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Association of accelerometer-measured physical activity and midlife income: A Northern Finland Birth Cohort 1966 Study

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Abstract
This study investigated the association between physical activity (PA) and midlife income. The population-based data comprised employed members of the Northern Finland Birth Cohort 1966 ($N=2797$). Using binned scatterplots and polynomial regressions, we evaluated the association between accelerometer-measured moderate PA (MPA), vigorous PA (VPA), and moderate-to-vigorous PA (MVPA) at 46 years old and register-based income at 50 years old. The models were adjusted for sex, marital status, number of children, education, adolescent PA, occupational physical strenuousness, and time preference. We found MPA ($p<0.001$), VPA ($p<0.05$), and MVPA ($p<0.001$) to associate curvilinearly with income. In subgroup analyses, a curvilinear association was found between MPA ($p<0.01$) and MVPA ($p<0.01$) among those with physically strenuous work, VPA among all females ($p<0.01$) and females with physically light work ($p<0.01$), and MPA and MVPA among all males and males with physically strenuous work ($p<0.05$; $p<0.01$; $p<0.05$; $p<0.05$, respectively) and income. The highest income benefits occurred at PA volumes higher than current PA guidelines. Linear associations between PA and income were found among females for MPA ($p<0.05$) and MVPA ($p<0.05$), among those with physically light work for MPA ($p<0.05$), VPA ($p<0.05$), and MVPA ($p<0.05$), and among females with physically strenuous work for VPA ($p<0.05$). We conclude that PA up to the current recommended level is associated with income, but MPA exceeding 505.4 min/week, VPA exceeding 216.4 min/week, and MVPA exceeding 555.0 min/week might have a negative association with income.

KEYWORDS
accelerometer-measured physical activity, economic analysis, income, middle age, population-based study, prospective study

1 | INTRODUCTION

Physical activity (PA) produces health[1,2] and economic[3–8] benefits. Current PA guidelines recommend weekly at least 150–300 min of moderate-intensity PA (MPA) or 75–150 min of vigorous-intensity PA (VPA), or an equivalent combination of them to promote health.[1,2] While current PA recommendations do not specify any maximum limits for PA, they imply that the more PA, the better.[2] However, it has been suggested that the health benefits of a physically active lifestyle may plateau or even decline with extreme PA after reaching a certain point.[9–12] Various studies report the turning point to be within current PA guidelines,[10,12] or higher.[9–11]

In recent years, many studies have investigated the associations between PA and productivity,[3,4,6–8] proposing 4%–25% of future income to be attributed to a previously physically active lifestyle.[3,4,6–8] A higher level of PA is potentially linked to higher productivity and income through improved health.[4] Moreover, there is strong evidence suggesting that PA enhances health,[1] and good health has been suggested to have positive impact on labor market outcomes.[13] PA has also been reported to be positively associated with work ability[14] and negatively with sickness absence.[15]

In economics, PA can be seen as an investment in future health and income.[16] While an individual decides how to allocate the 24 h of their day,[17] PA competes with other uses of time, including working, sleeping, homework, and other leisure activities. The amount of PA necessary to produce income benefits is unknown, but it has been suggested to be higher than current PA guidelines.[6] It is unclear whether there is a dose–response relationship between PA and income benefits.

This study aimed to investigate the association between PA and income and whether increasing PA is associated with additional income benefits among employed adults. This study took a novel approach by exploring whether the association between PA and income is also curvilinear like the association between PA and health. In addition, we aimed to determine the optimal PA level for obtaining income benefits.

2 | METHODS

2.1 | Study population

Data for the present study were drawn from the population-based Northern Finland Birth Cohort 1966 (NFBC1966)[18,19] follow-up at 46 years old, when the target population was $N = 10\,321$ (100%). All participants provided written informed consent, and the Ethical Committee of the Northern Ostrobothnia Hospital District in Oulu, Finland, approved the Northern Finland Birth Cohort Study (§94/2011), which was conducted according to the Declaration of Helsinki of 1983. Nordström et al.[18] provided extensive information about the follow-ups, attrition analyses, and representativeness of the NFBC1966 study in general.

Because we were especially interested in the influence of PA on income, we included only employed individuals in this study. Eligible participants were those employed throughout the time between when the PA data for the 46-years follow-up survey were collected and when the data of income to be predicted were collected, that is December 31, 2012 to December 31, 2016. To avoid large outliers, data were winsorised 1% ($N = 30$) upper tail of the income distribution.

The final sample, presented in Figure 1, included 2797 employed members (27.1% of the target population) of this cohort (1643 females and 1154 males) from whom the data were available.

2.2 | Physical activity

The main explanatory variable was accelerometer-measured PA at the age of 46. The members of the NFBC1966 attending the clinical examination at the age of 46 were asked to wear a triaxial accelerometer (Hookie AM20; Traxmeet Ltd.) on the right side of their hip for 14 consecutive days to measure their PA. Participants were instructed to wear the accelerometer during all waking hours, except when engaged in water-based activities. The accelerometer was blinded, so it did not provide feedback to the user. To be included in the analyses, the participants were required to provide at least four valid measurement days, with each valid day defined as ≥10 h of monitor-wearing time. Raw acceleration signals were collected and stored at 100 Hz. The accelerometer data were segmented into 6-s epochs, and mean amplitude deviation (MAD) was computed for each segment.[20] From the 6-s MAD values, monitor non-wear time was detected and removed using a previously validated approach for count-based accelerometer data. MPA (3.0–6.0 metabolic equivalent of task (MET)) and VPA (≥6.0 MET) were then identified based on the previously validated threshold set for MAD values.[20] Time spent in each activity category (minutes/day) was obtained by dividing the total time by the number of valid days. Time spent in moderate-to-vigorous PA (MVPA; ≥6.0 MET) was determined as the sum of the minutes per day spent in MPA and VPA.

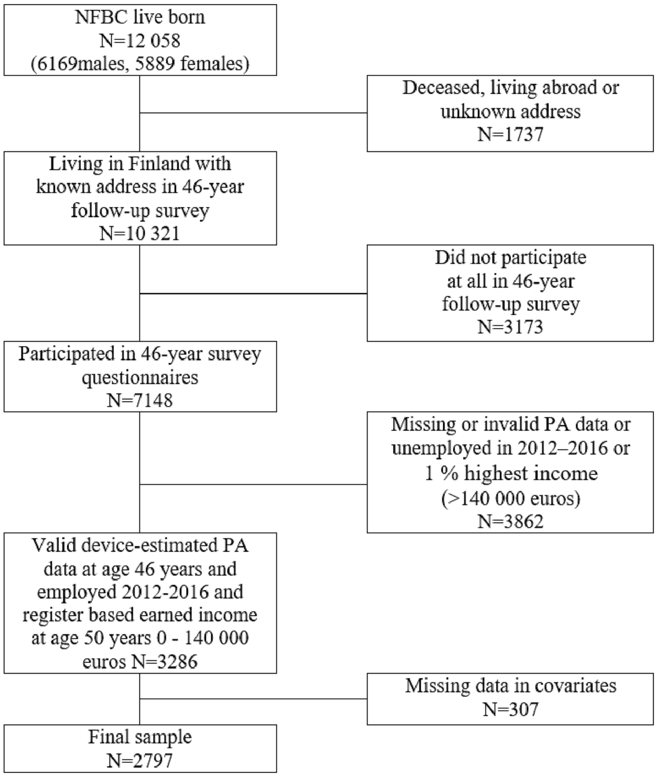

FIGURE 1 Study sample of the Northern Finland Birth Cohort 1966 (NFBC1966).

2.3 | Income

The information on participants' taxable income was drawn from the Finnish Tax Administration in 2016 when the age of participants was 50 years. The variable included annual wage and salary earnings, self-employment earnings, and social income transfers such as sick leave, and parental leave benefits. The study sample included individuals with annual taxable income between 0 and 140 000 € (mean: 39 641 €; SD: 18 929 €). We also included the self-employed and entrepreneurs in our sample. Zero income is explained by the fact that they can have either earned income, capital, or assets. Thus, there are nine participants who had 0 € income in 2015, but they might have had capital or assets instead. Income reflects current productivity, while capital and assets reflect decisions and investments done in the past (i.e., in previous years and decades). Thus, we decided to use earned income instead of capital and assets.

2.4 | Covariates

Based on previous literature, the main correlates of adulthood PA are sex,[3] marital status, family status (living with children under the age of 18 years), education,[21] history of childhood PA,[22] work-time PA (WTPA),[23] and time preference, that is, whether the person is more future-oriented or more presence-oriented.[24] These are also potential correlates and determinants of adulthood income.[3,25–27] Thus, we utilized them as covariates in our analyses.

The information on participants' marital status, number of children under the age of 18 years, and lifetime highest educational achievement at age 46 was obtained from the register of the Central Statistical Office of Finland.[28] The education level was classified according to the International Standard Classification of Education 2011.[29] In the analysis, we used education level as a dichotomized variable, and those with at least a bachelor's degree were categorized in the high education group. PA at age 14 was determined according to Tammelin et al.,[22] and participants were dichotomized to physically active and inactive at age 14.

The WTPA was assessed by asking the participants at 46 years old how often they engaged in the following physical tasks/activities when working: "(1) hard physical labor that is strenuous for the whole body, (2) repetitive movements, (3) standing in one place, (4) leaning forward, (5) having to twist your back, (6) constant moving or walking from one place to another, (7) lifting loads of 1–15 kg, (8) lifting loads of >15 kg, (9) working with upper limbs raised so that your arm is above your shoulder, and (10) sitting still". The alternative responses for each activity were (a) never or very rarely, (b) rarely, (c) occasionally, (d) often, and (e) very often. The participants at 46 years who had performed at least one of the high-intensity tasks (1, 6 and 8)[30] often or very often (options d or e) were assigned to the physically strenuous work group. Those who had performed none of the intense tasks often (options a–c) were assigned to the physically light work group.

The measure for time preference captured discount rates at age 46 from a hypothetical questionary-based experiment, which explored whether the individual is more present or future oriented. The experiment asked: "Let us assume you have two alternative ways to receive money: In option 'A', you will receive 1000 € in 2 days; in option 'B', you will receive the mentioned money in 9 days. Compare the sums of money and the waiting periods of options 'A' and 'B', and circle either A or B based on which sum of money you would like to receive in each of the seven options in which option 'B' is (1) 1012 €, (2) 1025 €, (3) 1037 €, (4) 1050 €, (5) 1075 €, (6) 1100 €, and (7) 1200 €". If the participant chose "A" in all seven cases, the discount factor has a value of 0; answered "B" only in Case 7 but "A" in others, the value is 1; chose "B" in Cases 6–7 but "A" in others, the value is 2 and so on till the value 7 is given by choosing "B" in all seven cases. Thus, the higher the value, the lower the sum of money motivating the participant to wait, indicating a higher future orientation.[31] We used the discount factor as a continuous variable.

2.5 | Statistical analyses

First, the associations between MVPA at age 46 and income at age 50 were graphically evaluated using binned scatterplots[32,33] illustrated in Figure 2. Binned scatterplots provide a graphical representation of the nonparametric association between MVPA and income. A binned scatterplot condenses information from a scatterplot by grouping the *x*-axis variable (MVPA at age 46) into equal-sized bins and computing the mean of MVPA and *y*-axis variable (income at age 50) within each bin, and then creating a scatterplot of these data points.

Binned scatterplots revealed a curvilinear association between MVPA (MET ≥3.0) at age 46 and income at age 50, with the strongest positive association between PA and income at the beginning of the curve (Figure 2).

Based on the binned plot and to calculate the turning-point of the PA–income association curve, we formed the following curvilinear (i.e., second-order polynomial) model for our empirical analyses:

$$\text{Income}_{i,2016} = c + \beta_1 \text{PA}_{i,2012} + \beta_2 \text{PA}^2_{i,2012} + \alpha X_i + \varepsilon, \quad (1)$$

where Income refers to income at age 50 (in 2016), i refers to an individual, c is a constant term, PA is physical activity at age 46 (in 2012), β_1 is the coefficient of PA, which measures

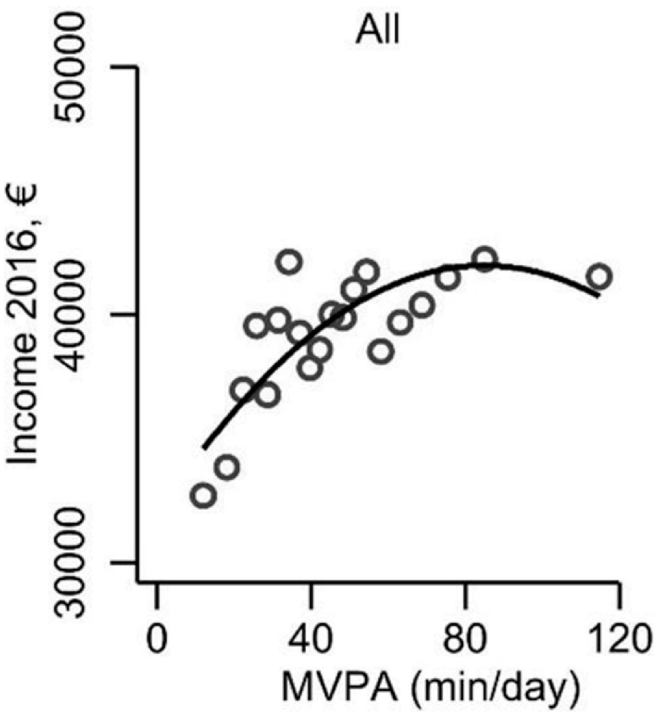

FIGURE 2 Binned scatter between accelerometer-measured MVPA = moderate-to-vigorous physical activity (MET ≥ 3.0) at age 46 and the future income at age 50. *Source*: NFBC1966 2012 & 2016. Binned scatter grouped the adulthood PA variable into 20 equal-sized bins, computed the mean of the adulthood PA and future income within each bin, and created a scatter of these data points. The plotted quadratic fit line is estimated using the underlying data. The graph was produced using the Stata program binned scatter.[32,33]

the effect of PA on income, β_2 is the coefficient of PA^2 and measures the effect of PA^2 on income, X refers to covariates, α is the coefficient of the covariates, and ε is the stochastic error term.

The point where the derivative of the $Income_{i,2016}$-function equals zero reveals the lowest or the highest point of PA in correlation to income (See Appendix S1).

We used polynomial regressions between accelerometer-measured daily PA minutes in categories (1) MPA, (2) VPA, and (3) MVPA at age 46 and income at age 50. Eventually, we adjusted the models for potential covariates sex, marital status, education, number of children under the age of 18 years, PA at age 14, WTPA, and time preference. We then graphed the adjusted predictions[34] from the estimated models with the covariates. Finally, we performed polynomial regression analyses separately for females and males, those with physically strenuous work, and those with light work. All analyses were conducted using the Stata statistical software package (version 16.1 for Windows; StataCorp LLC).

3 | RESULTS

Table 1 shows the descriptive characteristics of the study sample. On average, males had higher MPA at age 46 than females ($p < 0.05$), which also generated higher MVPA in males than females ($p < 0.05$). The mean annual income at age 50 was 39 640 € (SD 18 920 €) (35 700 €; SD 15 558 € for females and 45 260 €; SD 21 670 € for males). Those doing physically light work had statistically significantly lower MPA ($p < 0.05$) and MVPA ($p < 0.05$) but higher VPA ($p < 0.05$) than those doing physically strenuous work.

The results of the second-order polynomial regression analyses on the association between PA and income are

TABLE 1 Baseline characteristics of the study sample in the Northern Finland Birth Cohort 1966 (NFBC1966) expressed as means (SD) or percentages (frequencies).

	Total (*N* = 2797)	Females (*N* = 1643)	Males (*N* = 1154)	Physically light work[a] (*N* = 1672)	Physically strenuous work[a] (*N* = 1125)
MPA 2012 (min/day)	44.4	41.0[b]	49.2[b]	43.1[c]	46.2[c]
(SD)	(22.8)	(20.0)	(25.7)	(20.8)	(25.5)
VPA 2012 (min/day)	3.3	3.4	3.3	3.7[c]	2.8[c]
(SD)	(7.0)	(6.6)	(7.5)	(7.2)	(6.8)
MVPA 2012 (min/day)	47.7	44.4[b]	52.5[b]	46.8[c]	49.0[c]
(SD)	(24.9)	(22.3)	(27.6)	(23.2)	(27.2)
Income 2016 (€)	39 641.5	35 696.6[b]	45 258.0[b]	43 832.0[c]	33 413.5[c]
(SD)	(18 919.7)	(15 557.7)	(21 670.1)	(20 430.3)	(14 316.6)
Female, %	59%	–	–	60%	58%
(N)	(1643)	–	–	(995)	(648)
Married/registered partnership 2012, % (*N*)	67% (1866)	65%[d] (1072)	69%[d] (794)	69%[e] (1150)	64%[e] (716)
High education 2012, % (*N*)	36% (1003)	37% (605)	34% (398)	45% (745)	23% (258)
Number of children <18 years 2012 (SD)	1.26 (1.24)	1.11[b] (1.07)	1.47[b] (1.42)	1.29 (1.20)	1.22 (1.29)
Physically active at age 14, % (*N*)	78% (2189)	73%[d] (1196)	86%[d] (993)	79% (1328)	77% (861)
Physically strenuous work 2012, % (*N*)	40% (1125)	39% (648)	41% (477)	–	–
Discount factor 2012, mean (SD)	5.10 (2.08)	5.05 (2.09)	5.18 (2.07)	5.25[c] (2.01)	4.89[c] (2.16)

Abbreviations: min, minute; MPA, moderate-intensity physical activity (3.0–6.0 MET); MVPA, moderate-to-vigorous-intensity physical activity (≥3.0 MET); VPA, vigorous-intensity physical activity (≥6.0 MET); y, years.

[a]A participant was classified into the physically strenuous work group if they reported engaging in at least one high-intensity physical task/activity when working often or very often, and into the physically light work group otherwise.

[b]Differs between females and males at 5% significance level, *t*-test.

[c]Differs between physically light and strenuous work at 5% significance level, *t*-test.

[d]Differs between females and males at 5% significance level, Pearson chi-squared test.

[e]Differs between physically light and strenuous work at 5% significance level, Pearson chi-squared test.

Source: NFBC1966 2012 & 2016.

presented in Table 2. Appendix S2, Table 4, shows the detailed results of the polynomial regression analyses with the coefficients of covariates.

A curvilinear association was observed between accelerometer-measured MPA, VPA, and MVPA at 46 years and income at 50 years. The curvilinear associations remained after adjusting for covariates (Table 2). The highest income among the entire study group was revealed at the following PA levels: 72.2 min/day (=505.4 min/week) of MPA, 30.9 min/day (=216.4 min/week) of VPA, and 79.3 min/day (=555.0 min/week) of MVPA.

Among those doing physically strenuous work, MPA and MVPA were also curvilinearly associated with income ($p<0.01$; Table 2). The highest income was revealed at the following PA levels: 67.3 min/day (=471.1 min/week) of MPA and 71.9 min/day (=503.2 min/week) of MVPA. Linear associations between PA and income were found among those doing physically light work for all PA intensity levels ($p<0.05$, $p<0.05$, and $p<0.05$, respectively) and those doing physically strenuous work for the VPA ($p<0.05$).

Fitted values of the estimated models between PA at 46 years and income at 50 years among the entire study population are graphed in marginal plots (Figure 3).

Graphs show the predicted income values for given levels of PA, with the values of model covariates at their observed values and averaged across observations. The small percentage of participants with the highest amount of PA, shown in the binned scatter graphs (Figure 1), created large confidence intervals at the highest PA amounts seen in the marginal plot graphs (Figure 3).

The sex-specific results from the polynomial regression are presented in Table 3. Appendix S3, Table 5, shows the detailed results from the polynomial regression analyses with the coefficients of covariates.

According to the univariate analyses, there seemed to be a curvilinear association between MPA, VPA, and MVPA at age 46 and income at age 50. However, when the models were adjusted for marital status, education, and the number of children under 18, the curvilinear associations became insignificant between MPA and MVPA and income among females and VPA and income among males. After adjusting with additional covariates, including work strenuousness, PA at age 14, and discount factor, the curvilinear associations between VPA and income among females and both MPA and MVPA and income among males remained statistically significant ($p<0.01$, $p<0.05$, and $p<0.01$, respectively; Table 3). The highest income was observed among females at 20.8 min/day (=145.3 min/week) of VPA and among males at 62.8 min/day (=439.6 min/week) of MPA and 72.9 min/day (=510.9 min/week) of MVPA. However, among females, MPA and MVPA were linearly associated with income ($p<0.05$; $p<0.05$).

The polynomial regression analyses according to work strenuousness were conducted separately for females and males (see Table 3, columns 4 and 5 for females, and 9 and 10 for males). We found a statistically significant curvilinear association between adulthood VPA and income among females doing physically light work ($p<0.01$), in which 20.6 min/day (=144.3 min/week) of VPA was associated with the highest income. Among females with physically strenuous work, analyses revealed a linear association between VPA and income ($p<0.05$). Additionally, statistically significant curvilinear associations between both MPA and MVPA and income were found among males doing physically strenuous work ($p<0.05$ in both cases), in which 65.6 min/day (=458.9 min/week) of MPA and 69.4 min/day (=485.9 min/week) of MVPA were associated with the highest income.

4 | DISCUSSION

This population-based study provided first-time evidence of a curvilinear association between accelerometer-measured PA and midlife income. MPA, VPA, and MVPA were curvilinearly associated with income, reflecting increasing PA to be associated with greater productivity benefits to a certain turning point and then plateauing or even declining income as PA volume continues to increase. Curvilinear associations were also found among those doing physically strenuous work for MPA and MVPA with midlife income. In addition, among all females and females doing physically light work VPA, and among all males and males doing physically strenuous work MPA and MVPA had curvilinear associations with income. Linear associations were observed among those doing physically light work for all PA intensity levels, among those doing physically strenuous work for VPA, among females for MPA and MVPA, and among females doing physically strenuous work for VPA with income.

Our findings support the previous literature on a positive association between PA and future income.[3,4,6–8] Previous studies have been based on self-reported participation in PA.[3,4,6–8] Our study differs from previous studies because we used accelerometer-measured PA reflecting not only leisure time PA (LTPA) but also all other PA domains. In addition, we used PA volume as a continuous variable and were able to evaluate the dose–response association between PA and future income. We found PA to be positively associated with income up to the current PA guidelines level and higher, but, at least in some cases, plateauing and declining income with extreme PA. This might suggest that the currently recommended PA level

TABLE 2 Association between accelerometer-measured PA with different intensity levels at age 46 and income at age 50 according to the polynomial regression analyses.

	Income 2016					
	All				Physically light work	Physically strenuous work
	(1)	(2)	(3)	(4)	(5)	(6)
Panel 1: Moderate-intensity physical activity (MPA) 2012						
MPA (β_1)	46.55**	232.8***	157.4***	137.4***	151.5*	118.1**
	(14.39)	(37.07)	(33.66)	(35.93)	(66.77)	(40.62)
MPA^2 (β_2)		−1.508***	−1.165***	−0.951***	−0.893	−0.877**
		(0.277)	(0.251)	(0.271)	(0.582)	(0.272)
Constant (c)	37135***	32624***	32581***	34906***	33250***	28554***
	(719.1)	(1094)	(1204)	(1653)	(2486)	(1991)
Observations (N)	3286	3286	3286	2797	1672	1125
R^2	0.003	0.012	0.196	0.247	0.221	0.127
Panel 2: Vigorous-intensity physical activity (VPA) 2012						
VPA (β_1)	205.8***	448.3***	364.8***	282.9***	300.0*	237.5*
	(45.84)	(88.62)	(80.20)	(85.88)	(118.1)	(118.0)
VPA^2 (β_2)		−6.445**	−5.950**	−4.575*	−4.040	−4.721
		(2.017)	(1.822)	(2.023)	(2.890)	(2.621)
Constant (c)	38513***	38104***	36042***	38402***	37295***	31657***
	(362.6)	(384.1)	(701.9)	(1289)	(1848)	(1484)
Observations (N)	3286	3286	3286	2797	1672	1125
R^2	0.006	0.009	0.196	0.246	0.221	0.122
Panel 3: Moderate-to-vigorous-intensity physical activity (MVPA) 2012						
MVPA (β_1)	56.14***	236.9***	164.4***	142.4***	149.2*	120.2**
	(13.18)	(35.91)	(32.61)	(34.70)	(61.38)	(39.55)
MVPA^2 (β_2)		−1.396***	−1.090***	−0.898***	−0.768	−0.836**
		(0.258)	(0.234)	(0.251)	(0.497)	(0.258)
Constant (c)	36521***	31935***	31972***	34515***	32978***	28360***
	(710.3)	(1104)	(1200)	(1640)	(2439)	(1964)
Observations (N)	3286	3286	3286	2797	1672	1125
R^2	0.005	0.014	0.197	0.248	0.222	0.127
Covariates						
Sex			×	×	×	×
Marital status 2012			×	×	×	×
High education 2012			×	×	×	×
Number of children under 18 years 2012			×	×	×	×
Physically strenuous work 2012				×		
Physically active at age 14				×	×	×
Discount factor 2012				×	×	×

Note: Robust standard errors are in parentheses. Columns (1)–(4) show the results of polynomial regression analyses for the whole study sample. Columns (1)–(2) show the association analyses of only the studied PA intensity levels, in linear and quadratic form, respectively. Column (3) shows the results after adjusting for sex, marital status, high education, and number of children <18 years old. Column (4) shows the results after adjusting for marital status, high education, number of children <18 years old, physically strenuous work, PA at age 14, and discount factor. Columns (5)–(6) show the results of polynomial regression analyses for the study sample divided into two groups: those classified into the physically strenuous work group, and those classified into the physically light work group, respectively. A participant was classified into physically strenuous work group if they reported engaging in at least one high-intensity physical task/activity when working often or very often, and into physically light work group otherwise. The results are adjusted for sex, marital status, high education, number of children <18 years old, PA at age 14, and discount factor. The level of statistical significance: ***$p<0.001$, **$p<0.01$, *$p<0.05$.

Abbreviations: MPA, moderate-intensity physical activity (3.0–6.0 MET); MVPA, moderate-to-vigorous -intensity physical activity (≥3.0 MET); VPA, vigorous-intensity physical activity (≥6.0 MET).

Source: NFBC1966 2012 & 2016.

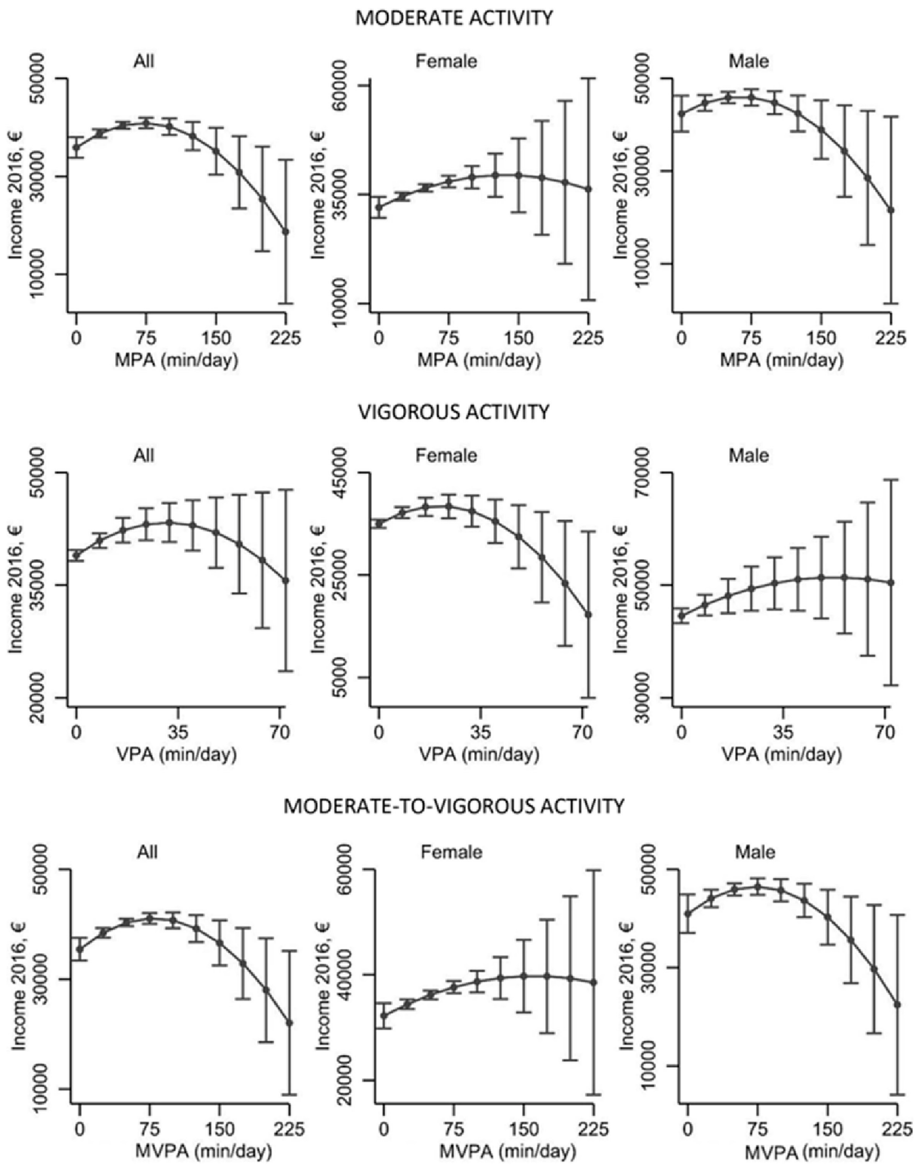

FIGURE 3 Adjusted predictions of the future income at age 50 for given levels of accelerometer-measured PA at age 46 with a pointwise 95% confidence intervals. Predictions are made with the values of model covariates (marital status, education level, number of children <18 years of age, physically strenuous work, history of childhood PA, and discount factor, and sex only in whole study population analyses), at their observed values and averaged across observations. The graphs were produced using Stata programs margins and marginsplot (StataCorp. Stata 17 Base Reference Manual. 2021. College Station, TX: Stata Press. https://www.stata.com/bookstore/base-reference-manual/). MPA, moderate physical activity; MVPA, moderate-to-vigorous physical activity; VPA, vigorous physical activity. *Source*: NFBC1966 2012 & 2016.

is profitable, but extreme PA levels might be harmful to productivity.

PA has been previously suggested to link to higher productivity and income through improved health.[4] Our findings reflect the earlier evidence of the curvilinear association between PA and health[9–11] and cardiovascular disease (CVD)-related[9,10] and all-cause mortality,[9] with the greatest PA-induced benefits at the beginning of the curve and absent additional benefits, that is, a declining curve after reaching a specific PA volume.[9–11] The amount of PA yielding the maximal health benefits has been reported in different studies to be in the range of current PA recommendations[10,12] or higher.[9–11] It would be rationalized that the PA–income association might be mediated via health[4] and the ability to work[14,15] benefits of PA. In a previous study of the NFBC1966, the costs of sick leaves lasting 11 days or longer and disability pensions from 2012 to 2020 were reported to be significantly higher among the physically inactive than the physically active.[35] This report supports our explanation of reduced sickness as the potential mechanism between PA and income benefits. However, the maximal mortality benefits

TABLE 3 Sex-specific association between accelerometer-measured PA with different intensity levels at age 46 and income at age 50 according to the polynomial regression analyses.

	Income 2016									
	Females					**Males**				
				Physically light work	**Physically strenuous work**				**Physically light work**	**Physically strenuous work**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Panel 1: Moderate-intensity physical activity (MPA) 2012										
MPA (β_1)	220.5***	144.0**	109.8*	142.1	68.87	120.0*	92.36	116.8	91.02	134.8
	(49.91)	(46.39)	(47.72)	(75.71)	(53.64)	(60.59)	(55.90)	(60.79)	(122.3)	(70.78)
MPA^2 (β_2)	−1.265**	−0.686	−0.405	−0.496	−0.350	−1.197**	−0.959**	−0.930*	−0.796	−1.028*
	(0.446)	(0.414)	(0.427)	(0.697)	(0.463)	(0.401)	(0.370)	(0.408)	(1.007)	(0.421)
Constant (c)	29 035***	25 636***	27 560***	24 345***	26 171***	42 266***	31 544***	32 100***	29 767***	23 925***
	(1278)	(1303)	(1681)	(2497)	(1902)	(1971)	(2001)	(3012)	(4697)	(3649)
R^2	0.017	0.162	0.205	0.161	0.165	0.010	0.162	0.219	0.154	0.068
Panel 2: Vigorous-intensity physical activity (VPA) 2012										
VPA (β_1)	456.4***	371.5***	335.9***	367.1**	284.2*	590.3***	340.4*	260.7	241.5	213.3
	(94.90)	(87.73)	(97.15)	(130.9)	(143.6)	(161.1)	(149.6)	(154.7)	(217.1)	(217.2)
VPA^2 (β_2)	−7.790***	−7.374***	−8.090**	−8.904**	−6.727	−7.977*	−4.095	−2.485	0.901	−4.130
	(2.238)	(2.067)	(2.548)	(3.238)	(4.415)	(3.512)	(3.253)	(3.312)	(5.246)	(4.117)
Constant (c)	34 372***	29 471***	30 811***	28 552***	28 078***	43 119***	32 420***	34 879***	31 562***	27 439***
	(421.7)	(665.0)	(1227)	(1745)	(1392)	(670.3)	(1065)	(2415)	(3492)	(2741)
R^2	0.012	0.160	0.203	0.157	0.167	0.012	0.160	0.219	0.161	0.056
Panel 3: Moderate-to-vigorous-intensity physical activity (MVPA) 2012										
MVPA (β_1)	186.3***	124.4**	94.06*	114.8	68.52	176.7**	130.9*	151.3*	130.0	143.4*
	(46.23)	(42.93)	(44.79)	(71.92)	(49.94)	(59.55)	(55.00)	(59.40)	(109.4)	(69.94)
MVPA^2 (β_2)	−0.871*	−0.496	−0.293	−0.329	−0.311	−1.370***	−1.067**	−1.038**	−0.848	−1.033*
	(0.384)	(0.356)	(0.375)	(0.619)	(0.403)	(0.384)	(0.354)	(0.386)	(0.832)	(0.408)
Constant (c)	29 320***	25 822***	27 839***	24 929***	26 078***	40 032***	30 074***	30 834***	28 246***	23 460***
	(1261)	(1285)	(1664)	(2492)	(1866)	(2002)	(2013)	(3000)	(4544)	(3628)
R^2	0.018	0.162	0.205	0.160	0.166	0.010	0.162	0.220	0.156	0.069
Covariates										
Marital status 2012		×	×	×	×		×	×	×	×
High education 2012		×	×	×	×		×	×	×	×
Number of children <18 years 2012		×	×	×	×		×	×	×	×
Physically strenuous work 2012			×					×		
Physically active at age 14			×	×	×			×	×	×
Discount factor 2012			×	×	×			×	×	×
Observations (N)	1927	1927	1643	995	648	1359	1359	1154	677	477

Note: Robust standard errors are in parentheses. Columns (1) and (6) show the association analyses only the studied PA intensity levels included. Columns (2) and (7) show the results after adjusting for marital status, high education, and number of children <18 years old. Columns (3) and (8) show the results after adjusting for marital status, high education, number of children <18 years old, physically strenuous work, PA at age 14, and discount factor. Columns (4), (5), (9), and (10) show the results separately for those with light and strenuous work according to sexes after adjusting for marital status, high education, number of children <18 years old, PA at age 14, and discount factor. A participant was classified into the physically strenuous work group if they reported engaging in at least one high-intensity physical task/activity when working often or very often, and into physically light work group otherwise. The results after adjusting for marital status, high education, number of children <18 years old, PA at age 14, and discount factor. The level of statistical significance: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

Abbreviations: MPA, moderate-intensity physical activity (3.0–6.0 MET); MVPA, moderate-to-vigorous -intensity physical activity (≥3.0 MET); VPA, vigorous-intensity physical activity (≥6.0 MET); y, years.

Source: NFBC1966 2012 & 2016.

of accelerometer-measured PA have been reported to occur at 24 min/day MVPA,[12] which is a much lower PA volume than our findings concerning MVPA volume associated with the highest income.

Another explanation for the curvilinear association between PA and income might be time allocation preferences. An individual decides how to allocate 24 h of the day to different time uses.[17] The excessive time used for PA reduces the time available for work or skills development and thus reduces possibilities for career advancements. It is possible that participating in PA is positively related to income by enhancing networking, teamwork skills, sociability, and discipline; this, in turn, promotes career development.[36] However, there is a turning point after which the additional time used for PA steals time from work and skills development so much that it might negatively affect career development, leading to decreased income.

In addition, at the whole study group level, we found linear associations among those doing physically light work for all PA intensity levels, and those doing physically strenuous work for VPA with midlife income. This reflects that the more MPA, VPA, and MVPA among those with physically light work and the more VPA among those with physically strenuous work, the better income. However, among females with physically light work MPA and MVPA had no association, and VPA had a curvilinear association with income, while we found no associations among males with physically light work. The probability of being physically active has been associated positively with occupational status[36] and negatively with job strain.[37] Because of our WTPA-grouping method, the physically light work group included both highly educated individuals with high income and probably high LTPA and blue-collar workers with lower education, lower income, physically light, but repetitional physically burdensome work and probably low LTPA. The heterogeneity of members of our physically light work group might annul the possible underlying PA—income—associations.

One notable feature is the difference between the results for females and males. Linear associations were observed among females for MPA and MVPA with income. Among males, the associations for MPA and MVPA with income were curvilinear. Females and males prefer different types of PA.[22] Therefore, one possible explanation for the divergent results may be the type of PA itself. For example, Finnish females typically participate more often in walking, cycling, and (home)gymnastics, whereas males participate more often in running, ball games, and gym training.[22] Accelerometer PA measurements have been studied in relation to energy expenditure while walking and running,[38] and the measured values are not directly applicable during tasks performed on skates, skis, or bicycles and in sports that are not performed on foot.[38] Some of the PA types favored by females might not be detected with an accelerometer, which might disturb our results. Moreover, PA preferred by males[22] is more often fixed according to time and place, whereas females' favorable PA types[22] are more often independent of time and place. Thus, among males, time allocation decisions might be a stronger mediator between PA and income than among females, and the excessive time used (MPA > 439.6 min/week or MVPA >510.9 min/week) for time- and place-fixed PA reduces the time available for work or skills development, thus reducing possibilities for income advancements. Among females, excessive time devoted to PA seems not to have a negative impact on future income because according to our results, the more MPA or MVPA, the higher income among females.

It is also possible that some unobserved, pre-existing variables could cause both high PA participation in adulthood and high midlife income.[36] Those variables, such as drive, motivation,[4] goal setting and reaching skills, lower value of leisure,[7] discipline, and confidence,[4,7] deal with time preference. To alleviate this problem, we used time preference as a covariate. In addition, the health effects of LTPA and WTPA have been reported to differ from each other.[11,23,39] The health benefits of PA have been suggested as limited only to LTPA,[40] while intense WTPA has been reported to have no health benefits[11] or as associated with an increased risk of long-time sick leaves[40] and CVD-related[39] and all-cause mortality,[23,39] even after adjustments for other confounding factors (socioeconomic status, LTPA, and a healthy lifestyle).[39] We used physically strenuous work as a covariate to alleviate the possible different effects of WTPA and LTPA. We found curvilinear associations between VPA and income in the analysis of the entire study sample but linear associations among both subgroups of participants with physically light and strenuous work. Adding time preference together with physically strenuous work and PA at age 14 to the models discharged the linear association seen in the non-adjusted model between VPA and income among males, while the association was curvilinear among females, and other results remained similar. Among females doing physically strenuous work, VPA had a linear association with income and among females with physically light work, VPA had a curvilinear association with income. Among males with physically strenuous work, MPA and MVPA had curvilinear associations with midlife income and VPA and among males with physically light work any PA intensity had no associations with income. We could not verify the quality and distributions of PA (LTPA/WTPA), which may disrupt our results.

In cross-sectional settings, income has been suggested to have an association with and even a causal effect on PA participation.[21] To avoid reverse causality, or at least to minimize its effect, the PA data were collected in 2012 (at age 46 of participants) and the income data were collected in 2016 (at age 50 of participants), and income data in 2012 were not utilized. Currently, the latest available information regarding NFBC1966 cohort members' income is available at 50 years of age. Most of the previous studies concerning associations between PA and future income have used >10 years of follow-up times,[3,6,7] but 9 years,[4] and 1 year[8] follow-up times have also been used.

Our study had several strengths. First, potential biases from self-reported assessments were avoided by using accelerometer-measured PA and register-based income and covariates. Second, a comprehensive set of covariates alleviated the effect of unobserved underlying factors on the results. Third, because the participants were born around the same year and the information on participants' taxable income was drawn in 2016 when all the participants were 50 years old, any risk of bias arising from macroeconomic fluctuation or age affecting income was low. Fourth, our un-selected population-based data represented individuals from all sectors of the economy and occupations. Fifth, by using a population-based study design, we avoided sample bias. Finally, our large, systematically collected, high-quality follow-up data, combined with extensive Finnish registers, offered the possibility of multidisciplinary research that could generate new insights.

Our study also had some limitations. Our study protocol, 4 years of follow-up time and 1 year (2016) of income data, did not allow us to show evidence of the long-term relationship between PA and income or changes in these. Because of the short follow-up time, reverse causation is also possible. Even if we tried to minimize the underestimation of PA by including only the participants' accelerometer wearing days with ≥10 h to the analyses, there is a possibility of underestimating the amount of PA because of the accelerometer used. Accelerometer PA measurements have been studied in relation to energy expenditure while walking and running,[38] and the measured values were not directly applicable during tasks performed on skates, skis, or bicycles and in sports not performed on foot.[38] Additionally, the used accelerometer did not measure water-based activities at all. Furthermore, including the total employed study population despite their health status generated some problems. While a curvilinear association between PA and health consequences has been seen in healthy adults and individuals with elevated cardiovascular risk factors, some studies have found a linear association between PA and mortality in CVD patients.[11] Therefore, including CVD patients in the study might have affected the results concerning the extent of the association between PA and income. Moreover, although more than 85% of the original cohort members were alive in Finland during the latest follow-up, only 27.1% participated and provided valid accelerometer data, in addition to other data needed for the present study—possibly those who were healthier and more active. This might induce selection bias and limit the generalizability of the results.

According to our study, it seems to be beneficial, from the productivity, in this case income maximization, perspective, to support individuals to be physically active at least up to the current recommended PA level. However, we showed that increasing PA much higher than the current PA guidelines is not always optimal. We found that, after a certain point, additional PA may be related to lower income. The negative health effects of excessive PA, decisions concerning time allocation, or occupational sorting are the possible mediators between extreme PA and decreasing income.

5 | CONCLUSIONS

In this population-based study, we showed a curvilinear association between accelerometer-measured adulthood MPA, VPA, and MVPA and midlife income. The association was strongest at the beginning of the curve, and the highest income benefits occurred at 505.4 min/week MPA, 216.4 min/week VPA, and 555.0 min/week MVPA when viewed at the level of the entire middle-aged employed population-based study group.

6 | PERSPECTIVE

From the health[1,2,9–11] and productivity[3,4,6–8] perspective, it seems beneficial to be physically active—at least up to current recommended PA levels. However, extreme PA might not be optimal from both the health[9–11] and income perspectives. According to our results, increasing PA at least up to recommended PA levels is associated with increasing income, but when viewed at the level of the middle-aged employed population-based study group, additional MPA beyond 505.4 min/week, VPA beyond 216.4 min/week, and MVPA beyond 555.0 min/week are related to lower income. Among the NFBC1966 members of whom the accelerometer-measured PA data at age 46 were available, 10.7% exceeded MPA of 505.4 min/week, 1.1% exceeded VPA of 216.4 min/week, and 9.9% exceeded MVPA of 555.0 min/week.

AUTHOR CONTRIBUTIONS

Hanna Junttila: Conceptualization, Methodology, Investigation, Data curation, Mathematical calculations, Writing—original draft, Writing—review and editing, Visualization. Mikko Vaaramo: Conceptualization, Methodology, Formal analysis, Data curation, Writing—review and editing, Visualization. Sanna Huikari: Conceptualization, Methodology, Investigation, Writing—review andediting, Visualization. Jaana Kari: Conceptualization, Methodology, Writing—review and editing. Anna-Maiju Leinonen: Data curation, writing—review and editing. Vahid Farrahi: Resources, Data curation—Hookie accelerometer AM20 (Traxmeet Ltd., Espoo, Finland), Writing—review and editing. Raija Korpelainen: Conceptualization, Investigation, Resources, Writing—review and editing, Supervision, Project administration, Funding acquisition. Marko Korhonen: Conceptualization, Methodology, Writing—review and editing, Supervision, Project administration.

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CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

The data for this article were obtained from the population-based Northern Finland Birth Cohort 1966 (NFBC1966). The NFBC1966 data set comprises health-related participant data, and their use is therefore restricted under the regulations on professional secrecy (Act on the Openness of Government Activities, 612/1999) and sensitive personal data (Personal Data Act, 523/1999, implementing the EU data protection directive 95/46/EC). Due to these legal restrictions, the data from this study cannot be stored in public repositories or otherwise be made publicly available. However, data access may be permitted on a case-by-case basis upon request. Data sharing outside the research group is done in collaboration with the NFBC1966 group and requires a data-sharing agreement with the NFBC1966 representatives (NFBC1966, University of Oulu, https://www.oulu.fi/en/university/faculties-and-units/faculty-medicine/northern-finland-birth-cohorts-and-arctic-biobank).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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