Living area (1980)	0.01	0.03	0.784	-0.05 to 0.07	
Parents' cohabiting (1983)	0.04	0.17	0.818	-0.30 to 0.38	
Parents' cohabiting (1986)	-0.03	0.20	0.891	-0.42 to 0.36	
Parents' cohabiting (1989)	0.01	0.14	0.947	-0.27 to 0.29	
Parents' education (1980)	-0.04	0.04	0.344	-0.12 to 0.04	
Parents' income (1980)	0.01	0.02	0.497	-0.02 to 0.05	
Participants' body mass index (2007)	-0.00	0.01	0.636	-0.01 to 0.01	
Participants' education (2007)	-0.01	0.04	0.894	-0.08 to 0.07	
Participants' income (2007)	0.02	0.03	0.517	-0.03 to 0.07	
Participants' diet (2007)	0.01	0.01	0.066	-0.00 to 0.03	
Participants' alcohol use (2007)	0.11	0.04	0.003	0.04 to 0.19	
Participants' smoking status (2007)	0.05	0.02	0.009	0.01 to 0.09	
Participants' social support (2007)	0.05	0.04	0.219	-0.03 to 0.14	
Independent variables					
Mothers' physical activity	0.19	0.06	0.001	0.08 to 0.30	
Participants' age	0.01	0.00	0.025	0.00 to 0.02	
Mothers' physical activity x age	-0.01	0.00	0.002	-0.01 to -0.00	0.04

Model 3 (males)

Covariates

Birth cohort (1980)	-0.06	0.03	0.063	-0.11 to 0.00	
Living area (1980)	-0.13	0.05	0.019	-0.23 to -0.02	
Parents' cohabiting (1983)	0.37	0.37	0.322	-0.37 to 1.11	
Parents' cohabiting (1986)	-0.13	0.37	0.718	-0.87 to 0.60	
Parents' cohabiting (1989)	-0.42	0.26	0.099	-0.93 to 0.08	
Parents' education (1980)	-0.02	0.07	0.737	-0.17 to 0.12	
Parents' income (1980)	0.02	0.03	0.550	-0.04 to 0.07	
Participants' body mass index (2007)	0.01	0.01	0.363	-0.01 to 0.03	
Participants' education (2007)	0.08	0.06	0.196	-0.04 to 0.19	
Participants' income (2007)	0.05	0.03	0.138	-0.02 to 0.12	
Participants' diet (2007)	0.02	0.01	0.129	-0.01 to 0.04	
Participants' alcohol use (2007)	-0.05	0.05	0.272	-0.14 to 0.04	
Participants' smoking status (2007)	0.02	0.03	0.513	-0.04 to 0.08	
Participants' social support (2007)	0.06	0.06	0.354	-0.07 to 0.18	
Independent variables					
Mothers' physical activity	-0.16	0.09	0.074	-0.34 to 0.02	
Participants' age	-0.03	0.00	<0.001	-0.04 to -0.02	
Mothers' physical activity x age	0.01	0.00	<0.001	0.00 to 0.01	0.18

[a]Parents' cohabiting in 1980 was excluded from the analyses due to collinearity.