OPEN

The Individual-Level Productivity Costs of Physical Inactivity

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ABSTRACT

KARI, J. T., I. NERG, S. HUIKARI, A.-M. LEINONEN, M. NURKKALA, V. FARRAHI, R. KORPELAINEN, and M. KORHONEN. The Individual-Level Productivity Costs of Physical Inactivity. *Med. Sci. Sports Exerc.*, Vol. 55, No. 2, pp. 255–263, 2023. **Purpose:** This study estimated the long-term individual-level productivity costs of physical inactivity. **Methods:** The data were drawn from the Northern Finland Birth Cohort 1966, to which the productivity cost variables (sick leaves and disability pensions) from Finnish registries were linked. Individuals (N = 6261) were categorized into physical activity groups based on their level of physical activity, which was measured in three ways: 1) self-reported leisure-time moderate- to vigorous-intensity physical activity (MVPA) at 46 yr old, 2) longitudinal self-reported leisure-time MVPA at 31–46 yr old, and 3) accelerometer-measured overall MVPA at 46 yr old. The human capital approach was applied to calculate the observed costs (years 2012–2020) and the expected costs (years 2012–2031). **Results:** The results showed that the average individual-level productivity costs were higher among physically inactive compared with the costs among physically active. The results were consistent regardless of the measurement type of physical activity or the period used. On average, the observed long-term productivity costs among physically inactive individuals were €1900 higher based on self-reported MVPA, €1800 higher based on longitudinal MVPA, and €4300 higher based on accelerometer-measured MVPA compared with the corresponding productivity costs among physically active individuals. The corresponding difference in the expected costs was €2800, €1200, and €8700, respectively. **Conclusions:** The results provide evidence that productivity costs differ according to an individual's level of physical activity. Therefore, investments in physical activity may decrease not only the direct healthcare costs but also the indirect productivity costs paid by the employee, the employer, and the government. **Key Words:** INDIRECT COSTS, PHYSICAL ACTIVITY, ACTIVITY MONITOR, HUMAN CAPITAL APPROACH, COHORT STUDY, REGISTER-BASED DATA

In recent years, there has been growing research interest in the economic costs that may be attributed to physical inactivity. Typically, studies on this topic examine either the direct healthcare costs or the indirect productivity costs of physical inactivity. In sum, it is estimated that the annual direct cost attributable to physical inactivity ranges from 0.3% to 4.6% of the national healthcare expenditure (1–5). At the global level, it is estimated that the direct and the indirect costs of physical inactivity in 2013 amounted to around $68 billion (1).

In addition to the direct healthcare costs, the indirect productivity costs of physical inactivity have been examined (1,6–8). Typically, studies aiming to investigate such costs calculate them using one of two methods—namely, the friction cost approach (FCA) or the human capital approach (HCA) (2). The FCA demonstrates the employers' perspective on the costs, whereas the HCA focuses on employees' perspective related to the same costs (9). As one example of such research, Ding

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et al. (1) calculated these costs using FCA. The costs consisted of productivity costs due to physical inactivity-related deaths, and the aggregate-level prevalence of physical inactivity was drawn from self-reported surveys. As a result, they found that the global indirect cost stemming from physical inactivity in 2013 was approximately $13.7 billion (INT$) (1). Another recent study examined not only the costs attributable to physical inactivity but also the costs attributable to excess weight and smoking across British Columbia in 2013 (7). The physical inactivity rates were based on self-reports, in which individuals were categorized as physically inactive if their leisure-time daily energy expenditure was less than 1.5 kcal·kg^{-1}. In total, the indirect costs attributable to physical inactivity, smoking, and excess weight using the HCA and FCA methods were $3756 and $238 million, respectively (7). Finally, using the HCA method, the indirect costs of physical inactivity in China were shown to be approximately US$3.3 billion in 2007 (8). These costs included the costs of illness, injury-related work disability, and premature deaths stemming from five noncommunicable diseases (8). Similarly as Ding et al. (1) and Krueger et al. (7), the study used an aggregate-level information on physical inactivity, which was based on self-reports; individuals were categorized as physically inactive if the recommended level of physical activity for health was not reached (8).

Taken together, the estimated indirect costs have varied substantially depending on the chosen approach, time horizon, and other methodological considerations (2). The costs have mostly been calculated using population attributable fractions. This means that the productivity costs are calculated for all-cause mortality or for certain diseases linked to physical inactivity as an outcome (e.g., coronary heart disease, stroke, hypertension, colon cancer, breast cancer, and type 2 diabetes) (1,2). Following this, methods such as HCA and FCA have been applied to calculate the indirect productivity costs. Regarding physical inactivity levels, most previous studies have used aggregate-level information on the prevalence of physical inactivity based on self-reported data (1,2,7,8). Therefore, less is known about the individual-level productivity costs of physical inactivity. In addition, information about the productivity costs that are calculated using device-based measures of physical activity apart from self-reported measures is limited (2). Finally, to our knowledge, no previous studies have examined productivity costs using longitudinal information on physical activity.

In this study, we address the existing research gap and examine the individual-level long-term productivity costs of physical inactivity using the HCA method. The study augments the previous literature in three ways: First, the productivity costs are calculated using individual-level information on physical activity, including both self-reported and accelerometer-measured physical activity. Of these, self-reported physical activity reflects leisure-time physical activity, whereas accelerometer-measured physical activity depicts overall daily physical activity. Second, the costs are calculated using longitudinal information on self-reported physical activity. Finally, the variables reflecting productivity costs—that is, information on sick leaves and disability pensions—are drawn from Finnish registries. This mitigates the possible measurement error in the outcome variable. We hypothesize that the individual-level productivity costs are higher among physically inactive compared with their physically more active counterparts. If the results are as hypothesized, this highlights the importance of investing in programs that could push individuals toward a physically more active lifestyle. This could further improve individuals' work ability, providing both personal and societal benefits. From a policy perspective, higher physical activity levels could decrease the productivity costs paid by the employers and the society.

METHODS

Study population. A study sample consisting of 6261 participants was drawn from the Northern Finland Birth Cohort 1966 (NFBC1966; University of Oulu, 1966) (10), to which the variables illustrating individual-level productivity costs, including sick leaves and disability pensions, were linked from the two following Finnish registries: 1) the Social Insurance Institution of Finland (SII) and 2) the Finnish Centre for Pensions (FCP).

The NFBC1966 is an ongoing population-based study in which the cohort members (originally N = 12,058) have been monitored from the prenatal period onwards. The participants and their parents have given written informed consent before participating in the NFBC1966 study. So far, follow-ups have been conducted at 1, 14, 31, and 46 yr of age (see Nordström et al. [11] for additional information about the follow-ups, attrition analyses, and the representativeness of the NFBC1966 study). The present study uses data collected at 31 and 46 yr of age (see Supplemental Fig. 1, Supplemental Digital Content, Flow chart of the study sample, http://links.lww.com/MSS/C714). The follow-up study at 46 yr of age was conducted under the Declaration of Helsinki and approved by the Ethical Committee of the Northern Ostrobothnia Hospital District in Oulu, Finland (94/2011).

Register-based data. Individual-level data from Finnish registers were provided by the NFBC1966. In addition to the individual-level sick leaves and disability pensions data from SII and FCP, annual information on occupational status and the level of education was provided for each NFBC1966 participant by Statistics Finland. To discount all monetary values into 2019 euros, the monetary value multiplier from Statistics Finland and the annual data on gross domestic product (GDP) growth in Finland from the World Bank were used. For a more detailed description of the register-based data collection protocol, see Rissanen et al. (9).

Self-reported leisure-time physical activity. Self-reported leisure-time physical activity was assessed using the same questionnaire at 31 and 46 yr of age. Participants were asked how often and for how long at a time they participated in moderate- to vigorous-intensity physical activity (MVPA) during their leisure time (see Supplemental Table 1, Supplemental Digital Content, Questions on leisure-time physical activity, http://links.lww.com/MSS/C714) (12). By multiplying the frequency and duration by each other, the data were expressed as weekly minutes of physical activity. For the analysis, the participants were further divided into two groups according to whether they met the current physical activity recommendations for health at 46 yr of age (at least 150 min of MVPA throughout the week): 1) physically inactive (MVPA <150 min·wk^{-1}) and 2) physically active (MVPA ≥150 min·wk^{-1}) (13).

For longitudinal information on self-reported leisure-time physical activity, the four following groups were formed according to whether physical activity recommendations for health were reached at 31 and 46 yr of age: 1) stable inactive (MVPA <150 min·wk^{-1} at both ages), 2) decreasingly active (MVPA ≥150 min·wk^{-1} at 31 yr of age but <150 min·wk^{-1} at 46 yr of age), 3) increasingly active (MVPA <150 min·wk^{-1} at 31 year of age but ≥150 min·wk^{-1} at 46 yr of age), and 4) stable active (MVPA ≥150 min·wk^{-1} at both ages).

Accelerometer-measured physical activity. At 46 yr of age, in addition to self-reports, the overall daily physical activity of those study participants attending the clinical examination was measured using a waist-worn triaxial accelerometer (Hookie AM20; Traxmeet Ltd., Espoo, Finland) continuously for 2 wk. The participants were advised to wear the accelerometer during all waking hours except when engaged in water-based activities. The accelerometer was set to measure and store raw acceleration signals at 100 Hz. Raw acceleration data were segmented into 6-s epochs, and the mean amplitude deviation (MAD) of the resultant acceleration was calculated for each segment (14). Moderate-intensity physical activity (3–5.99 METs) and vigorous-intensity physical activity (≥6 METs) were identified based on a previously validated threshold set for MAD values (14), and the time spent at each activity level (min·d^{-1}) was calculated by dividing the total time by the number of valid days. The triaxial hip-worn accelerometer, together with the MAD approach, has been validated against other measurement methods in several studies (14,15).

For the statistical analysis, the overall amounts of time spent in moderate-intensity and vigorous-intensity physical activity were combined, after which the participants were divided into tertiles according to their MVPA time (low MVPA, medium MVPA, and high MVPA). To be eligible for the analyses, the accelerometer had to be used for at least four valid days, with a valid day being one with at least 600 min of accelerometer wearing time per day. The nonwearing time was detected based on a previously validated approach for count-based accelerometer data, as described elsewhere (16).

Productivity costs. Individual-level long-term productivity costs were estimated using data on sick leaves and disability pensions collected from the SII and FCP registers. We collected all data on sick leaves (including rehabilitation support) and disability pensions in the period of 2012–2020. The productivity costs were estimated with the absent days from work multiplied by the daily value of production. All costs were presented in euros and in 2019 monetary value.

Statistical analyses. The HCA method was applied to calculate the individual-level indirect productivity costs. The daily value of production was estimated from the median wages of the specific occupational groups in the Finnish population of the same age (born in 1965–1967), stratified by sex. Thereafter, these occupation-specific values were adjusted for future labor force participation by considering the proportion of life disability-free (PLDF), national unemployment rate, and the overall decline of work ability in the NFBC1966 population. These adjustments were based on Rissanen et al. (9) and Targoutzidis (17). The productivity costs (PC) in the HCA model were estimated as follows:

$$\mathrm{PC} = \text{daily value of production} \times t \times \mathrm{PLDF} \times (1-u) \times \mathrm{WAD},$$

where t is the time of absence in days, PLDF is the disability-free life expectancy divided by life expectancy, WAD is the estimated coefficient of overall decline of work ability in NFBC1966, and u is the national annual unemployment rate in Finland. The population-level data, including PLDF and national annual unemployment rates, were obtained from the open-access materials of the Finnish Institute for Health and Welfare (https://sotkanet.fi/sotkanet/en/index) and from Statistics Finland (https://www.stat.fi/index_en.html). The median wages of specific occupational groups in the Finnish population were obtained from FOLK personal data modules (https://www.stat.fi/tup/mikroaineistot/aineistot_en.html).

The costs included the observed and the expected productivity costs. The observed productivity costs were calculated for the years 2012–2020, and the costs consisted of the actual (observed) costs of sickness absences and disability pensions. The expected productivity costs, in turn, were calculated until 2031, which is the expected retirement year of the NFBC1966 participants. More precisely, the expected costs were calculated for the years 2012–2031, and in addition to the observed productivity costs of sickness absences and disability pensions until 2020, the costs consisted of the expected costs of permanent disability pensions until the retirement age (until 2031).

As an additional analysis, the HCA method was used in two subsamples. First, the productivity costs were calculated for a subsample, which consisted of individuals who had poor perceived health when physical activity was measured. Physical inactivity is a known risk factor for several noncommunicable diseases and premature mortality (13,18). By contrast, poor health is shown to be related to higher amounts of sickness absences (19), and higher amounts of sickness absences are shown to be a risk factor for future disability pensions (20). Therefore, we can suggest that those who have poor perceived health may have a higher probability of sick leaves and disability pensions. An open question is whether and how the productivity costs among those with poor perceived health vary according to physical activity level.

Second, productivity costs were calculated for a low-education subsample. Education is highly correlated with labor market outcomes (21,22). For example, lower education is related to an approximately a half a million euro decrease in lifetime earnings (21). At the same time, from the employers' and the societal perspective, this may lead to lower productivity costs because of sick leaves and disability pensions. An open

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TABLE 1. Descriptive statistics of the study sample.

	Source	Mean (SD) Combined	Mean (SD) Males	Mean (SD) Females	*P*
Self-reported leisure-time MVPA at 31 yr of age (min·wk^{-1})	NFBC1966	94 (112)	102 (123)	87 (102)	<0.001
Self-reported leisure-time MVPA at 46 yr of age (min·wk^{-1})	NFBC1966	115 (120)	111 (120)	118 (120)	0.015
Longitudinal self-reported leisure-time MVPA	NFBC1966				<0.001
Stable inactive		57.9%	56.8%	58.7%	
Decreasingly active		12.6%	13.9%	11.5%	
Increasingly active		18%	15.7%	19.8%	
Stable active		11.6%	13.7%	10.0%	
Accelerometer-measured overall MVPA at 46 yr of age (min·d^{-1})	NFBC1966	47 (25)	51 (28)	43 (23)	<0.001
Sick days (2012–2020)	SII	56 (126)	46 (112)	65 (136)	<0.001
Disability pension, days in 2012–2020	FCP	55 (299)	51 (293)	58 (304)	0.188
At least tertiary education (%)	NFBC1966	30.0	27.1	32.3	<0.001
Poor perceived health in 1997 (%)	NFBC1966	29.7	29.7	29.8	0.932
Poor perceived health in 2012 (%)	NFBC1966	32.9	34.6	31.5	0.012

P values for gender differences (*t*-test, ANOVA, or chi-squared test).
NFBC1966, Northern Finland Birth Cohort 1966; SII, Social Insurance Institution of Finland; FCP, Finnish Centre for Pensions.

question is whether and how the productivity costs among those with low levels of education vary according to physical activity level. These additional analyses focused on observed productivity costs, that is, the costs over the period of 2012–2020.

Before the HCA analysis, the correlation coefficients were calculated to illustrate the unconditional association between different measures of physical activity (self-reported leisure-time MVPA, longitudinal self-reported leisure-time MVPA, and accelerometer-measured overall MVPA) and productivity cost measures (sick leaves and disability pensions). All analyses were conducted using R version 4.1.2 (2021-11-01), and the analyses were based on complete cases; that is, the analyses included only individuals who had no missing data on each physical activity variable of interest.

RESULTS

Descriptive evidence. Table 1 reports the descriptive statistics of the study sample. According to physical activity measures, the self-reported leisure-time MVPA at 31 yr of age, longitudinal self-reported leisure-time MVPA between 31 and 46 yr of age, and accelerometer-measured overall MVPA were higher among males compared with females, whereas self-reported leisure-time MVPA at 46 yr of age was higher among females compared with males. Regarding productivity cost measures in the years 2012–2020, on average, females had more sick days compared with males ($P < 0.001$). However, no sex-specific differences were observed in the number of disability pension days. According to the correlation coefficients (Table 2), each physical activity measure (self-reported leisure-time MVPA at 31 and 46 yr of age and accelerometer-measured overall MVPA) was negatively related to sick leaves and disability pensions.

Self-reported leisure-time MVPA and productivity costs. Table 3 presents the average productivity costs for self-reported leisure-time MVPA at 46 yr of age. According to the results, the average productivity costs in the years 2012–2020 were higher among physically inactive individuals compared with physically active. For example, the average productivity costs of physically inactive individuals were €9300 (€8900 among males and €9600 among females). The corresponding productivity costs among physically active individuals were approximately €2000 lower, with the costs being €6600 among males and €8000 among females. In general, the productivity costs in all model specifications were higher among females than among males.

Regarding the expected productivity costs until the retirement age (Table 3, right-hand side), the costs were higher among physically inactive than among physically active individuals. On average, among physically inactive individuals, the expected productivity costs were €14,200 (€14,300 among males and €14,100 among females), whereas the corresponding costs among physically active individuals were €11,400 (€10,600 among males and €12,000 among females).

Longitudinal self-reported leisure-time MVPA and productivity costs. The average productivity costs based on longitudinal self-reported leisure-time MVPA are reported in Table 4. In general, despite the time period used (2012–2020 vs

TABLE 2. Correlation coefficients of physical activity and productivity cost measures.

	Self-Reported Leisure-Time MVPA at 31 Yr Old (min·wk^{-1})	Self-Reported Leisure-Time MVPA at 46 Yr Old (min·wk^{-1})	Accelerometer-Measured Overall MVPA at 46 Yr Old (min·d^{-1})	Sick Leaves (2012–2020)	Disability Pension (2012–2020)
Self-reported leisure-time MVPA at 31 yr old (min·wk^{-1})	1.000				
Self-reported leisure-time MVPA at 46 yr old (min·wk^{-1})	0.325***	1.000			
Accelerometer-measured overall MVPA at 46 yr old (min·d^{-1})	0.162***	0.286***	1.000		
Sick leaves (2012–2020)	−0.026*	−0.031*	−0.056***	1.000	
Disability pension (2012–2020)	−0.027*	−0.028*	−0.060***	0.423***	1.000

Combined sample of females and males.
*Significance at the 0.05 level.
**Significance at the 0.01 level.
***Significance at the 0.001 level.

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TABLE 3. The individual-level long-term productivity costs in Euros based on self-reported leisure-time MVPA at 46 yr old.

	HCA	
	Years 2012–2020 (Observed)	Years 2012–2031 (Expected)
Panel A: pooled (n = 5906)		
Physically inactive (n = 4160)	9300	14,200
Physically active (n = 1746)	7400	11,400
Panel B: males (n = 2607)		
Physically inactive (n = 1845)	8900	14,300
Physically active (n = 762)	6600	10,600
Panel C: females (n = 3299)		
Physically inactive (n = 2315)	9600	14,100
Physically active (n = 984)	8000	12,000

In the HCA, the daily value of production is estimated by the median wage of specific occupational groups in the Finnish population of the same age (born between years 1965 and 1967), stratified by sex. The HCA estimate is adjusted with future labor force participation. All costs are presented in 2019 value.
The cutoff for adequate level of MVPA for health is ≥150 min·wk^{-1}. The term "physically inactive" is used if the weekly MVPA <150 min, and the term "physically active" when the weekly MVPA ≥150 min.

2012–2031) or sex, the productivity costs were highest among stable inactive individuals. For example, the average productivity costs in the years 2012–2020 were €9700 among stable inactive individuals (€9600 among males and €9900 among females). During the same period, the average productivity costs of stable active individuals, in turn, were €7900 (€7500 among males and €8300 among females). Regarding the expected productivity costs up to retirement age (2012–2031), the costs among stable inactive and stable active individuals were, on average, €15,100 (€15,500 among males and €14,800 among females) and €13,900 (€13,400 among males and €14,500 among females), respectively.

Accelerometer-measured overall MVPA and productivity costs. Table 5 reports the average productivity costs according to accelerometer-measured overall MVPA at 46 yr of age. In line with the results based on self-reported leisure-time MVPA at 46 yr of age, the average productivity costs were highest among individuals with low levels of MVPA. The results remained the same regardless of the time period used (2012–2020 vs 2012–2031) or whether focusing on the pooled sample of females and males, males only, or females only. For example, among individuals with low MVPA, the observed average productivity costs were €10,800 (€12,200 among males and €10,100 among females). At the same time, the costs among individuals with high MVPA were approximately €4300 lower, with the costs being €6500 (pooled sample), €5200 (among males), and €7700 (among females). When focusing on the expected productivity costs (years 2012–2031), the costs among individuals with low MVPA were €17,800 (€21,000 among males and €16,100 among females), whereas the costs among those with high MVPA were €9,100 (€7,700 among males and €10,400 among females).

TABLE 4. The individual-level productivity costs in Euros based on longitudinal self-reported leisure-time MVPA between 31 and 46 yr old.

	HCA	
	Years 2012–2020 (Observed)	Years 2012–2031 (Expected)
Panel A: pooled (n = 5906)		
Stable active (n = 672)	7900	13,900
Stable inactive (n = 3354)	9700	15,100
Increasingly active (n = 1042)	7100	9700
Decreasingly active (n = 728)	7400	11,000
Panel B: males (n = 2607)		
Stable active (n = 350)	7500	13,400
Stable inactive (n = 1455)	9600	15,500
Increasingly active (n = 402)	5800	8400
Decreasingly active (n = 356)	6200	10,200
Panel C: females (n = 3299)		
Stable active (n = 322)	8300	14,500
Stable inactive (n = 1899)	9900	14,800
Increasingly active (n = 640)	7900	10,600
Decreasingly active (n = 372)	8400	11,700

In HCA, the daily value of production is estimated by the median wages of specific occupational groups in Finnish population of the same age-group (born between years 1965 and 1967), stratified by sex. The HCA estimate is adjusted with future labor force participation. All costs are presented in 2019 value.
Physical activity groups between 31 and 46 yr of age are formulated as follows: 1) stable inactive if MVPA <150 min·wk^{-1} at both ages, 2) decreasingly active if MVPA ≥150 min·wk^{-1} at 31 yr old but <150 min·wk^{-1} at 46 yr old, 3) increasingly active if MVPA ≤150 min·wk^{-1} at 31 yr old but >150 min at 46 yr old, and 4) stable active if MVPA ≥150 min·wk^{-1} at both ages.

TABLE 5. The individual-level productivity costs in Euros based on accelerometer-measured overall MVPA at 46 yr old.

	HCA	
	Years 2012–2020 (Observed)	Years 2012–2031 (Expected)
Panel A: pooled (n = 5906)		
Low MVPA (n = 1446)	10,800	17,800
Medium MVPA (n = 1467)	7300	11,300
High MVPA (n = 1506)	6500	9100
Panel B: males (n = 2607)		
Low MVPA (n = 510)	12,200	21,000
Medium MVPA (n = 616)	8300	13,600
High MVPA (n = 743)	5200	7700
Panel C: females (n = 3299)		
Low MVPA (n = 936)	10,100	16,100
Medium MVPA (n = 851)	6500	9700
High MVPA (n = 763)	7700	10,400

In the HCA, the daily value of production is estimated by the median wage of specific occupational groups in the Finnish population of the same age (born between years 1965 and 1967), stratified by sex. The HCA estimate is adjusted with future labor force participation. All costs are presented in 2019 value.
Participants were divided into tertiles according to their accelerometer-measured overall MVPA time: low MVPA, medium MVPA, and high MVPA.

Productivity costs according to perceived health and level of education. In the additional analysis, the observed productivity costs of physical inactivity were calculated for the following two subsamples: 1) those with poor perceived health at the time when physical activity was measured

TABLE 6. The individual-level productivity costs in Euros based on self-reported leisure-time MVPA at 46 yr old.

	HCA with Poor Perceived Health, Years 2012–2020 (Observed)		HCA with Low Level of Education, Years 2012–2020 (Observed)	
	N	PC	N	PC
Panel A: pooled				
Physically inactive	1625	15,500	2781	10,100
Physically active	291	15,800	1111	7100
Panel B: males				
Physically inactive	757	14,500	1268	9900
Physically active	130	13,800	482	5700
Panel C: females				
Physically inactive	868	16,300	1513	10,400
Physically active	161	17,500	629	8100

The cutoff for adequate level of MVPA for health is ≥150 min·wk^{-1}. The term "physically inactive" is used if the weekly MVPA <150 min, and the term "physically active" when the weekly MVPA ≥150 min. PC = productivity costs.
All costs are presented in 2019 value.

and 2) those with low levels of education. Table 6 reports the results based on self-reported leisure-time MVPA at 46 yr of age. The corresponding results for longitudinal self-reported leisure-time MVPA and accelerometer-measured overall MVPA are presented in the Supplemental Tables 2 and 3 (see Supplemental Table 2, Supplemental Digital Content, Individual level productivity costs in Euros based on longitudinal self-reported leisure-time MVPA between ages 31 and 46, http://links.lww.com/MSS/C714; and Supplemental Table 3, Supplemental Digital Content, Individual level productivity costs in Euros based on accelerometer-measured overall MVPA at age 46, http://links.lww.com/MSS/C714).

The results that focused on individuals with poor perceived health showed slightly higher productivity costs among physically inactive males compared with physically active males (Table 6, left-hand side, panel B). Among females, in turn, the average productivity costs were higher among those who were physically active compared with those who were physically inactive. Similar findings were observed regarding accelerometer-measured overall MVPA (see Supplemental Table 3, Supplemental Digital Content, http://links.lww.com/MSS/C714): Among males, the average productivity costs were highest among individuals with low MVPA compared with other physical activity groups. On average, the productivity costs among those with low MVPA were €21,300, whereas the corresponding costs among individuals with high MVPA were €7100. Among females, in turn, the productivity costs were higher among individuals with high MVPA compared with the costs among those with low MVPA (see Supplemental Table 3, left-hand side, Panel C, Supplemental Digital Content, http://links.lww.com/MSS/C714). Regarding longitudinal self-reported leisure-time MVPA, the results were less clear-cut. Among males, the productivity costs were highest among stable active individuals (see Supplemental Table 3, left-hand side, Panel B, Supplemental Digital Content, http://links.lww.com/MSS/C714). Among females, in turn, the productivity costs were lower among stable active compared with stable inactive with the costs being highest among increasingly active individuals (see Supplemental Table 2, left-hand side, Panel C, Supplemental Digital Content, http://links.lww.com/MSS/C714). On average, the productivity costs among stable active females with poor perceived health were €14,600, whereas the costs, for example, among stable inactive were €15,800.

The analysis that focused on individuals with a low level of education (Table 6, right-hand side, Supplemental Tables 2 and 3, right-hand side, Supplemental Digital Content, http://links.lww.com/MSS/C714) indicated that the average productivity costs were higher among physically inactive individuals compared with the costs among physically active. The results remained constant regardless of sex or the measurement type of physical activity (Table 6, and Supplemental Tables 2 and 3, Supplemental Digital Content, http://links.lww.com/MSS/C714). As shown in Table 6, on average, the observed productivity costs among physically inactive individuals with a low level of education were €10,100 (€9,900 among males and €10,400 among females), whereas the corresponding costs for physically active were €7,100 (€5,700 among males and €8,100 among females).

DISCUSSION

In summary, this study used a population-based cohort study including register-based information on individuals' sick leaves and disability pensions to investigate the individual-level productivity costs of physical inactivity. The results showed that regardless of the used period or the physical activity measure, the average productivity costs were higher among physically inactive individuals compared with the productivity costs among physically active individuals. On average, the observed individual-level productivity costs among physically inactive individuals were €1900 higher based on self-reported leisure-time MVPA, €1800 higher based on longitudinal self-reported leisure-time MVPA, and €4300 higher based on accelerometer-measured overall MVPA compared with the productivity costs among physically active individuals. The corresponding differences in the expected costs between physically inactive and physically active individuals were €2800, €1200, and €8700, respectively.

A recent systematic review summarized the existing studies focusing on the economic burden of physical inactivity (2). Of the 40 eligible studies, 27 focused on direct healthcare costs, and 13 also estimated indirect productivity cost. Of these, 10 studies applied the HCA method. In brief, the yearly aggregate-level productivity costs varied, for example, from $13.7 billion (INT$) at the global level (1) to US$3.3 billion in China (8), $3.7–4.3 billion in Canada (3,23), and $673.5 million in British Columbia (7). Although the HCA method has been applied previously, it has mostly been implemented using the population attributable fraction approach, which produces aggregate-level productivity costs. In addition, the level of physical activity has been defined differently across studies (2). Therefore, the comparison between the earlier findings and ours is not straightforward. Nevertheless, our findings add to the current literature by showing that the long-term individual-level productivity costs differ according to the level of physical activity.

In general, the HCA method used in the present study takes an employee's perspective, which means that the results depicted the individual-level productivity losses due to absences from work (24). These losses are, for example, reductions in earnings because of absences. This means that productivity losses occur to individual employees. However, in reality, in countries like Finland, and in many other developed nations, the employee's productivity losses are covered by the employer and society; that is, the employer and society pay for sickness absences and disability pensions (25–27). According to Finnish legislation, for example, the employer is responsible for paying an employee a full wage for the first 10 d of sickness absence (27). Sickness absences lasting longer than 10 d and early retirements due to disability, in turn, are covered by the SII (25,26). Reductions in earnings may also decrease tax revenues received by the government. Therefore, it is important to bear in mind that although the results of the present study show individual-level costs, there are also other indirect costs that arise due to these absences that are paid for by the employer and society.

The results of the present study show that the individual-level productivity costs are higher among physically inactive compared with physically more active, but the causality cannot be interpreted. Intuitively, one explanation for the higher productivity costs of physical inactivity is health. Physical inactivity is associated with higher health risks (18), which may lead to lower work ability or weaker labor market attachment (28,29). Such issues may further lead to a higher probability of sickness absences and disability pensions (19,20). Our results indirectly support this assumption because in each model specification, the average productivity costs were higher when we focused on the results based on the poor perceived health subsample compared with the costs based on the full sample.

Another plausible explanation for the higher productivity costs of physical inactivity is education. Our results suggested that among the low-education subsample, the average productivity costs were highest among physically inactive. The results remained stable regardless of the measurement type of physical activity. According to previous literature, higher education has been shown to be related to higher physical activity (30,31). Similarly, higher physical activity has been shown to be related to higher incomes (32–35). From employees' perspective, higher education and higher levels of physical activity may lead to higher incomes, which may bring about higher productivity costs once absences (sick leaves or disability pensions) occur. Lower levels of education and lower levels of physical activity, in turn, may lead to lower incomes and lower productivity costs once absences occur. However, this trend was not detected in our results.

The higher productivity costs of physical inactivity may also be spurious. This means that higher productivity costs may stem from unobserved factors, such as an individual's personality and ability that correlate with the level of physical activity and productivity cost measures. Thus, higher productivity costs may have arisen regardless of the level of physical activity. Therefore, to further increase our understanding about the costs, and most importantly, to increase our awareness of how these costs could be prevented, it would be valuable for future studies to explore the factors behind the costs and the potential mechanisms between physical inactivity and costs in more detail. An interesting avenue for future research would also be to investigate the productivity costs of physical inactivity by considering daily sedentary time (16,36,37).

The use of register-based information on productivity costs and the longitudinal setting of the study extends the previous literature in two important ways. First, the number of sickness absences and early retirements because of disability may vary greatly on a yearly or on an individual level. For example, as shown in Table 1, females had more sickness absences compared with males. However, most previous studies have used aggregate-level information on the productivity cost measures or information based on cross-sectional surveys (2,3,23). This strategy does not allow the exploration of individual-level variation or the yearly variation in the productivity cost measures. In this study, we overcame this problem by using individual-level information on productivity cost measures. Each measure was drawn from Finnish registries. In addition, instead of cross-sectional information on sickness absences or disability pensions, in this study, the variables were longitudinal and covered the period from 2012 to 2020. Because the descriptive statistics suggested that, on average, both the level of physical activity and the amount of absences vary according to sex, the sex-specific productivity costs were also calculated. An existing limitation in using such registries was that the productivity cost measures, which were not included in the registries, were not included in our analyses. An example of such a productivity cost measure is presenteeism. This exclusion, however, may suggest that the productivity costs demonstrated in the present analysis are, in fact, an underestimation of the actual productivity costs of physical inactivity.

Second, the productivity costs were calculated using individual-level information on physical activity, including both self-reported and device-based measured physical activity. Of these, self-reported physical activity depicted whether the recommended level of physical activity for health was reached during leisure time (36), and the accelerometer-measured physical activity illustrated the overall daily physical activity. According to the literature, the amount of daily physical activity may depend on the physical activity measurement method—that is, whether physical activity is measured with self-reports or devices (38). Many previous studies investigating the productivity costs of physical inactivity have used the prevalence of physical inactivity in the population as the basis for their calculations (2). In most cases, this measure is drawn from cross-sectional surveys and is based only on self-reported physical activity. In addition, this aggregate-level prevalence does not capture long-term information about physical activity behavior. In the present study, we also calculated costs using long-term information on physical activity. This means that the productivity costs were estimated based on changes in physical activity levels during adulthood. Although this information was based on self-reported questionnaires, it provides essential information about physical activity type and context (39). Additionally, focusing on changes in physical activity is an important aspect because the levels of physical activity may vary during the life course (40).

The detriments of physical inactivity and the importance of physical activity for health and well-being are well documented (13,18,36,41). Unsurprisingly, research on the economic costs of physical inactivity and the economic benefits of physical activity has emerged in recent years. At the global level, it is estimated that the direct and indirect costs of physical inactivity on five major noncommunicable diseases and all-cause mortality were around $68 billion in 2013 (1). Of these costs, the indirect productivity costs were approximately $14 billion. By contrast, physical activity has been shown to be positively related to several economic outcomes, such as higher earnings, higher employment, and lower unemployment (32–35,42). The present study further increases our awareness about the economic outcomes of physical inactivity by showing the individual-level productivity costs: The average productivity costs stemming from sickness absences and disability pensions were higher among physically inactive individuals compared with the costs among physically active.

CONCLUSIONS

We are persuaded that these findings can be generalized to other developed countries with similar physical activity behavior and labor market participation with some caveats (41,43). Specifically, given the within-country data, which includes a homogenous sample in terms of age and ethnicity, the monetary values of the results are not necessarily directly generalizable to other countries, *per se*. However, the generic nature of the HCA method makes the results generalizable to other countries and contexts. From a policy perspective, the findings of the present study should encourage policymakers and employers to invest in programs and interventions aimed at promoting working-age individuals' participation in physical activity. This could further maintain and increase individuals' work ability and productivity. In a broader context, possibilities to increase the labor force's work ability are essential because population aging and expected increases in life expectancy may lead countries to extend working lives by increasing the state pension age (44). This extension will require that a sufficient proportion of the working-age population should be able to work longer.

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NFBC data are available from the University of Oulu, Infrastructure for Population Studies. Permission to use the data can be applied for research purposes via an electronic material request portal. In the use of data, we follow the EU general data protection regulation (679/2016) and the Finnish Data Protection Act. The use of personal data is based on a cohort participant's written informed consent at his/her latest follow-up study, which may cause limitations to its use. Please contact the NFBC project center (NFBCprojectcenter(at)oulu.fi) and visit the cohort website for more information.

The authors declare no conflict of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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