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CHANGES IN LEISURE-TIME PHYSICAL ACTIVITY, FUNCTIONING, WORK DISABILITY AND RETIREMENT

A FOLLOW-UP STUDY AMONG EMPLOYEES

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ACADEMIC DISSERTATION

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ABSTRACT

Physical inactivity is a significant risk factor for non-communicable diseases. It has also been associated with a decline in functioning and a higher risk of work disability. However, there is limited evidence concerning the causes and consequences of changes in physical activity. Most Finnish adults of working age do not meet the recommendations for health-enhancing physical activity, and people tend to become less physically active as they age. Increasing activity levels among older age groups could enhance functioning and work ability among the ageing population.

The aim of this thesis was, first, to examine how changes in physical activity are associated with subsequent health functioning, sickness absence and disability retirement. The physical and mental health functioning and sickness absence attributable to musculoskeletal and mental causes were examined separately. Second, the intention was to investigate how physical activity changes after the transition to statutory retirement and during post-retirement years.

The research was part of the Helsinki Health Study being carried out at the Department of Public Health, University of Helsinki. The baseline surveys were conducted in 2000-2002 (N=8,960, response rate 67%) among employees of the City of Helsinki aged 40-60. The employees who responded to the baseline survey were followed up in two later surveys, meanwhile the cohort aged and some of the employees retired. The phase-2 follow-up survey was conducted in 2007 (N=7,332, response rate 83%) and phase 3 in 2012 (N=6,814, response rate 79%). The survey data were linked with register data on sickness absence from the Social Insurance Institution of Finland, and on disability retirement from the Finnish Centre for Pensions among those who consented to the register linkage (N=6,606). The register data on sickness absence and disability retirement includes medically confirmed diagnoses. Sickness absence periods were followed up from phase 2 until 2009, and disability retirement from phase 2 until 2013.

Increased physical activity was associated with better physical health functioning and decreased activity with worse physical health functioning. There were fewer associations between changes in physical activity and mental health functioning. Increases in physical activity were associated with a lower risk of sickness absence. Vigorous physical activity was especially beneficial for physical health functioning and contributed to a lower risk of sickness absence attributable to musculoskeletal diseases. In contrast, a higher intensity of physical activity had less of an effect on mental functioning and sickness absence attributable to mental causes. In some cases, moderate-intensity physical activity was more beneficial to mental health functioning than higher-intensity activity. In addition, adopting vigorous physical activity was associated with a lower risk of disability retirement, and decreasing the

intensity from vigorous to moderate or low was associated with a higher risk. Physical activity increased after the transition to statutory retirement, but declined a few years after retirement.

Given the results of this study, ageing employees and retirees engaging in a low level of physical activity should be encouraged to increase the level. Vigorous activity could also be promoted, at least among healthy individuals. The transition to statutory retirement is a good opportunity to promote physical activity and thereby facilitate a change for the better. It is also important to support the maintenance of physical activity in the years following the transition to retirement.

TIIVISTELMÄ

Vähäinen liikunta-aktiivisuus on merkittävä kroonisten sairauksien riskitekijä. Aiemmissa tutkimuksissa vähäinen liikunta-aktiivisuus on yhdistetty myös toimintakyvyn alenemiseen ja suurempaan työkyvyttömyyseläkkeen riskiin. Aiempaa näyttöä liikunta-aktiivisuuden muutosten taustatekijöistä ja seurauksista on kuitenkin vähän, koska aiemmat tutkimukset ovat pääosin tarkastelleet liikunta-aktiivisuutta vain yhdessä mittauspisteessä. Suurin osa suomalaisista työikäisistä ei liiku terveysliikuntasuositusten mukaan. Lisäksi liikunta-aktiivisuus vähenee iän myötä. Liikunta-aktiivisuuden muutosten tutkiminen on yhteiskunnallisesti merkittävää, koska lisääntynyt aktiivisuus voisi parantaa ikääntyvän väestön työ- ja toimintakykyä.

Tämän tutkimuksen ensimmäisenä tavoitteena oli tarkastella, kuinka liikunta-aktiivisuuden muutokset olivat yhteydessä tulevaan toimintakykyyn, sairauspoissaoloihin ja työkyvyttömyyseläkkeisiin. Fyysistä ja psyykkistä toimintakykyä sekä tuki- ja liikuntaelinsyihin ja mielenterveyssyihin perustuvia sairauspoissaoloja tarkasteltiin erikseen, koska yhteydet liikunta-aktiivisuuden muutosten ja työ- ja toimintakyvyn fyysisten ja psyykkisten osa-alueiden välillä voivat olla erilaisia. Toisena tavoitteena oli tarkastella, kuinka liikunta-aktiivisuus muuttuu vanhuuseläkkeelle siirtymisen jälkeen ja eläkkeelle siirtymistä seuraavina vuosina.

Tutkimus on osa Helsingin yliopiston kansanterveystieteen osastolla tehtävää Helsinki Health Study -tutkimusta. Tutkimuksen peruskyselyt toteutettiin postikyselyinä vuosina 2000–2002 (N=8960, vastausprosentti 67 %) Helsingin kaupungin kyseisinä vuosina 40–60-vuotiaiden työntekijöiden keskuudessa. Peruskyselyyn vastanneita seurattiin kahdella seurantakyselyllä. Seurannan aikana tutkittavat ikääntyivät ja osa seurattavista eläköityi. Kyselyn toinen vaihe toteutettiin vuonna 2007 (N=7332, vastausprosentti 83 %) ja kolmas vaihe vuonna 2012 (N=6814, vastausprosentti 79 %). Rekisteriyhdistelyyn suostuneiden vastaajien (N=6606) kyselytiedot yhdistettiin Kelan sairauspoissaolorekisterin tietoihin vähintään kymmenen päivää kestäneistä sairauspoissaoloista ja Eläketurvakeskuksen eläkerekisterin tietoihin työkyvyttömyyseläkkeistä. Sairauspoissaoloja seurattiin vuodesta 2007 vuoteen 2009 ja työkyvyttömyyseläkkeitä vuodesta 2007 vuoteen 2013.

Lisääntynyt liikunta-aktiivisuus oli yhteydessä parempaa tulevaan fyysiseen toimintakyvyn ja vähentynyt liikunta-aktivisuus huonompaan. Yhteydet liikunta-aktiivisuuden muutosten ja psyykkisen toimintakyvyn välillä olivat vähäisempiä. Lisääntynyt liikunta-aktiivisuus oli yhteydessä pienempään sairauspoissaolojen riskiin. Liikunta-aktiivisuuden lisääminen vähäisestä tai kohtuullisesta rasittavaan oli yhteydessä pienempään

työkyvyttömyyseläkkeiden riskiin. Vastaavasti liikunta-aktiivisuuden vähentäminen rasittavasta kohtuulliseen tai vähäiseen aktiivisuuteen oli yhteydessä suurempaan työkyvyttömyyseläkkeen riskiin. Rasittava liikunta oli erityisen hyödyllistä suhteessa tuki- ja liikuntaelinsairauksista johtuvien sairauspoissaolojen ehkäisyyn ja fyysisen toimintakyvyn ylläpitoon. Liikunnan intensiteetillä oli vähemmän merkitystä suhteessa mielenterveyssyistä johtuviin sairauspoissaoloihin ja psyykkiseen toimintakykyyn. Työtekijöiden liikunta-aktivisuus lisääntyi eläkkeelle jäämisen jälkeen, mutta lisäys oli lyhytkestoinen.

Tulosten perusteella keski-ikäisiä ja ikääntyviä työntekijöitä kannattaa työpaikoilla kannustaa lisäämään liikunta-aktiivisuuttaan. Terveitä työntekijöitä voi kannustaa myös rasittavan liikunnan harrastamiseen. Vanhuuseläkkeelle siirtyminen voi olla sopiva vaihe edistää liikunta-aktiivisuutta esimerkiksi liikunta-interventioilla, koska ihmiset saattavat elämänmuutosten yhteydessä muuttaa herkemmin liikuntatottumuksiaan. On kuitenkin tärkeää huolehtia myös liikunta-aktiivisuuden ylläpidosta eläköitymistä seuraavina vuosina, jotta eläkkeelle jäämisen yhteydessä mahdollisesti tapahtuneet positiiviset muutokset liikunta-aktiivisuudessa säilyvät mahdollisimman pitkään.

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I Holstila, A., Mänty, M., Rahkonen, O., Lahelma, E. and Lahti, J. (2016), Changes in leisure-time physical activity and physical and mental health functioning: a follow-up study. Scandinavian Journal of Medicine & Science in Sports, 2016 Sept, [Epub aheaf of print]

II Holstila, A., Rahkonen, O., Lahelma, E., & Lahti, J. (2016). Changes in Leisure-Time Physical Activity and Subsequent Sickness Absence Due to Any Cause, Musculoskeletal, and Mental Causes. Journal of Physical Activity and Health, 13(8), 867–873.

III Lahti, J., Holstila, A., Mänty, M., Lahelma, E., & Rahkonen, O. (2016). Changes in leisure time physical activity and subsequent disability retirement: A register-linked cohort study. The International Journal of Behavioral Nutrition and Physical Activity, 13(1), 99. Doi: 10.1186/s12966-016-0426-2

IV Holstila, A., Mänty, M., Rahkonen, O., Lahelma, E., & Lahti, J. (2017). Statutory retirement and changes in self-reported leisure-time physical activity: a follow-up study with three time-points. BMC Public Health, 17(1), 528. Doi: 10.1186/s12889-017-4455-9

The publications are referred to in the text by their roman numerals.

ABBREVIATIONS

BMI	Body mass index
CI	Confidence interval
GEE	Generalized estimating equations
HR	Hazard ratio
IRR	Incidence rate ratio
LLI	Limiting longstanding illness
LTPA	Leisure-time physical activity
MET	Metabolic equivalent
PA	Physical activity
RR	Rate ratio
SEP	Socioeconomic position
SF-36	Short Form 36 Health Survey

1 INTRODUCTION

Physical inactivity is one of the main causes of non-communicable diseases such as cardiovascular diseases, stroke, cancer and diabetes (Beaglehole et al. 2011). Chronic disease risk factors such as physical inactivity, smoking and overweight are increasing in significance, especially in older age groups. Globally, physical inactivity is one of the leading risk factors contributing to premature death and a reduced number of healthy life years in high- and middle-income countries. (WHO 2009) Moreover, physical activity reduces the risk of functional limitation (Paterson & Warburton 2010) and work disability among ageing employees.

The World Health Organisation recommends that adults should engage in at least 150 minutes of moderate-intensity physical activity or 75 minutes of vigorous physical activity, or the equivalent in combination, per week, and muscle-strengthening activity at least twice a week (WHO 2010). The majority of people in Finland (Mäkinen et al. 2012) do not comply with these recommendations, and the situation is similar in many Western countries, including the United States (Haskell et al. 2007). Older adults are even less likely than younger adults to follow the recommendations (Mäkinen et al. 2012), and levels of physical activity tend to decline with advancing age (Jefferis et al. 2014).

Because the proportion of over-65-year-olds in the population will increase rapidly over the coming decades in Finland and other Western countries (OECD 2014), there will be larger numbers of people who are likely to have problems with health and independent living. The loss of functioning has high costs and a severe impact on the quality of living. Work disability also has adverse consequences for individuals, including the risk of subsequent economic and social deprivation (Henderson et al. 2005). Sickness absence and productivity loss are also costly for society and employers. The indirect cost of physical inactivity in Canada has been estimated to be 3.6 per cent of the country's total expenditure on healthcare (Janssen 2012), for example, and a Finnish study (Tolonen et al. 2016) reported an association between physical inactivity and increasing direct costs of sickness absence to the employer.

Musculoskeletal and mental diseases are the most common causes of work disability (Social Insurance Institution of Finland 2012). Physical activity may be associated differently with physical and mental functioning, and with work disability on the grounds of musculoskeletal and mental illness. Studies on the associations between physical activity and depression (Teychenne et al. 2008) and between the prescribing of psychotropic medication (Lahti et al. 2013) and physical and mental health functioning (Lahti et al. 2016), indicate that the intensity of physical activity could be less significant for mental than for physical health.

Promoting physical activity among the middle-aged and older people could help to prevent functional decline and work disability in the ageing population. New evidence on the determinants of change in physical activity would contribute to the development of more effective ways of implementing interventions. Physical activity changes during the life course, but the extent to which these changes are gradual or are associated with key life transitions such as marriage, becoming a parent or approaching the end of working life and retirement remains unclear (Corder et al. 2009). An enhanced understanding of how physical activity changes at different stages of the life course could facilitate the planning and the timing of related interventions.

Little is known about the associations between changes in physical activity and subsequent work disability and functioning, or about how activity changes during post-retirement years. The aim in the present study is to narrow these knowledge gaps. The investigation focuses on changes in physical activity and their associations with functioning, work disability and statutory retirement, and covers both mental and physical aspects of work disability and functioning. The study was conducted among a cohort of middle-aged employees. The participants obviously aged during the follow-up, and many of them retired. It is likely that their health behaviour and functioning while employed and during the early years of retirement will affect their functioning as older adults.

2 THE CONCEPTS OF THE STUDY

Physical activity

Physical activity denotes any bodily movement produced by the skeletal muscles that increases energy expenditure (Bouchard et al. 2012; Caspersen 1989). On a wider behavioural level it covers leisure-time activity, everyday travelling or commuting, and occupational activity and chores. A high energy demand is still common in many occupational positions, but a heavy occupational demand tends to be associated with a low level of leisure-time physical activity. (Bouchard et al. 2012)

The present study focuses on leisure-time physical activity, including commuting. Leisure-time physical activity is physical activity in which individuals choose to engage based on personal needs and interests during their discretional time. Sport is a form of such activity that includes elements of competitiveness. Exercise, in turn, is motivated by a desire to keep fit, or to improve physical performance or health. The reasons for engaging in leisure-time physical activity may also be non-health-related, such as the thrill of speed, competitiveness, the social contacts or just to have fun. (Bouchard et al. 2012) Conscious motivations are unlikely to be the only drivers of leisure-time physical activity, which could be conceptualised in a wider sense as health behaviour that is linked to attitudes or orientations and individual resources all of which influence each other (Abel et al. 2000).

Physical activity can be studied in terms of different dimensions, duration, type, frequency, intensity and volume (World Health Organization 2010). The volume of an activity comprises its intensity, duration and frequency in any given period, and can be expressed as MET-hours. Metabolic equivalents of physical activity (METs) indicate the ratio of the working metabolic rate to the resting metabolic rate, one MET being the metabolic rate of sitting. (Ainsworth et al. 2000)

Individual levels of physical activity are not stable over the life course, and change during adolescence, adulthood and old age (Kjønniksen et al. 2008; Kirjonen et al. 2006; Parsons et al. 2006). As a health behaviour, physical activity has been found to be less stable than smoking or alcohol consumption (Kirjonen et al. 2006). The consequences and determinants of any changes could differ from those of persistent activities or activity measured only at one time point. Research on the effects of increasing physical activity later in life on work disability and functioning is also relevant from the policy-making perspective. Moreover, risks associated with physical inactivity may be underestimated when they are assessed based on a single measurement of physical activity at baseline, given the likely changes in activity levels during the follow-up (Andersen 2004).

Functioning

The World Health Organisation's (2001) International Classification of Functioning, Disability and Health provides a conceptual framework for functioning, which it defines as an umbrella term for all bodily functions, participation and activities. Disability is described as a dysfunction and limitation related to participating in activities. Bodily functions are connected to changes in physiological systems and anatomic structures, whereas activities and participation are connected to capacities and performance. Functioning is formulated in terms of health status and contextual factors, both of which are personal and environmental. It is a vital aspect of health that governs work ability, participation in leisure activities and the carrying out of household chores.

There are several measures of physical and mental functioning. The Short Form 36 Health Survey (SF-36), which is widely used, covers a broad spectrum of health and indicates the self-perceived impact of ill health and bodily pain on functioning. It is considered a generic measure in that it is not age-, disease- or treatment-specific. It consists of eight subscales and can be compressed in two component summary scales covering physical and mental health functioning. (Ware et al. 1994 & Ware et al. 1993) Chapter 5 contains a more detailed description of the SF-36 measure. Other survey measures are also available, such as Euro Quality of Life 5 dimension (EQ-5D) scale (EuroQol Group 2007), as well as objective measures such as the timed up-and-go test for the elderly (Podsiadlo & Richardson 1991).

Work disability

Work disability relates to the concrete financial and social consequences of restricted functioning and disability. It is of concern to many stakeholders including supervisors, co-workers, employers, labour unions, healthcare providers, insurers and governments. (Young et al. 2005) Early studies on work disability focused mainly on individual conditions, and the effects of external factors such as workplace conditions, insurance cover and family circumstances have been recognised only since the 1980s (Pransky et al. 2011). On the conceptual level there has been a shift from biomechanical models emphasising disease-based causes of disability to biopsychosocial models that also account for the psychosocial dimension of work disability (Sullivan et al. 2005).

There is no simple comprehensive definition of work disability that is acceptable to legislators, healthcare practitioners and researchers. The deeper the research into work ability, the more multidimensional is the concept. The holistic work ability model is based on achieving a balance between human resources and work. Human resources include health and functional capacity, but also knowledge and skills, motivation, attitudes and values. Work has just as many dimensions: conditions, contents and demands, community and organisational aspects, as well as supervision and management. (Ilmarinen et al. 2008 & Ilmarinen et al. 2006)

Sickness absence and disability retirement are used as measure work disability in the present study, and are strongly based on official medical and legal definitions of work ability. The focus is less on the continuum from ability to disability, and more on absence from work as opposed to lowered work ability while working.

Although long-term work disability is connected to social and work-related factors, Marmot et al. (1995) also found that long-term sickness absence was strongly associated with general ill health. They therefore suggested that sickness absence could be used as an integrated measure of physical, psychological and social functioning in working populations. It has also been associated with cardiovascular disease, cancer, all-cause and alcohol-related mortality, and suicide (Vahtera et al. 2004).

Statutory retirement

Just as changes in physical activity could lead to disability retirement, the transition to statutory retirement could be a potential determinant of changes in physical activity. Life-course transitions such as retirement could be seen as opportunities to make lifestyle changes that could be identified in the promotion of healthy ageing (Ding et al. 2016). The transition to retirement is a critical event that usually occurs later during the life course, and could affect physical activity. It has been shown in previous studies that life changes influence participation in physical activity (Allender et al. 2008).

According to Kim and Moen's (2002) life-course ecological model, retirement could be linked to psychosocial well-being through changes in economic, socio-relational and personal resources, resulting in financial problems, a reallocation of time as a resource, the easing of pressures related to working role, a shift in social relations and a sense of personal control, for example.

Researchers focusing on the effects of becoming retired should make a distinction between statutory and other forms of retirement. The transition to statutory retirement and transition to disability retirement are life-events that may well be perceived differently, and the causes of disability retirement could also limit engagement in physical activity.

The associations of changes in physical activity with functioning, work disability and the transition to statutory retirement

The focus in the first part of this study is on how changes in physical activity relate to subsequent functioning and work disability. The second part concentrates on how physical activity changes during the transition to statutory retirement and in post-retirement years. Within this analytical framework, the transition to statutory retirement is considered a potential determinant of changes in physical activity and functioning and work disability consequences of changes in physical activity. This does not mean that there are no associations in the other direction, but they are not studied in this thesis.

There are several potential mechanisms between changes in physical activity and subsequent functioning and work disability. It is likely that different associations and mechanisms operate depending on whether the changes in physical activity relate to musculoskeletal or mental disorders. Similarly the mechanisms linking physical activity with either physical or mental health functioning are likely to differ. Physical activity could counteract musculoskeletal diseases and help to maintain physical functioning in terms of increasing bone-mass and improving flexibility, general endurance, motor skills and muscle strength (Vuori 2001). Physical activity may also be beneficial to mental health in its effect on several neurotransmitters and the release of neurotrophic factors related to better cognitive functioning and the modulation of depression (Deslandes et al. 2009).

Some of the mechanisms linking changes in physical activity with mental health are social and psychological, which are potentially more independent in relation to the intensity of physical activity than physiological mechanisms. Physical activity could enhance mental health in stimulating social interaction and inclusion, a sense of direction in life, achievement opportunities and the reconstruction of more positive identities (Mason & Holt 2012).

Retirement could be associated with increased physical activity through changes in resources, well-being and role expectations. The transition to retirement also requires individuals to establish new daily routines to replace those imposed externally related to work (Jonsson et al. 2001).

3 LITERATURE REVIEW

3.1 CHANGES IN PHYSICAL ACTIVITY AND FUNCTIONING FROM MIDDLE AGE ONWARDS

Several previous studies report positive associations between physical activity and functioning among middle-aged and older adults. In some of them (Balboa-Castillo et al. 2011; Gebel et al. 2014; Lahti et al. 2010; Lahti et al. 2016), physical activity was measured only at single time point. Positive dose-response associations between the level of physical activity and both concurrent and subsequent levels of functioning were found in one study conducted among Australian women (Heesch et al. 2012).

Other research (Choi et al. 2013; Tessier et al. 2007; Wolin et al. 2007; Williams et al. 2014) has focused on changes in physical activity in relation to functioning. A British study (Williams et al. 2014) examined associations between changes in physical activity measured 20 years apart at baseline in 1988-1991 and at follow-up in 2008-2011, as well as physical functional limitations, impairment in activities of daily living and objectively measured functioning measured at a single time point in 2008-2011. According to the findings, increased physical activity was associated with a lower likelihood of functional limitations, impairment in the activities of daily living and poor results in the objectively measured 'up and go' test, and decreased physical activity with a higher likelihood of functional limitations. Another study from the UK (Choi et al. 2013) conducted among women examined changes in physical activity measured between seven and eight years apart, as well as concurrent changes in functioning measured on the Euro quality of life 5 dimension (EQ-5D) scale incorporating, mobility, self-care, usual activities, pain/discomfort and anxiety/depression. There was a positive association between an increase in physical activity and both maintained and increased functioning. (Table 1)

According to a French study (Tessier et al. 2007) focusing on changes in both physical activity and functioning between 1998 and 2001, increased physical activity was associated with better concurrent mental health functioning summary scores on the SF-36 among women, and with better scores on the SF-36 subscales contributing to mental and physical health among women and men. One study (Wolin et al. 2007) conducted among a cohort of female nurses from the US examined the associations between changes in physical activity and functioning measured at multiple time points. Changes in physical activity were measured in 1986-1996 and changes in functioning in 1996-2000 on biennial questionnaires. Increases in physical activity were associated with subsequent increases in all the SF-36 subscales except for the general health perceptions scale, which was not examined. The associations were strongest on the physical-functioning and role limitations subscales because physical problems contributed more to physical health functioning than to mental health functioning. (Table 1)

No previous studies (Choi et al. 2013; Tessier et al. 2007; Williams et al. 2014; Wolin et al. 2007) on the association between changes in physical activity and functioning examined the effect of the intensity of the physical activity, hence the earlier evidence on the subject is based on studies in which physical activity was measured at a single time point. Studies reporting an association between vigorous physical activity in particular and physical health functioning include one conducted in a large Australian cohort (Gebel et al. 2014), an earlier study on the Helsinki Health Study cohort (Lahti et al. 2010), which is also used in the present study, and a study that examined the Helsinki Health Study cohort together with British and Japanese employee cohorts (Lahti et al. 2016). An association was also found in the first of these studies (Gebel et al. 2014) between the intensity of physical activity and physical functioning independently of the volume of physical activity.

The study on Finnish, British and Japanese public-sector employees (Lahti et al. 2016) also examined mental health functioning, and it was found that the intensity of physical activity was somewhat less important for mental health functioning than physical health functioning. The differences in mental health functioning between inactive and moderately active employees from Finland were similar to the differences between the inactive and the vigorously active. There was a significant difference in mental health functioning only between the inactive and the vigorously active among the British employees, whereas there were no statistically significant differences in functioning between the different levels of physical activity among the Japanese employees.

Table 1. Studies on the associations between changes in physical activity and functioning.

Reference	Country/ population /N (women W%)	Study design	Leisure-time physical activity (LTPA)	Functioning	Covariates	Main statistical method	Main results
Choi et al. 2013	UK, The British Women's Heart and Health Study, elderly women (aged 60–79 in 1999/2000) randomly selected from general-practice lists in 23 towns, N=1926 (W%=100)	Change in LTPA – concurrent change in functioning, baseline: questionnaire and health examination 1999/2000, follow-up: questionnaire 2007	Self-reported participation in moderate and vigorous activity during the previous week: moderate or vigorous activity was categorised as follows: 0 h per week, >0-2 h per week; >2 h per week, -> BL & FU cross tabulated ->nine categories	Euro quality of life 5 dimension (EQ-5D) scale -> binary variable on change: maintained or improved/ deteriorated	Age, smoking status, alcohol consumption, fruit or vegetable intake, life-course SEP score and a medical history of comorbidities	Logistic regression	Those who increased their PA from zero to >2 hours per week (OR=2.21, 95% CI 1-.22-4.01) or had consistently > 2 hours PA per week (OR=1.94, 95% CI 1.34-2.82) were more likely to maintain or improve their functioning compared to those engaging in no physical activity.
Tessier et al. 2007	France, Healthy participants of the follow-up surveys of The Supplementation en VItamines et Minéraux Antioxidants Study, based on a population sample of men aged 45-60 and women aged 35-60 in 1998, N= 3891 (W%=58)	Change in LTPA – concurrent change in functioning, two questionnaires in 1998 and 2001	Responders reported activities on a pre-established list of activities they have undertaken at least ten times during the previous year and their frequency and duration -> PA hours per week were calculated	SF-36, physical and mental component summary scores sub-scales (physical functioning, bodily pain, general health, vitality, social functioning, and mental health)	Age, educational level and change in body mass index, smoking status, professional status, place of residence, time watching TV, and functioning and LTPA at baseline	Linear regression	Change in time spent on physical activity was positively associated with change in mental component summary scores among women (β=0.23, $p<0.001$). Positive associations were also found among men and women on the physical functioning, mental health and vitality sub-scales, and on social functioning among women.

W=women, LTPA= leisure–time physical activity, PA= physical activity, BL=baseline, FU=follow-up, OR=odds ratio, CI=confidence interval, SF-36= Short Form 36 Health Survey

Table 1. Continues

Reference	Country/ population /N (women %)	Study design	Leisure-time physical activity (LTPA)	Functioning	Covariates	Main statistical method	Main results
Williams et al. 2014	UK, The Southall and Brent REvisited (SABRE) study, a triethnic (European, South Asian and African Caribbean) population aged 40-69 in 1988-1991 recruited from primary-care registers in north-west London, N=1418 (1391 for objective functioning) (W%=24)	Change in PA from BL to FU, functional limitations at FU, questionnaire and clinical and anthropometric measurements at BL 1988-1991 and at FU 2008-2011	Self-reported participation in sport, walking, cycling > change between the baseline and follow-up tertiles of physical activity	Functional limitations and activities of daily living (ADLs) dichotomized as impairment (at least in one aspect) or not, objective 'up and go' test dichotomized as ≤12 seconds >12 seconds/ and self-reported	Age, gender, ethnic group, weight change, BL smoking, manual occupation, sedentary behaviour, weight, height, physical activity, self-rated health, coronary heart disease, diabetes, hypertension, asthma and arthritis	Logistic regression	Persistently high (OR=0.21, 95% CI 0.41-0.76) PA and changing PA from low to high (OR=0.23, 95% CI 0.10-0.56) compared to persistently low were inversely associated, and a decrease in PA from high to low was positively associated (OR=3.11, 95% CI 1.67-5.81) with functional limitation. There were similar associations with objective disability and ADLs, except for a decrease in PA.
Wolin et al. 2007	U.S., The Nurses' Health Study, female registered nurses aged 40-67 in 1989, N=63,152 (W%=100)	Change in PA in 1989-1996, functioning in 1996 and changes in functioning in 1996-2000, questionnaire surveys conducted biennially since 1976	Self-reported participation in named activities (changes in the question during the follow-up)-> slope of change in physical activity z-score (calculated by subtracting the mean MET-hours/week of the year from the participants' mean MET-hours/week and dividing by the standard deviation) into quartiles	SF-36, subscales physical functioning, role limitations due to emotional problems, role limitations due to physical problems, bodily pain, vitality, social functioning, and mental health	Age, BL physical activity, BL SF-36 score, smoking, and BMI	Ordinary least-squares regression	Increase in physical activity was associated with a positive change in all the examined SF-36 sub-scales. The associations were strongest with physical functioning (β =1.82, 95% CI 1.45-2.19) and role limitations due to physical problems (β =1.81, 95% CI 1.09-2.53).

W=women, LTPA= leisure–time physical activity, PA= physical activity, BL=baseline, FU=follow-up, OR=odds ratio, CI=confidence interval, SF-36= Short Form 36 Health Survey

3.2 CHANGES IN PHYSICAL ACTIVITY AND SICKNESS ABSENCE

According to a recent review (Amlani & Munir 2014), there is still insufficient evidence concerning the association between physical activity and sickness absence, and a better understanding of the most effective combinations of frequency, intensity, time and type of physical activity as a preventative strategy is needed. Several previous studies (Eriksen & Bruusgaard 2002; Holopainen et al. 2012; Lahti et al. 2012; Lahti et al. 2010; Proper et al. 2006; Quist et al. 2014; van Amelsvoort et al. 2006) report an inverse association between leisure-time physical activity and the risk of sickness absence, although others (Christensen et al. 2007; Haukka et al. 2014; Rabacow et al. 2014) indicate no association. Two earlier studies conducted among the Helsinki Health Study cohort (Lahti et al. 2012, Lahti et al. 2010) and a Dutch study (Proper et al. 2006) reported stronger associations between vigorous physical activity and a lower risk of sickness absence than between moderate activity and sickness absence.

Various studies (Haukka et al. 2014; Holopainen et al. 2012; van Amelsvoort et al. 2006) focus on the association between physical activity and sickness absence related to different disease groups. According to the results of an earlier study on the Helsinki Health Study cohort (Holopainen et al. 2012) investigating medically confirmed long-term sickness absence periods (>3 months) during a seven-year follow-up, vigorous physical activity was associated with a lower risk of long-term sickness absence due to both musculoskeletal and mental causes, as well as due to any cause. Haukka et al. (2014) examined self-reported sickness absence on the grounds of musculoskeletal pain measured at nine time points within 24 months among Finnish kitchen employees, but found no association between leisure-time physical activity and sickness absence on those grounds. Another study (van Amelsvoort et al. 2006) examined self-reported sickness absence and their self-reported ICD-coded causes during a 2.5-year follow-up among an employee cohort from the Netherlands representing different sectors and trades (Kant et al. 2003): it reported a lower risk of sickness absence due to musculoskeletal causes among emloyees who engaged in lesure-time physical activity twice a week than among the less active employees.

Most previous studies are based on a single measure of physical activity. However, according to a study on the Helsinki Health Study Cohort (Lahti et al. 2012) focusing on the association between changes in physical activity and subsequent short (<3 days) and longer (>3 days) periods of sickness absence followed-up for 2.8 years, emergent and persistent vigorous physical activity was associated with a lower risk of both short and longer sickness absence periods.

3.3 CHANGES IN PHYSICAL ACTIVITY AND DISABILITY RETIREMENT

Evidence from several previous studies (Fimland et al. 2015; Friis et al. 2008; Hagen et al. 2002; Krokstad et al. 2002; Lahti, Rahkonen, et al. 2013; Robroek, Schuring, et al. 2013) and one meta-analysis (Robroek, Reeuwijk, et al. 2013) implies that physical activity measured at a single time point is associated with a lower risk of disability retirement. According to the results of a ten-year follow-up of the extensive Norwegian Nord-Trøndelag Health Study (Krokstad et al. 2002), inactive women and men aged 50-66 faced a higher risk of disability retirement than those who did physical exercise once a week. The results of another study (Hagen et al. 2002) based on the same survey data and on register data with a seven-year follow-up identified an association between belonging to the lowest percentile of physical activity and a higher risk of disability retirement on the grounds of back pain. It was further reported in a study (Fimland et al. 2015) from a later phase of the Nord-Trøndelag Health Study conducted fifteen years later that leisure-time physical activity was inversely associated with disability retirement due to any cause and to musculoskeletal causes and mental causes among Norwegian employees over a nine-year follow-up. A study (Friis et al. 2008) on a Danish cohort of nurses also reported an association between a sedentary lifestyle and a higher risk of disability retirement in a nine-year follow-up. Findings from a nationally representative Finnish study (Ahola et al. 2011) focusing on the relationship between common mental illness and disability retirement over a seven-year follow-up revealed associations between physical inactivity and a higher likelihood of disability retirement compared with those engaged in physical activity at least once a week that caused sweating or shortness of breath. However, the association disappeared following adjustment for sociodemographic, work-related, and health-behaviour factors. An association between physical inactivity and a higher risk of self-reported disability retirement was also found in a four-year follow-up study among European employees from 11 countries (Robroek, Schuring, et al. 2013) . The associations were somewhat stronger for musculoskeletal causes. According to the findings from a previous six-year follow-up study based on the Helsinki Health Study data (Lahti, Rahkonen, et al. 2013), vigorous activity in particular was associated with a lower risk of disability retirement. Fimland et al. (2015) also reported stronger associations among participants who engaged in activities causing sweating and shortness of breath than among those engaging in moderate activities.

There is little evidence on the associations between changes in physical activity and the risk of disability retirement. One study (Ropponen et al. 2011) conducted among a Swedish twin cohort examined the association between changes in physical activity measured at two points 25 years apart and subsequent disability retirement over a mean follow-up time of six years. According to the findings, decreased activity was positively associated with a risk of disability retirement attributable to any cause, but the association was not statistically significant when familial confounding was controlled for. The results also indicated a lower risk of disability retirement due to musculoskeletal diseases among the persistently inactive and those who increased their activity compared with the persistently active, but only when familiar confounding was controlled for.

3.4 THE TRANSITION TO RETIREMENT AND CHANGES IN PHYSICAL ACTIVITY

Previous studies (Barnett et al. 2014; Barnett et al. 2012; Brown et al. 2009; Ding et al. 2016; Evenson et al. 2002; Feng et al. 2016; Lahti et al. 2011; Touvier et al. 2010; Stenholm et al. 2016) report increases in physical activity following the transition to retirement. It was found in an Australian study conducted among women (Brown et al. 2009) that along with other life-course transitions, transition to retirement was associated with an increase in physical activity from none to low activity or from low activity to active. Another Australian cohort study (Ding et al. 2016) identified an inverse association between retirement and insufficient physical activity. It was further reported in a French (Touvier et al. 2010) study that the transition to retirement was associated with a positive change in both time spent on moderate and low leisure-time physical activity and MET-hours. There was no change in the case of vigorous activity. A previous study (Lahti et al. 2011) on the Helsinki Health Study cohort further reported an increase in time spent on physical activity following the transition to statutory retirement, whereas there was no change among disability retirees. An increase in vigorous, moderate and light physical activity among full-time and part-time retirees was also reported in a recent study (Feng et al. 2016) from the US, along with a decrease in all three intensities of physical activity among those who retired on the grounds of disability. Another study from the US (Evenson et al. 2002) reported a higher likelihood of remaining physically active among retirees than among the continuously employed across race and gender groups: white women and men and African-American men were more likely to adopt physical activity after retirement, although there was no such association among African-American women. Finally, a study (Barnett et al. 2014) from the UK reported a decrease in the total volume of physical activity, including occupational physical activity (MET hours/week), following the transition to retirement, but an increase in leisure-time physical activity.

Most of the previous studies have measured physical activity only at a single time point after transition to retirement and there is limited evidence on whether the increase in activity is short-term or long-term, or on how physical activity changes during the post-retirement period. According to the findings from a Finnish study (Stenholm et al. 2016) examining changes in physical activity after the transition to retirement, an increase in total physical activity during the transition phase was followed by a decrease during the post-retirement period. No increase in physical activity was reported in another study (Slingerland et al. 2007) from the Netherlands based on just one measurement 13 years after the transition to retirement, which could indicate that the increase in activity diminishes over time. A Belgian study (Van Dyck et al. 2016) in which participants who had recently retired before the baseline were compared with those retiring during a two-year follow-up reported increases in cycling and moderate-to-vigorous physical activity among the recently retired, and a decrease in these actives among those in the transition period. This could indicate that change in physical activity does not happen immediately after retirement.

3.5 A SUMMARY OF THE PREVIOUS RESEARCH

It could be concluded from the many studies on the subject (Balboa-Castillo et al. 2011; Choi et al. 2013; Gebel et al. 2014; Lahti 2011; Lahti et al. 2016; Tessier et al. 2007; Wolin et al. 2007; Williams et al. 2014) that leisure-time physical activity is associated with subsequent functioning. The associations were reported with regard to both physical health functioning and mental health functioning (Lahti et al. 2016; Tessier et al. 2007; Wolin et al. 2007). Vigorous physical activity appears to be especially beneficial to physical health functioning (Gebel et al. 2014; Lahti 2011; Lahti et al. 2016). It could be implied from the little evidence there is of an association between the intensity of physical activity and subsequent mental health functioning, that the intensity of physical activity is not as important for mental health functioning as it is for physical health functioning (Lahti et al. 2016). There is limited evidence on the associations between changes in physical activity and subsequent functioning.

Previous studies have shown that physical activity is associated with both subsequent sickness absence (Eriksen & Bruusgaard 2002; Holopainen et al. 2012; Lahti et al. 2012; Lahti et al. 2010; Proper et al. 2006; Quist et al. 2014; van Amelsvoort et al. 2006) and subsequent disability retirement (Fimland et al. 2015; Friis et al. 2008; Hagen et al. 2002; Krokstad et al. 2002; Lahti, Rahkonen, et al. 2013; Robroek, Schuring, et al. 2013). There is some evidence of an association between physical activity and subsequent disability retirement due to musculoskeletal and mental causes (Fimland et al. 2015; Robroek, Schuring, et al. 2013), but the associations could be stronger in the case of musculoskeletal causes (Robroek, Schuring, et al. 2013). Physical activity has also been associated with sickness absence due to musculoskeletal (van Amelsvoort et al. 2006; Holopainen et al. 2012) and mental causes (Holopainen et al. 2012). However, diagnosis-specific examination of sickness absence is still based on only a few studies (Holopainen et al. 2012; van Amelsvoort et al. 2006).

Little is known about the associations between changes in the intensity of physical activity and mental health functioning in particular, given that the few studies that examined changes in physical activity and subsequent functioning (Williams et al. 2014; Wolin et al. 2007) did not consider the intensity of the activity. Moreover, only a few studies focused on the association of changes in physical activity with work disability (Lahti et al. 2012; Ropponen et al. 2011), and there is limited evidence concerning the association between leisure-time physical activity and sickness absence on the grounds of a medically confirmed diagnosis.

Increases in physical activity following the transition to statutory retirement and changes in leisure-time physical activity have been widely reported, despite a reported decrease in total physical activity including commuting and occupational physical activity. Most studies focusing on the association between the transition to retirement and changes in leisure-time physical activity rely on one post-retirement measurement of physical activity, and thus shed little light on whether any increase in physical activity after retirement is long-term or short-term.

4 THE AIMS OF THE STUDY

This study examined changes in physical activity among ageing employees and retirees. The main focus was on the associations between changes in physical activity and functioning and work disability, and specifically on whether such associations are different in the physical and mental domains of functioning and work disability. In addition, the determinants of changes in physical activity were addressed as the association between transition to retirement and physical activity were examined.

The specific aims of the study were to examine:

1. the associations between changes in physical activity and subsequent physical and mental health functioning (Sub-study I)
2. the associations between changes in physical activity and subsequent sickness absence due to musculoskeletal, mental and any causes (Sub-study II)
3. the association between changes in physical activity and subsequent disability retirement (Sub-study III)
4. whether physical activity changes after the transition to statutory retirement and during post-retirement years (Sub-study IV).

5 METHODS

5.1 STUDY DESIGN AND DATA COLLECTION

Helsinki Health Study phase 1 baseline mail questionnaire surveys were conducted in 2000, 2001 and 2002 among employees of the City of Helsinki who reached the ages of 40, 45, 50, 55 and 60 in those years. A phase 2 survey was conducted in 2007 and a phase 3 survey in 2012. (Table 2)

Sickness absence and disability pensions were used to measure work disability. Data on sickness absence, retirement and mortality during the follow-up were obtained from the registries of the Social Insurance Institute of Finland, the Finnish Centre for Pensions and Statistics Finland. Register data was linked with the survey data for those consenting to the external linkage (6,606, 90% of the respondents to the first follow-up). According to non-response and attrition analyses responders and consenters broadly represent the target population (Lahelma et al., 2013, Table 2)

Table 2. The survey and register data used in the present study

Helsinki Health Study (HHS) mail surveys	**Register linkages**
Target population: municipal employees of the City of Helsinki aged 40, 45, 50, 55 and 60 (Sample N=13,344)	Sickness absence spells >9 days following a medically confirmed diagnosis from the Social Insurance Institute of Finland 2006–2009
Phase 1: 2000–2002 (N=8,960) Response rate 67%	Retirement register data from the Finnish Centre for Pensions 2004–2013
Phase 2: 2007 (N=7,332) Response rate 83%	Causes of death register data from Statistics Finland, from the HHS baseline until 2013
Phase 3: 2012 (N=6,814) Response rate 79%	

5.2 PARTICIPANTS

Eighty per cent of the participants were women, which represents the gender distribution of municipal-sector employees in Finland (KT Local Government Employers 2014). The mean age at baseline was 49.4 years. The employees represented a large variety of non-manual and manual occupations. More than a third of them were managers and professionals at baseline, and one third were routine non-manual workers. The proportion of semi-professionals was somewhat lower, at 18.8 per cent, and manual workers were the smallest group with a proportion of 15.1 per cent. A large proportion of the employees, i.e. 42.4 per cent, experienced the transition to full-time retirement during the follow-up. (Table 3)

Table 3. The participants by background characteristics in phases 1, 2 and 3 (%)

	Phase 1	Phase 2	Phase 3
Women	80	81.5	81.7
Occupational position[1]			
Managers and professionals	30.2	30.7	31.6
Semi-professionals	18.8	19.2	19.5
Routine non-manuals	36.0	36.1	35.3
Manuals	15.1	13.9	13.6
Retired	0	21.4	42.4
N[2]	8786	7168	6668

[1] measured at baseline; [2] those without missing information

5.3 VARIABLES

Physical activity

The same question was used in all phases of the HHS mail surveys to measure leisure-time physical activity, which as mentioned previously includes commuting. Physical activity was divided into four levels of intensity: activity equivalent to walking, brisk walking, jogging and running. The respondents were asked to evaluate how many hours per week, on average, they had engaged in each level of activity in the previous 12 months in accordance with the following five alternatives: not at all, less than half-an-hour, between half and one hour, between two and three hours, and four hours or more.

The physical activity was converted into metabolic equivalent (MET) values by multiplying the time used in a single activity by the estimated MET value of the intensity level and adding the values of all the activity levels combined. Physical activity was classified in three categories: low, meaning an activity level of less than 14 MET-hours per week; moderate, meaning 14 or more MET-hours per week and including activities of moderate intensity equivalent to walking or brisk walking; and vigorous meaning 14 or more MET-hours per week, including some vigorous activity equivalent to jogging or running. Combining the three activity groups at phase 1 and phase 2 yielded a variable with nine categories describing changes and persistence in physical activity. (Lahti, 2011) The cut-off point of 14 MET-hours per week is based on the recommended level of physical activity approximately equivalent to energy expenditure of 1,000 kilocalories per week, which is sufficient to offset several risk factors of inactivity. (Fogelholm et al. 2005).

The persistently low activity group was used as a reference category to assess the association between changes in physical activity and subsequent sickness absence, the assumption being that the analyses would yield information on the impacts of persistent moderate and vigorous activity, as well as impacts of changes in the level of activity on sickness absence. The analytical strategy developed during the process of conducting the sub-studies. The examination of the associations between changes in physical activity and subsequent functioning and disability retirement focused more on changes in physical activity, which is the main subject of the thesis. Persistently low, persistently moderate and persistently vigorous activities were used as reference categories in Sub-studies I and III. These analyses provided more information on changes between moderate and vigorous activity. Continuous change in minutes spent on physical activity was used to examine the association between the transition to old-age retirement and physical activity.

Health related functioning

The Short Form 36 Health Survey (SF-36; Ware 2000), a widely-applied measure, was used to assess health related functioning in all three phases. The SF-36 comprises 36 questions, and the following eight subscales: physical functioning, role limitation due to physical problems, bodily pain, general health perceptions, mental health, role limitations due to emotional problems, social functioning and vitality. Physical and mental component scores compressed from the eight subscales by means of factor analysis were used in this study. Scores in the US general population range from zero to one hundred, the mean being 50 and the standard deviation 10. Higher scores on the physical and mental components represent better functioning.

Sickness absence

Register data on long-term sickness absence spells of at least ten working days with a medically confirmed diagnosis was obtained from the register of the Social Insurance Institution of Finland. The analyses in this study concerned the number of sickness absence benefit periods due to any cause, musculoskeletal (ICD-10 M00-M99) and mental causes (ICD-10 F00–F99) were analysed. The follow-up period was from the return of the phase 2 questionnaire to 2009 or until death or retirement. The mean follow-up time was 2.3 years. Register data on mortality was obtained from the registers of Statistics Finland. The number of sickness absence spells was analysed instead of the number of sickness absence days. Analysing the number of spells in relation to days at risk is more suitable for studying the risk factors of sickness absence, whereas examining numbers of sickness absence days is more efficient when the aim is to evaluate a disease burden in a given population (Hensing et al. 1998). In addition because the number of absence spells was analysed instead of days, the results are not dominated by few prolonged sickness absence spells.

Disability retirement

Register data from the Finnish Centre for Pensions (2004-2013) was used in the analyses of disability retirement. The mean follow-up time was 6.0 years. The investigation covered all (permanent, temporary and partial) disability pensions, the granting of which requires a medically confirmed diagnosis stating that the illness substantially reduces work ability. The emphasis in this study was on the risk of disability retirement on any grounds. Given the lack of cases, retirement attributable to musculoskeletal (ICD-10 M00-M99) and mental causes (ICD-10 F00–F99) were examined only descriptively. The follow-up period was from the return of the phase 2 questionnaire to 2013, or until death, another type of retirement or reaching the age of 63 (which is the limit for granting disability pensions in Finland).

Statutory retirement

The transition to statutory retirement was examined as a potential determinant of changes in physical activity. Information on transition to retirement was obtained from phase 3 of the HHS-study, where employment status, the date of the retirement and type of the pension were requested. Retirement status was classified into continuously employed (i.e. working during the whole follow-up period), firstly retired (retiring between phases 1 and 2), and secondly retired (retiring between phases 2 and 3). Those who retired in the six months before the follow-up were classified as still employed because physical activity was measured for the whole year preceding the surveys.

Covariates

There are several factors that could affect changes in physical activity, functioning and work disability. Socioeconomic position has been associated with changes in physical activity (Mäkinen et al. 2010; Seiluri et al. 2011) as well as with functioning (Chandola et al. 2007) and sickness absence (Kristensen et al. 2010; Piha et al. 2010), for example, and working conditions have been associated with work disability (Silva-Junior & Fischer 2014; Laaksonen et al. 2010). Other types of health behaviour such as smoking and drinking may also affect functioning, work disability and the ability to engage in physical activity, as can the body mass index (Laaksonen et al. 2009; Laaksonen et al. 2006; Woo et al. 2007). There is also a risk of reverse causation between changes in physical activity and functioning and work disability outcomes, given that ill health may also influence physical activity. The transition to retirement may well affect functioning as well as changes in physical activity. It was found in one study (Mein et al. 2003) that mental health functioning improved but among retirees declined among the continuously employed. Critical life events other than the transition to retirement, such as divorce, separation or the death of a spouse or partner may also produce changes in physical activity (Brown et al. 2009). In the light of these findings the following covariates were decided upon: gender, age, socioeconomic position, marital status, changes in smoking, alcohol intake and body mass index (BMI), limiting longstanding illness (LLI), the physical and mental strenuousness of work, and earlier sickness absence.

Data on occupational position was obtained from the registers of the City of Helsinki, and from the survey data for those who did not consent to register linkage. The surveys included an open question about the current position, categorised in four groups: managers and professionals, semi-professionals, routine non-manual workers and manual workers. The numbers of sickness absence spells from the year preceding the follow-up were obtained from the register of the Social Insurance Institution of Finland.

Information on smoking, drinking and BMI, LLI strenuousness of work and marital status was obtained from the survey data. The employees graded their work in terms of physical and mental strenuousness as very hard, somewhat hard, somewhat light, or very light. Physical strenuousness was categorised as hard if the employees defined it as very or somewhat hard. Mental strenuousness was categorised as hard if the employees defined it as very hard. The strenuousness of work was used as a covariate in Sub-studies II and III, which had work disability outcomes. The question on marital status included five response options, single, co-habiting, married, divorced or separated, and widowed. It was categorised as single, married or cohabiting, and divorced or widowed. Marital status was used as a covariate only in Sub-study IV. The participants were asked whether they had a longstanding illness, and if so whether it restricted their work or other daily tasks. Limiting longstanding illness (LLI) was dichotomised as those who reported an illness and consequent limitations and those who did not. The participants were asked whether they currently regularly smoked cigarettes, a pipe or cigars. Those who responded 'yes' were categorised as smokers. Binge drinking was used as an indicator of alcohol intake. The responders were asked how often they drank at least six alcohol portions on a single occasion: the response options were never, less than monthly, once a month, once a week, a few times a week, and daily or almost daily. Binge drinking was dichotomised as those who reported binge drinking at least once a week and those who did not. BMI was calculated by dividing the self-reported weight of the participant by their self-reported height in metres squared. BMI was categorised as overweight ($BMI \leq 25$ kg/m2) and normal weight ($BMI > 25 kg/m^2$) in Sub-studies II and III, and was used as continuous variable in Sub-studies I and IV.

Phase 1 data was used to assess gender, age and socioeconomic position, and the strenuousness of work. Changes in smoking between phases 1 and 2 were categorised in Sub-studies II and III as persistent non-smokers, those who stopped smoking, those who started smoking and persistent smokers. Changes in BMI, drinking (Sub-studies II and III) and LLI (Sub-study III) were categorised in a similar manner. Time-variant data on all the covariates except gender, age and socioeconomic position was used in Sub-studies I and IV.

5.4 STATISTICAL METHODS

Descriptive analyses were conducted using cross-tabulations and comparing means. Negative binomial regression was the main method applied for analysing the association between changes in physical activity and subsequent sickness absence. Cox regression was used to analyse the association between the changes in physical activity and the risk of subsequent disability retirement. Negative binomial models for repeated measurements using generalised estimating equations (GEE) were used to examine the changes in physical activity after the transition to retirement and during post-retirement years. Linear mixed models were used as the main method of analysing the association between changes in physical activity and subsequent changes in health related functioning. Women and men were analysed together in all the sub-studies. There were no statistically significant gender interactions. The analyses were performed with SPSS version 22 for Windows.

GEE and linear mixed models were applied in Sub-studies I and IV: they are considered more suitable for analysing longitudinal data than traditional regression methods in that they take into account the fact that repeated observations for individuals are not independent (Ghisletta & Spini 2004; Twisk 2013). Mixed models are the most well-known methods that incorporate the correlated repeated measures. However, linear mixed models assume normal distribution (Hoekstra & Twisk 2015) of the residuals of the outcome, and because the physical-activity variable did not comply with this assumption negative binomial models for repeated measurements using GEE were used in Sub-study IV.

The analyses were adjusted for the covariates using three or four models. The first adjustments were for age and gender, followed by SEP, job-exposure characteristics, marital status and changes in other health behaviours. BMI and LLI as well as previous sickness absence were adjusted for separately in the third model, or in separate models. This was done because adjusting for them could potentially be considered over-adjustment: they are variables that could be affected by changes in physical activity.

5.5 ETHICAL CONSIDERATIONS

The ethical guidelines of the University of Helsinki and Finnish legislation including the Personal Data Act are followed in the study protocol. The Ethics committees of the City of

Helsinki and the University of Helsinki, Department of Public Health have approved the Helsinki Health Study Protocol.

The employees were informed that participating in the survey was voluntary. The register linkages were made only for the respondents who gave their written consent. The respondents were informed that it was possible to withdraw permission for data linkage. Confidentiality, anonymity and data protection were assured, meaning that giving information for study purposes involved no personal risk. The participants were also informed about this, as well as about the other ethical guidelines.

The results of the Helsinki Health Study and the present study have been presented to the management of the human resources and occupational health departments of the City of Helsinki. The fact that the City of Helsinki has acquired information about issues related to work disability among its employees means that the study results could also benefit the participants on a personal level in addition to generally enhancing the promotion of public health. In general, in terms of weighing up the risks and benefits of the study, confidentially and informed consent, the Helsinki Health study complies fully with the World Medical Association's Declaration of Helsinki on ethical principles for medical research involving human subjects (World Medical Association 2013).

6 RESULTS

6.1 CHANGES IN PHYSICAL ACTIVITY DURING THE FOLLOW-UP

The weekly volume of physical activity at phase 1 was, on average, 29.1 MET-hours among the employees who responded to the physical activity question in all three phases of the study (N=6048). Men were more active than women. The mean MET-hours per week was 33.1 among the men and 28.3 among the women. There was a slight increase in the volume of physical activity in both genders between phases 1 and 2, and a slight decrease between phases 2 and 3. There were similar changes in time spent on leisure-time physical activity as in MET-hours. (Figure 1 & Figure 2) According to the one-way analysis of variance ($p<0.01$), the changes in mean MET-hours and in time spent on leisure-time physical activity during the follow-up were statistically significant among all the employees and women, but not among the men (data not shown).

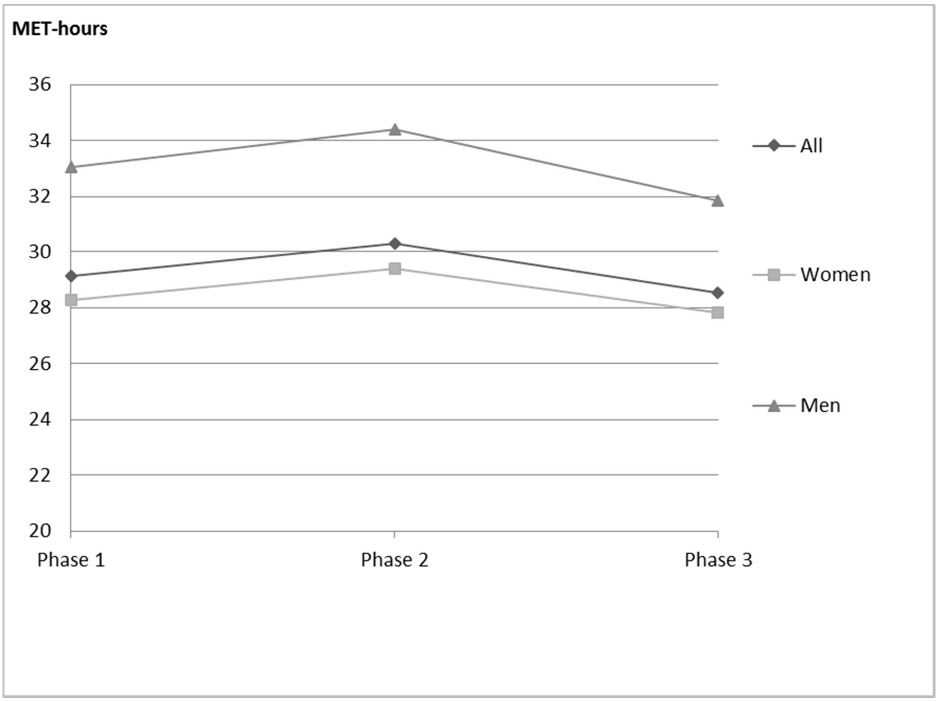

Figure 1. Changes in leisure-time physical activity (mean MET-hours per week) from phase 1 to phase 3 among all employees (N=6048), women (N=4975) and men (N=1073)

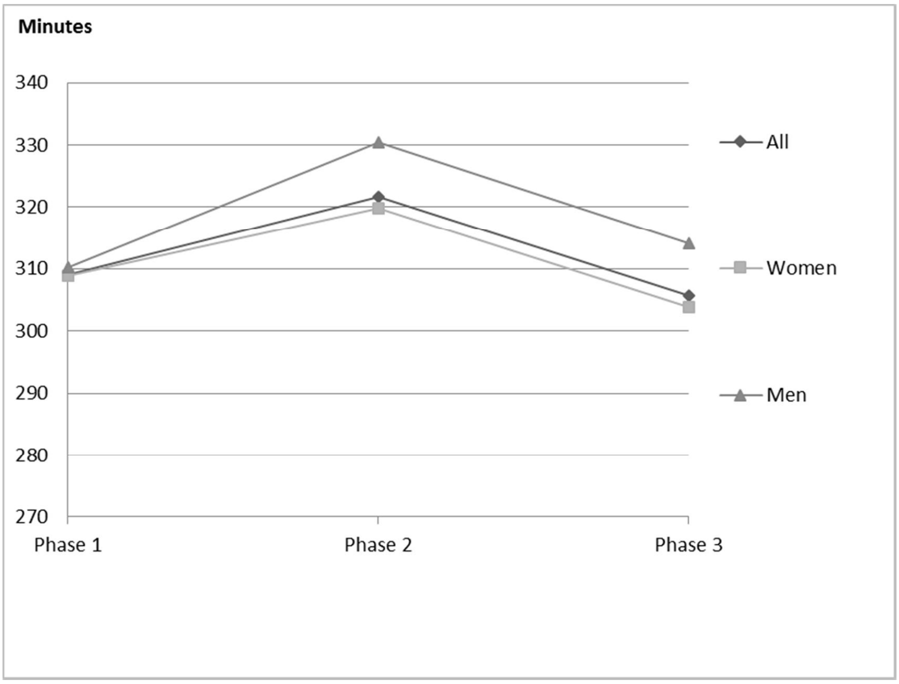

Figure 2. Changes in time spent on leisure-time physical activity (minutes/week) from phase 1 to phase 3 among all employees (N=6048), women (N=4975) and men (N=1073)

Most of the employees did not change their level of physical activity between low, moderate and vigorous from phase 1 to phase 2. Persistent moderate and vigorous physical activity was common: a quarter of the respondents were persistently moderately active, and one fifth were persistently vigorously active, whereas only 11 per cent reported a persistently low level of activity. Changes in physical activity from low to moderate, moderate to low, moderate to vigorous and vigorous to moderate were almost as common as persistent low activity. Changes between low and vigorous physical activity were the rarest. (Figure 3)

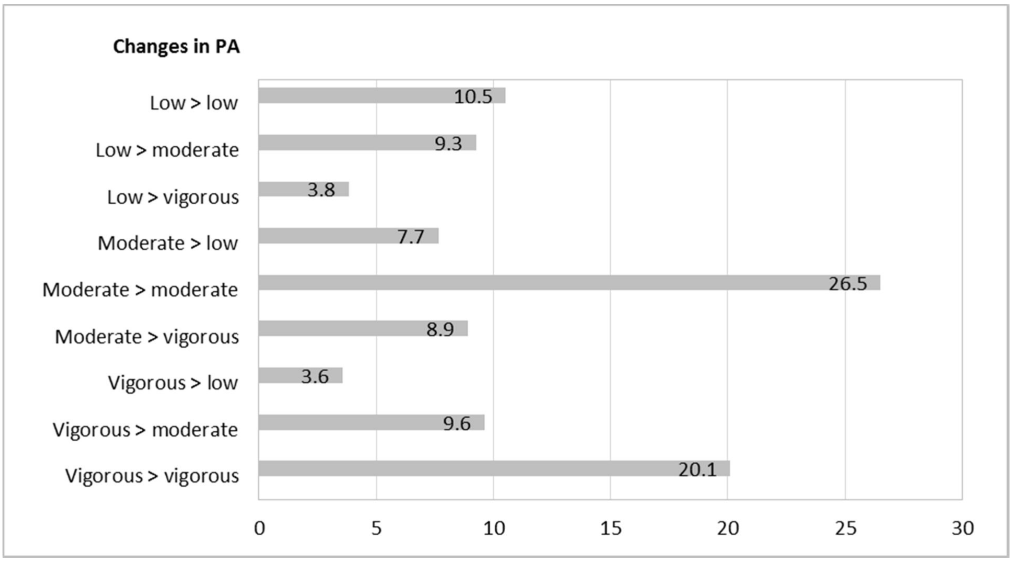

Figure 3. The proportion (%) of the participants in the changes-in-physical-activity groups between phases 1 and 2 (N=6048)

6.2 CHANGES IN PHYSICAL ACTIVITY AND SUBSEQUENT PHYSICAL AND MENTAL HEALTH FUNCTIONING

Sub-study I examined the associations between changes in physical activity and both physical and mental health functioning. The analysis included 5,475 employees and retirees. The mean summary scores for physical health functioning varied from 49.4 to 46.9 between phases 1 and 3 of the follow-up, and there was a decrease in all activity categories. The mental health functioning summary scores changed in the opposite direction, from 51.8 to 53.0. (Appendix 1)

Physical health functioning

All the examined changes in physical activity were associated with the subsequent level of physical health functioning: increases in physical activity were associated with better physical health functioning. The associations were stronger when the level of activity changed from low to vigorous (β 5.38, CI 4.12 to 6.65) rather than from low to moderate (β 3.10, CI 2.13 to 4.07) compared with persistently low activity. Decreases in levels of physical activity were associated with subsequent lower levels of physical health functioning. (Table 4)

Adjustments for socioeconomic position, smoking and employment status did not change the associations, whereas adjusting for limiting longstanding illness and body-mass index attenuated them slightly.

Mental health functioning

Increasing the level of physical activity from low to moderate compared with persistently low was associated with better subsequent mental health functioning (β 1.40, CI 0.4 to 2.38). On the other hand, decreasing the activity level from moderate to low (β -2.04, CI 2.95 to -1.13) compared with persistently moderate, or from vigorous to low (β -2.15, CI -1.89 to -1.84) compared with persistently vigorous, was associated with worse subsequent mental health functioning.

The associations for changes in physical activity from low to moderate and moderate to low remained following adjustment for occupational position, smoking and employment status. Adjusting for LLI and BMI attenuated them slightly. In cases of change from vigorous to low, the associations attenuated slightly following adjustment for occupational position, smoking and employment status, but adjusting for LLI and BMI did not change them further. (Table 5)

Table 4. The associations between changes in physical activity and subsequent physical health functioning, beta coefficients and 95% confidence intervals (CI) (N=5575)

	Model 1			Model 2			Model 3		
	β	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**
Low>low	ref.			ref.			ref.		
Low>moderate	3.10	(2.13-4.07)	<0.001	3.04	(3.78-6.33)	<0.001	2.17	(1.30-3.03)	<0.001
Low>vigorous	5.38	(4.12-6.65)	<0.001	5.06	(2.06-4.01)	<0.001	3.32	(2.18-4.45)	0.375
Moderate>moderate	ref.			ref.			ref.		
Moderate>low	-2.67	(-3.55-(-1.78))	<0.001	-2.72	(-3.61-(-1.83))	<0.001	-1.91	(-2.70-(-1.12))	<0.001
Moderate>vigorous	3.08	(2.26-3.90)	<0.001	3.02	(2.19-3.85)	<0.001	2.27	(1.54-3.01)	<0.001
Vigorous>vigorous	ref.			ref.			ref.		
Vigorous>low	-3.81	(-5.03-(-2.58))	<0.001	-3.61	(-4.84-(-2.37))	<0.001	-2.53	(-3.63-(-1.43))	<0.001
Vigorous>moderate	-2.37	(-3.20-(-1.54))	<0.001	-2.09	(-2.93-(-1.26))	<0.001	-1.49	(-2.23-(-0.75)	<0.001

Model 1: adjusted for age and gender

Model 2: adjusted for age, gender, occupational socioeconomic position, employment status and smoking

Model 3: adjusted for age, gender, occupational position, employment status, smoking, limiting longstanding illness and body mass index

Table 5. The associations between changes in physical activity and subsequent mental health functioning, beta coefficients and 95% confidence intervals (CI) (N=5475)

	Model 1			**Model 2**			**Model 3**		
	β	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**
Low>low	ref.			ref.			ref.		
Low>moderate	1.40	(0.40-2.38)	0.006	1.34	(0.33-2.34)	0.009	1.20	(0.20-2.20)	0.018
Low>vigorous	0.81	(-0.48-2.09)	0.222	0.61	(-0.70-1.92)	0.361	0.44	(-0.87-1.75)	0.510
Moderate>moderate	ref.			ref.			ref.		
Moderate>low	-2.04	(-2.95-(-1.13))	<0.001	-2.01	(-2.93-(-1.09))	<0.001	-1.93	(-2.84-(-1.01))	0.001
Moderate>vigorous	0.41	(-0.43-1.25)	0.336	0.54	(-0.31-1.40)	0.214	0.46	(-0.39-1.32)	0.289
Vigorous>vigorous	ref.			ref.			ref.		
Vigorous>low	-2.15	(-3.40-(-0.90))	0.001	-1.89	(-3.17-(-0.62))	0.004	-1.84	(-3.11-(-0.57)	0.004
Vigorous>moderate	-0.69	(-1.54-0.15)	0.109	-.54	(-1.40-0.32)	0.216	-0.47	(-1.33-0.38)	0.277

Model 1: adjusted for age and gender

Model 2: adjusted for age, gender, occupational position, employment status and smoking

Model 3: adjusted for age, gender, occupational position, employment status, smoking, limiting longstanding illness and body mass index

6.3 CHANGES IN PHYSICAL ACTIVITY AND SUBSEQUENT SICKNESS ABSENCE

Sub-study II examined the associations between changes in physical activity and subsequent sickness absence periods lasting at least ten working days. Separate analyses were conducted for absence attributable to any cause, musculoskeletal causes and mental causes.

The analyses covered 4,010 employees. Those who were retired or not otherwise employed during phase 2 and respondents with missing values in the main variables were excluded. The employees were followed up from phase 2 until the end of 2009, or until death or retirement. The mean follow-up time was 2.3 years. There were 1,541 sickness absence spells during the follow-up, of which 585 were related to musculoskeletal and 248 to mental causes. Over 100 person-years there were 18.6 periods of sickness absence, 7.0 attributable to musculoskeletal and 2.8 to mental causes. (Table 6)

Sickness absence due to all causes

Following adjustment for age and gender, persistently moderate (RR 0.83, CI 0.69 to 0.98) and vigorous (RR 0.57, CI 0.48 to 0.69) activity, and changes in activity from low to vigorous (RR 0.63, CI 0.46 to 0.86), from moderate to vigorous (RR 0.57, CI 0.45 to 0.72) and from vigorous to moderate (RR 0.67, CI 0.54 to 0.83) were associated with a lower risk of subsequent sickness absence. Adjustment for occupational position, job exposure characteristics and changes in other health behaviours attenuated the associations such that persistently moderate activity and increasing activity from low to vigorous were no longer associated with a lower risk of sickness absence. Further adjustment for BMI or earlier sickness absence did not markedly change the associations. (Table 7)

Sickness absence due to musculoskeletal causes

In a model adjusted for age and gender, persistently moderate (RR 0.62, CI 0.30 to 0.99) and persistently vigorous (RR 0.58, CI 0.36 to 0.96) compared with persistently low activity were associated with a lower risk of sickness absence due to mental causes. Adjusting for occupational position, job-exposure characteristics and changes in other health behaviours attenuated the associations, which remained similar following adjustment for BMI. Adjusting for earlier sickness absence instead of BMI restored the lower risk among those with persistently moderate activity. (Table 9)

Table 6. Periods of sickness absence per 100 follow-up years by change in physical activity (N=4010)

Phase 1		Low			Moderate			Vigorous		
Phase 2	All	Low	Moderate	Vigorous	Low	Moderate	Vigorous	Low	Moderate	Vigorous
N	4010	379	345	159	305	937	375	167	404	939
All (SA/100 years)	18.3	24.9	17.6	15.2	24.4	21.4	14.2	20.3	16.9	13.5
Musculoskeletal (SA/100 years)	7.0	10.1	7.0	2.9	8.5	9.1	5.1	7.3	7.1	4.4
Mental (SA/100 years)	2.8	3.9	2.2	3.5	4.5	2.6	3.5	2.8	2.5	2.1

Table 7. Any sickness absence spells (> 9 days) by changes in physical activity: rate ratios (RR) and their and their 95% confidence intervals (CI), (N=4010)

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	RR	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Low>low	1		1		1		1	
Low>moderate	0.70	(0.56-0.88)	0.74	(0.56-0.97)	0.75	(0.57-0.99)	0.80	(0.60-1.05)
Low>vigorous	0.63	(0.46-0.86)	0.73	(0.50-1.05)	0.75	(0.52-1.08)	0.79	(0.55-1.15)
Moderate>low	0.97	(0.79-1.21)	0.94	(0.72-1.23)	0.95	(0.73-1.24)	0.88	(0.67-1.16)
Moderate>moderate	0.83	(0.69-0.98)	0.85	(0.69-1.06)	0.86	(0.70-1.07)	0.84	(0.67-1.04)
Moderate>vigorous	0.57	(0.45-0.72)	0.64	(0.48-0.84)	0.68	(0.51-0.90)	0.68	(0.51-0.91)
Vigorous>low	0.84	(0.64-1.11)	0.88	(0.63-1.23)	0.90	(0.65-1.27)	0.90	(0.64-1.26)
Vigorous>moderate	0.67	(0.54-0.83)	0.72	(0.55-0.94)	0.75	(0.58-0.98)	0.75	(0.57-0.98)
Vigorous>vigorous	0.57	(0.48-0.69)	0.68	(0.54-0.85)	0.73	(0.57-0.92))	0.71	(0.56-0.90)

Model 1: adjusted for age and gender

Model 2: adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline and job exposure characteristics at follow-up

Model 3: adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline, job exposure characteristics at follow-up and changes in BMI

Model 4 adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline, job exposure characteristics at follow-up and previous sickness absence

Table 8. Sickness absence due to musculoskeletal causes (> 9 days) by change in physical activity: rate ratios (RR) and their 95% confidence intervals (CI), (N=4010)

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	RR	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Low>low	1		1		1		1	
Low>moderate	0.70	(0.47-1.02)	0.75	(0.50-1.11)	0.76	(0.51-1.14)	0.81	(0.54-1.21)
Low>vigorous	0.30	(0.15-0.59)	0.39	(0.19-0.78)	0.42	(0.21-0.84)	0.41	(0.20-0.83)
Moderate>low	0.84	(0.58-1.23)	0.82	(0.56-1.21)	0.83	(0.56-1.23)	0.71	(0.47-1.06)
Moderate>moderate	0.87	(0.65-1.17)	0.88	(0.65-1.19)	0.91	(0.67-1.24)	0.78	(0.56-1.07)
Moderate>vigorous	0.50	(0.33-0.75)	0.58	(0.38-0.89)	0.66	(0.43-1.01)	0.62	(0.40-0.96)
Vigorous>low	0.75	(0.46-1.21)	0.82	(0.50-1.35)	0.88	(0.53-1.45)	0.80	(0.47-1.34)
Vigorous>moderate	0.69	(0.48-1.00)	0.76	(0.52-1.11)	0.85	(0.58-1.25)	0.75	(0.51-1.12)
Vigorous>vigorous	0.46	(0.32-0.64)	0.58	(0.41-0.81)	0.68	(0.48-0.97)	0.60	(0.42-0.86)

Model 1: adjusted for age and gender

Model 2: adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline and job exposure characteristics at follow-up

Model 3: adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline , job exposure characteristics at follow-up and changes in BMI

Model 4 adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline, job exposure characteristics at follow-up and previous sickness absence

Table 9. Sickness absence due to mental causes (> 9 days) by change in physical activity: rate ratios (RR) and their 95% confidence intervals (CI), (N=4010)

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	RR	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Low>low	1		1		1		1	
Low>moderate	0.55	(0.30-1.04)	0.59	(0.31-1.11)	0.59	(0.32-1.11)	0.64	(0.34-1.22)
Low>vigorous	0.91	(0.45-1.84)	1.03	(0.51-2.09)	1.03	(0.51-2.09)	1.16	(0.56-2.41)
Moderate>low	1.13	(0.66-1.93)	1.22	(0.71-2.10)	1.21	(0.70-2.08)	1.08	(0.61-1.91)
Moderate>moderate	0.62	(0.30-0.99)	0.69	(0.43-1.10)	0.68	(0.42-1.10)	0.61	(0.37-1.00))
Moderate>vigorous	0.86	(0.50-1.56)	0.96	(0.56-1.66)	0.96	(0.55-1.67)	1.03	(0.59-1.82)
Vigorous>low	0.74	(0.35-1.56)	0.76	(0.36-1.63)	0.76	(0.36-1.62)	0.73	(0.38-1.27)
Vigorous>moderate	0.62	(0.35-1.10)	0.67	(0.87-1.20)	0.66	(0.36-1.19)	0.70	(0.38-1.27))
Vigorous>vigorous	0.58	(0.36-0.96)	0.66	(0.40-1.08)	0.65	(0.39-1.07)	0.62	(0.37-1.04)

Model 1: adjusted for age and gender

Model 2: adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline and job exposure characteristics at follow-up

Model 3: adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline, job exposure characteristics at follow-up and changes in BMI

Model 4 adjusted for age, gender, changes in smoking and binge drinking, occupational position at baseline, job exposure characteristics at follow-up and previous sickness absence

6.4 CHANGES IN PHYSICAL ACTIVITY AND SUBSEQUENT DISABILITY RETIREMENT

Sub-study III examined the associations between changes in physical activity and subsequent disability retirement. The employees were followed-up from phase 2 until 2013, or until retirement or death. The mean follow-up time was 6.0 years. During the follow-up 264 employees were granted disability retirement. The highest proportion of disability retirement events (10%) involved employees whose activity level was persistently low, but a similar proportion involved those who decreased their physical activity from vigorous to low (9.8%), or from moderate to low (9.2%). The proportion of disability retirements was lower among those who were persistently vigorously active (3.5%), or had increased their activity level from low to vigorous (3.2%) or from moderate to vigorous (4%). (Table 10)

Following adjustment for gender and age, increases in physical activity from low to vigorous (HR 0.31, CI 0.12 to 0.79) or from moderate to vigorous (HR 0.47, CI 0.27 to 0.82) were associated with a lower risk of disability retirement, whereas decreasing the level from vigorous to low (HR 2.78, CI 1.53 to 5.05) or to moderate (HR 1.95, CI 1.18 to 3.21) was associated with a higher risk. Adjusting for occupational position, the strenuousness of work, smoking, and binge drinking attenuated the associations slightly, nevertheless they remained. Finally, adjusting for BMI, LLI or earlier sickness absence attenuated them further. (Table 11)

Table 10. Disability retirement events by physical activity change groups (N=3943).

Phase 1		Low			Moderate			Vigorous		
Phase 2	All	Low	Moderate	Vigorous	Low	Moderate	Vigorous	Low	Moderate	Vigorous
N	3943	370	336	158	294	915	371	164	400	935
Disability retirement events (%)	264 (6.7)	37 (10.0)	23 (6.8)	5 (3.2)	27 (9.2)	79 (8.6)	15 (4.0)	16 (9.8)	29 (7.2)	33 (3.5)

Table 11. The risk of subsequent disability retirement (2007-2013) by changes in physical activity: hazard ratios (HR) and their 95% confidence intervals (CI), (N=3943)

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	HR	**95% CI**	**HR**	**95% CI**	**HR**	**95% CI**	**HR**	**95% CI**	**HR**	**95% CI**
Low>low	1		1		1		1		1.	
Low>moderate	0.65	(0.39-1.10)	0.70	(0.41-1.17))	0.72	(0.42-1.21)	0.85	(0.51-1.44)	0.83	(0.49-1.40)
Low>vigorous	0.31	(0.12-0.79)	0.38	(0.15-0.97)	0.40	(0.16-1.03)	0.44	(0.17-1.11)	0.40	(0.16-1.02)
Moderate>moderate	1		1		1		1		1.	
Moderate>low	1.11	(0.72-1.72)	1.05	(0.68-1.63)	1.03	(0.66-1.59)	1.07	(0.69-1.66)	0.96	(0.62-1.50)
Moderate>vigorous	0.47	(0.27-0.82)	0.50	(0.28-0.86)	0.53	(0.30-0.92))	0.60	(0.34-1.04)	0.55	(0.32-0.96)
Vigorous>vigorous	1		1		1		1		1.	
Vigorous>low	2.78	(1.53-5.05)	2.42	(1.32-4.41)	2.25	(1.23-4.13)	2.02	(1.10-3.68)	2.56	(1.40-4.68)
Vigorous>moderate	1.95	(1.18-3.21)	1.70	(1.03-2.82)	1.64	(0.99-2.81)	1.61	(0.97-2.66)	1.75	(1.06-2.89)

Model 1: adjusted for age and gender

Model 2: adjusted for age, gender, occupational position, strenuousness of work, smoking and binge drinking

Model 3: adjusted for age, gender, occupational position, strenuousness of work, smoking, binge drinking and BMI

Model 4 Adjusted for age, gender, occupational position, strenuousness of work, smoking, binge drinking and LLI

Model 5 Adjusted for age, gender, occupational position, strenuousness of work, smoking, binge drinking and earlier sickness absence

6.5 THE TRANSITION TO STATUTORY RETIREMENT AND CHANGES IN PHYSICAL ACTIVITY

Sub-study IV examined the association between the transition to statutory retirement and changes in physical activity. The study population comprised 2,902 employees and retirees, of whom 851 retired between phases 1 and 2 (*retired1)*, and 948 between phases 2 and 3 (*retired2):* 1,108 remained continuously employed.

Between phases 1 and 2 physical activity increased on average by 33 minutes among the retired1 group and 15 minutes among the retired2 group. There was very little change among the continuously employed, just a two-minute mean increase. There was an average decrease in physical activity between phases 2 and 3 of 34 minutes in the retired1 group and 20 minutes among the continuously employed, in contrast with a continuing increase of nine minutes in the retired2 group. (Figure 4)

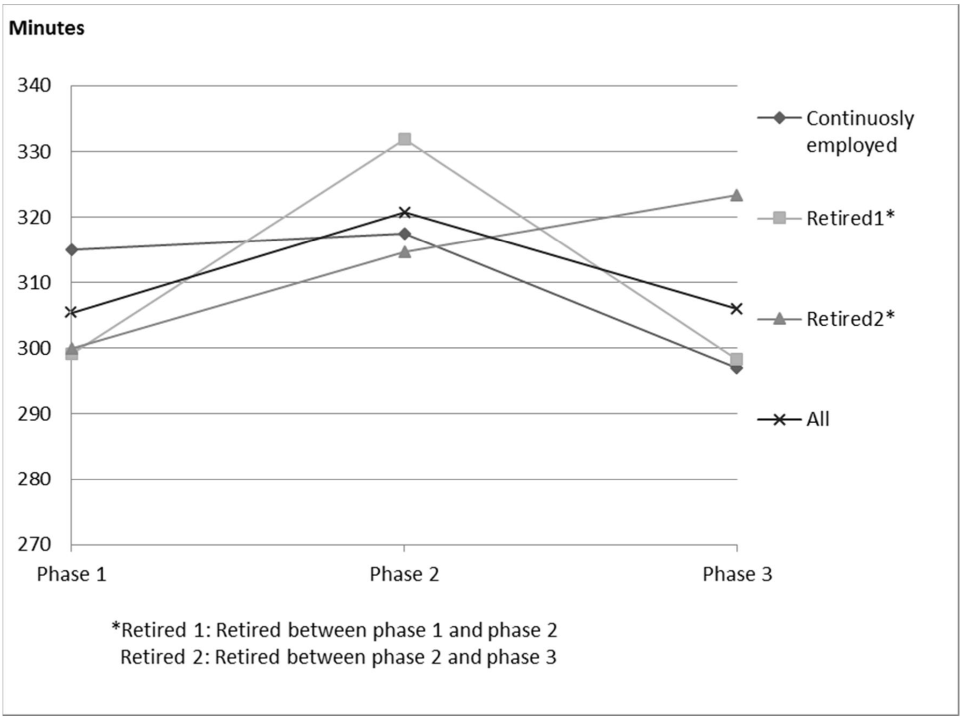

Figure 4. Average time spent on physical activity per week by employment status

The age- and gender-adjusted models indicated a bigger increase in physical activity in the retired1 group than among the continuously employed (IRR=1.10, 95% CL 1.04–1.17) between phases 1 and 2, during which time they retired. There was a similar difference (IRR=1.10, 95% CI 1.04–1.16) between the retired2 group and the continuously employed between phases 2 and 3. Adjusting for occupational class and marital status did not change these associations, whereas adjusting for smoking, LLI, and BMI attenuated them slightly. (Table 12 & Table 13)

Physical activity decreased more in the retired1 group than among the continuously employed between phases 2 and 3 (Figure 2) but there were no statistically significant differences except in model 3, in which all the covariates were adjusted for. (Table 13)

Table 12. The association between retirement status (N=2902) and change in time (min/week) spent on physical activity between phases 1 and 2

	Continuously employed	Retired1		Retired2	
	IRR	IRR	95% CI	IRR	95% CI
Model 1	1	1.10	(1.04-1.17)	1.04	(0.98-1.11)
Model 2.	1	1.10	(1.04-1.17)	1.04	(0.98-1.11)
Model 3.	1	1.07	(1.01-1.14)	1.03	(0.97-1.09)

Retired 1: Retired between phase 1 and phase 2

Retired 2: Retired between phase 2 and phase 3

Model 1. Adjusted for age and gender

Model 2. Adjusted for age, gender, occupational position and marital status

Model 3. Adjusted for age, gender, occupational position, marital status, smoking, LLI and BMI

Table 13. The association between retirement status (N=2902) and change in time (min/week) spent on physical activity between phases 2 and 3

	Continuously employed	Retired1		Retired2	
	IRR	IRR	95% CI	IRR	95% CI
Model 1	1	0.96	(0.91-1.02)	1.10	(1.04-1.16)
Model 2.	1	0.96	(0.91-1.02)	1.10	(1.04-1.16)
Model 3.	1	0.95	(0.89-1.00)	1.09	(1.02-1.15)

Retired 1: Retired between phase 1 and phase 2

Retired 2: Retired between phase 2 and phase 3

Model 1. Adjusted for age and gender

Model 2. Adjusted for age, gender, occupational position and marital status

Model 3. Adjusted for age, gender, occupational position, marital status, smoking, LLI and BMI

7 DISCUSSION

This study examined changes in physical activity, their consequences on physical functioning and work disability, and their determinants among employees and retirees. The evidence thus far is limited, and much of the earlier literature considers physical activity only at a single time point. Changes in physical activity are also significant from the public-health perspective: increasing the level of physical activity could improve the health, work ability and functioning of an ageing population, for example. The first aim of the study was to examine the associations between changes in physical activity and both subsequent health functioning and work disability. This included a separate investigation into the physical and mental aspects of health functioning and sickness absence. The second aim was to examine the transition to retirement as a potential determinant of change in physical activity.

7.1 MAIN FINDINGS

The mean volume and time spent on physical activity among the study participants increased slightly between the baseline in 2000-2002 and the follow-up in 2007, and then decreased slightly between 2007 and the second follow-up in 2012. Persistent moderate or vigorous activity was common among the participants, and only ten percent of them reported a persistently low activity level. Around a third of them changed their level of activity between low and moderate and moderate and vigorous, but changes between low and vigorous were rare.

Increased physical activity was associated with better and decreased physical activity with worse physical health functioning, whereas an increase from low to moderate activity was associated with better mental health functioning. Decreasing physical activity from moderate or vigorous to low was associated with worse mental health, and vigorous activity was more strongly associated with better physical health than moderate activity. According to the results, the intensity of the activity had less significance in the case of mental health.

Persistently vigorous and increased levels of physical activity were negatively associated with subsequent sickness absence. Vigorous activity was especially effective in avoiding sickness absences attributable to musculoskeletal causes. However, the level of intensity of physical activity was less important to the risk of sickness absence attributable to mental causes. Increasing the level of activity from low or moderate to vigorous was associated with a lower risk of subsequent disability retirement. Similarly, decreasing physical activity from vigorous to moderate or low was associated with a higher risk of disability retirement.

The transition to statutory retirement was associated with a modest increase in physical activity. Physical activity increased among employees during the periods in which they retired. However, this increase did not persist in post-retirement years, when the time spent on physical activity returned to the level preceding the transition.

7.2 COMPARISONS AND INTERPRETATIONS OF THE FINDINGS

The employees examined in this study were more physically active than the Finnish general population: one third of Finnish adults do not engage in any leisure-time physical activity (Mäkinen et al. 2012). Most of the roughly 20 percent of the participants who reported a low activity level in phases 1 and 2 of the study were not completely passive. The physical-activity measure used included commuting, which could partly explain the difference in the level of physical activity between these employees and the general population. However, the prevalence of commuting physical activity is also low in the general population. It has been shown that only 25 per cent of women aged 30-64 and 16.5 percent of men in this age group engaged in at least 15 minutes of physical activity during their daily commute (Mäkinen et al. 2012). It was also reported in a study (Kouvonen et al. 2013) conducted among Finnish public-sector employees recruited from 10 municipalities and 21 hospitals that 24 per cent of the participants engaged in an insufficient level of physical activity, defined as in the present study as less than 14 MET-hours weekly. Hence, the participants of the Helsinki Health Study and municipal employees in Finland appear to engage in similar levels of physical activity.

Participation in leisure-time physical activity has generally increased in Finland since the end of the 1970s (Borodulin et al. 2016; Heldan & Helakorpi 2014; Mäkinen et al. 2009). Inactivity decreased and engagement in vigorous activity several times a week increased among Finnish women and men from 2002-2012, the same period during which the present study was conducted. However, the increased physical activity in 2007 observed in the present study was not observed in the Finnish population (Borodulin et al. 2016). The increased physical activity after the transition to retirement reported in Sub-study IV could partly explain the increase in phase 2. It could also have been a cohort effect, or a coincidence.

The observed associations of increased physical activity with better physical health functioning and decreased activity with worse physical functioning reflects the findings of earlier studies on changes in physical activity and subsequent physical health functioning (Williams et al. 2014; Wolin et al. 2007). Fewer and weaker associations were observed between changes in physical activity and mental functioning. Previous studies have also reported associations between changes in physical activity and the SF-36 subscales contributing to mental health summary scores (Tessier et al. 2007; Wolin et al. 2007). Tessier et al. (2007) found positive associations between changes in physical activity and changes in mental health functioning, but only among women.

Several previous studies have revealed associations between physical activity and the risk of sickness absence (Eriksen & Bruusgaard 2002; Holopainen et al. 2012; Lahti et al. 2012; Lahti et al. 2010; Proper et al. 2006; Quist et al. 2014; van Amelsvoort et al. 2006). Similarly, associations between physical activity and disability retirement have been reported widely (Fimland et al. 2015; Friis et al. 2008; Hagen et al. 2002; Krokstad et al. 2002; Lahti, Rahkonen, et al. 2013; Robroek, Schuring, et al. 2013). The current study provided novel evidence to complement the findings of the earlier studies, which did not examine changes in physical activity. It showed that increased and persistent physical activity is associated with a lower risk of sickness absence, and that adopting vigorous activity is associated with a lower risk of disability retirement and decreasing the physical activity level from vigorous to low or moderate with a higher risk of disability retirement. The only previous study (Ropponen et al. 2011) examining changes in physical activity and disability retirement, conducted among a Swedish twin cohort, reported an association between decreased physical activity and all-cause disability retirement only when familial conditions were not adjusted for.

The findings from Sub-studies I and II revealed that vigorous physical activity was especially beneficial for physical functioning and for the prevention of sickness absence attributable to musculoskeletal diseases. The intensity of physical activity had less significance on mental health functioning and sickness absence due to mental diseases. Of the few studies (van Amelsvoort et al. 2006; Haukka et al. 2014; Holopainen et al. 2012) on the association between physical activity and sickness absence related to musculoskeletal causes, two (van Amelsvoort et al. 2006; Haukka et al. 2014) did not examine the intensity of the activity. An earlier study (Holopainen et al. 2012) on the Helsinki Health Study cohort examined associations between physical activity measured at a single time point and long (>3 months) sickness absence on the grounds of musculoskeletal and mental causes, but did not report similar differences between musculoskeletal and mental causes as found in this study. On the contrary, vigorous activity was also more beneficial than moderate activity in the case of sickness absence due to mental diseases. However, the associations were similarly stronger for musculoskeletal than for mental causes. The associations between changes in the intensity of physical activity and physical and mental health functioning reported here reflect previous findings from studies on the intensity of physical activity and physical (Gebel et al. 2014; Lahti 2011) and mental health functioning (Lahti et al. 2016), which nevertheless did not examine changes in physical activity. In addition, our results on mental health functioning and sickness absence due to mental causes are in line with previous results on depression (Teychenne et al. 2008) and psychotropic medication (Lahti, Lallukka, et al. 2013), indicating that the intensity of physical activity might not be as influential on mental outcomes.

There are different mechanisms linking physical activity with physical and mental health. The differences in these mechanisms could explain why vigorous physical activity has a stronger effect on the physical domains of work disability than on the mental domains. The mechanism through which physical activity affects physical health functioning and work disability attributable to musculoskeletal causes might be more strongly related to physical fitness than the mechanisms linking physical activity with mental health. Low back pain, for example, could be prevented or alleviated through enhanced muscle strength, muscular endurance, general endurance, and flexibility (Vuori 2001).

The social and psychological mechanisms linking physical activity with mental health could partly explain why the intensity of physical activity had a weaker effect on mental health functioning and sickness absence attributable to mental causes than on physical health functioning and sickness absence attributable to musculoskeletal causes. According to a qualitative review (Mason & Holt 2012) of exercise interventions among users of mental-health services, physical activity can provide opportunities for social contact and interaction, as well as a sense of meaning and achievement. Physical activity has also been associated with self-efficacy, which refers to the level of confidence in meeting the challenges at hand (Craft 2005). These factors could be independent of the intensity of the activity.

The neurological mechanisms behind physical activity and the pleasure people derive from it could also partly explain why vigorous activity is not especially beneficial for mental functioning. The results of studies on the positive impact of physical activity on mood indicate that higher intensities of physical activity might not be the most beneficial. One meta-analysis (Reed & Ones 2006) revealed an association between low-intensity exercise and self-reported positive activated affect following exercise. According to more theoretical approaches (Ekkekakis et al. 2005), the positive affect of physical activity could relate to its intensity, and moderate activity has a stronger positive affect than vigorous activity.

The findings from Sub-study II revealed an association between changing the level of physical activity from vigorous to moderate and a lower risk of all-cause sickness absence compared to persistently low activity. Hence, there may be situations in which vigorous physical activity is not much more beneficial in terms of work ability in addition to the prevention of the risk of sickness absence due to mental diseases. Vigorous physical activity could be associated with the risk of injury, for example, and it could aggravate certain musculoskeletal conditions such as osteoarthritis (WHO 2010; Vuori 2003). However, the results of Sub-study II do not strongly support this hypothesis: the association of change in physical activity from vigorous to moderate with sickness absence due to musculoskeletal diseases attenuated following adjustment for changes in other types of health behaviour, SEP and job exposure characteristics. In addition, given that the comparison group comprised those engaging in persistently low levels of activity, even a decrease in activity could somewhat easily be perceived as beneficial.

The finding of an increase in physical activity after the transition to statutory retirement is in line with the results of previous studies (Barnett et al. 2014; Barnett et al. 2012; Brown et al. 2009; Ding et al. 2016; Evenson et al. 2002; Feng et al. 2016; Lahti et al. 2011; Touvier et al. 2010; Stenholm et al. 2016). The reasons for increasing the amount of physical activity during the transition to retirement could include having more resources in terms of time and energy levels, attempting to maintain a daily structure, being influenced by close fellow retirees, and engaging in voluntary work (McDonald et al. 2015). Total physical activity may decrease, however, given that there is no commuting and no occupational physical activity.

It was reported in an earlier study that the increase in physical activity is not maintained in post-retirement years (Stenholm et al. 2016), and is implied in another (Slingerland et al. 2007) with a longer follow-up time that any increase in physical activity after the transition to retirement may be short-term. Yet another study (Van Dyck et al. 2016) examining recently retired people and those transitioning to retirement reported contradictory results, although the shorter follow-up time could explain that. There is some indication that the period shortly after the transition to retirement may be psychosocially different from later phases of the post-retirement period. According to a study on psychological well-being during the retirement transition, recently retired men felt better about their ageing process than longer-term retirees and those who were not yet retired (Kim & Moen 2002).

7.3 METHODOLOGICAL CONSIDERATIONS

Data

The Helsinki Health Study data was collected by means of postal questionnaires distributed among the employees of Helsinki City in three phases: phase 1 (2000-2002), phase 2 (2007 and phase 3 (2012). The employees were 40-60 years old in phase 1. The data included 8,960 participants in phase 1 (response rate 67%), 7,332 participants in phase 2 (response rate 87%) and 6,814 participants in phase 3 (response rate 87%). For those who consented to the linkage (N=6606), the survey data was combined with sickness absence register data from the Social Insurance Institute of Finland and disability register data from the Finnish Centre for

Pensions. The use of a large longitudinal dataset with multiple study points combined with register data linkages is a strength of this study.

The Helsinki Health Study data collection complies with the Finnish legislation on personal data and the ethical principles of the University of Helsinki. The study protocol was also approved by the Ethics committees of the City of Helsinki and the University of Helsinki, Department of Public Health. Anonymity and confidentiality have been assured, and the participants were informed about this as well as about other ethical guidelines in the study protocol.

Because the Helsinki Health Study is based on an employee cohort the results cannot be generalised to the general population. However, the City of Helsinki is one of the largest employers in Finland with 37,876 employees representing various non-manual and manual occupations (City of Helsinki 2016). Eighty per cent of the participants were women, which represents the gender distribution of municipal workers in Finland (KT Local Government Employers 2014). The large proportion of women could be considered another strength because most employee cohorts are male-dominated. Given the large proportion of women and the lack of significant gender interactions, men and women were pooled together in the analyses of the present study.

Employees are likely to be healthier than the Finnish population in general. Moreover, the participants who responded in all three phases are likely to be healthier than non-respondents. However, the results are likely to be more conservative among healthier individuals. Nevertheless, the non-response and attrition analyses carried out within the Helsinki Health Study showed that the data still satisfactorily represents the target population (Lahelma et al. 2013).

Measurements

The use of self-reported measurements for physical activity, physical and mental health functioning and most of the covariates could have cause some bias in the results of this study. Using self-reported measures of physical activity is vulnerable to over-estimation of the levels of physical activity (Shephard 2003). The physical activity question used in this study has not been validated, but a similar question has been validated in comparison to detailed interview (Waller et al. 2007). In fact, no question on physical activity has proved to be paramount (van Poppel et al. 2010). The Short Form 36 Health Survey (SF-36) measure is well validated and reliable (Hemingway et al. 1997), but same-source bias in Sub-study I is possible because both the exposure and the outcome measures are self-reported. However, because the results of the sub-studies with register-based outcomes are similar to those of Sub-study I, it is likely that this bias is not a large problem.

The measurement of leisure-time physical activity used in this study included commuting physical activity, which declines after the transition to retirement. This could potentially have biased the results on the associations between the transition to statutory retirement and physical activity examined in Sub-study IV. However, the findings are likely to be more conservative than if leisure-time physical activity had been examined without incorporating commuting physical activity. The decline in such activity counteracts the increase in leisure-time physical activity after the transition to retirement. The lack of measurement of occupational physical activity is also a limitation, because total physical activity may decrease even if leisure-time physical activity increases (Barnet et al. 2014).

Physical activity was used as a categorised variable in Sub-studies I-III because it enabled the examination of changes in the intensity of the physical activity. There are some problems related to the use of categorised variables: different cut-points could produce different results, for example. Sensitivity analyses were done using 15 and 13 MET-hours, instead of 14, as a cut-off point between categories, but the main results of the sub-studies did not change (data not shown). In addition, the use of different reference groups in Sub-studies I and III on physical and mental health functioning and disability retirement, and in Sub-study I on sickness absence limits the comparison across the sub-studies and across reference groups in Sub-studies I and III.

The possibility of reverse causation also limits the interpretation of the results. Changes in physical activity might be influenced by health problems, which in turn might contribute to subsequent functioning and work disability. Earlier sickness absence and limiting long-standing illness were adjusted for, thereby diminishing the effects of reverse causation. However, it was not possible to adjust for all the potential confounders: we were not able to consider, for example, the potential genetic components linking physical activity to work disability and functioning.

The use of register-based sickness-absence and disability-retirement measures based on medically confirmed diagnosis is a further strength of the present study. Self-reports on sickness absence may lead to under-reporting, hence the use of register-based data is more reliable. Employers are likely to report sickness absence correctly, because the Social Insurance Institution of Finland reimburses them for the longer sickness absence periods examined in this study.

7.4 IMPLICATIONS FOR THE HEALTH PROMOTION OF PHYSICAL ACTIVITY

The results of the present study reflect in many ways WHO (2010) recommendations for physical activity. Moving towards those recommendations seems to be beneficial to health among ageing employees and retirees. However, the results emphasise the clearer benefits of vigorous activity, which are not stressed in the recommendations. Meeting the recommendations either by engaging weekly in at least 150 minutes of moderate-intensity activity or 75 minutes of vigorous activity is presented as an equal choice. It is stated that additional health benefits can be achieved by engaging in 300 minutes of moderate physical activity or 150 minutes of vigorous activity, or in a combination of both. No reference is made to the additional benefits to be gained from vigorous compared with moderate activity. (WHO 2010)

With regard to the Finnish version of the recommendations it has been suggested that vigorous activity might be needed to achieve the best possible musculoskeletal and cardiorespiratory health and optimal energy-expenditure levels (Fogelholm et al. 2005). Bouchard et al. (2015) also mention the need to include goals for cardiorespiratory fitness levels in the national and global recommendations for physical activity. Higher fitness levels might require engagement in vigorous activity. The results of this study support the notion that vigorous activity could be more beneficial to health than moderate activity, especially to physical health functioning and the prevention of musculoskeletal diseases. Somewhat stronger evidence on this has been reported in previous studies reporting an association between the intensity of physical activity and a lower risk of both mortality (Gebel et al 2015; Lahti et al. 2014) and functional decline (Gebel et al. 2014), independently of the volume of physical activity. These results could reflect the reported independent association between cardiorespiratory fitness and all-cause mortality (Lee et al. 2011). The intensity of physical activity was not examined independently of the volume of activity in the present study. It is therefore possible that the larger benefits of adopting vigorous activity are partly attributable to the higher total volume of physical activity among those who engage in vigorous activity.

There are some arguments for not emphasising the health benefits of vigorous over moderate activity. Moderate activity could be more beneficial to older age groups given the smaller risk of injury than with vigorous activity (WHO 2010). Motivating inactive individuals to engage in moderate as opposed to vigorous activity may also be easier. In addition, the results of the present study indicate that moderate physical activity could be at least as beneficial to mental health functioning and sickness absence attributable to mental causes as vigorous activity. Given these results, there is no need to encourage people to engage in vigorous activity if the objective is the promotion of mental health.

8 CONCLUSIONS

Overall, the results of this study indicate that physical activity later in life slows down the age-related decline in functioning and work ability. The findings also imply that engaging in vigorous activity is especially beneficial for physical health and the prevention of sickness absence attributable to musculoskeletal causes. Moreover, the intensity of physical activity matters less to mental health functioning and the risk of sickness absence on the grounds of mental diseases. Persistent and emergent moderate physical activity could be even more beneficial in promoting mental health functioning and preventing sickness absence related to mental causes. The results further imply that the transition to retirement has a short-term impact on changes in physical activity: physical activity increases after the transition to statutory retirement, but the increase does not persist over post-retirement years.

Political decision makers should promote investment in encouraging physical activity among ageing employees as beneficial or even profitable. Work disability attributable to musculoskeletal and mental causes, and a decline in physical and mental health functioning could be alleviated through engaging in different types of physical activity. This could also be considered in the planning of interventions and health-promotion programmes for groups facing different risks. Vigorous physical activity could be promoted among healthy employees and retirees, targeting musculoskeletal health and physical health functioning. The transition to retirement may be a suitable stage of life at which physical-activity interventions could be efficiently implemented. However, it would also be important to support the maintenance of physical activity in the years following the transition to statutory retirement, given that the increase in activity levels evens out over time. Health promotion among retirees is especially important given that total physical activity may decline after the transition to retirement, despite an increase in leisure-time physical activity (Barnett et al. 2014).

Further studies on the determinants and consequences of changes in physical activity are still needed for the promotion of physical activity and the prevention of a decline in functioning and work ability. Subsequent studies could show the benefits of changes in muscle-strengthening activities, which are included in the recommendations for physical activity (World Health Organization 2010) but were not examined in the present study. In addition, various types of intervention could be introduced to increase and maintain physical activity among employees who are about to retire and those who have already retired. Alternatives ranging from mass-media interventions (Craig et al. 2003) to life-style counselling (Luoto et al. 2011) have been associated with positive changes in physical activity. However, health-enhancing physical-activity interventions in the workplace have not succeeded in reducing sickness absence (Pereira et al. 2015), hence the development of such interventions in further studies would be especially beneficial.

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APPENDICES

Appendix 1. Mean summary scores for physical and mental functioning by change in physical activity (N=5475)

Phase 1	**Low**			**Moderate**			**Vigorous**			
Phase 2	**Low**	**Moderate**	**Vigorous**	**Low**	**Moderate**	**Vigorous**	**Low**	**Moderate**	**Vigorous**	**All**
Physical health functioning										
Phase 1	45.6	48.2	49.9	47.3	48.4	50.4	50.2	50.9	52.3	49.4
Phase 2	43.7	47.1	49.8	44.0	46.6	50.5	47.3	48.3	51.3	47.8
Phase 3	42.7	45.3	48.1	43.7	46.0	48.9	46.5	47.8	50.3	46.9
Mental health functioning										
Phase 1	50.3	51.3	50.0	50.5	52.5	52.3	51.0	51.8	52.6	51.8
Phase 2	50.9	52.4	51.6	50.2	52.7	53.1	50.1	52.5	52.7	52.2
Phase 3	51.6	53.0	51.8	51.6	53.5	53.3	52.3	53.4	53.8	53.0
N	559	499	216	405	1434	498	193	536	1113	5475