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Concurrent changes in body mass index, physical functioning and self-rated health

Roosa Lintuaho

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In memory of my father.

UNIVERSITY OF TURKU
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ROOSA LINTUAHO: Changes in Physical Activity in Relation to Retirement Transition – Concurrent Changes in Body Mass Index, Physical Functioning and Self-rated Health
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ABSTRACT

This thesis aimed to examine changes in physical activity and body mass index (BMI) during working years and changes in physical activity concurrently with changes in BMI, physical functioning, and self-rated health during retirement transition. It examined two cohorts of public sector workers, from the Finnish Public Sector study (n=66,852) and the Finnish Retirement and Aging study (n=3,550). The data were collected using a repeated survey. Group-based multi-trajectory analysis was the main statistical method used.

During a 16-year follow-up in this working-age population, physical activity decreased and BMI increased, regardless of age or sex. The differences in the four identified groups were mainly related to their initial level of physical activity and BMI.

During the retirement transition, physical activity temporarily increased, independently of the pre-retirement activity level. BMI remained stable. BMI and physical activity were inversely connected: low activity was associated with a high BMI. During the retirement transition, lower physical activity was associated with a lower level of physical functioning and poorer self-rated health. Physical functioning and self-rated health improved along with physical activity during the transition, but the change was only temporary. Female sex, manual occupation and living alone were associated with lower physical activity, higher BMI, poorer physical functioning, and suboptimal self-rated health during the transition to retirement.

In conclusion, physical activity, physical functioning, and self-rated health temporarily increased during the retirement transition, but BMI remained stable. The changes in physical activity, physical functioning and self-rated health were interconnected. The results suggest that retirement is a timepoint that is sensitive to changes in lifestyle habits and that physical activity should be promoted among those about to retire, especially among those at risk of low physical activity after retirement.

KEYWORDS: body mass index; physical activity; physical functioning; retirement; self-rated health

TURUN YLIOPISTO
Lääketieteellinen tiedekunta
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ROOSA LINTUAHO: Fyysisen aktiivisuuden muutokset suhteessa eläköitymiseen – painoindeksin, fyysisen toimintakyvyn ja koetun terveyden samanaikaiset muutokset
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TIIVISTELMÄ

Väitöskirjan tavoitteena oli tutkia fyysisen aktiivisuuden sekä painoindeksin muutoksia työikäisillä sekä fyysistä aktiivisuutta eläköityvillä yhdessä painoindeksin, fyysisen toimintakyvyn ja koetun terveyden muutosten kanssa. Tutkimuksessa käytettiin kahta suomalaista seurantatutkimusta, jossa tutkittavat olivat julkisen sektorin työntekijöitä: Kunta- ja hyvinvointialan henkilöstön seurantatutkimusta (n=66 852) sekä Finnish Retirement and Aging -tutkimusta (n=3 550). Tiedonkeruu tapahtui toistetuilla kyselymittareilla. Keskeisenä tilastomenetelmänä käytettiin multitrajektorianalyysia.

Työikäisten 16 vuoden seurannassa aktiivisuus väheni ja painoindeksi nousi riippumatta iästä tai sukupuolesta. Neljä tunnistettua ryhmää erosivat toisistaan vain aktiivisuuden ja painoindeksin lähtötason perusteella.

Eläköitymisen yhteydessä fyysinen aktiivisuus väliaikaisesti nousi lähtötasosta riippumatta. Painoindeksi pysyi vakaana. Fyysinen aktiivisuus ja painoindeksi olivat käänteisesti yhteydessä: matala aktiivisuus liittyi korkeampaan painoindeksiin. Eläköityessä matalampi fyysinen aktiivisuus oli yhteydessä huonompaan fyysiseen toimintakykyyn ja huonommaksi koettuun terveyteen. Sekä fyysinen toimintakyky että koettu terveys paranivat aktiivisuuden noustessa eläköitymisen yhteydessä. Naissukupuoli, manuaalinen työ ja yksin eläminen olivat yhteydessä matalampaan aktiivisuuteen, korkeampaan painoindeksiin, matalampaan fyysiseen toimintakykyyn ja huonompaan koettuun terveyteen.

Yhteenvetona fyysinen aktiivisuus, fyysinen toimintakyky ja koettu terveys paranivat väliaikaisesti, mutta painoindeksi pysyi vakaana eläköitymisen yhteydessä. Tulokset osoittavat eläköitymisen olevan elämäntapamuutoksille herkkää aikaa. Eläköitymässä olevien, erityisesti vähän liikkuvien, fyysistä aktiivisuutta tulisi tukea.

AVAINSANAT: eläköityminen, fyysinen aktiivisuus, fyysinen toimintakyky, koettu terveys, painoindeksi

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Abbreviations

AIC	Akaike Information Criterion
APP	Average Posterior Probability
BIC	Bayesian Information Criterion
BMI	Body mass index
DLW	Doubly labelled water
FIREA	Finnish Retirement and Aging study
FPS	Finnish Public Sector study
GBTA	Group-based Multi-trajectory Analysis
ISCO	International Standard Classification of Occupation, -08 edition
MET	Metabolic Equivalent of Task
OR	Odds Ratio
RR	Risk Ratio
RRR	Relative Risk Ratio
WHO	World Health Organization

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by the Roman numerals:

I Tiusanen R, Saltychev M, Ervasti J, Kivimäki M, Pentti J, Stenholm S, Vahtera J. Concurrent changes in physical activity and body mass index among 66 852 public sector employees over a 16-year follow-up: multi-trajectory analysis of a cohort study in Finland, *BMJ Open* 2022;12:e057692. doi:10.1136/ bmjopen-2021-057692

II Lintuaho R, Saltychev M, Pentti J, Vahtera J, Stenholm S. Multi-trajectory analysis of changes in physical activity and body mass index in relation to retirement: Finnish Retirement and Aging Study. *PLoS ONE 2022;* 17(12): e0278405. https:// doi.org/10.1371/journal.pone.0278405

III Lintuaho R, Saltychev M, Pentti J, Vahtera J, Stenholm S. Concurrent changes in physical activity and physical functioning during retirement transition – a multi-trajectory analysis. *PLoS ONE 2023*; 18(10):e0293506. doi: 10.1371/journal.pone.0293506. eCollection 2023.

IV Lintuaho R, Saltychev M, Pentti J, Vahtera J, Stenholm S. Physical activity and self-rated health during retirement transition: a multitrajectory analysis of concurrent changes among public sector employees. *BMJ Open* 2023;13(9):e073876. doi: 10.1136/bmjopen-2023-073876.

1 Introduction

In Finnish, there is a saying that ‘movement is medicine’. Physical activity is indeed an important part of a healthy lifestyle. It has numerous health benefits and it reduces the risk of many chronic diseases (Liew et al., 2023), helps with weight maintenance and thus reduces the risk of obesity (Jakicic et al., 2019), improves physical functioning (Haapanen et al., 2022; Lahti et al., 2010) and self-rated health (Sperlich et al., 2020), and reduces all-cause mortality (Liew et al., 2023).

Retirement is an important life event that occurs in late mid-life and may result in many changes to daily routines (Sprod et al., 2017). Retirement has shown to be associated with increasing leisure-time physical activity (Gropper et al., 2020), and BMI can change during the retirement transition, but the direction of this change varies depending on sex and occupation (Forman-Hoffman et al., 2008; Nooyens et al., 2005; Stenholm et al., 2017). Studies of physical functioning during the transition to statutory retirement have reported mixed results: some show improvement (Jokela et al., 2010), some show deterioration (Byles et al., 2016; Stenholm et al., 2014), and others have found no change (Lahelma et al., 2019). Self-rated health has also been reported as changing during retirement transition, but the directions of the changes have varied (van der Heide et al., 2013). However, it is not known whether the changes observed in physical activity during the retirement transition are associated with concurrent changes in BMI, physical functioning, and self-rated health.

The aim of this thesis is to investigate the changes in physical activity and BMI during working years and the changes in physical activity concurrently with changes in BMI, physical functioning and self-rated health during retirement transition. It also examines sociodemographic and other lifestyle factors as the determinants of the observed changes.

2 Review of the Literature

2.1 Physical activity

The World Health Organization (WHO) defines physical activity as any bodily movement produced by skeletal muscles that requires energy expenditure (WHO, 2020). Physical activity can take place in different domains, such as the occupational domain (e.g., work-related or manual labour tasks), the domestic domain (e.g., chores, house and yard work, shopping), transportation (e.g., walking, cycling when commuting) and leisure-time (sports, exercise, hobbies). The dimensions of physical activity include mode (e.g., walking, running), frequency (e.g., activity bouts or times per week), duration and intensity (rate of energy expenditure). (Strath et al., 2013)

2.1.1 Measurement of physical activity

Physical activity can be measured in several ways. Doubly-labeled water method (DLW), in which water labeled with heavy byt non-radioactive forms of hydrogen and oxygen, is a gold standard for measuring total energy expenditure, however it is seldom used as it is expensive, time-consuming and cannot distinguish qualitative data (Melanson et al., 1996). In this method, doubly labelled water is consumed orally or via an injection and the concentration is then measured in two samples of body water. The carbon dioxide (CO_2) production can be measured using these measures, and thus the energy expenditure can be calculated (Schoeller et al., 1982).

Interviews and questionnaires are subjective measurement methods in which respondents estimate and report their physical activity. Questionnaires are useful for obtaining information from a large study population or for assessing average activity over longer periods of time, such as the previous three months. However, self-reported measures are prone to recall and information bias. Validation studies have shown many questionnaires to be valid and reliable for measuring vigorous leisure-time physical activity, but less accurate for measuring light- to moderate-intensity physical activity or specific activity domains such as occupational or domestic activity, and the comparing to DLW has lead to inconclusive results. The advantages of questionnaires include cost effectiveness, easy administration, determining discrete categories of activity level and repeatability (Jacobs et al., 1993; LaPorte et al., 1985; Strath et al., 2013; Sylvia et al., 2014).

Nowadays, physical activity can also be measured by different wearable devices. Pedometers can be used to count daily steps, but they do not provide information on the intensity of the activity. Accelerometers, small sensors worn at the wrist, hip or thigh, have now mostly replaced pedometers. Accelerometers measure accelerations of the body during activity and collect data that can be processed into different indicators, such as activity intensities, activity bouts and activity types (Strath et al., 2013). Energy expenditure during activity can be calculated via physiological measurements taken by, for example, a heart rate monitor, which shows the intensity rather than the mode of activity and picks up on other situations that may increase the heart rate during the day. Although sensors and devices provide more accurate and versatile information on physical activity, their use and data processing requires more time and resources.

2.1.2 Physical activity recommendations

For adults aged 18 to 64 years, WHO recommends at least 150 to 300 minutes of moderate-intensity physical activity or at least 75 to 150 minutes of vigorous-intensity physical activity accompanied by muscle strengthening activities at least twice a week. For older adults, the recommendations also include physical activity that emphasises functional balance and strength training at least three times a week (WHO, 2020). In Finland, the recommendations for physical activity are provided by the UKK institute, based on the recommendations by the US Health and Human services (Olson, 2018). For adults aged 18 to 64, these recommendations include light physical activity as often as possible, at least 150 minutes of moderate physical activity or at least 75 minutes of vigorous physical activity, and muscle strengthening activities at least twice a week. For adults aged over 64, the recommendations also include balance and flexibility activities at least twice a week (UKK-instituutti, 2019). In the Healthy Finland study carried out in 2022–2023, 75% of Finnish men and 71% of women reported engaging in leisure-time physical activity for several hours per week, but only 46% of men and 38% of women met the physical activity recommendations. The proportion of the population that follow the recommendations decreases with age: participants in younger age groups meet the physical activity recommendation more often than the older adults (including those of retirement age) (Lahti, 2023).

2.1.3 Health benefits of physical activity

Physical activity is beneficial for health in many ways. Meta-analyses of exercise intervention trials have reported a decrease in blood pressure (Cornelissen et al., 2013), and improvement in adiposity levels and glucose metabolism (Lin et al., 2015). Numerous follow-up studies have shown that physical activity reduces weight gain in both initially normal and overweight participants (Brown et al., 2016; Droyvold et al., 2004; Jakicic et al., 2019; Moholdt et al., 2014; Sui et al., 2013). A recent meta-analysis of prospective cohort studies with device-measured physical activity concluded that higher physical activity and less sedentary behaviour decrease the risk of mortality due to cardiovascular diseases as well as all-cause mortality (Liew et al., 2023). In addition, higher physical activity has been associated with longer healthy life expectancy (Leskinen et al., 2018). In older adults, physical activity has shown to improve bone mineral density and thus, decrease the risk of osteoporosis (Marques et al., 2012). There is evidence that higher physical activity is associated with a lower risk of breast cancer and colon cancer (Rezende et al., 2018). Physical activity has also shown to improve mood and reduce the symptoms of depression (Dishman et al., 2021; Taylor et al., 2004). There is some evidence that physical activity could reduce the severity of chronic pain (Geneen et al., 2017; Taylor et al., 2004).

2.1.4 Changes in physical activity over the lifespan

The intensity and frequency of physical activity vary according to the individual but can also change according to different life situations. Previous observational studies have examined changes in physical activity over follow-ups of more than 20 years. A study in Canada found four distinct trajectories of changes in leisure-time physical activity during a 22-year-follow-up: consistently low physical activity (56%), consistently high physical activity (12%), increasing physical activity (25%) and decreasing physical activity (7%) (Barnett et al., 2008). Women and older participants were less active. A study in Norway found that 27% of its participants decreased and 20% increased their leisure-time physical activity levels over a 28-year follow-up (Morseth et al., 2011). A study by Kirjonen et al. (2006) among Finnish industrial workers aged 18–64 at baseline observed a decrease in the proportion of people with high leisure-time physical activity in five- and 10-year-follow-ups, followed by an increase in a 28-year follow-up. Older age was associated with decreasing physical activity. Baseline inactivity was a predictor of later inactivity, especially among blue-collar workers, women, and those with initially poor self-rated health.

Some life events seem to be associated with changes in physical activity. Two systematic reviews have reported changes in physical activity associated with change of school, entering the workforce, getting married, pregnancy, becoming a parent and retirement (Engberg et al., 2012; Gropper et al., 2020). In addition to these life events that occur in early adulthood, retirement has shown to modify physical activity behaviour (Barnett et al., 2012): leisure-time and household-related physical activity have increased while total physical activity and active transportation have decreased. As the large generation of baby boomers are now reaching retirement age, the changes associated with retirement are of current interest in this thesis.

2.2 Retirement

Retirement is a major life event and alters daily routines as work no longer dominates the day (Sprod et al., 2017). The retirement transition consists of the final months in the workforce, retirement itself, and the months following the exit from working life.

In Finland, the pension system consists of earnings-related pension, which is based on the salary during working years, national pension, which is paid based on permanent residency in Finland and guarantee pension, which ensures a minimum level of pension for those whose earnings-related pension is small. In addition to old-age pension paid after an individual reaches their retirement age, pension benefits include disability pension for those unable to work, and survivors' pension paid after the death of a spouse or family provider (Ritola et al., 2023). Retirement age varies by the birth year and it rises in intervals of three months for each birth cohort: it is 64 years and six months for those born in 1960 and 65 years for those born between 1962 and 1964. For those born after that, retirement age is tied on life expectancy. Employees are encouraged to retire later by increasing the pension if the earnings-related pension is deferred beyond the retirement age (Ritola et al., 2023).

2.2.1 Health and lifestyle effects of retirement

It has been reported that the retirement transition is beneficial for health in many ways.

The duration and quality of sleep may increase, and sleep problems diminish (Myllyntausta et al., 2020; Myllyntausta et al., 2018). In a Finnish study Myllyntausta et al (2020) found that accelerometer-based sleep increased after retirement compared to prior working days and decresed compared to prior days off. In another Finnish study, Myllyntausta et al (2018) found that nonrestorative sleep and waking up too early decresed after retirement, but there was no difference in problems falling asleep and maintaining sleep.

The transition to retirement may influence headaches and low back pain: Sjösten et al (2011) found that transition to retirement decreased headache prevalence especially among those with a high amount of work stress (Sjösten et al., 2011). On the other hand, Plouvier et al (2011) found that low back pain was associated with exposure to heavy physical work during the final working years, but the difference between exposed and unexposed diminished after retirement (Plouvier et al., 2011)

Psychological distress may decrease after retirement, especially among those with greater job strain due to high job demands and low decision authority (Lahdenpera et al., 2022).

In a systematic review by Xue et al (2020), retirement seemed to reduce smoking or have no impact on it in 12 out of 14 studies and increased in one study. Retirees who felt that they had to retire involuntarily, were at higher risk for increased smoking (Henkens et al., 2008; Xue et al., 2020).

The evidence on the altered use of alcohol after retirement has been controversial – some studies have shown an increase and other studies a decrease in alcohol consumption. (Xue et al., 2020)

Changes in BMI have also been inconclusive – different studies have observed different results of no change, increase or decrease in BMI after retirement. Retiring from physically demanding jobs has been associated with increasing BMI (Stenholm et al., 2017).

The potential effects of retirement on some other health aspects are less clear. A systematic review by Xue et al. assessed the impact of retirement on cardiovascular disease and its risk factors. US studies have found that retirement has no impact on cardiovascular disease, whereas European studies, except for French studies, have found that the risk of cardiovascular disease has increased after retirement. The impact on diabetes and hypertension is also unclear: some studies have found no relation between retirement and diabetes or hypertension, some have shown a decrease in both, and others have shown an increase in diabetes incidence, blood pressure levels and risk of metabolic syndrome onset after retirement. (Xue et al., 2020)

The effect of retirement on diet is also uncertain: some studies have reported no dietary change after retirement, whereas others have reported changes towards either healthier or unhealthier habits (Ali-Kovero et al., 2020; Celidoni et al., 2020; Xue et al., 2020).

2.2.2 Physical activity and retirement

Many previous original reports and systematic reviews have shown that self-reported leisure-time physical activity increases during the retirement transition (Barnett et al., 2012; Engberg et al., 2012; Evenson et al., 2002; Feng et al., 2016; Holstila et al., 2017; Karjala et al., 2023; Lahti et al., 2011; Sjösten et al., 2012; Stenholm et al., 2016), although according to some studies this increase is only temporary (Holstila et al., 2017; Karjala et al., 2023; Stenholm et al., 2016; Van Dyck et al., 2016). Table 1 presents a summary of previous studies on the subject. Most of these studies have reported explicit changes in self-reported leisure-time physical activity, although some accelerometer-based studies have reported varying changes in total physical activity depending on sex and occupation (Pulakka et al., 2020). The type of retirement may also affect the intensity of physical activity after retirement (Feng et al., 2016; Lahti et al., 2011): disability retirement, for example, has been associated with lower physical activity than statutory retirement (Stenholm et al., 2016), especially among blue-collar workers (Karjala et al., 2023). Reports on sex-related differences in physical activity around the transition to retirement have been inconsistent. Sjösten et al. (2012) found that women increased their physical activity more than men, whereas Touvier et al. (2010) and Lahti et al. (2011) reported a greater increase in physical activity among men, and Stenholm et al. (2016) found no sex-related differences.

Table 1. Overview of original studies of changes in physical activity during retirement transition.

Study	n	Follow-up	Measurement of physical activity	Reported change in physical activity
Evenson, 2002, USA	7,782	6 years	Leisure-time (self-reported)	Increase
Sjösten, 2012, France	2,711	8 years	Leisure-time (self-reported)	Increase
Barnett, 2014,UK	3,334	10 years	Leisure-time and total (self-reported)	Increase in leisure-time physical activity Decrease in total physical activity
Stenholm, 2016, Finland	9,488	12 years	Leisure-time (self-reported)	Increase during retirement transition Decrease after retirement
Feng, 2016, USA	5,754	2 years	Leisure-time (self-reported)	Increase
Holstila, 2017, Finland	6,814	12 years	Leisure-time (self-reported)	Increase
Sprod, 2017, Australia	124	1 year	Leisure-time and total (self-reported)	Increase in leisure-time physical activity Decrease in total physical activity
Jones, 2018,USA	1,012	9 years	Total (self-reported)	Increase in light physical activity Decrease in moderate to vigorous physical activity
Pulakka, 2020, Finland	562	1 year	Total (accelerometer)	Men in non-manual work: increase Women in manual work: decrease Women in non-manual work and men in manual work: no change
Henning, 2021, Sweden	1,033	3 years	Leisure-time (self-reported)	Increase
Karjala, 2023, Finland	3,325	15–17 years	Leisure-time (self-reported)	Statutory retirement: increase during retirement transition, decrease after retirement Disability retirement: decrease

In addition, the type of work from which a person retires may affect the changes during the retirement transition. Retiring from manual work has been associated with a decrease or smaller increase and non-manual work with a steeper increase in leisure-time physical activity (Barnett et al., 2012; Chung et al., 2009; Karjala et al., 2023; Van Dyck et al., 2016). Higher socioeconomic status has constantly been associated with increasing physical activity, and lower socioeconomic status with decreasing physical activity after retirement (Barnett et al., 2012; Stenholm et al., 2016; Vansweevelt et al., 2022). The combined effect of sex and type of work has also been assessed: women retiring from non-manual work have shown no change in physical activity, whereas women retiring from manual work have reduced their physical activity. Men retiring from non-manual work have increased their physical activity whereas no change has been observed among men retiring from manual work (Pulakka et al., 2020).

2.3 BMI, physical functioning and self-rated health – associations between physical activity and retirement

2.3.1 Weight and BMI

Overweight and obesity are defined as abnormal or excess fat accumulation (WHO, 2005). BMI is a screening tool, calculated as weight divided by the square of height, expressed in kg/m^2. Although BMI is a useful measure in most common situations, its validity may sometimes be limited, for example, in cases of unusually high muscle mass or short stature (Keys et al., 1972). The WHO guidelines use the following BMI categorisation: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), obesity I (30–34.9 kg/m^2), obesity II (35– 39.9 kg/m^2) and obesity III (≥ 40 kg/m^2) (WHO, 2005).

Obesity is a vastly growing epidemic worldwide and causes many health problems, including type 2 diabetes, cardiovascular disease, increased mortality, non-alcoholic fatty liver disease, hypertension, stroke, hypercholesterolemia, gout, asthma, sleep apnoea, gallstones, atrial fibrillation, dementia, depression, deep vein thrombosis and lung embolism, kidney disease, multiple cancers (most importantly post-menopausal breast cancer and colon cancer), osteoarthritis and back pain (Ageno et al., 2008; Aune et al., 2014; Beuther et al., 2007; Bhaskaran et al., 2014; Everhart, 1993; Global Burden of Disease Obesity Collaborators 2017; Guh et al., 2009; Loomis et al., 2016; Luppino et al., 2010; Mokdad et al., 2003; Tufik et al., 2010; Wanahita et al., 2008; Whitmer et al., 2008; Zheng et al., 2015). In 2015, 12% of the adult population of the world were obese (Global Burden of Disease Obesity

Collaborators 2017). In Finland, 27% of men and 30% of women aged over 20 were obese in 2022 (Lehtoranta, 2023)

Overweight and obesity are caused by a long-term positive energy balance due to a person's energy intake exceeding their energy consumption. Several factors are proposed to increase the risk of obesity, including physical inactivity and sedentary behaviour (Silveira et al., 2022), diet (Fogelholm et al., 2012), genetics (Locke et al., 2015), lower socioeconomic status (Ball et al., 2005), stress (Chen et al., 2012), depression (Needham et al., 2010), loneliness (Lauder et al., 2006), and too little sleep (Cappuccio et al., 2008).

Follow-up studies have reported that BMI increases with advancing age. Studies with 10- to 22-year follow-ups have observed an overall increase in BMI in the general population (Brown et al., 2016; Droyvold et al., 2004; Lewis et al., 2000; Moholdt et al., 2014; Yang et al., 2019). In a ten-year follow-up, people with normal weight were less likely to become overweight (Lewis et al., 2000). Maintaining a normal weight has been associated with higher educational status and low-risk alcohol consumption, whereas the odds of maintaining a normal weight seem to be lower among blue-collar workers, smokers, and people with at least one chronic condition (Brown et al., 2016). Weight gain has shown to slow down with old age: although weight gain occurs at all ages, younger participants tend to gain more weight than older ones (Brown et al., 2016; Chung et al., 2009; Lewis et al., 2000).

Some studies have found that physical activity protects against weight gain. In their systematic review, Jakicic et al. concluded that there is strong evidence that moderate to vigorous physical activity attenuates weight gain, but the same could not be verified for low-intensity physical activity (Jakicic et al., 2019). Physical activity has reduced weight gain associated with ageing, and has played a greater role in preventing weight gain than in weight loss (Erlichman et al., 2002). Physical activity and BMI are clearly associated with each other, yet the strength of this association seems to vary at different stages of life and to decrease with old age (Jakicic et al., 2019). Physical activity can also attenuate the health risks caused by obesity; being active in spite of obesity can reduce the risk of physical disability (Rejeski et al., 2010).

Life events such as retirement may induce changes in lifestyle habits and lead to changes in BMI. Reports on the association between retirement and changes in BMI have been controversial (Table 2). Chung et al. reported that retirement might have increased the BMI among their 11,000 study participants (Chung et al., 2009). Studies stratified by sex have reported weight increases among retiring women, especially among those retiring from blue-collar jobs (Forman-Hoffman et al., 2008; Stenholm et al., 2017). Decreasing BMI among retiring men has been reported, especially among those retiring from sedentary jobs (Nooyens et al., 2005; Stenholm et al., 2017). On the other hand, one earlier study found no change in BMI among retiring men (Forman-Hoffman et al., 2008). It has been suggested that the type of work might be essential in this association – manual work has been associated with weight gain during retirement (Chung et al., 2009; Nooyens et al., 2005). Weight gain during the retirement transition has also been associated with older retirement age, lower income and initial overweight (Chung et al., 2009; Chung et al., 2009).

Table 2. Changes in BMI, physical functioning and self-rated health during retirement transition.

Study	n	Follow-up	Reported changes
		BMI	
Nooyen, 2005, Netherlands	288	5 years	Physically active job: increase; sedentary job: decrease
Forman–Hoffman, 2008, USA	3,725	8 years	Women: increase; men: no change
Chung, 2009, USA	10,565	8 years	Increase
Stenholm, 2017, Finland	5,426	8 years	Women: increase; men: decrease
		Physical functioning	
Mein, 2003, UK	1,010	10 years	Deterioration
Jokela, 2010, UK	7,584	15 years	Statutory retirement: improvement; disability retirement: deterioration
Stenholm, 2014, USA	17,844	18 years	Deterioration
Byles, 2016, Australia	21,608	2–4 years	Deterioration
Mänty, 2016, Finland	1,658	12 years	Improvement associated with physical workload and environmental hazards, otherwise deterioration
Mänty, 2018, Finland	2,330	5–7 years	Statutory retirement: no change; disability retirement: deterioration
Lahelma, 2019, Finland	6,976	12 years	No change
Haapanen, 2022, Finland	1,709	10 years	Deterioration or no change
Lallukka, 2023, Finland	3,901	20 years	Statutory retirement: decrease; disability retirement: decrease during retirement transition, increase after retirement
		Self-rated health	
Westerlund, 2009, France	14,714	14 years	Improvement
Szabo, 2019, New Zealand	1,368	8 years	Mostly deterioration
Stenholm, 2020, Finland	8,572	6–8 years	Mostly no change

2.3.2 Physical functioning

Functioning has been defined as the physical ability to perform different daily life-related tasks and activities such as work, studies, self-care, hobbies and care for others (Finnish Institute for Health and Welfare, 2021). Functioning can be described using the International Classification of Functioning (ICF), which describes functioning on three levels: body structures and functions; performance partly built on these and participation in life situations and community life (Jimenez Bunuales et al., 2002). Another way to approach functioning is by dimensions, which include physical functioning, mental functioning, cognitive functioning and social functioning (Finnish Institute for Health and Welfare, 2021). Physiological properties that influence physical functioning include muscular strength and endurance, endurance fitness, joint mobility, control of bodily positions and movements and the functions of the central nervous system (Finnish Institue for Health and Welfare, 2021). Physical functioning may be affected by, for example, chronic health conditions and cognitive functioning, sensory factors (such as vision and hearing), environmental factors (such as social and professional support, educational level, access to facilities and information) and behavioural factors (such as regular exercise, preference of activity, perception of ability, nutrition and smoking) (Painter et al., 1999).

Higher physical activity has been associated with better physical functioning (Haapanen et al., 2022; Kulmala et al., 2016; Lahti et al., 2016). In contrast, low physical activity has been associated with declining physical functioning after retirement (Mänty et al., 2018). Higher physical activity may protect against developing physical restrictions and improve the probability of recovering from already developed limitations (Haight et al., 2005). It has been suggested that not all types of physical activity are beneficial: for example, heavy physical work has been associated with more severe restrictions to physical functioning than light work (Kulmala et al., 2016; Leino-Arjas et al., 2004). Vigorous exercise and housework, on the other hand, have been found to protect against poor physical functioning (Leino-Arjas et al., 2004).

The effect of retirement on physical functioning is not clear (Table 2). Some follow-up studies have found that overall physical functioning declines with advancing age, regardless of retirement (Lahelma et al., 2019; Mein et al., 2003; Mänty et al., 2018), whereas others have found that physical functioning declines during the retirement transition (Byles et al., 2016). Studies that compare the retired and those still working have also reported different results. Whereas one study has found retirees' physical functioning to be more limited (Stenholm et al., 2014), another study has observed better functioning among those who have retired due to old age than among those who have stayed at work (Jokela et al., 2010). Thus, it could be assumed that physical functioning development has different paths during the retirement transition, as was also stated in a scoping review by Saha et al (2023). A trajectory analysis following retired men found five different trajectories with different initial levels of disability: three with no change in physical functioning and two with declining physical functioning (Haapanen et al., 2022).

Higher physical activity has been constantly linked to better physical functioning during and after the transition to retirement (Haapanen et al., 2022; Haight et al., 2005; Mänty et al., 2016). High leisure-time physical activity has also shown to protect against declining physical functioning (Leino-Arjas et al., 2004). As some people experience declining physical functioning during the retirement transition, and yet physical activity tends to increase during the retirement transition, the concurrent changes in physical activity and physical functioning should be further investigated.

Numerous factors affect physical functioning during and after the retirement transition. Lower educational or occupational status have been reported to be associated with poorer physical functioning before and after retirement (Lallukka et al., 2023; Mänty et al., 2016; Saha et al., 2023; Stenholm et al., 2014), but one study has found that higher occupational status might be associated with a steeper decline in physical functioning (Mänty et al., 2018). Female sex and obesity have also been associated with poorer physical functioning (Mänty et al., 2016; Stenholm et al., 2014). The increasing amount of chronic health conditions among retired people seems to be worsening their physical functioning (Stenholm et al., 2014). Occupational status may affect the severity of functioning limitations. Greater exposure to physical workload and workplace-related environmental hazards has been reported to be associated with poorer physical functioning before retirement and after retirement than among those not exposed (Mänty et al., 2016; Saha et al., 2023), although physical functioning has then improved after the transition to retirement (Mänty et al., 2016). The imbalance of effort-reward system while working has also been associated with declining physical functioning after retirement (Saha et al., 2023).

2.3.3 Self-rated health

Self-rated health is measured by, for example, asking participants to rate their health on a Likert-type scale from one to five. This has proven to be a valid scale for describing health on a population level (Idler et al., 1997). Poor self-rated health has been reported to be independently associated with higher mortality, increased use of prescribed drugs and greater use of social and health services (Bath, 1999). Having a chronic health condition and multimorbidity are clearly associated with lower self-rated health (Marques et al., 2018). Poor working conditions, low socioeconomic status, male sex, physical conditions, depression, musculoskeletal problems, sleep problems and longer sick leaves have been associated with poorer self-rated health regardless of age and old age as an individual risk factor (Hoertel et al., 2022).

Regular physical activity has shown to associate with good self-rated health and to lower the odds of declining or suboptimal self-rated health (Sperlich et al., 2020). Physical activity can act as a moderator between multimorbidity and self-rated health – physically more active people often have better self-rated health, regardless of multimorbidity (Marques et al., 2018).

It has been reported that self-rated health changes during the retirement transition (Table 2). Depending on other demographic and lifestyle factors, retirement may have either beneficial or detrimental effects on self-rated health. A systematic review found three studies reporting improvement, one reporting deterioration, and six reporting no difference or insignificant results concerning change in self-rated health in relation to retirement (van der Heide et al., 2013). Using trajectory analysis, two previous studies have observed different paths of changes in self-rated health during the retirement transition. Szabo et al. identified three groups with declining, recovering or maintaining self-rated health (Szabo et al., 2019). Stenholm et al. in turn observed four clusters with different trajectories: sustained good, from good to suboptimal, from suboptimal to good, and sustained suboptimal (Stenholm et al., 2020). Retiring due to health reasons, job strain and high job demands, low to medium socioeconomic status, non-professional occupation, and more than one chronic condition have been associated with greater benefit from retirement (Hoertel et al., 2022; van der Heide et al., 2013; Westerlund et al., 2009). On the other hand, some studies have reported declining self-rated health among those who retire from high positions and who are generally healthy and have a good income (Szabo et al., 2019; van der Heide et al., 2013). In contrast, Stenholm et al. found that the ‘sustained good health’ group had more professionals and the ‘sustained suboptimal health’ group had more manual workers, whereas higher physical activity was associated with ‘sustained good health’. Female sex and higher occupational status predicted improved self-rated health, whereas lower occupational status, higher job strain and a physically demanding job predicted declining self-rated health after retirement in a study by Stenholm et al. (Stenholm et al., 2020)

2.4 Gaps in previous literature

Despite these previous studies of changes in physical activity, BMI, physical functioning, and self-rated health during the transition to retirement, very little is known about their concurrent changes, although they are likely to be linked to each other.

In previous follow-up studies BMI has increased less among physically active participants in general (Droyvold et al., 2004; Erlichman et al., 2002; Jakicic et al., 2019), but the effect of retirement on concurrent changes in BMI and physical activity has not been studied before.

High physical activity has been associated with better physical functioning and self-rated health during the retirement transition (Haapanen et al., 2022; Haight et al., 2005; Kulmala et al., 2016; Leino-Arjas et al., 2004; Mänty et al., 2018; Sperlich et al., 2020; Stenholm et al., 2020; Westerlund et al., 2009), but concurrent changes in physical activity and physical functioning or self-rated health have not been studied.

There is evidence that physical activity, BMI, physical functioning, and self-rated health may substantially change during the retirement transition. Based on previous research results, it could be assumed that physical activity may affect all these changes. However, no research has been conducted on how these changes are linked.

3 Aims

The aim of this thesis is to address the gaps in previous knowledge by examining changes in physical activity and BMI during a person’s working years and to study the changes in physical activity *and* the changes in BMI, physical functioning and self-rated health around the time a person makes the transition into retirement. It also aims to identify the pre-retirement sociodemographic and other lifestyle factors that could be associated with these changes in physical activity, BMI, physical functioning, and self-rated health.

The specific aims of the thesis are:

1) to examine concurrent changes in BMI and physical activity over a 16-year follow-up among the working-age population. (Study I)

2) to examine concurrent changes in physical activity and BMI around the time of the retirement transition and how sociodemographic factors are associated with these changes. (Study II)

3) to examine concurrent changes in physical activity and physical functioning during the retirement transition and how sociodemographic and lifestyle factors are associated with these changes. (Study III)

4) to examine concurrent changes in physical activity and self-rated health during the retirement transition and how sociodemographic and lifestyle factors are associated with these changes. (Study IV)

4 Materials and Methods

4.1 Study population

Participants were drawn from two large Finnish cohort studies: the Finnish Public Sector (FPS) study and the Finnish Retirement and Aging (FIREA) study.

The FPS is a dynamic cohort study, initiated in 1997/1998, with follow-up intervals every two to four years (Vahtera et al., 2002). It consists of public sector employees of ten Finnish towns and five hospital districts or health and social service organisations, who had a job contract for a minimum of six months when the study started. The data for the current study included responses to five questionnaires administrated in 2000–2002, 2004–2005, 2008–2009, 2012–2013, and 2016–2017. The eligible cohort of the FPS study comprised 154,656 employees, of whom 122,969 had responded at least once during 2000–2017. The response rates by each survey are presented in table 3.The baseline for the current study was the response to the surveys in 2000–2002 or 2004–2005. A total of 68,176 participants had responded to these surveys. Of these, 66,852 had provided information on physical activity and BMI at baseline and were thus included in Study I. The respondents provided their informed, written consent for their data to be used in the study. The FPS study was approved by the Hospital District of Helsinki and Uusimaa.

Table 3. Response rates of Study I.

Year	n	response rate
2000–2002	48,009	68%
2004–2005	56,081	67%
2008–2009	69,389	69%
2012–2013	79,118	68%
2016–2017	81,136	67%

FIREA is an ongoing longitudinal cohort study that follows ageing workers from their final years of working life, through statutory retirement, and into old age (Stenholm et al., 2023). The sample consists of public sector employees who in 2012 worked in one of the selected towns in Southwest Finland or one of the selected five hospital districts included in the study, and who retired between 2014 and 2019 (n=10,629). The participants were contacted 18 months prior to their estimated retirement date, which was obtained from the register kept by the pension provider for public sector employees (Keva). The actual retirement date was self-reported. The participants responded to questionnaires sent annually before and after retirement, and after this the data centred around the time of retirement. Study II had two possible survey waves before retirement – Waves -2 and -1 and two possible waves after retirement– Waves 1 and 2, and Studies III and IV had three possible waves after retirement – Waves 1, 2 and 3. Retirement occurred between Waves -1 and 1. Study II's sample consisted of 3,351 participants and Studies III and IV of 3,550. Figure 1 shows the flowchart of the sample. The respondents provided written, informed consent for their data to be used. FIREA follows the Declaration of Helsinki and has been approved by the Ethics Committee of the Hospital District of Southwest Finland.

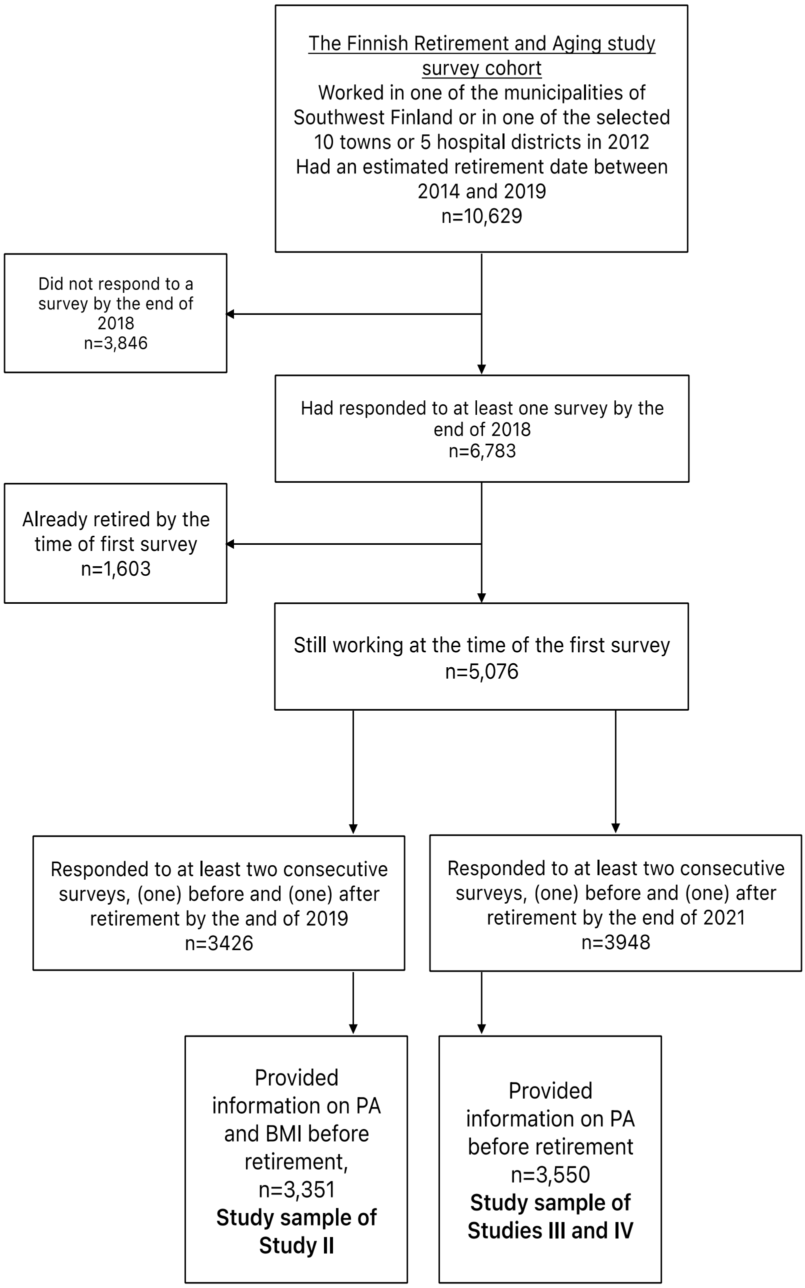

Figure 1. Flowchart of sample formation in Studies II, III and IV.

4.2 Measurement of main outcome variables

4.2.1 Physical activity

Both the FPS and FIREA measured physical activity using a self-reported survey instrument (Kujala et al., 1998; Stenholm et al., 2023). The participants were asked to estimate their average weekly hours of leisure-time and commuting physical activity in activities comparable to walking, brisk walking, jogging, or running within the previous year by ‘not at all’; ‘less than half an hour’; ‘one hour’; ‘two to three hours’ or ‘four hours or more’. The time spent on each activity level in hours per week was multiplied by the average energy expenditure of each activity, expressed in Metabolic Equivalents of Task (MET). MET describes the amount of energy consumed in comparison to resting; one MET unit of 3.5 ml/kg/minute corresponds to oxygen consumption while calmly sitting (Jette et al., 1990). The multipliers for different activities were 3.5 for walking, 5 for brisk walking, 8 for jogging, and 11 for running (Ainsworth et al., 2011). Weekly physical activity was expressed as MET-h/week. Physical activity was used as a continuous variable in the statistical analysis. For interpreting the results, physical activity was defined as low (<14 MET-h/week), moderate (14 to <30 MET-h/week) or high (≥30 MET-h/week). This definition was chosen because physical activity lower than 14 MET-h/week (approximately the equivalent of 168 minutes of brisk walking) has been reported to be associated with a higher risk of cardiovascular disease (Tanasescu et al., 2002) and a physical activity level of 30 MET-h/week (the equivalent of 6 hours of brisk walking) has shown to be needed for weight management (Fogelholm, 2005).

4.2.2 BMI

In the FPS and FIREA the participants were asked to report their height in cm and weight in kg, which were used to calculate BMI as weight/height^2 (kg/m^2) in each study wave. When BMI was an outcome variable in Study I and Study II, it was used as a continuous variable in statistical analysis. For interpreting the results, BMI was categorised as normal weight (<25 kg/m^2), overweight (25–29.9kg/m^2) and obesity (≥30 kg/m^2) (WHO, 2005). In Study I, BMI was also categorised as severe obesity (≥35 kg/m^2) as in the Finnish Current Care Guidelines (Lihavuus (lapset, nuoret ja aikuiset). Käypä hoito -suositus.2023). In Study II, obesity was further categorised as type I (BMI 30–34.9 kg/m^2) and type II (BMI ≥35 kg/m^2) in line with the WHO guidelines (WHO, 2005). In Studies III and IV, BMI was used as a covariate and categorised as ‘normal weight and overweight’ (BMI <30 kg/m^2) vs ‘obesity’ (BMI ≥30 kg/m^2) (WHO, 2005).

4.2.3 Physical functioning

Physical functioning was used as an outcome variable in Study III. It was assessed using the SF-36 survey (Brazier et al., 1992), which is a 36-item set of generic quality of life measures that has been translated into Finnish (Aalto, 1999). Of the survey's 36 questions, 10 concern physical functioning as a subscale, and these were included in the study. The respondents were asked to what extent (a great extent; a small extent; not at all) their health problems restrict the following activities: 1) vigorous activities, i.e. running, heavy lifting; 2) moderate activities, i.e. vacuum cleaning; 3) carrying or lifting groceries; 4) climbing several flights of stairs; 5) climbing one flight of stairs; 6) bending, kneeling or stooping; 7) walking more than a mile; 8) walking several blocks; 9) walking one block, and 10) bathing or dressing. The score of the entire scale was calculated as a sum of the averages of the individual answers. Thus, the scale ranged from 0 to 100, with higher points describing better physical functioning.

4.2.4 Self-rated health

Self-rated health was used as an outcome variable in Study IV. It was elicited in each study wave. Participants were asked to rate their health on a five-point Likert-type scale: 1–good, 2–rather good, 3–average, 4–rather poor, or 5–poor. For the analysis, the result was dichotomised; 3–5 as 'suboptimal health' vs 1–2 as 'optimal health', because average, rather poor and poor self-rated health have been associated with higher mortality than rather good and good self-rated health (Jylha et al., 1998).

4.3 Measurement of sociodemographic and lifestyle factors

In Study I, age was defined in years and divided into two age groups: ≤50 and >50. Sex was obtained from the employer's register.

In Studies II, III and IV, information was obtained in the last possible wave before retirement, Wave 1. This information covered age in years, sex, and occupational title, which was obtained from the register of the pension provider, coded according to the International Standard Classification of Occupations (ISCO) and dichotomised as 'professionals' (ISCO major groups 1–4) vs 'service and manual workers' (ISCO major groups 5–9). In addition, marital status, dichotomised as 'married or co-habiting' vs 'single'; smoking status, dichotomised as 'current smokers' vs 'never smokers and former smokers'; alcohol consumption, which was obtained as units consumed weekly and converted into grams of pure alcohol, dichotomised as 'risk use' (>288g/week for men >192g/week for women) vs 'nonrisk use', as per the national recommendations in the Finnish Current Care Guidelines (Alkoholiongelmat. Käypä hoito -suositus.2015).

4.4 Statistical analysis

The characteristics of the participants were reported as means and standard deviations (SD) or absolute numbers and percentages, depending on what was appropriate.

Group-based multi-trajectory analysis (GBTA) was used to investigate the developmental trajectories (a course of outcome over time) of physical activity and BMI, physical activity and physical functioning, and physical activity and self-rated health. The GBTA is a form of finite mixture modelling for analysing data on longitudinal repeated measures (Nagin et al., 2018; Nagin et al., 2010). It is a data-driven form of analysis that can distinguish and describe the subpopulations (clusters) that exist within a studied population, whereas conventional statistics only show the average outcome over time. The trajectories of such subpopulations may differ substantially from each other as well as from the average trajectory observed in the overall population. Multi-trajectory analysis enables the concurrent outcomes of two or more variables to be studied (Nagin et al., 2018). Group-based trajectory analysis deals with missing data by fitting the model using maximum likelihood estimation. This generates asymptotically unbiased parameter estimates assuming the data are missing at random (Shearer et al., 2016). The censored (also known as 'regular') normal GBTA model was used. The model's goodness-of-fit was judged by running the procedure several times with a number of clusters, starting from one and increasing the number of trajectory groups in intervals of one until the size of the smallest group fell below a pre-agreed cut-off (5%). The Bayesian Information Criterion (BIC), Akaike information criterion (AIC) and average posterior probability (APP) were used to confirm the goodness-of-fit. Linear, quadratic and cubic regression models were tested, and the cubic model was retained for use in the analysis. The cut-off for the smallest group was set at ≥5% of the entire cohort. Physical activity was used as a continuous variable in all the studies, as well as BMI in Study II and physical functioning (SF-36 score) in Study III. Study IV treated self-rated health as a categorised variable. For sensitivity analysis, self-rated health was also used as a continuous variable. The analysis was conducted separately for each study. In Study I, the analysis was performed separately in two age groups; ≤50 years and >50 years, and for sensitivity analysis the age groups were also divided by gender resulting in four groups: women ≤50 years, men ≤50 years, women >50 years and men >50 years.

Study I only presented the results of the GBTA. Studies II, III and IV, additionally used multinomial regression analysis to describe the associations of sociodemographic and lifestyle factors with the probability of being classified into a particular cluster. The results were presented as OR in Study II, RRR in Study III and RR in Study IV, together with their 95% confidence intervals (95% CIs). The ratios were adjusted for age and sex and the ratio for sex was adjusted for age.

The analyses were performed using Stata/IC Statistical Software: Release 17. College Station (StataCorp LP, TX, USA). An additional Stata module – 'traj' – was required to conduct the group-based trajectory analysis. This module is freely available for both SAS® and Stata software (Jones BL, 1999).

5 Results

5.1 Characteristics of study populations

Table 3 presents the characteristics of the study populations used in this thesis. In Study I, the mean age at baseline was 44.7 (SD 9.4) years, and 80% were women. Mean physical activity was 27.7 (SD 24.8) MET-h/week and mean BMI 25.1 kg/m^2 (SD 4.1). In Studies II, III and IV, the mean age at baseline ranged from 63.3 to 63.4 (SD 1.4) years, 83% were women, and 64–65% had a professional occupation. Mean physical activity was 23.7 (SD 19.8) MET-h/week and mean BMI 26.8 kg/m^2 (SD 4.5). Of the Study III and IV respondents, 24% reported suboptimal self-rated health and the mean SF-36 score for physical functioning was 87.8 (SD 15.7). In Studies III and IV, 31% of the respondents were single, 9% were current smokers and 2% consumed alcohol over the risk limits. The mean retirement age in Studies II, III and IV was 63.9 (SD 1.34). The characteristics of studies II, III and IV are presented in table 4.

Table 4. Descriptive characteristics of FPS participants at baseline (I) and FIREA participants at pre-retirement (II–IV). Absolute numbers and % or means and standard deviations.

Variable	Study I	Study II	Study III	Study IV
Sample size	66,852	3,351	3,550	3,550
Age in years, mean (SD)	44.7 (9.4)	63.3 (1.4)	63.4 (1.4)	63.4 (1.4)
Sex, n (%)				
Women	53,468 (80%)	2,783 (83%)	2,949 (83%)	2,949 (83%)
Men	13,384 (20%)	568 (17%)	601 (17%)	601 (17%)
Occupation, n (%)				
Professional		2,133 (64%)	2,283 (65%)	2,283 (65%)
Manual or service worker		1,190 (36%)	1,239 (35%)	1,239 (35%)
Physical activity, MET-h/week Mean (SD)	27.7 (24.8)	23.7 (19.8)	23.7 (19.8)	23.7 (19.8)
Physical activity, n (%)				
Low (< 14 MET-h/week)		1,263 (38%)	1,332 (38%)	1,332 (38%)
Moderate (<30 MET-h/week)		1,022 (31%)	1,079 (31%)	1,079 (31%)
High (≥30 MET-h/week)		1,066 (32%)	1,239 (35%)	1,239 (35%)
Average BMI, Mean (SD)	25.1 (4.1)	26.8 (4.5)	26.8 (4.5)	26.8 (4.5)
BMI, n (%)				
<30 kg/m^2		2,627 (78%)	2,569 (72%)	2,569 (72%)
≥30 kg/m^2		724 (22%)	981 (28%)	981 (28%)
Suboptimal self-rated health, n (%)				
No			2,690 (76%)	2,690 (76%)
Yes			853 (24%)	853 (24%)
Physical functioning, Mean (SD)			87.8 (15.7)	87.8 (15.7)

SD: Standard Deviation
BMI: Body Mass Index
MET: Metablic Equivalent of Task

5.2 Concurrent changes in physical activity and BMI during working years (Study I)

The 16-year follow-up study of 66,852 public sector employees identified four trajectory groups among those less than or 50 years old and those over 50 years old. The four-trajectory model was chosen because the next five-cluster model resulted in the smallest group, which fell below the pre-agreed cut-off of 5%. In addition, BIC, AIC and APP were sufficient for the four-cluster model in both age groups (Table 5).

Table 5. Goodness-of-fit of group-based trajectory analysis models. The chosen models are in bold.

Model	Smallest group		BIC[1]	AIC[2]	APP[3]
	n	%			
Age ≤**50 years**					
1-cluster	31,797	100%	-905,561	-905,509	1
2-cluster	8,234	26%	-869,531	-869,432	0.94
3-cluster	3,331	10%	-851,542	-851,397	0.92
4-cluster	**1,490**	**5%**	**-841,703**	**-841,510**	**0.89**
5-cluster	898	3%	-835,396	-835,157	0.87
Age **>50 years**					
1-cluster	35,055	100%	-869,200	-869,148	1
2-cluster	9,690	28%	-836,174	-836,076	0.93
3-cluster	3,845	11%	-819,600	-819,454	0.91
4-cluster	**1,888**	**5%**	**-809,601**	**-809,409**	**0.89**
5-cluster	999	3%	-803,977	-803,738	0.87

[1]Bayesian Information Criterion, [2]Akaike information criterion, [3]Average posterior probability.

The trajectories of the age groups were very similar (Figure 2). The identified trajectory groups were:

Group 1: Normal weight and high physical activity (38% among the ≤50-year group, 32% among the >50-year group). The physical activity of the younger respondents showed a slight increase towards the end of the follow-up and BMI increased slightly during the follow-up. Among the older respondents, BMI remained stable and physical activity decreased.

Group 2: Overweight and moderate physical activity (39% among the ≤50-year group, 42% among the >50-year group). The physical activity of both the younger and older respondents declined, but the decline was steeper among the older participants. BMI steadily increased among the younger participants and remained almost stable among the older participants.

Group 3: Class I obesity and moderate physical activity (18% among the ≤50-year group, 21% among the >50-year group). In both age groups, physical activity decreased, and BMI increased. The changes were greater among the younger respondents.

Group 4: Class II obesity and moderate physical activity (5% among the ≤50-year group, 5% among the >50-year group). Physical activity decreased and BMI increased in both age groups. The decline of physical activity attenuated among the younger respondents, whereas among the older respondents it accelerated towards the end of the follow-up. After the increase observed at the beginning of follow-up, BMI remained stable among the younger participants and decreased slightly among the older participants.

When stratified for sex, the results were relatively similar. The trends were equal, but the men had higher physical activity levels than the women of the same age group. The decrease in physical activity was greater among the men than among the women in the normal weight or overweight groups.

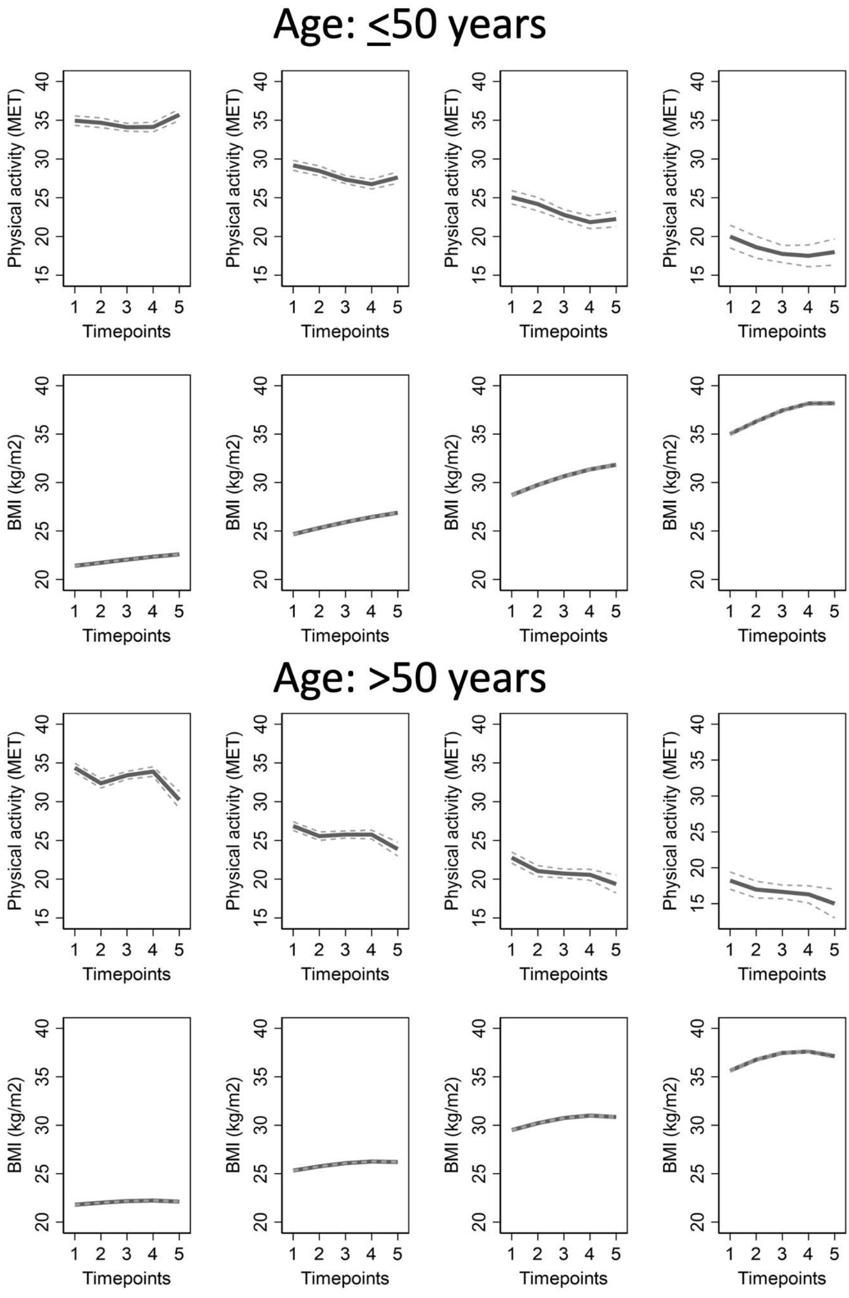

Figure 2. Trajectories of physical activity and BMI among public sector employees aged □ 50 and >50 years. The 95% confidence intervals are shown as dotted lines. The time between each response is approximately four years. The scale for physical activity is different in group 4. Originally published in BMJ Open. Reproduced under CC-BY NC licence.

5.3 Concurrent changes in physical activity and BMI during retirement transition (Study II)

During the transition to retirement, four trajectories of concurrent changes in physical activity and BMI were identified (Figure 3) among 3,351 public sector employees. The four-cluster model was chosen because the next, five-cluster model fell below the pre-agreed cut-off of 5%. In addition, BIC (-81161.68), AIC (-81011.84) and APP (0.94) were sufficient for this model (Table 6).

Table 6. Goodness-of-fit of group-based trajectory analysis models. The chosen model is in bold.

Model	Shape of trajectory	Smallest group		BIC[1]	AIC[2]	APP[3]
		n	%			
1-cluster	cubic	3,351	100%	-89157.68	-89117.18	1.0
2-cluster	cubic	1,048	31%	-85086.16	-85009.22	0.96
3-cluster	cubic	382	11%	-82673.30	-82559.91	0.95
4-cluster	linear	205	6%	-81095.94	-81010.90	0.94
4-cluster	**cubic**	**207**	**6%**	**-81161.68**	**-81011.84**	**0.94**
5-cluster	cubic	66	2%	-79903.10	-79716.82	0.94

[1]Bayesian Information Criterion; [2]Akaike Information Criterion; [3]Average Posterior Probability.

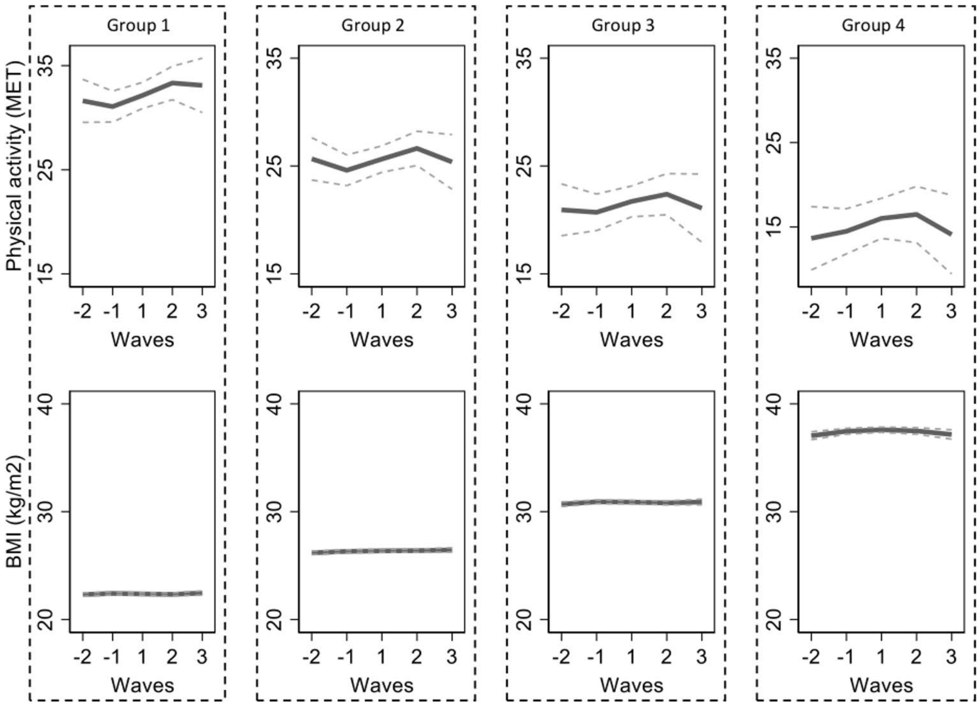

Figure 3. Trajectories of concurrent changes in physical activity and BMI during retirement transition. All study waves are one year apart. The scale of physical activity is different in group 4. Originally published in PLoS ONE. Reproduced under CC-BY 4.0 licence.

The identified trajectory groups were:

Group 1: Stable normal weight and high physical activity (32%): During the follow-up, BMI remained the same at the normal weight level. Initially high physical activity of approximately 31 MET-h/week decreased slightly prior to retirement, increased by 2.7 units during the retirement transition, and eventually stabilised at around 33 MET-h/week after retirement.

Group 2: Stable overweight and moderate physical activity (39%): BMI was stable during the follow-up at approximately 26 kg/m^2. Initially moderate physical activity decreased slightly prior to retirement, increased by two units during the retirement transition, and decreased again during the post-retirement years, returning to the initial level of 25 MET-h/week.

Group 3: Stable Class I obesity and moderate physical activity (23%): No changes in BMI of approximately 31 kg/m^2 occurred throughout the follow-up. Initially moderate physical activity first increased during the retirement transition by 1.4 units and then slightly decreased, returning to the initial level of 20 MET-h/week.

Group 4: Stable Class II obesity and low physical activity (6%): Throughout the follow-up, BMI remained stable at approximately 37 kg/m^2. Low physical activity of 10 MET-h/week increased by 2.3 units during and after the retirement transition, but eventually decreased to 11 MET-h/week.

There were some differences in the associations between sociodemographic and lifestyle factors within the trajectory groups. Women were less likely than men to be in the ‘Stable overweight and moderate physical activity’ and the ‘Stable class I obesity and moderate physical activity groups than the ‘Stable normal weight and high physical activity’ group. There were fewer manual workers in the ‘Stable normal weight and high physical activity’ group than in the other groups, but only the ‘Stable Class I obesity and moderately high physical activity’ group showed a statistically significant difference to the ‘Stable normal weight and high physical activity’ group. The ‘Stable Class II obesity and low physical activity’ group had fewer co-habiting participants. Table 7 shows the OR of being classified into a specific group.

Table 7. Associations between sociodemographic factors and trajectory clusters. Group 1 used as reference. Statistically significant results are in bold.

Variable/group	n	%	OR	95% CI	
Women vs men	women/men				
Group 1 Stable normal weight and high physical activity	943/125	88/12	1.0		
Group 2 Stable overweight and moderate physical activity	1023/284	78/22	**0.48**	**0.38**	**0.60**
Group 3 Stable Class I obesity and moderate physical activity	636/133	83/17	**0.63**	**0.49**	**0.83**
Group 4 Stable Class II obesity and low physical activity	181/26	87/13	0.92	0.59	1.45
Co-habiting vs single	co-habiting/single				
Group 1 Stable normal weight and high physical activity	746/298	71/29	1.0		
Group 2 Stable overweight and moderate physical activity	946/325	74/26	1.13	0.95	1.35
Group 3 Stable Class I obesity and moderate physical activity	531/220	70/30	0.96	0.79	1.18
Group 4 Stable Class II obesity and low physical activity	117/84	58/42	**0.56**	**0.41**	**0.76**
Manual workers vs professionals	manual/professional worker				
Group 1 Stable normal weight and high physical activity	352/705	33/67	1.0		
Group 2 Stable overweight and moderate physical activity	463/833	36/64	1.11	0.94	1.32
Group 3 Stable Class I obesity and moderate physical activity	293/472	38/62	**1.24**	**1.02**	**1.51**
Group 4 Stable Class II obesity and low physical activity	82/123	40/60	1.34	0.98	1.82

OR=Odds Ratio.
ORs are adjusted for age and sex (OR for sex is adjusted for age). Originally published in PLoS ONE.

5.4 Concurrent changes in physical activity and physical functioning during retirement transition (Study III)

For 3,550 public sector employees, a four-trajectory model of concurrent changes in physical activity and physical functioning was chosen (Figure 4). The next, five-cluster model fell below the pre-agreed cut-off of 5% and the smallest APP for a four-trajectory model was sufficient at 0.89. In addition, BIC and AIC (BIC) were closer to zero for the four-trajectory model than for the models with a smaller number of trajectory groups (Table 8).

Table 8. Goodness-of-fit of group-based trajectory analysis models. The chosen model is in bold.

Number of clusters	Shape of trajectory	Smallest group		BIC[1]	AIC[2]	APP[3]
		n	%			
1	Cubic	3,550	100	103,735	103,694	1.0
2	Cubic	952	27	101,470	101,392	0.92
3	Cubic	310	9	99,682	99,567	0.93
4	Cubic	**239**	**7**	**98,844**	**98,667**	**0.89**
5	Cubic	110	3	98,532	98,311	0.88

[1]Bayesian Information Criterion; [2]Akaike Information Criterion; [3]Average Posterior Probability. Originally published in PLoS ONE. Reproduced under CC-BY 4.0 licence.

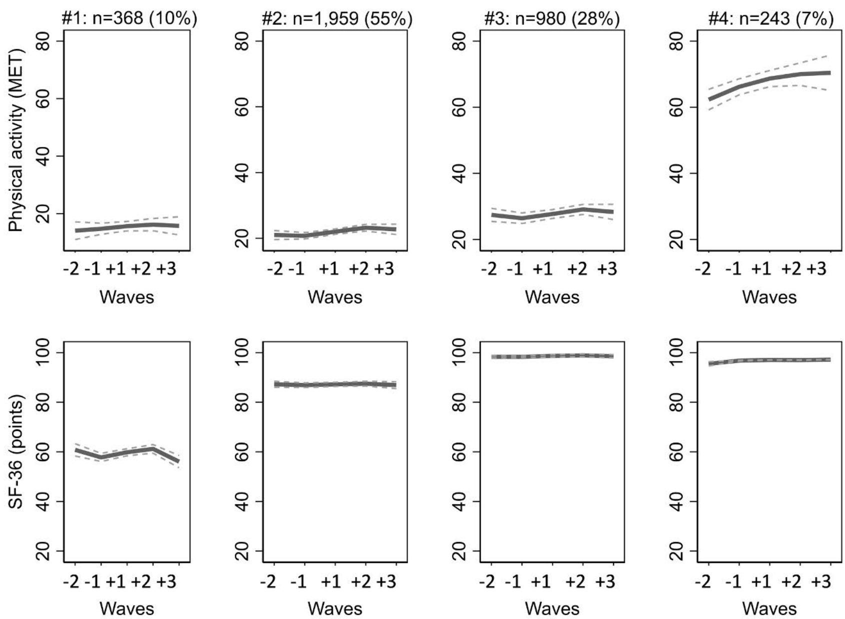

Figure 4. Trajectories of concurrent changes in physical activity and physical functioning during retirement transition. All study waves are one year apart. Originally published in PLoS ONE. Reproduced under CC-BY 4.0 licence.

The following groups were identified:

Group 1: Low physical activity and declining physical functioning (10%). Physical activity was low, 12 MET-h/week, before retirement then increased above the moderate activity limit to 14.9 MET-h/week during the retirement transition, and eventually decreased to 14.2 MET-h/week after retirement. Physical functioning was at a moderate level of 59.9 points before retirement, increased slightly during the retirement transition to 60.7 points, and then decreased to 56.1 points after retirement.

Group 2: Moderate physical activity and steady high physical functioning (55%). Physical activity was moderate, 20 MET-h/week, before retirement then increased slightly during the retirement transition to 22.4 MET-h/week. Physical functioning remained steady at a high level, from 87.3 points before to 87.9 points after retirement.

Group 3: Moderate physical activity and steady excellent physical functioning (28%). Initially, physical activity was on a moderate level of 27.7 MET-h/week but decreased before retirement to 25.7 MET-h/week then increased during the retirement transition to 28.5 MET-h/week. Physical functioning remained steady, at 98.6 to 99.1 points before and after retirement, respectively.

Group 4: Increasing high physical activity and steady excellent physical functioning (7%). The high physical activity of 63.2 MET-h/week before retirement peaked during the retirement transition to 71.3 points and stabilised after retirement to approximately 70 points. Physical functioning remained at almost the maximal level, ranging from 94.9 to 97.0 points throughout the follow-up.

Table 9 shows the associations between sociodemographic and lifestyle factors and the trajectory groups. The ‘Moderate physical activity and steady high physical functioning’ group was chosen as a reference group. The ‘Low physical activity and declining physical functioning’ group had more women and the ‘Moderate physical activity and steady excellent physical functioning’ and ‘Increasing high physical activity and steady excellent physical functioning’ groups had more men. The ‘Moderate physical activity and steady excellent functioning’ and ‘Increasing high physical activity and steady excellent physical functioning’ groups had less manual and service workers, but there was no difference in occupational status between those in the ‘Low physical activity and declining physical functioning’ and ‘Moderate physical activity and steady high physical functioning’ groups. Participants with a BMI ≥30 kg/m^2 were more likely to be categorised into the ‘Low physical activity and declining physical functioning’ group than into the ‘Moderate physical activity and steady high physical functioning’ group, and less likely to be in groups with excellent physical functioning than in the ‘Moderate physical activity and steady high physical functioning’ group. Smoking was more common in the ‘Low physical activity and declining physical functioning’ group and less common in the ‘Increasing high physical activity and steady excellent physical functioning' group than in the 'Moderate physical activity and steady high physical functioning' group. Risky use of alcohol was more common in the 'Low physical activity and declining physical functioning' group and less common in the 'Increasing high physical activity and steady excellent physical functioning' group. Marriage or co-habiting were more common in the 'Moderate physical activity and steady excellent physical functioning' group and less common in the 'Low physical activity and declining physical functioning' group.

Table 9. Relative Risk Ratios (RRR) of being classified into specific trajectory group. Group 2 is used as a reference. RRRs are adjusted for age and sex (RRR for sex is adjusted for age).

Variable/group	RRR	95% CI	
Women vs men			
Group 1: Low PA[a] and declining PF[b]	**1.55**	**1.09**	**2.20**
Group 2: Moderate PA and steady high PF	1.00		
Group 3: Moderate PA and steady excellent PF	**0.80**	**0.66**	**0.98**
Group 4: Increasing high PA and steady excellent PF	**0.57**	**0.42**	**0.79**
Married or co-habiting vs single			
Group 1: Low PA and declining PF	**0.76**	**0.60**	**0.96**
Group 2: Moderate PA and steady high PF	1.00		
Group 3: Moderate PA and steady excellent PF	**1.27**	**1.07**	**1.51**
Group 4: Increasing high PA and steady excellent PF	1.29	0.95	1.74
Manual or service workers vs professional workers			
Group 1: Low PA and declining PF	1.14	0.91	1.43
Group 2: Moderate PA and steady high PF	1.00		
Group 3: Moderate PA and steady excellent PF	**0.77**	**0.66**	**0.91**
Group 4: Increasing high PA and steady excellent PF	**0.72**	**0.53**	**0.97**
BMI ≥30 vs BMI <30 kg/m^2			
Group 1: Low PA and declining PF	**3.27**	**2.60**	**4.12**
Group 2: Moderate PA and steady high PF	1.00		
Group 3: Moderate PA and steady excellent PF	**0.32**	**0.26**	**0.40**
Group 4: Increasing high PA and steady excellent PF	**0.24**	**0.15**	**0.37**
Current smokers vs former or never smokers			
Group 1: Low PA and declining PF	**1.67**	**1.20**	**2.33**
Group 2: Moderate PA and steady high PF	1.00		
Group 3: Moderate PA and steady excellent PF	0.75	0.56	1.01
Group 4: Increasing high PA and steady excellent PF	**0.44**	**0.23**	**0.84**
Risky users of alcohol vs non-risky users			
Group 1: Low PA and declining PF	**2.24**	**1.30**	**3.86**
Group 2: Moderate PA and steady high PF	1.00		
Group 3: Moderate PA and steady excellent PF	**0.42**	**0.22**	**0.79**
Group 4: Increasing high PA and steady excellent PF	0.38	0.12	1.23

[a] Physical activity; [b] Physical functioning

5.5 Concurrent changes in physical activity and self-rated health during retirement transition (Study IV)

Among 3,550 public sector employees, three trajectories of concurrent changes in physical activity and self-rated health were identified (Figure 5). The next, four-cluster model fell below the pre-agreed cut-off of 5% and the smallest APP was sufficient at 0.93 for the three-cluster model. Compared to the two-cluster model, a three-cluster model demonstrated BIC and AIC values closer to zero (Table 10).

Table 10. Goodness-of-fit of group-based trajectory analysis models. The chosen model is in bold.

Number of clusters	Shape of trajectory	Smallest group		BIC[1]	AIC[2]	Smallest APP[3]
		n	%			
1	Cubic	3,550	100	66,605	66,568	1.0
2	Cubic	861	24	64,626	64,552	0.94
3	**Cubic**	**308**	**9**	**62,956**	**62,845**	**0.93**
4	Cubic	64	2	62,434	62,286	0.89

[1]Bayesian Information Criterion, [2]Akaike information criterion, [3]Smallest average posterior probability. Originally published in BMJ Open. Reproduced under CC-BY 4.0 licence.

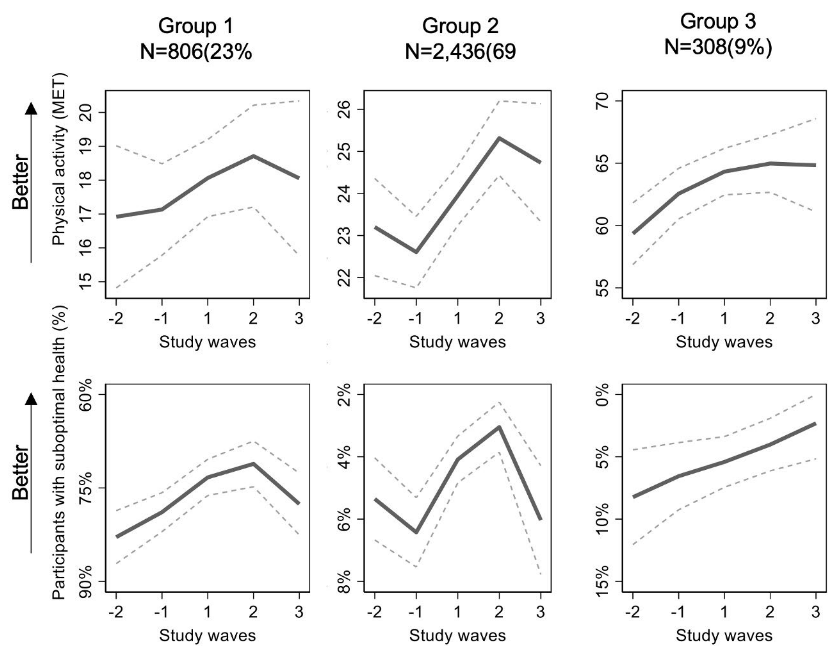

Figure 5. Trajectories of concurrent changes in physical activity and self-rated health during retirement transition. All study waves are one year apart. The scales are different for each group. Originally published in BMJ Open. Reproduced under CC-BY 4.0 licence.

The identified trajectory groups were:

Group 1: Moderate physical activity and suboptimal self-rated health (23%): Physical activity was at a moderate level of 17.1 MET-h/week before retirement. First, it increased slightly to 18.1 MET-h/week and then decreased somewhat. The trajectory of self-rated health mirrored the changes in physical activity: 79% reported suboptimal health prior to retirement and 71% reported suboptimal health 18 months after retirement, after which self-rated health began deteriorating.

Group 2: Moderate physical activity and good self-rated health (69%): Physical activity was at a moderate level of 22.6 MET-h/week six months before retirement and increased during the retirement transition to 24.4. MET-h/week. After this, physical activity decreased slightly, nevertheless staying above the initial level. In this group, only 6% of the respondents reported suboptimal health before retirement. This proportion decreased to 3% eighteen months after retirement, after which the percentage of people with suboptimal health grew again to 6%.

Group 3: High physical activity and good self-rated health (9%): physical activity increased from 62.6 MET-h/week before retirement to 65 MET-h/week after retirement. There was no decline in physical activity after the retirement transition, unlike in the other two groups. The portion of respondents with suboptimal health decreased from 7% to 4%.

Table 11 shows the associations between sociodemographic and lifestyle factors and trajectory groups. Compared to the ‘Moderate physical activity and suboptimal self-rated health’ group, the ‘Moderate physical activity and good self-rated health’ and ‘Increasing high physical activity and good self-rated health’ groups had more married or co-habiting people, fewer manual workers, less participants with a BMI ≥ 30 kg/m^2, fewer smokers, and fewer risky users of alcohol. Comparison of the most active groups showed that the ‘Increasing physical activity and improving self-rated health’ group had fewer women, people with a BMI ≥ 30 kg/m^2 and smokers than the ‘Moderate physical activity and good self-rated health’ group. There were no statistically significant differences between occupation in these two groups.

Table 11. Risk Ratios (RR) of being classified into a specific trajectory group. Group 1: Moderate physical activity and suboptimal self-rated health. Group 2: Moderate physical activity and good self-rated health. Group 3: Increasing physical activity and improving self-rated health. RRs adjusted for age and sex (RR for age adjusted only for age). Originally published in BMJ Open. Reproduced under CC-BY 4.0 licence.

Group	**Reference group**					
	1		**2**		**3**	
	RR	95% CI	RR	95% CI	RR	95% CI
Women vs men						
1	1	–	0.82	0.66 to 1.01	1.29	0.94 to 1.78
2	1.23	0.99 to 1.51	1	–	1.59	1.19 to 2.11
3	0.77	0.56 to 1.07	0.63	0.47 to 0.84	1	–
Co-habiting vs single						
1	1	–	0.81	0.68 to 0.96	0.68	0.50 to 0.91
2	1.23	1.04 to 1.47	1	–	0.84	0.64 to 1.10
3	1.48	1.10 to 1.99	1.20	0.91 to 1.57	1	–
Manual workers vs professional workers						
1	1	–	1.30	1.10 to 1.53	1.52	1.14 to 2.02
2	0.77	0.65 to 0.91	1	–	1.17	0.90 to 1.52
3	0.66	0.50 to 0.88	0.86	0.66 to 1.11	1	–
BMI ≥30 vs BMI <30						
1	1	–	2.82	2.38 to 3.33	4.05	5.23 to 11.58
2	0.35	0.30 to 0.42	1	–	2.76	1.88 to 4.05
3	0.13	0.09 to 0.19	0.36	0.25 to 0.53	1	–
Current smokers vs never/former smokers						
1	1	–	1.47	1.13 to 1.90	3.19	1.72 to 5.93
2	0.68	0.52 to 0.88	1	–	2.18	1.20 to 3.95
3	0.31	0.17 to 0.58	0.46	0.25 to 0.83	1	–
Risky users of alcohol vs non-risky users						
1	1	–	1.66	1.05 to 2.62	4.33	1.31 to 14.39
2	0.60	0.38 to 0.96	1	–	2.62	0.81 to 8.46
3	0.23	0.07 to 0.77	0.38	0.12 to 1.24	1	–

5.6 Loss to follow-up

Potential differences between the basic characteristics of the respondents and drop-offs at each wave in FIREA (Studies II-IV) were checked (Table 12). While there were some statistically significant differences, the absolute figures were mostly alike across both groups. It was assumed that such a mild discrepancy hardly affected the main results.

Table 12. Loss to follow-up by each study wave in FIREA.

Wave/variable		**Missing n (%)**	**Respondents n (%)**	**Total n (%)**	**p-value[a]**
Wave B2		1,383 (39)	2,167 (61)	3,550 (100)	
Sex	Men	212 (15)	389 (18)	601 (17)	0.042
	Women	1,171 (85)	1,778 (82)	2.949 (83)	
Self-rated health	Optimal	12 (86)	1,715 (79)	1,727 (79)	0.56
	Suboptimal	2 (14)	445 (21)	447 (21)	
Marital status	Single	405 (29)	683 (32)	1,088 (31)	0.159
	Co-habiting	978 (71)	1,484 (68)	2,462 (69)	
Occupational status	Manuals and technicians	807 (59)	1,476 (69)	2,283 (65)	<0.001
	Managers and professionals	566 (41)	673 (31)	1,239 (35)	
BMI	<30 kg/m^2	999 (72)	1,570 (72)	2,569 (72)	0.888
	≥30 kg/m^2	384 (28)	597 (28)	981 (28)	
Wave A1		28 (1)	3,522 (99)	3,550 (100)	
Sex	Men	5 (18)	596 (17)	601 (17)	0.895
	Women	23 (82)	3,522 (83)	2,949 (83)	
Self-rated health	Optimal	20 (80)	2,825 (81)	2,845 (81)	0.928
	Suboptimal	5 (20)	675 (19)	680 (19)	
Marital status	Single	8 (29)	1,080 (31)	1,088 (31)	0.811
	Co-habiting	20 (71)	2,442 (69)	2,462 (69)	
Occupational status	Manuals and technicians	16 (57)	2,267 (65)	2,283 (65)	0.393
	Managers and professionals	12 (43)	1,227 (35)	1,239 (35)	
BMI	<30 kg/m^2	23 (82)	2,546 (72)	2,569 (72)	0.245
	≥30 kg/m^2	5 (18)	976 (28)	981 (28)	
Wave A2		724 (20)	2,826 (80)	3,550 (100)	
Sex	Men	134 (19)	467 (17)	601 (17)	0.29
	Women	590 (81)	2,359 (83)	2,949 (83)	
Self-rated health	Optimal	22 (85)	2,249 (80)	2,271 (80)	0.554
	Suboptimal	4 (15)	564 (20)	568 (20)	
Marital status	Single	253(35)	835 (39)	1,088 (31)	0.005
	Co-habiting	471 (65)	1,991 (70)	2,462 (69)	
Occupational status	Manuals and professionals	476 (66)	1,807 (64)	2,283 (65)	0.354
	Managers and professionals	242 (34)	997 (36)	1,239 (35)	
BMI	<30 kg/m^2	512 (71)	2,057 (73)	2,569 (72)	0.266
	≥30 kg/m^2	212 (29)	769 (27)	981 (28)	
Wave A3		2,117 (60)	1,433 (40)	3,550 (100)	
Sex	Men	370 (17)	231 (16)	601 (17)	0.29
	Women	1,747 (83)	1,202 (84)	2,949 (83)	
Self-rated health	Optimal	7 (47)	1,094 (77)	1,101 (76)	0.007
	Suboptimal	8 (53)	334 (23)	342 (24)	
Marital status	Single	691 (33)	397 (28)	1,088 (31)	0.002
	Co-habiting	1,426 (67)	1,036 (72)	2,462 (69)	
Occupational status	Manuals and technicians	1,382 (66)	901 (63)	2,283 (65)	0.148
	Managers and professionals	719 (34)	520 (37)	1,239 (35)	
BMI	<30 kg/m^2	1,532 (72)	1,037 (72)	2,569 (72)	~1.0
	≥30 kg/m^s	585 (28)	396 (28)	981 (28)	

[a]p-value from Pearson X^2-test

6 Discussion

This thesis examined changes in individuals' physical activity and BMI during their working years and changes in physical activity together with concurrent changes in BMI, physical functioning, and self-rated health during retirement transition. Over the 16-year follow-up, physical activity decreased and BMI increased during working years. During the retirement transition, physical activity temporarily increased, while BMI remained stable. Also during the retirement transition, low physical activity was associated with decreasing physical functioning, while improving physical activity was associated with better self-rated health. Overall, during the retirement transition, changes in physical activity were interconnected with changes in BMI, physical functioning and self-rated health.

6.1 Decrease in physical activity during working years and temporary increase during retirement transition

A steady decline in leisure-time physical activity with advancing age was observed during working years. Previous studies have also observed this change (Achttien et al., 2020; Caspersen et al., 2000; Kirjonen et al., 2006). In the current study, the trends were similar among men and women, although the men reported higher levels of physical activity than the women. Previous studies have suggested that despite women having lower leisure-time physical activity than men (Barnett et al., 2008; Caspersen et al., 2000), the change in the level of physical activity with advancing age might not be associated with sex (Achttien et al., 2020).

Leisure-time physical activity was found to increase temporarily during the retirement transition. This finding was in line with those of numerous previous studies (Barnett et al., 2012; Engberg et al., 2012; Evenson et al., 2002; Feng et al., 2016; Henning et al., 2021; Holstila et al., 2017; Lahti et al., 2011; Sjösten et al., 2012; Stenholm et al., 2016). This increase could be due to altered daily routines resulting in more spare time after retirement (Sprod et al., 2017). The temporary nature of this increase in physical activity has also been described earlier (Holstila et al., 2017; Stenholm et al., 2016; Van Dyck et al., 2016). The phenomenon of a mere transitory increase in physical activity could be explained by the 'honeymoon phase' at the beginning of retirement, when people are motivated by their additional free time to increase their physical activity. This may eventually wear off, and people may go back to their old habits. Previous studies have also shown that inactivity becomes more common with advancing age (Caspersen et al., 2000; Kirjonen et al., 2006). Thus, retirement may only cause a short-term alteration in an otherwise declining trajectory of physical activity. In their systematic review of qualitative studies on changes in physical activity after retirement, Barnett et al. found that improved health due to retirement, acquiring new routines, seeking new challenges, opportunities to meet new people, and lifelong patterns of physical activity motivated new retirees to be more physically active. They also suggested that planned physical activity sessions are required to maintain physical activity. They also found that even though retirees expected to gain health benefits with more physical activity, this did not motivate them to be more active and relapses to inactivity were rather common. The pursuit of increased physical activity after retirement may meet some obstacles, including the low personal value of recreational physical activity or lack of time due to other activities, such as taking care of family members, household work and hobbies. For some, the lack of an appropriate level of competition decreased physical activity. (Barnett et al., 2012)

Previous studies have reported inconsistent results regarding sex-related differences in changes in physical activity during the retirement transition. Touvier et al. (2010) observed a greater increase in physical activity among men, whereas Sjösten et al. (2012) reported a greater increase in physical activity among women. In the present study, men were more likely to be classified into trajectory groups with steadily high or improving physical activity than women. In 2022, the Healthy Finland survey reported that 80% of men and 74% of women were engaged in recreational physical activity around retirement age (Lahti, 2023). Women may be more likely to take care of grandchildren than men (Hopflinger et al., 2006), and may generally do more housework than men (Geist et al., 2018), which perhaps leaves less time for leisure-time physical activity.

According to previous research, improvement in physical activity during the retirement transition is associated with retiring from non-manual work and higher socioeconomic status (Barnett et al., 2012; Chung et al., 2009; Vansweevelt et al., 2022). Pulakka et al. observed that manual work was associated with a decrease in total physical activity but observed no such association for non-manual work among retiring women. For men, retirement from manual work was not associated with a change in total physical activity, whereas retirement from non-manual work was related to increased total physical activity (Pulakka et al., 2020). In line with previous findings, this thesis shows that manual work predicts a higher probability of being classified into the least physically active trajectory groups. It could be speculated that those who retire from non-manual work exercise and pursue active hobbies during the free time they did not have before. In contrast, those who retire from manual work could be seeking rest. Lifelong physical activity habits may continue even after retirement – those in physically demanding jobs might not have had the time and energy for leisure-time physical activity and their personal value of such activity may thus be low (Barnett et al., 2012).

6.2 Increase in BMI and decrease in physical activity during working years

Among the working-age participants, all four identified trajectories of changes in physical activity and BMI displayed decreasing physical activity and increasing BMI over the 16-year follow-up. The decline in physical activity and the increase in BMI were greater among the obese respondents with low levels of physical activity. A similar increase in BMI as ageing progresses has been seen in previous follow-up studies (Brown et al., 2016; Lewis et al., 2000; Yang et al., 2019).

In the current study, there was a clear association between higher physical activity and lower BMI. Moreover, the changes mirrored each other: when physical activity decreased, BMI increased. Previous studies have also found clear associations between higher physical activity and lower BMI (Brown et al., 2016; Droyvold et al., 2004; Jakicic et al., 2019). Moholdt et al. found a dose-response effect: the higher the physical activity, the lower the weight gain over a 22-year follow-up (Moholdt et al., 2014).

The current activity guidelines for cardiovascular health recommend 150 minutes of moderate or 75 minutes of vigorous physical activity per week (WHO, 2020). Some previous studies have argued that these recommendations are not sufficient for maintaining normal weight (Erlichman et al., 2002; Jakicic et al., 2019; Moholdt et al., 2014), and the findings of the current study support this: only high physical activity at a level of 35 MET-h/week (equivalent of seven or more hours of brisk walking per week) was associated with normal BMI. Although physical activity between 14 and 30 MET-h/week was categorised as 'moderate' – because lower activity has been associated with a higher risk of cardiovascular disease (Tanasescu et al., 2002) – physical activity below the level of 25 MET-h/week (equivalent of five or less hours of brisk walking weekly) was associated with obesity. In addition, the lower the initial level of physical activity, the greater the increase in BMI.

The increase in BMI was greater among the younger participants. This supports previous findings that weight gain slows down with advancing age (Brown et al., 2016; Lewis et al., 2000).

6.3 Stable BMI despite increase in physical activity during retirement transition

Physical activity increased and BMI remained stable during the transition to retirement. Four groups with different initial levels of physical activity and BMI, and different trajectories of concurrent changes in physical activity and BMI were identified. Female sex was associated with a higher probability of being classified into a group with stable overweight or obesity and moderately high physical activity. In turn, retiring from non-manual work increased the probability of belonging to a group with stable, normal BMI and high physical activity.

Previous research on the changes in BMI during the retirement transition has been inconclusive, emphasising the role of sex-related differences in these changes. Some studies have observed a decrease in BMI among men after retirement (Nooyens et al., 2005; Stenholm et al., 2017), while others have reported no such phenomenon (Forman-Hoffman et al., 2008). BMI has been reported to increase among women during the retirement transition (Forman-Hoffman et al., 2008; Stenholm et al., 2017). The current findings were not stratified by sex, but women had lower odds of being categorised into a small group with normal weight and high physical activity.

The participants of the current study were predominantly white-collar workers: 64% were professionals, which could explain the overall stable trajectory of BMI. This is in line with previous research findings that retiring from manual work increases BMI, whereas retiring from sedentary work is not associated with weight gain (Chung et al., 2009; Nooyens et al., 2005). Also consistent with previous reports, manual workers were less likely to be categorised into a group with normal weight and high physical activity. Higher socioeconomic status has constantly been associated with lower BMI (Brown et al., 2016; Chung et al., 2009) and higher physical activity (Barnett et al., 2012; Vansweevelt et al., 2022).

Although 60% of the participants met the current guidelines for physical activity (WHO, 2020), only 40% were of normal weight. As suggested earlier, the current physical activity guidelines seemed inefficient for maintaining normal weight in both the working-age and older populations (Erlichman et al., 2002; Jakicic et al., 2019; Moholdt et al., 2014).

The increase in physical activity was not accompanied by changes in BMI during the retirement transition in Study II, although this association was observed in Study I in the working-age population over a longer follow-up period. Supporting these findings, a systematic review by Jakicic et al. (2019) argues that the association between physical activity and BMI may diminish with advancing age. Higher physical activity, however, was associated with lower BMI, as also described in other studies (Jakicic et al., 2019; Moholdt et al., 2014). The difference between the changes observed in the working-age population and the changes observed during the retirement transition could possibly be explained by the specifics of the data, which noted only leisure-time physical activity and commuting, leaving other types of physical activity unanalysed. For example, in manual occupations, work-related physical activity may be the most significant contributor to total physical activity. Thus, retiring from manual work could reduce total daily physical activity, leading to a decrease in energy consumption and an increase in BMI. Another example of potentially relevant but unavailable data in this research, may be information on dietary habits, which have shown to change after retirement (Ali-Kovero et al., 2020). The follow-up periods also differed substantially; working-age employees were followed for 16 years, whereas retirees were followed for four years around the retirement transition.

6.4 Low physical activity associated with decreasing physical functioning during retirement transition

Four different trajectories of concurrent changes in physical activity and physical functioning were found around the time of the retirement transition. The group with low initial physical activity showed deteriorating physical functioning, whereas the other three groups with higher levels of initial physical activity showed stable physical functioning during the retirement transition. Singles, females, obese participants, smokers and risky users of alcohol were more likely to be classified into a group with low physical activity and declining physical functioning than those in the reference group who had a moderate level of physical activity and good stable physical functioning. In turn, married or co-habiting participants, males, professionals, non-risky users of alcohol and non-obese participants were more likely to be included in groups with initially moderate or increasing physical activity and steady excellent physical functioning than those in the reference group.

Previous studies have reported mixed results on this matter. Some have observed a deterioration in physical functioning during the retirement transition (Byles et al., 2016; Jokela et al., 2010; Stenholm et al., 2014), others have seen no such phenomenon (Mänty et al., 2018). These differences could be due to the specifics of the studied samples. In contrast, other similar studies have utilised larger nationally representative samples of up to 21,600 participants (Byles et al., 2016), whereas Mänty et al. investigated a relatively small sample of 2,300 employees of a single municipality.

In line with the current findings, previous research has associated male sex and higher socioeconomic status with better physical functioning during the retirement transition (Stenholm et al., 2014). In contrast, some previous studies have observed a greater decline in physical functioning after retirement related to a higher occupational grade (Mänty et al., 2018). These differences could again be explained by the different study populations; Stenholm et al. studied 18,000 older citizens from the USA, whereas Mänty et al. studied 2,300 employees of a single Finnish municipality.

Consistent with the present findings, higher BMI and obesity have been associated with a greater risk of physical disability (Rejeski et al., 2010).

Meeting the current recommendations of 150 minutes of moderate or 75 minutes of vigorous physical activity (WHO, 2020) was associated with better physical functioning: physical functioning was poor in the group with initial physical activity of less than 14 MET-h/week (approximately 170 minutes of moderate physical activity) and good in all the other three groups with initial physical activity ranging from 20 to 60 MET-h/week. No difference between physical functioning was observed in the groups that had moderate or high physical activity, in other words, those who met the activity recommendations.

6.5 Increasing physical activity associated with improved self-rated health during retirement transition

Self-rated health improved during the retirement transition in all three identified trajectories, although for two out of the three groups, this improvement was temporary. Only a small group that consisted of 9% of the participants with initially high physical activity demonstrated stably increasing physical activity and improving self-rated health throughout the follow-up. The changes in physical activity and self-rated health positively mirrored each other during the retirement transition – when physical activity improved, so did self-rated health. Manual work, obesity, living alone, smoking, and risky use of alcohol were associated with a higher probability of being in a group with the lowest activity and poorest self-rated health.

Previous research has also observed changes in self-rated health in connection with retirement. The reported direction of these changes, however, has varied. Westerlund et al. found an improvement in self-rated health after retirement (Westerlund et al., 2009), but a systematic review on the subject had inconclusive results – three of the included studies reported an improvement in self-rated health, one observed a deterioration, and four reported no change (van der Heide et al., 2013).

In this study, lower physical activity was associated with poorer self-rated health according to multi-trajectory analysis. Previous studies have reported similar results: lower physical activity has been linked to poorer self-rated health (Papp et al., 2022; Park et al., 2022; Sperlich et al., 2020). Poorer self-rated health has been associated with lower socioeconomic status, overweight and lower physical activity (Hoertel et al., 2022; Stenholm et al., 2020), whereas good self-rated health has been associated with normal weight, non-smoking and a higher level of physical activity (Stenholm et al., 2020).

In this study, the improvement in self-rated health was most prominent in a group with initially poorer self-rated health and a greater proportion of people retiring from manual work. This corresponds to previous results. Earlier studies have found declining self-rated health after retirement among those in high positions (van der Heide et al., 2013), and among wealthy and healthy participants (Szabo et al., 2019), whereas retiring from non-professional work with low to medium socioeconomic status (Szabo et al., 2019), poor working conditions prior to retirement, and high job strain (van der Heide et al., 2013) have been associated with improved self-rated health after retirement.

6.6 Strengths and limitations

The main strengths of the study were its large samples and prospective repeated measures design. All the analyses were based on multiple measures, which enabled detailed examination of within-individual changes over time. In Study I, the follow-up was long, 16 years. In Studies II, III and IV, the surveys were repeated annually around the retirement transition to better evaluate the effect of retirement. GBTA can distinguish different paths of changes occurring over time better than more traditional methods that only show the average outcome over time. The participants were public sector employees and thus covered many different occupations from manual to professional, which increased the generalisability of the findings.

However, some weaknesses should be considered. Physical activity, BMI, physical functioning, self-rated health, alcohol consumption, smoking and marital status were self-reported, which might cause information bias (Connor Gorber et al., 2007). In this study, only leisure-time and commuting activity was assessed, which excludes work-related activity and other active transportation. Thus, the total daily physical activity was unknown. Before retirement, work-related physical activity could constitute a large proportion of total physical activity, which may lead to a decrease in total physical activity, even if leisure-time physical activity increases. The absence of commuting activity after retirement could also lead to a decrease in total physical activity, if active commuting wasn't replaced by another type of physical activity. Although, an accelerometer-based study by Pulakka et al (2020) showed that active commuters were more engaged in physical activity than other participants and managed to maintain their activity after retirement transition as well.

The questionnaire used to assess physical activity has not been validated, but a similar questionnaire has (Kujala et al., 1998). The advantage of the questionnaire is repeatability and easiness for study participants and as seen in the results of these studies, the ability to categorize the participants to different activity levels. The measure considers all types of physical activity; light, moderate and vigorous. Yet, as all self-reported measures, it is prone to memory bias and participant reactivity (Sylvia et al., 2014). The questionnaire is also limited by the ceiling effect: the longest duration option for each activity was “four hours or more”. Therefore, in order to achieve higher physical activity levels, more vigorous activity is needed since low activity (walking, 3,5 MET, maximum 4 hours per week) would result in maximum of 14 MET-h/week. Physical activity of 14-30 MET-h/week was categorized “moderate”, which would require at least some more vigorous activity than peaceful walking. In order to achieve “high” level of physical activity (>30 MET-h/week), a participant would either have to walk peacefully for the maximum of 4 hours and briskly for the maximum of 4 hours or have some more vigorous activities (jogging, running) as well. An accelerometer-based measure would propably have been more precise in measuring physical activity, but given the large sample of over 16 000 participants in Study I and over 3000 participants in Studies II-IV, it would not have been feasible.

The results of Study III might be affected by the fact that the SF-36 might be too approximate a scale for the purpose of the study. Most of the participants were in good health and able to work until statutory retirement. This may induce a ceiling effect for the SF-36, which means that it is possible that even a maximum score could not exclude mildly reduced functioning in reality.

Although the type of retirement was not explicitly defined in the FIREA data, due to the inclusion criteria (participants who were working 18 months prior to their estimated retirement date and who retired during follow-up), most of the participants were able to keep working until their statutory retirement. Thus, they were probably in better health than the general population, which includes those who retire prematurely due to health conditions. The generalisability of the findings to the general population might also be affected by the fact that the sample was predominated by stably employed women and professionals, although this distribution is common in the Finnish public sector.

The main type of analysis, the group-based trajectory analysis, is a data-driven form of defining subgroups in a larger sample, which results in trajectory groups that are not assigned by researchers. The strength of the GBTA is its ability to distinguish different paths of change in outcomes over time compared to more traditional methods that only show the average change over time. The multitrajectory method treats both variables as important as the other, thus the results are not emphasized by the change in either physical activity or BMI, physical functioning or self-rated health.

These results show associations between the changes in physical activity and BMI, physical activity and physical functioning and physical activity and self-rated health, but the direction of these associations could not be studied in this setting. Better health and functioning probably leads to being more active than those in worse condition, and physical activity probably induces better health and functioning.

It is also possible that other unidentified confounding factors, such as dietary habits or certain diseases might have affected the results.

6.7 Implications and future research

The results of this thesis imply that the transition to retirement is a period during which people experience concurrent changes in lifestyle factors and in several domains of health and functioning such as physical activity, physical functioning and self-rated health. The age-related decline in physical activity changes at this point towards greater physical activity. The temporary nature of improvement in physical activity around the retirement transition highlights the importance of targeting recent retirees in order to extend and magnify this improvement. High physical activity before retirement and an increase in physical activity during the retirement transition were associated with positive changes in physical functioning and self-rated health. Physical activity should be promoted to improve health and to sustain the decline of physical functioning associated with ageing. Barriers to sufficient physical activity should be actively evaluated and minimised. As physical activity tends to start declining already at working age, lifelong promotion of physical activity to maintain good functioning, normal weight and better general health after retirement should be considered.

In order to tackle the increasing inactivity seen in all age groups, the current government's Get Finland Moving programme aims in increasing physical activity of every age group. The measures include promotion of physical activity in a phenomenom-oriented way by different administrative sectors of the government ministries, such as physical activity counselling, know-how related to physical activity and taxation that encourages to everyday physical activity (*Suomi Liikkeelle*, 2024). The programme includes for instance measures to encourage walking and cycling and use of nature as a part of recreational activity. Physical activity of retired citizens is being promoted in many municipalities by offering free or low-cost entries to swimming pools and gyms owned by the municipality. Some wellbeing service counties offer age based guidance services for all citizens when they turn 75. Such services could be expanded to resent retirees in order to promote healthy habits including diet and physical activity. Due to the reform of health care system in Finland launched in 2023, 21 wellbeing service counties are responsible for organising health, social and rescue services (Finnish Ministry of Social Affairs and Health, 2024), yet the 309 municipalities are responsible for promotion of welfare (Finnish Minstry of Social Affairs and Health, 2024). The separation of the responsible administrative sectors could lead to varied supply of services in different regions. The results of these phenomena and programmes need to be further evaluated.

Studies with longer follow-ups after retirement are needed to further evaluate the long-term changes in physical activity after retirement. Further research may suggest some means to attenuate the increase in physical activity seen during the retirement transition and to promote physical activity for those at risk of it declining after retirement. Intervention studies of manual workers and those who do not meet the physical activity recommendations prior to retirement are needed in particular, as these individuals are at a greater risk of becoming physically inactive after retirement. The optimal timing of such interventions should be defined, as changes in physical activity may not progress at a steady pace and a decline in physical activity is observed already prior to retirement among some people.

7 Conclusions

Generally, the results of this thesis suggest that physical activity temporarily increases in connection with retirement confirming previous observations. Both during working age and transition to retirement, the level of physical activity is associated with many factors. Although the changes in physical activity vary in different groups, it often follows some clear patterns. Normal weight, better general functioning and self-rated health, higher occupational status, male sex, no smoking, and modest alcohol consumption correlate with an increase in physical activity. In turn, female sex, manual work and living alone are the main risk factors for lower physical activity, higher BMI, poorer physical functioning, and suboptimal self-rated health. Adherence to current physical activity recommendations predicts better physical functioning after retirement. On the other hand, physical activity at the recommended level alone is not connected with maintaining a normal weight. In order to stay at a normal weight, physical activity significantly exceeding the recommendations is required.

These findings could be useful when planning guidelines and interventions to maintain physical activity for ageing workers and retired citizens. Retirement is a timepoint in life when changes occur in physical activity and therefore, might be a suitable time for occupational health care or primary health care providers to promote better physical health.

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