Physical activity level as a predictor of healthy and chronic disease-free life expectancy between ages 50 and 75

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Abstract

Background: Physical activity promotes healthy aging. However, little is known about the relationship between physical activity levels and healthy and chronic disease-free life expectancy (LE). The study aim was to examine healthy and chronic disease-free LE between ages 50 and 75 and across various levels of physical activity by sex and different occupational statuses.

Methods: 34,379 women (mean age 53.2 (SD 2.9) years) and 8,381 men (53.6 (SD 3.2) years) from the Finnish Public Sector study were categorized into five physical activity levels (inactive to vigorously active) according to self-reported physical activity and into three occupational statuses at the first observation point. Partial life expectancy between ages 50 and 75 based on discrete-time multistate life table models was defined using two health indicators: healthy LE based on self-rated health and chronic disease-free LE based on chronic diseases. The average follow-up time for health indicators was 6.8 (SD 5.2) years.

Results: A clear dose-response relationship between higher physical activity levels and increased healthy and chronic disease-free LE in men and women, and within occupational statuses was found. On average, vigorously active men and women lived 6.3 years longer in good health and 2.9 years longer without chronic diseases between ages 50 and 75 compared to inactive individuals. The difference in years in good health between vigorously active and inactive individuals was largest in individuals with low occupation status (6.7 years).

Conclusion: Higher levels of physical activity increase healthy and chronic disease-free years similarly in men and women, but more among persons with low than with high occupational status.

Keywords: health expectancy, physical activity, occupational status, chronic diseases

Introduction

Physical inactivity is recognized as one of the leading modifiable risk factors for global disease [1,2] and economic [3] burden. It is thus evident that by being physically active the risk of several chronic diseases [4–6], functional limitations [7], and premature death [8] can be reduced. As people live longer than ever, the ultimate goal is to increase healthy years of life [9]. Health expectancy is a useful summary measure of a population´s health that expresses the average number of years that a person can expect to live in "full health" by taking into account years lived less than full health due to disease and/or disability. As health expectancy captures both the "quantity" and "quality" of lived years by considering simultaneously both health and mortality [10], it is more informative than life expectancy alone and allows comparing proportion of life spent in good health across different population groups.

Characteristics of healthy lifestyle, including physical activity, have been shown to contribute to longer life expectancy and more years in good health [11–15]. However, only few studies have examined the association between physical activity levels and health expectancy. Studies to date, based on various physical activity assessment methods and health expectancy indicators in different adult cohorts, have shown that the recommended physical activity level is associated with more years with good self-rated health [16], and more years without disabilities [17], cardiovascular disease [11,18] and diabetes [19] compared to low physical activity level. However a steep gradient between leisure-time physical activity and socioeconomic status has been observed so that leisure-time physical activity, specifically vigorous leisure-time physical activity, is less prevalent among people with lower socioeconomic position [20]. Because there are major inequalities in health expectancy by socioeconomic position [10], there is need to examine the extent to which the association between physical activity levels and health expectancy varies by socioeconomic status.

The objective of this study was to examine health expectancies between ages 50 and 75 across inactivity to vigorous physical activity in men and women, and in various occupational statuses in a large prospective occupational cohort from Finland. Health expectancy was defined using two different health indicators: healthy life expectancy based on self-rated health and chronic disease-free life expectancy based on chronic diseases.

Methods

Participants

The data is derived from five study waves of the Finnish Public Sector study (FPS). The FPS study, established in 1997/1998, comprises all 151,901 employees with ≥6 month job contract in any year from 1991/2000 to 2005 in 10 towns and 5 hospital districts in Finland. Survey data has been collected by repeated surveys in 4-year intervals on all 103,866 cohort members, who were at work in the participating organizations during the surveys in the years 1997/1998 (wave 1, response rate 70%), 2000/2001 (wave 2, 68%), 2004 (wave 3, 66%), 2008 (wave 4, 71%), and 2012 (wave 5, 69%). Follow-up survey data of the respondents who had retired or left the organizations were collected in 2005 (wave 3, response rate 68%), 2009 (wave 4, 64%) and 2013 (wave 5, 65%). The FPS study was approved by the Ethics Committee of the Hospital District of Helsinki and Uusimaa.

Overall, 84,848 participants responded to the survey questionnaire at least once (response rate 82%). For the analysis we used data from 42,760 participants who were aged 50 to 75 years at the first observation point for which also a valid data on physical activity and occupational status was available. The first observation point, in which a participant was aged 50 to 75 years, was the study wave 1 for 5,175 participants, study wave 2 for 13,003 participants, study wave

3 for 9,182 participants, study wave 4 for 8,085 participants, and study wave 5 for 7,315 participants. Overall 74% of the participants (n=31,810) had health indicator data from >1 study waves. On average, participants provided health indicator data from 2.5 (SD 1.2) study waves with the average of 6.8 (SD 5.2) years between the first and last observation point. Participants mortality was followed via linked register data until Dec 31, 2013 or until they reached the age of 76 years.

Demographic characteristics

Age, sex and occupational title of the participants at the first observation point were obtained from the employers' registers. Occupational status, an indicator of socio-economic position, was derived from occupational titles according to the Classification of Occupations by Statistics Finland and categorized to: high (e.g. physicians, teachers), intermediate (e.g. registered nurses, technicians), and low (e.g. maintenance workers, cleaners).

Measurement of physical activity

Physical activity was assessed with a questionnaire at the first observation point. The responders were asked to estimate their average weekly hours of physical activity/exercise (including both leisure-time and commuting activity) within the previous year in walking, brisk walking, jogging and running, or activities of equivalent intensities [21]. Each intensity level had five response alternatives of which the class mid-points were used for the calculation of time spent in physical activity: no activity, less than 0.5 hours (15 min used for calculation), ~1 hours (45 min), 2-3 hours (2.5 h), and ≥4 hours/week (5 h). The time spent on activity at each intensity level in hours per week was multiplied by the average energy expenditure of each activity, expressed in metabolic equivalent (MET). For example, walking, brisk walking, jogging and running corresponded to 3.5, 5, 8 and 11 METs, respectively [22]. The volume of physical activity was quantified as MET-hours per week.

The participants were categorized into five physical activity levels according to their volume of physical activity at the first observation point: inactive participants (physical activity <7 MET-h/week), and participants having low (≥7 to <14 MET-h/week), moderate (≥14 to <30 MET-h/week), high (≥30 to <60 MET-h/week), and vigorous (≥60 MET-h/week) activity levels.

Outcome measures

Self-rated health: The participants were asked to rate their general health status at each observation point. The response alternatives were: very good, good, average, fair and poor, from 1 to 5, respectively. Responses were dichotomized by categorizing response scores 1–2 as good health and scores 3–5 as sub-optimal health. Health expectancy indicator based on self-rated health is named as healthy life expectancy (LE).

Chronic diseases: Presence of the following chronic diseases was ascertained at each observation point by asking 'has a doctor ever told you that you have …': heart disease (heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems); stroke (stroke or transient ischemic attack); chronic lung disease (chronic bronchitis or emphysema or asthma); cancer (cancer or a malignant tumor of any kind except skin cancer); and diabetes (diabetes or high blood sugar). Individuals were defined as having a chronic disease if they reported "yes" to one or more of these conditions. The presence of chronic diseases the first observation point included any chronic diseases reported before the age of 50 from available information on respondents. Health expectancy indicator based on chronic diseases is named as chronic disease-free LE.

Mortality was ascertained from linked register data from the Finnish Population Register Center with a follow-up censored on 31 December on 2013, i.e. the year in which data collection last took place.

Statistical analyses

We applied multistate models to longitudinal data to obtain transition probabilities between health states. Discrete-time multistate life table models were used to estimate partial LE and health expectancies between ages 50 and 75 (period of 26 years). The analyses were conducted for both indicators of health expectancy. For healthy LE, there were four possible transitions between the health states, namely: healthy to sub-optimal health (onset), sub-optimal health to healthy (recovery), healthy to dead, and sub-optimal health to dead. For chronic disease-free LE, there were only three possible transitions as, by definition, recovery was not possible.

The age-specific transition probabilities by sex, occupational status and physical activity levels were estimated from multinomial logistic models with age (in years), sex and occupational status as covariates. Partial LE, healthy LE and chronic disease-free LE between ages 50 and 75 were then calculated based on these estimated transition probabilities using a stochastic (micro-simulation) approach [23]. Individual trajectories for a simulated cohort of 100,000 persons were generated with distributions of covariates at the starting point based on the observed prevalence by five year age group, sex, occupational status and level of physical activity. Partial LE, healthy LE and chronic disease-free LE between ages 50 and 75 were then calculated as the average from these trajectories for men and women and for different occupational statuses by physical activity levels. Computation of 95% confidence intervals (CI) (from 2.5^{th} and 97.5^{th} percentiles) for these multistate life table estimates was performed using a bootstrap method with 500 replicates for the whole analysis process (multinomial analysis and simulation steps).

All analyses were conducted in SAS 9.2 using the SPACE (Stochastic Population Analysis of Complex Events) program (http://www.cdc.gov/nchs/data_access/space.htm) [23]. This program uses the stochastic (i.e. microsimulation) approach to estimate health expectancy as

opposed to another well-known program, IMaCh (Interpolation of Markov Chains) which uses a deterministic approach [24].

Results

Characteristics for men and women at the time of the first observation are shown in Table 1. Overall 42% of men and 27% of women were categorized with high occupational status, and 34% and 17% with low occupational status, respectively. At the first observation point every third men and women rated their health sub-optimal and a quarter had at least one chronic disease. A fifth of men and 17% of women were categorized as being inactive, and 10% and 6% for vigorous activity levels, respectively. There was no difference in high and vigorous level activity by occupational status, but physical inactivity was more common among low (24%) than high occupational groups (15%). Also the mean level of physical activity was lower in the low occupational group (24.8 (SD 24.9) MET-hours/week) compared to high occupational group (25.6 (SD 21.7) MET-hours/week) ($p=0.005$).

Table 2 shows the estimates for partial LE, healthy LE and, for the difference between partial LE and health LE, that is, sub-optimal LE between ages 50 and 75 by sex, occupational status and physical activity levels. There was a clear dose-response relationship between higher physical activity level and increased healthy years for both men and women; the vigorously active men lived 6.7 years and vigorously active women 5.8 years longer in good health compared to inactive men and women. The proportion of years in good health was 79% among men and 78% among women who engaged in vigorous activity, whereas inactive men spent only 54% and inactive women 56% of years in good health (Appendix 1A available in Age and Aging online). Within all occupational statuses, there was a dose-response relationship between physical activity levels and proportion of healthy life. The higher the status, the larger

proportion of life was spent in good health at each level of activity (Appendix 1B available in Age and Aging online). The difference in years in good health between vigorously active and inactive individuals was smallest for individuals with high occupational status (4.4 years) and largest for individuals with low occupational status (6.7 years).

Results for the estimated partial LE, chronic disease-free LE, and life expectancy with chronic diseases between ages 50 and 75 by sex, occupational status and physical activity levels are shown in Table 3. A graded relationship of more years without chronic diseases with higher physical activity levels was observed for both men and women. Vigorously active men lived 3.3 years and vigorously active women 2.7 years longer without chronic diseases compared to inactive men and women. Increase in physical activity level from inactivity to vigorous extended the proportion of life spent without chronic diseases from 46% to 57% among men and from 48% to 57% among women, respectively (Appendix 2A available in Age and Aging online). The difference in chronic disease-free LE between vigorously active and inactive individuals was similar within occupational statuses (Appendix 2B available in Age and Aging online).

Discussion

This study examined how physical activity level was associated with healthy and chronic disease-free LE between ages 50 and 75. We found a clear dose-response relationship between higher physical activity level and longer healthy and chronic disease-free LE. The vigorously active individuals (men and women) lived 6.3 years longer in good health and 2.9 years longer without chronic diseases than inactive individuals between ages 50 and 75 although the difference in partial LE between vigorously active and inactive individuals was only one year. Our findings are in line with the previous studies showing that high physical activity levels

extend years in good health compared to low activity levels [11,16–19]. In contrast to earlier studies, physical activity was quantified as MET-hours/week and then categorized according to the limits and multiplies of the current physical activity recommendations [25]. This grouping enabled us to include also inactive individuals far below the current physical activity recommendations to the analysis and thus examine more detailed dose-response relationship between physical activity levels and healthy LE and chronic disease-free LE in a very large cohort of middle-aged and older individuals.

Other novelties of our study include the estimation of health expectancy by physical activity levels in individuals having different occupational statuses. We found a clear dose-response relationship between higher levels of physical activity and healthy and chronic disease-free LE within occupational statuses. In concordance with earlier research [10], at each level of activity, healthy LE was the shorter the lower the status was. However, our findings showed that the additional benefit of higher levels of physical activity on healthy LE was most notable in the low status jobs (e.g. maintenance workers, cleaners), 6.7 years, and least notable in high status jobs (e.g. physicians, teachers), 4.4 years. Low occupational status associates with high occupational physical activity [20], but unlike leisure-time physical activity occupational physical activity often consists of monotonous movements and prolonged activity without sufficient recovery breaks and has been shown to result with reduced cardiovascular health and more musculoskeletal problems [26]. Therefore, according to our findings people with low occupational status would particularly gain more healthy life years by increasing leisure and/or commuting physical activity. Compared to healthy LE, the differences between vigorously active and inactive individuals for chronic disease-free LE were smaller and more similar within and between occupational statuses. The smaller differences for chronic disease-free LE than for healthy LE could be due to fact that self-reported health is a more holistic measure of health than presence of chronic diseases.

The present study extends the findings which have shown that physical activity associates with reduced prevalence of chronic diseases [6] and lowered mortality risk [8] in a dose-response manner. As physical activity improves endurance and strength [27], prevents falls [28], and reduces disability [29], and cognitive decline and dementia [30] among the elderly, engagement to physical activity and avoidance of sedentary time are the key tools to promote healthy aging.

Major strength of this study is that it is based on a large prospective cohort study with high response rate and multiple measurements of self-rated health and chronic diseases over a long follow-up period. The use of microsimulation to estimate healthy LE and chronic disease-free LE provides internally consistent results. However, the study also has some limitations that should be acknowledged. The use of self-reported data on (combined leisure and commuting) physical activity and for the outcome measures may lead to both reporting and classification bias. However, self-reported physical activity data is frequently used to study prevalence of different physical activity levels in large populations [31]. We could not exclude the possibility of reverse causality that low physical activity at the first observational point was a result of chronic disease(s). Also we did not measure physical job exposure or occupational physical activity, thus we were not able to examine the role of occupational physical activity on the health expectancy outcomes. Another limitation is the use of only five chronic health conditions, namely heart disease, stroke, chronic lung disease, cancer and diabetes, to estimate chronic disease-free LE, leaving e.g. musculoskeletal disorders out of the analysis. In addition to self-rated health and diseases, functional status is an important outcome among older adults, thus there is call for further studies examining the association between physical activity levels and disability-free life expectancy. The results of this study are based on microsimulation and transition probabilities and not direct observation of LE or transitions. Also due to the chosen statistical approach other lifestyle factors (such as obesity, diet, or smoking) which could confound the relationships shown were not controlled for in the analysis. Finally, in our study

the life expectancy analyses was limited to ages of 50 and 75. Therefore more studies in older age groups are needed to conclude of the relationship between physical activity levels and health expectancy in elderly people.

Conclusion

Higher physical activity levels are associated with longer healthy and chronic disease-free LE between ages 50 and 75 in a dose-response manner. On average, vigorously active men and women lived 6.3 years longer in good health and 2.9 years longer without chronic diseases than inactive individuals. Increased healthy and chronic disease-free years by physical activity levels was seen within occupational statuses. The difference in years lived healthy between vigorously active and inactive individuals was most remarkable in persons with low occupation status.

Key points:

Because people live longer than ever, the ultimate goal is to increase healthy years of life.

Higher physical activity levels associate with longer healthy and chronic disease-free life expectancy between ages 50 to 75.

The benefit of higher levels of physical activity on healthy life expectancy was most notable in people with low status jobs.

Competing interest:

None declared.

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Tables

Table 1. Characteristics of the participants by sex at the time of first observation.

Characteristic	Men (%)	Women (%)
Sample size (n)	8,381	34,379
Mean (SD) age	53.6 (3.2)	53.2 (2.9)
Occupational status		
High	42	27
Intermediate	24	56
Low	34	17
Sub-optimal self-rated health	37	34
Chronic disease	26	26
Physical activity level		
Inactive	20	17
Low	17	20
Moderate	29	30
High	24	27
Vigorous	10	6

The first observation point refers to the survey wave each participant was included in the dataset; Presence of chronic diseases includes illness reported at or before the first observation time point.

Table 2. Partial life expectancy, healthy life expectancy and sub-optimal life expectancy between ages 50 and 75 by sex, occupational status and physical activity levels.

Category	n (%)	Partial life expectancy	Healthy life expectancy	Sub-optimal life expectancy
		Years (95% CI)	Years (95% CI)	Years (95% CI)
Sex				
Men				
Inactive	1690 (20)	23.4 (23.0-23.8)	12.5 (11.7-13.0)	10.8 (10.5-11.6)
Low	1454 (17)	24.1 (23.6-24.3)	14.0 (13.3-14.6)	10.1 (9.4-10.7)
Moderate	2421 (29)	24.3 (24.0-24.6)	16.2 (15.7-16.6)	8.1 (7.7-8.6)
High	2011 (24)	24.4 (24.1-24.6)	17.3 (16.6-17.6)	7.1 (6.8-7.7)
Vigorous	805 (10)	24.5 (24.2-25.0)	19.2 (18.4-19.9)	5.2 (4.8-6.1)
Women				
Inactive	5798 (17)	24.6 (24.4-24.8)	13.8 (13.4-14.2)	10.8 (10.4-11.1)
Low	6733 (20)	24.9 (24.8-25.1)	15.4 (14.9-15.7)	9.5 (9.3-10.0)
Moderate	10408 (30)	25.1 (24.9-25.1)	16.9 (16.6-17.1)	8.1 (7.9-8.4)
High	9291 (27)	25.1 (24.9-25.2)	17.7 (17.4-18.0)	7.4 (7.1-7.6)
Vigorous	2149 (6)	25.2 (25.0-25.4)	19.6 (18.9-20.0)	5.6 (5.2-6.3)
Occupational status				
High				
Inactive	1971 (15)	24.6 (24.4-24.9)	16.8 (16.1-17.2)	7.9 (7.5-8.4)
Low	2481 (19)	25.0 (24.8-25.1)	17.8 (17.2-18.2)	7.2 (6.8-7.7)
Moderate	4173 (33)	25.1 (24.9-25.3)	19.2 (18.8-19.4)	6.0 (6.7-6.3)
High	3306 (26)	25.1 (25.0-25.3)	20.1 (19.7-20.3)	5.0 (4.8-5.4)
Vigorous	854 (7)	25.1 (24.9-25.5)	21.2 (20.9-21.9)	3.9 (3.3-4.2)
Intermediate				
Inactive	3483 (16)	24.4 (24.2-24.7)	13.5 (13.2-14.1)	10.9 (10.3-11.2)
Low	4110 (19)	24.8 (24.6-25.0)	15.1 (14.6-15.4)	9.7 (9.4-10.3)
Moderate	6411 (30)	25.0 (24.8-25.1)	16.7 (16.2-16.8)	8.3 (8.1-8.7)
High	5915 (28)	25.0 (24.8-25.1)	17.5 (17.2-17.9)	7.5 (7.1-7.8)
Vigorous	1464 (7)	25.2 (24.8-25.3)	19.7 (18.9-20.0)	5.5 (5.1-6.3)
Low				
Inactive	2034 (24)	23.7 (23.4-24.1)	9.9 (9.3-10.3)	13.8 (13.3-14.4)
Low	1596 (19)	24.3 (24.0-24.5)	11.1 (10.5-11.6)	13.2 (12.7-13.7)
Moderate	2245 (26)	24.4 (24.1-24.6)	12.6 (12.3-13.1)	11.8 (11.3-12.2)
High	2081 (24)	24.5 (24.2-24.7)	13.6 (13.3-14.2)	10.9 (10.2-11.2)
Vigorous	636 (7)	24.6 (24.1-25.0)	16.6 (15.1-16.8)	8.1 (7.8-9.5)

Sub-optimal life expectancy is the difference between partial and healthy life expectancy

Table 3. Partial life expectancy, chronic disease-free life expectancy and life expectancy with chronic diseases between ages 50 and 75 by sex, occupational status and physical activity levels.

Category	n (%)	Partial life expectancy	Chronic disease-free life expectancy	Life expectancy with chronic diseases
		Years (95% CI)	Years (95% CI)	Years (95% CI)
Sex				
Men				
Inactive	1690 (20)	23.3 (22.9-23.7)	10.8 (10.0-11.3)	12.5 (12.0-13.3)
Low	1454 (17)	23.9 (23.6-24.4)	11.6 (11.1-12.4)	12.4 (11.5-12.9)
Moderate	2421 (29)	24.2 (23.9-24.4)	12.6 (12.1-13.3)	11.6 (10.9-12.1)
High	2011 (24)	24.3 (24.0-24.5)	13.3 (12.9-14.1)	10.9 (10.2-11.4)
Vigorous	805 (10)	24.5 (24.2-25.0)	14.1 (13.1-14.9)	10.5 (9.7-11.4)
Women				
Inactive	5798 (17)	24.5 (24.3-24.7)	11.8 (11.2-12.0)	12.8 (12.5-13.3)
Low	6733 (20)	24.9 (24.7-25.1)	12.8 (12.4-13.3)	12.1 (11.6-12.5)
Moderate	10408 (30)	25.0 (24.9-25.1)	13.4 (13.1-13.8)	11.6 (11.2-11.9)
High	9291 (27)	25.1 (24.9-25.2)	14.1 (13.8-14.4)	11.0 (10.6-11.3)
Vigorous	2149 (6)	25.2 (25.0-25.4)	14.5 (13.8-15.1)	10.7 (10.1-11.4)
Occupational status				
High				
Inactive	1971 (15)	24.6 (24.3-24.8)	12.0 (11.1-12.3)	12.6 (12.3-13.5)
Low	2481 (19)	24.9 (24.8-25.1)	12.9 (12.1-13.4)	12.0 (11.6-12.8)
Moderate	4173 (33)	25.0 (24.9-25.2)	13.5 (13.0-13.9)	11.5 (11.1-12.0)
High	3306 (26)	25.0 (24.9-25.2)	14.1 (13.6-14.6)	10.9 (10.4-11.5)
Vigorous	854 (7)	25.2 (24.9-25.4)	15.0 (13.7-15.4)	10.2 (9.7-11.4)
Intermediate				
Inactive	3483 (16)	24.4 (24.1-24.6)	11.7 (11.2-12.2)	12.7 (12.2-13.2)
Low	4110 (19)	24.8 (24.6-25.0)	12.7 (12.2-13.2)	12.2 (11.6-12.6)
Moderate	6411 (30)	24.9 (24.7-25.0)	13.4 (13.0-13.8)	11.4 (11.1-11.9)
High	5915 (28)	25.0 (24.8-25.1)	14.2 (13.8-14.6)	10.8 (10.4-11.2)
Vigorous	1464 (7)	25.1 (24.8-25.4)	14.3 (13.8-15.2)	10.8 (9.9-11.3)
Low				
Inactive	2034 (24)	23.6 (23.3-24.0)	10.8 (10.1-11.2)	12.9 (12.4-13.6)
Low	1596 (19)	24.1 (23.9-24.6)	11.7 (11.5-12.9)	12.5 (11.3-12.6)
Moderate	2245 (26)	24.4 (24.1-24.6)	12.4 (11.9-13.0)	12.0 (11.4-12.5)
High	2081 (24)	24.6 (24.2-24.7)	13.0 (12.3-13.5)	11.5 (11.0-12.1)
Vigorous	636 (7)	24.6 (24.2-25.0)	13.5 (12.5-14.4)	11.1 (10.4-12.1)

Appendixes

Appendix 1 Proportion of life spent in good health by sex (A), occupational status (B) and physical activity levels between ages 50 and 75.

Appendix 2 Proportion of life spent without chronic diseases by sex (A), occupation status (B) and physical activity levels between ages 50 and 75.