UNIVERSITY OF TURKU

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To my family, near and far

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ABSTRACT

This study aimed at examining how different characteristics of sleep change during transition from full-time work to statutory retirement. Changes in sleep were examined among public sector employees in Finland using data from two longitudinal cohorts, the Finnish Public Sector (FPS) study and the Finnish Retirement and Aging (FIREA) study. Sleep was measured with self-reports and wrist-worn accelerometers up to 6 years before and 6 years after retirement. Changes in sleep duration, different types of sleep difficulties, daytime tiredness, and sleep loss due to worry, as well as in the timing of sleep, time spent in bed, and sleep efficiency were examined. Furthermore, information on different pre-retirement sociodemographic, work, and health factors was obtained and changes in sleep were examined in relation to these different pre-retirement characteristics.

During the transition to retirement, sleep duration increased by approximately 22 minutes (ranging from 19 minutes to 25 minutes depending on the measurement interval around retirement and the sleep measure that was used). The prevalence of sleep difficulties decreased during the retirement transition and particularly the prevalence estimates of waking up too early in the morning and nonrestorative sleep were observed to decrease. Decreases were observed also in the prevalence of daytime tiredness and sleep loss due to worry. Compared to working days prior to retirement, both in bed and out bed times were delayed, and thus, retirement was associated with a later sleep-wake rhythm. Factors associated with the sleep changes during the retirement transition were identified, including short sleep duration, job strain, and psychological distress prior to retirement.

In conclusion, statutory retirement is associated with longer sleep duration and less sleep difficulties for many retirees retiring from public sector work. As there seems to be more inadequate sleep, sleep difficulties, and daytime tiredness during the final working years than after retirement, this study also highlights the importance of promoting sleep health of older employees.

KEYWORDS: Sleep, sleep duration, sleep difficulties, daytime tiredness, retirement, work, work stress, accelerometry

TURUN YLIOPISTO
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TIIVISTELMÄ

Tämän tutkimuksen tavoitteena oli selvittää, kuinka unen eri osa-alueet muuttuvat siirryttäessä kokoaikaisesta työstä ikäperusteiselle eläkkeelle. Unen muutoksia tutkittiin suomalaisilla kunta-alan työntekijöillä käyttäen Kunta10- ja Sairaala-henkilöstön hyvinvointitutkimuksen sekä Aktiivisena eläkkeelle -tutkimuksen pitkittäisaineistoja. Unta mitattiin sekä kyselyillä että ranteessa pidettävällä liike-mittarilla. Tutkimuksessa selvitettiin muutoksia itsearvioidussa ja liikemittariin pohjautuvassa unen kestossa, erityyppisissä univaikeuksissa, päiväaikaisessa väsyneisyydessä ja huolien vuoksi valvomisessa sekä myös unen ajoituksessa, sängyssä vietetyssä ajassa ja unen tehokkuudessa. Tutkimuksessa tarkasteltiin myös, miten eläköitymistä edeltävät sosiodemografiset ja työhön sekä terveyteen liittyvät tekijät ovat yhteydessä unessa havaittuihin muutoksiin.

Eläkkeelle siirryttäessä unen kesto lisääntyi keskimäärin noin 22 minuutilla (vaihdellen 19 minuutista 25 minuuttiin riippuen mittausaikavälistä eläköitymisen ympärillä sekä käytetystä mittausmenetelmästä). Univaikeuksien esiintyvyys väheni eläköitymisen jälkeen ja erityisesti vähenivät liian aikaiset aamuheräämiset ja virkistämätön uni. Myös huolien vuoksi valvomisen ja päiväaikaisen väsyneisyyden havaittiin vähenevän. Eläköitymisen myötä uni-valverytmi siirtyi myöhäisemmäksi, sillä sekä nukkumaanmeno- että heräämisajat olivat eläköitymisen jälkeen myöhempiä kuin työpäivinä ennen eläköitymistä. Eläköitymistä edeltävistä tekijöistä lyhyt unen kesto, työn kuormittavuus ja heikko itsearvioitu terveys ennen eläköitymistä olivat yhteydessä unessa tapahtuviin muutoksiin eläköidyttäessä.

Tämän tutkimuksen tulokset osoittavat, että ikäperusteinen eläköityminen tarkoittaa monille muutosta kohti pidempää yöunta ja univaikeuksien vähentymistä. Tutkimus myös korostaa ikääntyneiden työntekijöiden riittävän ja hyvänlaatuisen unen tukemisen tärkeyttä osoittaessaan, että riittämätön uni, univaikeudet ja päiväaikainen väsymys ovat yleisempiä viimeisien työvuosien aikana kuin eläkkeellä.

AVAINSANAT: uni, unen kesto, univaikeudet, päiväaikainen väsyneisyys, eläköityminen, työ, työstressi, kiihtyvyysanturi

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Abbreviations

BMI	body mass index
CI	confidence interval
DSM	Diagnostic and Statistical Manual of Mental Disorders
FIREA	Finnish Retirement and Aging (study)
FPS	Finnish Public Sector (study)
GEE	general estimating equations
IQR	interquartile range
ISCO	the International Standard Classification of Occupations
MET	metabolic equivalent
OR	odds ratio
REST	the Retirement and Sleep Trajectories (study)
RR	risk ratio
SII	Social Insurance Institution of Finland
SD	standard deviation

List of Original Publications

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

I Myllyntausta S, Salo P, Kronholm E, Aalto V, Kivimäki M, Vahtera J, Stenholm S. Changes in Sleep Duration During Transition to Statutory Retirement: A Longitudinal Cohort Study. *Sleep*, 2017; 40(7): zsx087.

II Myllyntausta S, Salo P, Kronholm E, Pentti J, Kivimäki M, Vahtera J, Stenholm S. Changes in Sleep Difficulties During the Transition to Statutory Retirement. *Sleep*, 2018; 42(1): zsx182.

III Myllyntausta S, Salo P, Kronholm E, Pentti J, Oksanen T, Kivimäki M, Vahtera J, Stenholm S. Does Removal of Work Stress Explain Improved Sleep Following Retirement? The Finnish Retirement and Aging (FIREA) study. *Sleep*, 2019; 42(8): zsz109.

IV Myllyntausta S, Pulakka A, Salo P, Kronholm E, Pentti J, Vahtera J, Stenholm S. Changes in Accelerometer-Measured Sleep during the Transition to Retirement. *Sleep*, 2020; zsz318.

1 Introduction

Work does not end by working, and sleep not by sleeping.
Finnish proverb, a loose translation

Sleep is important for health and well-being. Both inadequate duration and quality of sleep have been associated with morbidity and mortality (Gallicchio & Kalesan, 2009; Cappuccio et al., 2010a; Cappuccio et al., 2010b; Ferrie, Kumari et al., 2011). Furthermore, another characteristic of sleep associated with health is the timing of sleep, that is, whether the sleep-wake cycle is aligned with the times the body is best prepared for sleep according to its biological time. Along with inadequate or poor quality sleep, mistimed sleep may lead to chronic sleep deficiency, which in turn may result in impairments of cognitive and motor performance, as well as development or worsening of chronic diseases (Luyster et al., 2012; Czeisler, 2015).

Many individual factors influence on when, how much and how well individuals sleep (Grandner, 2017). One of the major aspects that determines the timing and duration of sleep is work and hours used for working. Furthermore, the characteristics of work, such as work demands, work schedule, and work environment may also have an influence on sleep by, for example, disturbing the quality of sleep (Lallukka et al., 2010; Van Laethem et al., 2013). Therefore, significant changes in sleep could be expected, when people withdraw from the work force when they retire, as all these work-related factors are removed.

The "baby boomers" (i.e. the individuals born between 1946 and 1950) are currently reaching their statutory retirement ages in Finland. Retirement brings about major changes in individual's daily schedule, as hours previously used for working are divided for other daily activities. Studies have shown, for example, that after retirement the time used for physical activity increases (Sjösten et al., 2012; Stenholm et al., 2016). In terms of sleep, changes could be expected to occur especially in duration of sleep, as early morning awakenings and the use of alarm clock are no longer required after retirement.

However, not much is known on the association of the transition to retirement and sleep. Only few studies to date have followed older adults from their final working years into retirement and examined, how sleep changes during this transition (Vahtera et al., 2009; Marquié et al., 2012; Hagen et al., 2016). These few existing studies have indicated that retirement could be associated with decreases in sleep difficulties (Vahtera et al., 2009; Marquié et al., 2012), as well as with increases in the time used for sleeping (Hagen et al., 2016). More studies are needed, however, to more closely examine and clarify these potential changes in sleep during the transition to retirement. There is lack of information in terms of, for example, understanding how different types of sleep difficulties change, how much sleep duration increases during the retirement transition, when these changes occur in relation to retirement and whether they are similar for everyone. There is especially lack of objective data on the associations between retirement and sleep, as all the previous longitudinal studies have relied on self-reported sleep.

More information is needed on whether different changes in sleep after retirement are observed in different groups, for example, among those with different health status or different work characteristics before retirement. For example, the few previous studies on the changes in sleep during retirement transition have suggested that the removal of work-related stressors might be one of the key factors driving the changes in sleep (Vahtera et al., 2009). By examining these differences, it might be to possible to determine the reasons that drive the changes in sleep during the retirement transition and even to point to ways that could be used to improve sleep of older adults already during the working years. In particular, it would be important to determine, whether retirement is especially beneficial for certain groups in relation to their sleep. This could also help to identify groups of older employees whose sleep health might be at risk if staying longer in the work force due to, for example, postponed retirement ages.

The aim of this study was to examine how sleep changes during the transition from work to full-time statutory retirement. This study examined changes in both self-reported and accelerometer-based sleep and in different characteristics of sleep, the interest was focused especially on sleep duration, sleep difficulties, and timing of sleep. Furthermore, the aim was to also determine how various pre-retirement work, health, and sociodemographic factors are associated with possible changes in sleep around the transition to retirement.

2 Review of the Literature

2.1 Sleep

Sleep is a state of consciousness that can be differentiated from wakefulness based on differences in electrical activity of the brain and physiological functioning. Sleep is regulated by the interaction of homeostatic and circadian processes (Borbély, 1982; Borbély et al., 2016). The level of the homeostatic process rises during waking and declines during sleep, which means that the longer the person is awake, the higher the pressure is to sleep and vice versa. The circadian process is controlled by the internal circadian pacemaker that does not directly depend of prior sleep and waking, but is mainly influenced by environmental light and rhythms of core body temperature and melatonin. In interaction, these two processes determine the timing of sleep and as a result, also influence the duration and quality of sleep (Daan et al., 1984; Borbély et al., 2016). The underlying circadian rhythms are manifested as chronotype, the predisposition of an individual to sleep at a specific time during a 24-hour period. Furthermore, sleep behaviors and practices also vary between individuals, as there are many societal, environmental, and interpersonal factors that influence when, how much and how well individuals sleep (Grandner, 2017).

Sleep is also important for health and well-being (Ferrie et al., 2011). Associations between sleep and health have been mainly examined in relation to two characteristics of sleep: the duration and quality of sleep. Thus, understanding how different factors are associated with sleep duration and quality and how they are in turn associated with health outcomes is crucial in terms of health promotion and disease prevention.

2.1.1 Sleep Duration

The sleep need of each person is highly individual, determined by, for example, genetic factors, gender, and chronotype (Partinen et al., 1983; Ferrara & De Gennaro, 2001; Polo-Kantola et al., 2016). Adequate sleep duration has been defined as the daily amount of sleep after which one feels fully awake (i.e. not sleepy) and is able to sustain normal levels of performance during daytime (Ferrara & De Gennaro, 2001). Although it is not possible to say exactly how many hours of sleep each individual needs each night, some general recommendations have been given based on scientific (Ferrara & De Gennaro, 2001) evidence on the associations of sleep duration and health. According to The National Sleep Foundation, an optimal sleep duration for healthy adults (26–64 years) is from 7 to 9 hours, and for healthy older adults (≥65 years) from 7 to 8 hours (Hirshkowitz et al., 2015). As the need for sleep varies by age (Ohayon et al., 2004), different amount of sleep is recommended for each age group. Individuals far outside the recommended range, may be exhibiting symptoms of serious health problems or compromising their health. On the other hand, also individuals with a habitually shorter or longer need for sleep than the average, referred to as the “natural” short and long sleepers in the literature, have been recognized (Ferrara & De Gennaro, 2001).

Getting an inadequate amount of sleep has immediate effects on waking functioning and when continuing for a longer period, it may also negatively affect health. Sleep deprivation refers to a situation in which an individual sleeps less then they need. Sleep deprivation can occur either as an acute total sleep deprivation, when the individual is awake for a longer period of time that extends the typical waking hours, or as a partial sleep restriction, in which the individual repeatedly gets an inadequate amount of sleep per 24 hours, usually referred to as sleep debt (Basner et al., 2014; Banks et al., 2017). Partial sleep restriction is rather common among working individuals and is often associated with medical conditions or demands of work and social life (Banks, 2007; Basner et al., 2014), whereas total sleep deprivation in working adults is more often related to shift work (Banks et al., 2017). Sleep restriction has been associated with deficits in cognitive functioning, such as impairments in attention and working memory (Krause et al., 2017), as well as with negative changes in mood (Palmer & Alfano, 2017), which may in turn affect individual’s ability to perform in daily tasks, such as work, and in social relations. Habitual short sleep has consistently been found to be associated with several adverse effects on health and functioning, such as incident type 2 diabetes (Cappuccio et al., 2010a; Holliday et al., 2013; Shan et al., 2015; Grandner et al., 2016), cardiovascular diseases (Vgontzas et al., 2009; Cappuccio et al., 2011; Guo et al., 2013), weight gain and obesity (Patel & Hu, 2008; Cappuccio et al., 2008; Itani et al., 2017), poorer cognitive functioning (Ferrie et al., 2011; Spira et al., 2017), and mood disorders, such as depression (Jackowska & Poole, 2017; Paunio et al., 2015; Zhai et al., 2015).

However, it is not only chronic sleep restriction that has negative health outcomes. Epidemiological studies have found a U-shaped association between sleep duration and mortality (Gallicchio & Kalesan, 2009; Cappuccio et al., 2010b; da Silva et al., 2016), as well as with increased morbidity (Itani et al., 2017; Jike et al., 2018). This means that both shorter (<7 hours) and longer (>8 hours) sleep duration are associated with higher all-cause mortality (Gallicchio & Kalesan, 2009; Cappuccio et al., 2010b), as well as mortality due to specific conditions, such as cardiovascular diseases (Kronholm et al., 2011; da Silva et al., 2016). These associations have been observed similarly for self-reported and objective accelerometer-based sleep duration (Kripke et al., 2011). In addition, both a change of sleep duration into short sleep and an increase from mid-range sleep to long sleep have been associated with increased mortality along with stable short and long sleep durations (Hublin et al., 2007). However, as was recently pointed out in a study by Åkerstedt et al. (2019), the association between sleep duration and mortality might only apply for weekday sleep, as often only the usual or typical sleep duration of an individual is assessed, and the possible different sleep patterns on weekdays and weekends have not been taken into account. Furthermore, it has been debated, however, whether sleep durations deviating from the optimal range are a marker for different negative health outcomes, or is sleep in fact, a risk factor that actually causes some diseases (Marshall & Stranges, 2010; Ferrie et al., 2011).

In Finland, women were recently reported to sleep on average 7 hours and 24 minutes and men 7 hours and 18 minutes per 24 hours, with 14% of women and 16% of men reporting sleeping at a maximum of 6 hours per 24 hours in a population-based sample of adults over 30-year-old in the FinHealth study (Koponen et al., 2018). Women have also been shown to have a longer preferred sleep duration (Polo-Kantola et al., 2016) than men. Somewhat against a common belief, studies have not observed a major decline in sleep duration over the past decades neither in regard to self-reported (Bin et al., 2012) nor objectively measured sleep (Youngstedt et al., 2016). A systematic review on the trends of sleep duration in 15 developed countries showed that in some countries, self-reported sleep duration has even been observed to increase (Bin et al., 2012). Furthermore, a review on objectively measured sleep in studies from 1960 to 2013 by Youngstedt and colleagues (2016) did not find a significant change in total sleep time measured with either polysomnography or accelerometry, thus, corroborating the findings from the studies based on self-reported sleep. Although no consistent decline has been observed, some studies have observed minor decreases in sleep duration in various countries since the 1960s (Bin et al., 2012). In Finland, self-reported sleep duration was observed to have decreased by approximately 5.5 minutes per 10 years over 30 years (between 1972 and 2005) and this decrease was especially observed among working aged men (Kronholm et al., 2008). Kronholm et al. (2008) also observed that the proportion of those sleeping 7 hours had increased, and correspondingly, the proportion of those sleeping 8 hours had decreased, whereas the proportion of short (≤6 hours) and long (≥9 hours) sleepers remained quite stable over the examined 33 years.

2.1.2 Sleep Quality

No standard definition for sleep quality has been established, despite of sleep quality being widely studied (Krystal & Edinger, 2008; Ohayon et al., 2017). Thus, measuring sleep quality and providing recommendations for an adequate quality of sleep is more challenging than in the case of sleep duration. The indicators associated with the continuity of sleep, such as sleep latency, number of over 5-minute long awakenings during the night, wake after sleep onset, and sleep efficiency (the proportion of sleep of the time spent in bed), have been considered to be appropriate indicators of quality of sleep across the lifespan (Ohayon et al., 2017). This was suggested by the National Sleep Foundation (Ohayon et al., 2017) who aimed at defining those objective characteristics of sleep that are valuable in regard to sleep quality. National Sleep Foundation also determined expert recommendations on optimal quality of sleep, and for example, sleep efficiency of 85% or more was rated as indicating good sleep quality. For an individual sleeping in home setting, however, the objective characteristics of sleep are challenging to measure accurately, and thus, the recommendations seem to provide more use for research and clinical purposes. From an individual's point of view, their own perception of how they sleep might be more meaningful than the objective characteristics of their sleep. Although individual's sleep quality would be defined as good or even "normal" based on objective measurements, it is possible that the individual may still perceive his or her sleep quality as poor and consider sleep as a problematic aspect of their life (Edinger et al., 2000).

Another perspective on sleep quality is the presence of self-reported sleep difficulties or sleep disorders, such as insomnia, as different sleep difficulties are one of the key factors behind poor sleep quality. In Finland, almost two thirds of women and half of men over 30 years old reported experiencing insomnia symptoms in the FinHealth study (Koponen et al., 2018). Compared to men, women experienced more insomnia symptoms on average after 40 years of age and this gender difference was observed particularly among those aged 60–79 years (Koponen et al., 2018). The prevalence rates of self-reported sleep problems have been observed to vary between countries (van de Straat & Bracke, 2015) and in also in other countries than Finland, women have been shown to report more sleep problems than men (Arber et al., 2009; Jaussent et al., 2011; van de Straat & Bracke, 2015). Furthermore, ageing has been associated with an increase in objectively measured disturbed sleep, and overall, sleep becomes more fragmented with age, as the number of arousals and awakenings increases, and the ability to sleep seems to decrease (Cooke & Ancoli-Israel, 2011). However, based on longitudinal data, aging does not seem to be associated with an increase in self-reported dissatisfaction with sleep or sleep complaints (Salo et al., 2012).

Studies that have examined trends in sleep problems in different countries over the past decades have quite consistently observed an increasing trend in self-reported sleeping problems in general (Rowshan Ravan et al., 2010), as well as more specifically in insomnia-related symptoms and insomnia cases (Salo et al., 2012; Pallesen et al., 2014; Ford et al., 2015). In Finland, Kronholm et al. (2008; 2016) observed an increasing trend in occasional insomnia-related symptoms since 1972 based on self-reported sleep data from two surveys among the working-age population. However, although the results showed some evidence for increase in chronic insomnia symptoms (occurring “often” or “every day”) from 1970s to 2000s (Kronholm et al., 2008), no further increase in chronic insomnia symptoms was observed thereafter (Kronholm et al., 2016).

Poor sleep quality, often characterized as insomnia or disturbed sleep in the studies, has been associated with cardiometabolic consequeces, such as, hypertension and dyslipidemia (Meng et al., 2013; Clark et al., 2016; Jarrin et al., 2018) and type 2 diabetes (Cappuccio et al., 2010a), as well as with cardio-cerebral vascular events (He et al., 2017), poorer neurocognitive functioning (Fernandez-Mendoza et al., 2010; Ju et al., 2014), as well as many other mental and physical conditions (Sivertsen et al., 2014). Insomnia has also been associated with subsequent work disability and sickness absence (Salo et al., 2010; Salo et al., 2012; Rahkonen et al., 2012; Lallukka et al., 2014), disability retirement (Lallukka et al., 2011; Paunio et al., 2015), poorer quality of life (Reimer & Flemons, 2003; LeBlanc et al., 2007), and decrease in physical function in older adults (Dam et al., 2008; Stenholm et al., 2010).

2.1.3 Assessment of Sleep in Population Studies

Sleep can be measured with either self-reports, such as using questionnaires or a sleep diary, or more objectively, using polysomnography or accelerometers. In epidemiological studies, sleep duration has most often been measured by asking the participants to evaluate their typical or usual sleep duration (Lauderdale et al., 2008; Ferrie et al., 2011). Validated scales and indices have also been developed for the assessment of both sleep duration and sleep difficulties, including the Karolinska Sleep Questionnaire (Nordin et al., 2013), the Pittsburgh Sleep Quality Index (Buysse et al., 1989), and the Jenkins Sleep Problem Scale (Jenkins et al., 1988). These self-reports of sleep are highly practical and cost-effective method to acquire population-level estimates on typical sleep duration and prevalence of sleep difficulties also from larger populations (Zinkhan et al., 2014). Along with retrospective questions on typical sleep duration, self-reports of sleep can also be obtained using sleep diaries, which have been thought to better capture the actual sleep duration, but to also be subject to bias related to perception and recollection of sleep (Van Den Berg F et al., 2008). Self-reports on both sleep duration and quality have, however, have been shown to only moderately correlate with objective methods (Lauderdale et al., 2008; Zinkhan et al., 2014; Landry et al., 2015).

Polysomnography, the simultaneous measurement of eye movements and the electrical activity of the brain and the muscles, is the gold standard in objectively measuring sleep. It is, thus, regarded as most accurate in assessing both sleep duration and quality, as well as sleep architecture (Landry et al., 2015). However, as polysomnography often requires an overnight stay in a laboratory, it is not applicable in large cohort studies with multiple repeated measurements due to its costs and intricacy (Ferrie et al., 2011). Accelerometry (also known as actigraphy), is a measurement based on movements of a limb, typically the arm, that can be used as a more cost-effective and less intrusive method than polysomnography for repeatedly gathering information on sleep patterns in a home environment (Ancoli-Israel et al., 2003; Zinkhan & Kantelhardt, 2016). Accelerometers are easy to use, light-weight, and powered by batteries that allow them to be used for continuous measurements over multiple nights (Ancoli-Israel et al., 2003). Accelerometry is regarded as a valid method for measuring nighttime sleep-wake periods in individuals with average or good quality of sleep (Littner et al., 2003; Blackwell et al., 2008; Marino et al., 2013; Slater et al., 2015; Quante et al., 2018). Compared to polysomnography, wrist accelerometry has been shown to have high sensitivity to detect sleep, but moderate specificity, which means that it only moderately detects periods of wakefulness during sleep (Marino et al., 2013; Slater et al., 2015).

As different methods have been suggested to measure somewhat different dimensions of sleep, it may be useful to simultaneously use multiple different assessment methods (Van Den Berg et al., 2008; Landry et al., 2015). The additional use of more objective methods to measure sleep along with self-reports could eliminate recall and reporting biases and allow the examination of both sleep and wake, while also taking into account the individual's own experiences on their sleep.

2.1.4 Factors Associated with Sleep Duration and Quality

Various factors are associated with how much and how well individuals sleep, and these factors can be related to the individual, such as genetics, health, and lifestyle factors, as well as to the environment and society they live in (Hublin et al., 2013; Grandner, 2017). For example, approximately one-third of the variance in sleep duration has been found to be accounted by genetic factors, which means that two-thirds of the variance is accounted by environmental factors (Hublin et al., 2013). Both physical and mental health as well as changes in health with aging are associated with sleep duration and sleep quality of individuals. Some of the key factors disturbing sleep are stress (Åkerstedt, 2006; Kompier et al., 2012), depression (Argyropoulos & Wilson, 2005; Nutt et al., 2008), chronic pain (Jansson-Fröjmark & Boersma, 2012; Mathias et al., 2018), and chronic illnesses (Foley et al., 2004; Taylor et al., 2007; Koyanagi et al., 2014). The association of health with sleep seems to be especially visible among older individuals: It has been suggested, that the decrease observed with age in the ability to sleep is not in fact associated with aging per se, but to other factors that are associated with aging, such as increasing prevalence of chronic illnesses, depression, and increasing use of medication (Foley et al., 2004; Ancoli-Israel, 2009; Bliwise & Scullin, 2017). One particular factor in aging that is known to disturb sleep in women is menopause, as it is associated with both poorer perceived sleep quality and deterioration in sleep continuity, mostly because of vasomotor and depressive symptoms (Lampio et al., 2017; Baker et al., 2018). In addition, older age also increases risk of many sleep disorders, such as insomnia, sleep-disorders breathing (e.g. sleep apnea), REM sleep-behavior disorder, and restless legs syndrome or periodic limb movements in sleep (Neikrug & Ancoli-Israel, 2010; Cooke & Ancoli-Israel, 2011). In addition to health in general, also lifestyle choices, such as the consumption of coffee and energy drinks (Clark, I. & Landolt, 2017), alcohol use (Ebrahim et al., 2013), smoking (McNamara et al., 2014), and physical activity (Chennaoui et al., 2015) may influence sleep.

Socioeconomic and sociodemographic factors have also been associated with sleep duration and sleep quality. Those in a lower socioeconomic position report more often suboptimal sleep durations (both short and long sleep) (Grandner et al., 2010; Lallukka et al., 2012; Basner et al., 2014) and sleep problems (Arber et al., 2009). In addition, lower neighborhood socioeconomical status and neighborhood disadvantage have recently been connected with both short and long sleep duration as well as long daytime naps in the United States (Xiao & Hale, 2018). Married individuals have been observed to sleep better and to be more likely to have an optimal sleep duration than those living alone or being separated, divorced, or widowed (Grandner et al., 2010; Lallukka et al., 2012; van de Straat & Bracke, 2015).

Finally, also the surrounding society may have an impact on individuals' sleep. For example, sleep can be influenced, both directly and indirectly, by policies dictating, for example, saving time, and occupational health and safety (e.g. legislation on working hours) (Grandner, 2017). Also societal changes, such as the increase in the use of technology, may influence individuals' sleep. This can be seen in the growing interest and even concern over how the use of technology and especially media devices, such as smart phones or laptops, near bedtime impacts sleep (Exelmans & Van den Bulck, 2015; Carter et al., 2016). A shift towards a global 24 hour society may also pose a challenge for sleep health, as responsibilities and activities of both work and leisure time compete with sleep over the time available (Basner et al., 2014).

2.1.5 Work and Sleep

For a majority of adults, another activity that takes a great part of the 24 hours in addition to sleeping is working (Basner et al., 2014), and thus, it is not surprising that these two activities are highly interlinked. Sleep duration is often shorter on work days than on weekends or on leisure days (Basner et al., 2014; Polo-Kantola et al., 2016). In addition, time use data from the United States suggests that working is the dominant activity exchanged for less sleep among short sleepers (those sleeping less than 6 hours per 24 h) (Basner et al., 2014). Long sleepers (those sleeping more than 11 hours per 24 h), on the other hand, were shown to use much less time for working than mid-range sleepers (Basner et al., 2014). In addition, those working long hours (more than 10 h per day) have been shown to be more likely short sleepers (sleeping less than 6.5 hours) and that the inverse association between working hours and short sleep to be stronger for men than women (Chatzitheochari & Arber, 2009).

Employment status in general is also one of the factors that has been associated with sleep duration. Those in employment have reported shorter sleep duration compared to self-employed and those not working (Basner et al., 2014), although contradictory findings have also been observed (Lallukka et al., 2012). Work may also affect sleep through commuting: longer commuting duration to and from work has been associated with less sleep (Christian, 2012; Basner et al., 2014) and poorer sleep quality (Hansson et al., 2011). In Finland, the increase in occasional insomnia symptoms over the past decades was observed to be higher when the working population was examined compared to when the whole population was examined (Kronholm et al., 2016).

Working hours may also infuence sleep by dominating the timing of sleep, and this affects especially shift workers (both with and without night work) and those with a late chronotype (Wittmann et al., 2006; Juda et al., 2013). Shift work requires sleeping on irregular and suboptimal times, when the circadian clock is promoting wakefulness, and there is more daylight and noise that may disturb sleep (Drake & Wright, 2011; Juda et al., 2013). Shift workers indeed sleep more poorly than daytime workers (Åkerstedt, 2003), even after retirement from work (Monk et al., 2013). A study by Härmä et al. (2019) showed among Finnish public sector employees that long-term exposure to shift work with night shifts was associated with an increase in both fatigue during leisure days and being a long sleeper, whereas shift work without night shifts was associated with long sleep only. Normal work schedules, that typically start early in the morning, are also not well suited for the preferred sleep times of those with a late chronotype, the evening types, and this might lead to sleep debt on work days and a compensation of this debt on leisure days (Wittmann et al., 2006). Results from the Whitehall II cohort study have shown that long working hours (working more than 55 hours a week) are associated with incident sleep disturbances, including difficulties falling asleep, and shortened sleep duration (Virtanen et al., 2009). It has been suggested that the association between working hours and sleep disturbances could be at least partly explained by high job demands (Virtanen et al., 2009).

The association of work characteristics with sleep quality have also been studied. Especially the psychosocial characteristics of work have been examined in relation to sleep, mainly with studies using cross-sectional design (Åkerstedt, 2006; Van Laethem et al., 2013). Psychosocial work related stress and adverse work characteristics, such as high cognitive and emotional job demands, bullying, and high workload, are strongly associated with poor sleep quality (Lallukka et al., 2010; Van Laethem et al., 2013; Halonen et al., 2017). Also low work time control has been associated with an increased risk for sleep disturbances among those working normal 40-hour week, whereas among those working more than 40 hours a week, both very low and very high work time control were associated with disturbed sleep (Salo et al., 2014). It has been suggested that it is not in fact the work characteristics and work stress itself that disturb sleep, but the appraisal of the stressful events and conditions as well as the anticipation and worry over the subsequent day that impair sleep (Morin et al., 2003; Åkerstedt, 2006; Kompier et al., 2012). On the other hand, positive psychosocial factors, such as social support, job control, and organizational justice, have been associated with better sleep quality and fewer sleep disturbances (Kompier et al., 2012; Linton et al., 2015; Lallukka et al., 2017). Recent studies analyzing observational sleep data as a pseudo-trial have been able to shed light on the temporal association of work-related stressors and sleep outcomes by showing that increase in stressors, such as job strain and organizational justice, are associated with decreases in sleep quality, whereas favorable changes are associated with lower odds for persistence of poor quality sleep (Halonen et al., 2017; Lallukka et al., 2017).

It is also possible that work characteristics and sleep quality may mutually influence each other (Van Laethem et al., 2013). Insufficient and poor quality sleep have been associated with short-term and long-term work outcomes, such as reduced productivity and performance (Rosekind et al., 2010), occupational accidents and injuries (Uehli et al., 2014), absenteeism (e.g. sickness absence) (Kucharczyk et al., 2012; Lallukka et al., 2014; Madsen et al., 2016), and disability retirement or retirement due to poor health (Haaramo et al., 2012; Canivet et al., 2014; Hale et al., 2017). The reduced work performance and absenteeism due to sleep disturbances represents significant indirect and direct costs not only to the individual worker (Kucharczyk et al., 2012), but also to the employer and the society (Metlaine et al., 2005; Godet-Cayré et al., 2006; Kessler et al., 2011).

2.2 Retirement

2.2.1 Retirement as a Life Transition

Retirement is a major life transition that has notable impact on individual's daily schedule and daily activities, as the time previously used for working is freed for other activities (Sprod et al., 2017). Retirement has been shown to have beneficial effects on mental health (Westerlund et al., 2010; Fleischmann et al., 2019), but conflicting evidence has been observed for the effects of retirement on general and physical health (van der Heide et al., 2013). Studies have also shown changes in some lifestyle and health behaviors during the transition to retirement: While a majority of retirees seem to sustain a level of healthy alcohol use after retirement in Finland, some individuals have been observed to increase alcohol usage to a risky level at retirement, whereas for some, a slowly declining trend of risky alcohol use has been observed after retirement (Halonen et al., 2017). Retirement also seems to be associated with greater odds for cessation of smoking (Oshio & Kan, 2017; Pulakka et al., 2018). In addition, studies have shown increases in leisure-time physical activity during the retirement transition (Barnett et al., 2012; Sjösten et al., 2012; Stenholm et al., 2016), but also increases in self-reported total sedentary time, especially in regard to increasing television viewing and computer use (Leskinen et al., 2018), and objectively measured sedentary time among women (Suorsa et al., 2019).

All in all, the effects of retirement on health and health behaviors are complex, and may depend greatly on when, why and from which job people retire. Based on their findings among Dutch employees, van Solinge and Henkens (2008) have argued that the transition to retirement requires the person to adjust to the loss of his or her work role and social ties of work, as well as to develop a satisfactory lifestyle after retirement. In regard to satisfaction with retirement and post-retirement well-being, resources, such as finances, health, and marital relationship, seem to be of high relevance (Pinquart & Schindler, 2007; van Solinge & Henkens, 2008; Henning et al., 2016). The voluntariness of retirement may also play a role in adjustment to and satisfaction with retirement, especially in terms of early retirement. Retirement can be either involuntary, when the person is forced to retire due to health reasons, corporate reorganizations, or unemployment, or voluntary, when the retirement is due to preference for leisure instead of working (Shultz et al., 1998; Dorn & Sousa-Poza, 2010). Involuntary retirement seems to be more challenging for both adjustment to and satisfaction with retirement, as well as to general well-being after retirement, as it challenges the control over one's life (van Solinge & Henkens, 2008). After reaching the statutory retirement age, there are possibilities to continue working even when receiving pension, and thus, the retirees may choose whether they want to continue working or to fully withdraw from working life. Finally, the characteristics of the job the person retires from may be of importance in satisfaction with retirement; for example, retirement from a physically demanding may come as a relief, whereas retirement from a stimulating job with a great intrinsic value may lower the satisfaction with retirement (van Solinge & Henkens, 2008).

Retirement could be seen as an abrupt and definite withdrawal from a long-term job (Kantarci & Van Soest, 2008). However, there seems to be a change in the culture towards a more active lifestyle after retirement that can be seen, for example, in the increase of those working after retirement. In Finland, the number of individuals who work while drawing a pension has slowly grown in recent years, and according to Finnish Centre for Pensions, 9.3% of 63–67-year-old retirees were working at year end 2017 (Finnish Centre for Pensions, 2018; Kannisto, 2018). Most retirees do irregular or part time work, with third of statutory retirees working throughout the year in 2017 (Kannisto, 2018). Some retirees continue working for their pre-retirement employee, for example by being on a locum basis or by doing irregular, temporary jobs, whereas others may move to a completely new occupation or to self-employment (Beehr & Bennett, 2015; Fasbender et al., 2016). Working after retirement seems to be especially meaningful in terms of allowing the individual to retain their work role identity (Fasbender et al., 2016).

2.2.2 Retirement in Finland

In Finland, the retirement ages of the employees are regulated by the Public Sector Pensions Act. Until, the end of 2004, the statutory retirement age on public sector was generally 63-65 years, and from 2005 onwards, 63-68 years. Following a pension reform in January 2017, each age group has their own retirement age which is tied to the life expectancy (Keva, 2018). A similar mechanism for regulating retirement ages is being used in some other European countries as well, such as Denmark, Estonia, Netherlands, and Italy (Finnish Centre for Pensions, 2019). The retirement age is flexible, which means that the pension may be taken out within a certain age range. Thus, there is also an upper limit for how long a person can continue working. For example, for those born in 1957 the upper age is 68 years. However, both the lower and upper retirement will gradually increase, and at the moment, for those born in 1964 the statutory retirement age ranges from 65 to 70 years. Some employees have been able to keep their earlier retirement age from the previous pension acts in which pension ages were below 63 in some occupations. For example, the pension age for primary school teachers was 60 years. After the pension reform, employees may also retire on partial early old-age pension, years-of-service pension (for those who have worked in a strenuous and wearing work for a long time), or on full or partial disability pension (Keva, 2018).

2.2.3 Assessment of Retirement

Although retirement could be simply defined as withdrawal from paid working life, exactly defining and measuring retirement is in fact more challenging (Denton & Spencer, 2009; Beehr & Bennett, 2015). As was mentioned earlier, many people continue to work for pay after retirement, while already receiving a pension. Retirees may do temporary jobs or work shifts for their pre-retirement employer or even begin in an entirely new job or establish their own private business. Therefore, it may be challenging to correctly define when a person actually quits working, and thus, fully retires. Different definitions used for retirement in different studies causes difficulties in comparing between them (Maestas, 2010).

Denton and Spencer (Denton & Spencer, 2009) have summarized several measures that have been previously proposed and applied as indicators of retirement. Firstly, retirement can be seen as a complete absence of labor force participation, in which case information can be based on labor market measures. For example, retirement may be based on income tax returns and retirement year defined on the basis of a year of positive employment income followed by a year of zero employment income. Secondly, retirement may be indicated by a (possibly pre-defined, sufficient) reduction in either working hours, earnings, or both. Thirdly, retirement may be defined as receiving retirement income or pension. In Finland, for example, this information is provided by the Finnish Centre for Pensions, which coordinates all earning-related pensions for permanent residents in Finland. However, as a person may receive a pension while remaining in the labor force and continuing to work, receiving a pension does not always indicate withdrawal from paid working life. Finally, retirement status can be based on self-report. Questionnaires can be used, for example, to assess whether a person has completely retired and even to find out the exact date of retirement. On the other hand, if retirement is seen as quitting a long-term job with the same employer, questionnaires could assess, whether a person has left their main employer or changes career or employment later in life. Retirement can also be based on self-assessment of retirement status, that is whether the person describes themselves being retired or not. Self-assessed retirement, thus, indicates the mindset of the person rather than their economic situation, as a person can consider themselves being “retired” while also having a casual job. These different indicators of retirement may also be combined to assess retirement status. Challenges may rise, however, if these different sources provide discordant information of retirement status. For example, it could be challenging to define, whether a person is retired or nor, if they report a date of full-time retirement, but also have employment income after that date.

2.3 Retirement and Sleep

The first studies on the associations between retirement and sleep used cross-sectional design and compared sleep of retirees to sleep of those still in working life (Webb & Aber, 1985; Kronholm & Hyyppä, 1985; Ito et al., 2000) (Table 1). These studies provided somewhat discrepant findings in regard to this association. Some studies have shown retirees to report more sleep problems and to sleep longer on weekday nights than those of the same age who are still working (Webb & Aber, 1985; Ito et al., 2000; van de Straat & Bracke, 2015), while other show no differences in the frequency of sleep complaints when retirees are compared to a younger age group (Kronholm & Hyyppä, 1985).

However, to fully understand the associations of retirement and sleep, longitudinal studies following the same individuals from work into retirement are required. In the cross-sectional studies, comparisons of sleep before and after retirement are made between different individuals, for example between workers and non-workers or different age groups. This means that the differences that have been found between the groups in the cross-sectional studies may in fact be the result of the differences in the characteristics of individuals who have retired and individuals who have continued working. For example, the retired individuals may have retired due to health reasons, which may in turn be associated with their sleep, and thus, influence the association between retirement status and sleep in cross-sectional studies.

When the current study was initiated in 2016, only few longitudinal studies had examined the association between retirement and sleep with repeated measurements before and after retirement (Table 1). A decreasing trend in sleep disturbances after retirement was first observed among the French GAZEL cohort (Vahtera et al., 2009). The odds for general sleep disturbances were observed to be 26% lower during a 7-year post-retirement period compared to 7-year period prior to retirement. Furthermore, this reduction in sleep disturbances was especially prevalent for those with depression and mental fatigue prior to retirement and the decrease in sleep disturbances was suggested to result at least partly from the removal of work-related stressors. Changes in different types of sleep problems were examined in another French study, the VISAT study (Marquié et al., 2012). Self-reported sleep problems, such as difficulty maintaining sleep and difficulty getting back to sleep, were observed to increase with age up to mid-50s, but to remain rather constant after that, thus, not showing higher prevalence of sleep problems after retirement. In fact, among those who retired after the baseline measurement the prevalence of premature awakenings was observed to be lower in the follow-up measurements. Furthermore, a study on trajectories of sleep lost over worry from early midlife to older age, that did not study retirement in particular, highlighted retirement as one possible explanation for a declining trajectory of sleep lost over worry after 60 years of age (Salo et al., 2012). A recent study by van de Straat et al. (2019) also observed sleep disturbances to decrease after the transition to retirement among general working population in Sweden, especially among women, those retiring before the normative retirement age of 65 years, those working full-time, those lacking control over their working hours, and those who had high psychological work demands.

The first, and so far the only, study to longitudinally examine changes in self-reported sleep duration after retirement has been the Retirement and Sleep Trajectories (REST) study (Hagen et al., 2016), which showed sleep duration to be longer and bed times and wake times later after the transition to retirement. Compared to those who continued working over the follow-up period, those who retired had 15, 16, and 22 minutes longer sleep duration 1, 2, and 3 year post-retirement and this change was similar regardless of gender or mental health status. With advancing retirement age, however, the increase in sleep duration was observed to be shorter and the wake times were not as extended as among those retiring at an earlier age.

Associations between retirement and sleep can also be examined from the perspective of time use. Retirement is bound to change the daily schedule, as approximately eight hours used for working are replaced by other activities. A cross-sectional study on time use among a representative cohort of Americans 15 years and older observed retirees to use more time for sleeping than private sector employees, especially on weekday morning hours (Basner et al., 2014). Retirees were also observed to be less likely short sleepers (≤ 6 hours of sleep) and more likely long sleepers (≥ 11 hours of sleep) on weekdays, but less likely to be long sleepers on weekends and holidays. Retirees did not differ from employees in sleep duration on weekends and holidays. Another study examined changes in time use among 124 participants in Australia from pre-retirement into three, six, and 12 months after retirement and observed that approximately 30 minutes more time was used for sleeping three months after retirement than before retirement and this level was maintained throughout the follow-up period (Sprod et al., 2017).

The interest in the topic of retirement and sleep has grown in recent years, and a few longitudinal studies have emerged as a result (Table 1). However, to date, no longitudinal cohort study has examined changes in sleep during the transition to retirement by using more objective measures of sleep. A unique case study by Borbély et al. (2017) was the first to show changes in sleep after retirement by using a sleep measurement other than self-report, namely by accelerometry. Borbély measured his own sleep for over three decades and observed that his sleep duration declined with age, but this decline was reversed upon retirement. He also observed that the variation in sleep timing, which mainly manifested as longer sleep duration on weekends and on vacation compared to work days, was attenuated after retirement.

Table 1. Studies on the associations between retirement and sleep.

AUTHORS, PUBLICATION YEAR	STUDY POPULATION N (AGE, COUNTRY)	PARTICIPANTS	STUDY DESIGN	SLEEP MEASUREMENT	MAIN FINDINGS	COMMENTS
Kronholm & Hyyppä, 1985	594 (age groups 30–40, 50–60, and 71 years; Finland)	Retirees from a larger follow up population study and randomly chosen subjects from the population register of Turku City and its surrounding area	Cross-sectional	Sleep questionnaire with 65 multiple choice questions on sleep environment and sleep behavior, subjective feelings about wakefulness, satisfaction with the quality of sleep, dysfunctions associated with sleep (parasomnias), and depressive features	The 71-year-old retirees had earlier bed times and wake up times, shorter sleep time per night, more frequent naps than the other age groups However, they did not differ from 50–60-year-olds in sleeplessness, number of nocturnal arousals, sleep latency, snoring, or in the use of sleeping pills In fact, the 50–60-year-old individuals reported sleep complaints more frequently than the other age groups	The study suggests that no major worsening of sleep quality is associated with retirement.
Webb & Aber, 1985	40 (50–70-year olds; United States)	Active and retired employees of the University	Cross-sectional	Sleep diary (two weeks) and electroencephalographic recordings (4 nights)	Retirees had a longer sleep duration on weekday nights and earlier bed times on weekends than those who were working. Retired males had a longer sleep duration on weekend nights than male employees.	Longer sleep duration among retirees seems to be the results of earlier bed times rather than later awakenings.
Ito et al. 2000	518 (65-year olds; Japan)	65-year old residents enrolled in a population-based health examination in Nagoya	Cross-sectional	Questionnaire on sleep disturbances (i.e. difficulty falling asleep, frequent awakening at night, and not feeling rested in the morning)	Working men reported difficulties falling asleep less frequently than non-working men. No other differences in the frequency of sleep disturbances were observed among men, and no differences among women.	Retirement is associated with a higher prevalence of difficulties falling asleep among men.
Vahtera et al. 2009	14,714 (retirement age M = 55 years)	Employees from the French national gas and electricity company (the GAZEL cohort)	Prospective cohort study with annual measurements before and after retirement	One-item survey question on the occurrence of sleep difficulties during the previous 12 months	Overall levels of sleep disturbances were markedly reduced in the years following retirement, compared to years prior to retirement. Most pronounced reduction in sleep disturbances was observed among those with depression and mental fatigue prior to retirement.	Retirement is associated with a substantial and sustained decrease in sleep disturbances.

Marquié et al. 2012	623 (age groups at baseline: 32, 42, 52, and 62; France)	Employees of various companies from Southern France, (Aging, Health, & Work study, VISAT cohort)	Prospective cohort study with repeated measurements (baseline, +5 years, +10 years) and cross-sectional	Questionnaire assessing, e.g. the frequency of difficulty falling asleep, difficulty maintaining sleep, difficulty getting back to sleep, premature awakening, and hypnotic medication use during in the last month	The frequencies of difficulty falling asleep and hypnotic use increased fairly linearly with age. The frequencies of self-reported difficulty maintaining sleep, difficulty getting back to sleep, and premature awakening increased up to mid-50s, but remained constant after that. A significant reduction in premature awakenings was observed among those who retired during the study period (n = 111).	Although sleep complaints were more frequent with age, some reductions are observed after retirement.
van de Straat & Bracke, 2015	54,722 (mean age 67.1 years; 16 countries)	The Survey of Health Aging and Retirement in Europe (SHARE) cohort	Cross-sectional (cross-national comparison)	Single-item survey question on the occurrence of sleep difficulties during the previous 6 months	Retirees reported more sleep problems than those who were employed, self-employed, or those women who were homemakers. Only those who were permanently sick or disabled had a higher prevalence of sleep problems.	
Hagen et al. 2016	993 (mean age at baseline 60.1 years, United States of America)	The Retirement and Sleep Trajectories (REST) study cohort	Prospective cohort study with with repeated measurements before and after retirement	Self-administered questionnaire assessing bed times, wake times, and sleep duration on weekdays and weekends	Overall self-reported sleep duration was observed to be 15, 16, and 22 min longer 1, 2, and 3 years post-retirement among retirees than among those who continued working full time over the same period Bed times and awakening times were also found to be later after retirement.	Sleep duration was longer among retirees on weekdays and shorter on weekends than among those still working
Borbély et al. 2017	1 participant (retired at the age of 67)	The first author composed the study sample	A case study (30 years continuous follow-up)	Accelerometer measurement from non-dominant wrist	Sleep duration declined with age, but this trend was reversed upon retirement. The variability in sleep, especially the difference between weekday and weekend sleep duration was attenuated after retirement.	The first study to use sleep measurements other than self-reports to examine associations between retirement and sleep.
van de Straat et al. 2019	2,011 (42.6% retired at the age of 65; Sweden)	The Swedish Longitudinal Study of Aging (SLOSH) study cohort	Prospective cohort study with biennial repeated measurements before and after retirement	The Karolinska Sleep Questionnaire (Nordin et al., 2013) (difficulties falling asleep, repeated awakenings with difficulties going back to sleep, premature awakening, and disturbed/restless sleep in the last three months)	Self-reported sleep disturbances decreased following retirement from paid work. The only work characteristics that predicted decreases in sleep disturbances were the number of working hours and control over working hours with those who had less work hours and more work-time control benefitting less from retirement.	

2.4 Gaps in Previous Research

Before the present study, little longitudinal research has been focused on whether full-time retirement from work is associated with changes in sleep. To the best of my knowledge, only two longitudinal studies, both from French cohorts, had examined changes in sleep difficulties following retirement when this PhD study was begun (Vahtera et al., 2009; Marquié et al., 2012). Furthermore, especially the studies on the association between retirement with sleep duration are scarce with only one previous study examining specifically the changes in sleep duration during the retirement transition (Hagen et al., 2016), and another, cross-sectional study observing differences in time use between employees and retirees (Basner et al., 2014).

In addition to the general lack of knowledge on the topic of retirement and sleep, the few existing studies have some methodological limitations. Firstly, in the REST study by Hagen et al. (2016) the estimates on the changes of sleep duration from 1 to 3 years postretirement were provided in comparison to those who continued working during the same time period, and as a result, it remained unclear, how much exactly does sleep duration change during the retirement transition. It is also unclear how sustained the potential changes in sleep duration are after retirement, as the follow-up period of the REST study was also rather short, reaching up to 3 years after retirement. It is also somewhat unclear, whether the changes in sleep duration occur immediately after retirement, although the study on changes in time use after retirement has indicated, that the changes in sleep duration could be visible already during the first months after the transition to retirement (Sprod et al., 2017). Thus, the changes in sleep duration following retirement need to be examined with both shorter and longer follow-up periods around retirement, to gain an insight on the timing and duration of the sleep changes.

Secondly, the study by Vahtera et al. (2009) was the first to provide important information on the association of retirement with sleep difficulties, but due to the rather crude measure of sleep difficulties in the GAZEL study, some evident gaps remained. Sleep difficulties were in that study assessed with a single survey question on the occurrence of sleep disturbances during the past 12 months, and thus, only a general perspective on the changes in sleep difficulties was provided, but no information on how specific types of sleep difficulties change after retirement. The VISAT study provided some preliminary findings in relation to this question by showing particularly premature awakenings decreasing after retirement (Marquié et al., 2012). However, only a small part of the participants (n = 111) retired during the follow-up period in their study. Finally, although especially those with depression and mental fatigue prior to retirement were observed to benefit from retirement in the GAZEL study, more research is needed to examine how the changes in sleep during the retirement differ based on pre-retirement characteristics of the participants and to determine, what are the mechanisms behind the sleep changes.

The role of the removal of work-related stressors, which is one of the main mechanisms suggested as driving the changes in sleep after retirement, needs to be examined in relation to different types of sleep difficulties. Furthermore, it would be important to study, whether the changes in sleep depend on how many different work stressors the person is exposed to, as work stressors tend to cluster in the same individuals. In particular, changes in a previously unexamined characteristic of sleep in relation to retirement, sleep loss due to worry, would be relevant to study when examining the role of removal of work stressors after retirement, as work-related factors might be one of the key factors generating worry among employees.

Finally, a major methodological limitation of the previous studies on the association of retirement and sleep is the reliance on self-reports to measure sleep. To the best of my knowledge, no longitudinal cohort studies have assessed the changes in sleep around retirement with more objective methods, such as accelerometers. Measuring sleep repeatedly before and after retirement would provide important information on both sleep and wake times during the night, as well as changes in the timing of sleep, that is in bed times and awakening times. By using accelerometer-based sleep, bias related to recollection and reporting could be avoided. Furthermore, when accelerometer sleep data is combined to diary data on, for example, working days, comparisons could be made between nights before working days and nights before non-working days prior to retirement.

3 Aims

The overall aim of this study was to examine how sleep duration, sleep difficulties, and other sleep characteristics change during the transition from work to full-time retirement. Furthermore, the aim was to determine how various pre-retirement work, health, and sociodemographic factors are associated with possible changes in sleep around the retirement transition.

The specific aims of this study were:

1. To describe how self-reported and accelerometer-based sleep duration change during the transition to statutory retirement and to examine when the changes in sleep occur in relation to the retirement transition. In addition, the aim is to define whether these changes in sleep duration differ between groups characterized by certain pre-retirement factors (Study I, III, and IV).

2. To examine how self-reported sleep difficulties, sleep loss due to worry, and daytime tiredness change during the transition to statutory retirement. Furthermore, the aim is to assess, whether the changes in sleep indicators are more pronounced in certain pre-retirement subgroups, focusing especially on those with work-related stress prior to retirement (Study II and III).

3. To study how accelerometer-based time in bed, sleep efficiency as well as the timing of sleep change during the transition to full-time retirement. Moreover, the aim is to separately examine changes in nights before working days and nights before days off prior to retirement (Study IV).

4 Materials and Methods

4.1 Participants and Study Design

Data for the original studies come from two ongoing longitudinal cohort studies from Finland: the Finnish Public Sector (FPS) study (Studies I and II) and the Finnish Retirement and Aging (FIREA) study (Studies III and IV).

The FPS study began in 1997/1998 and is conducted by the Finnish Institute of Occupational Health. The FPS targets all public sector employees in the service of 10 towns (Espoo, Naantali, Nokia, Oulu, Raisio, Tampere, Turku, Valkeakoski, Vantaa, and Virrat) and five hospital districts or health and social services organizations (hospital districts of Kanta-Häme, Pirkanmaa, Vaasa, Welfare District of Forssa, and Public Social Services and Health Care in the Jakobstad region). The questionnaires are sent biennially. In this study, data from surveys performed for the current employees in 2000–2002 (n = 48,498, response rate 68%), 2004 (n = 48,076, response rate 66%), and 2008 (n = 52,891, response rate 71%) were included, as well as data from surveys performed for the leavers in 2005 (n = 8,780, response rate 68%), 2009 (n = 16,758, response rate 64%), and 2013 (n = 26,015, response rate 65%). Surveys for employees from 2006 and 2010 were not used, because they did not include health-related questions (including sleep) and the hospital districts did not take part in the surveys on those years. Register-based information on retirement was only available until December 31, 2011 and as to focus was on retirement transition, no survey data were used after 2011 (e.g. 2012 and 2014). The FPS study includes data-linkage to Finnish Centre for Pensions, employers' records, Social Insurance Institution of Finland's (SII) Drug Reimbursement Register, Finnish Prescription Register, and Finnish Cancer Registry by using personal identity codes assigned to all citizens in Finland. The FPS study has been approved by the Ethics Committees of the Finnish Institute of Occupational Health and the Hospital District of Helsinki and Uusimaa. All FPS participants have given informed consent to participate in the study.

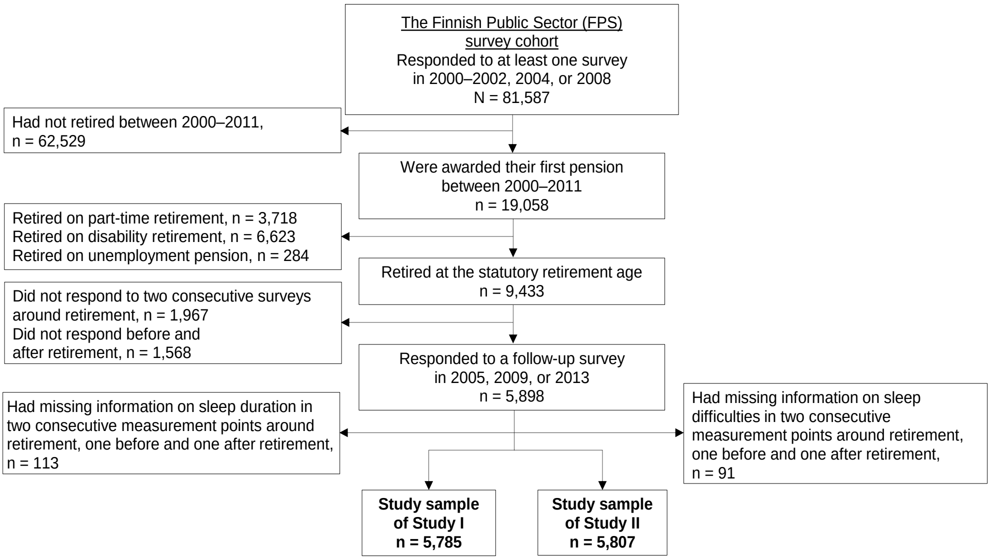

Figure 1. Flow chart of the selection of the samples into Studies I-II.

Figure 1 shows the selection of the study samples into the Studies I–II as a flow chart. For Studies I and II, the eligible population included those FPS cohort members who had responded to at least one survey in 2000–2002, 2004, or 2008 while working (N = 81,587). Of these respondents, 19,058 were awarded their first pension by the end of year 2011, of which 9,433 retired at the statutory retirement age as their first awarded pension scheme. As the focus in Studies I and II was to examine statutory retirement, respondents who retired on a part-time retirement (n = 3,718), disability retirement (n = 5,623), or due to unemployment (n = 284) were excluded. Furthermore, respondents were required to have had answered to surveys performed for retirees and other leavers in 2005, 2009, or 2013 and to have answered two consecutive surveys around retirement. In Study I, the focus was on sleep duration, and thus, the final analytical sample was restricted to those who had provided information on sleep duration in at least two consecutive surveys, one before and one after the transition to statutory retirement (n = 5,785). Similarly, in Study II, the final analytical sample was restricted to those who had provided information on sleep difficulties in at least two consecutive surveys, one before and one after the retirement transition (n = 5,807). Each participant could answer to a maximum of four surveys, and on average, the participants provided data on sleep duration from 3.6 (range 2–4) surveys (Study I) and on sleep difficulties from 3.7 (range 2–4) surveys (Study II) around the retirement transition.

The FIREA study was established in 2013 at the University of Turku and includes public sector employees working either in one of the 27 municipalities in Southwest Finland or in one of the selected 11 towns or five hospital districts around

Finland. The FIREA study survey cohort consists of persons having a statutory retirement date set between 2014 and 2019 (n=10,629). The participants were first contacted by sending them a questionnaire approximately 18 months prior to their statutory retirement date, and thereafter, the questionnaires were sent to the participants annually. The FIREA study has been approved by the Ethics Committee of Hospital District of Southwest Finland. All FIREA participants have given written informed consent to participate in the study.

Figure 2 shows the selection of the study samples into the Studies III–IV as a flow chart. For Study III, the eligible population included those FIREA survey cohort members who had responded to at least one survey by the end of year 2017 (n = 5,076). To be included in the study, the respondents were required to having been working at the time of the first questionnaires and having responded to two consecutive questionnaires around retirement, one before retirement and one after retirement between 2013 and 2017 (n = 2,082). The final analytical sample was restricted to those who had information on at least one of the sleep measurements of interest in the study from the questionnaires immediately before and after the transition to retirement (n = 2,053). On average, the participants provided data from 3.5 (range 2–5) questionnaires around the transition to retirement. Furthermore, the questions concerning work-related stressors (job strain, work time control, effort-reward imbalance, and organizational justice) were not included in the FIREA survey until 2016 and, thus, information on the work-related stressors was available only from 294 participants., Additional information on these stressors was obtained from the FPS survey to which a majority of the participants had taken part in when still at work. Of those who had answered to the FIREA survey before 2016, 1,526 (87%) gave permission to link their information from the FPS surveys to the information from the FIREA surveys.

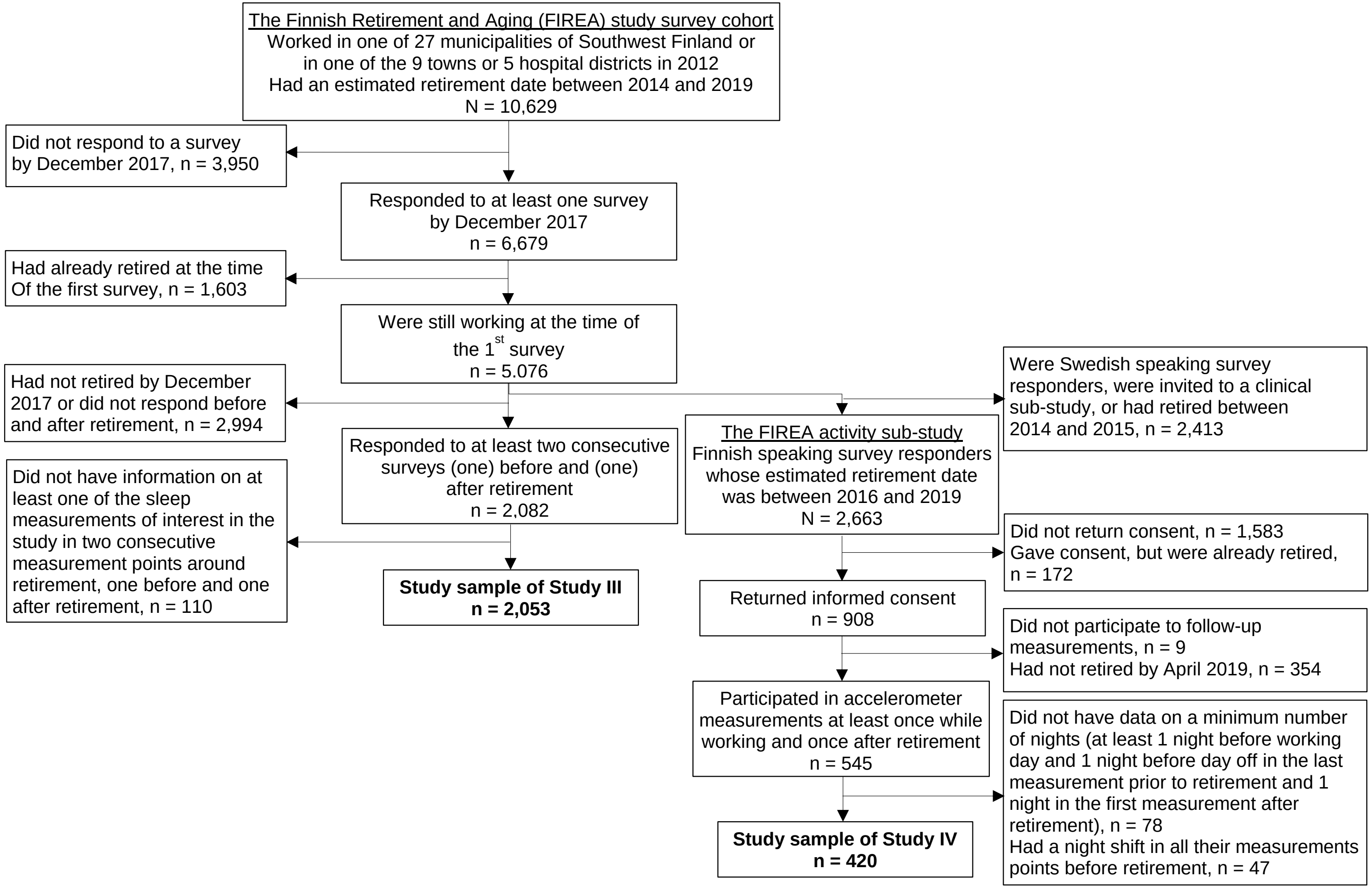

Figure 2. Flow chart of the selection of the samples into Studies III-IV.

Study IV was based on an activity sub-study which was conducted among those Finnish-speaking FIREA survey respondents whose statutory retirement date was set between 2016 and 2019 and who had answered to at least one survey by December 2017 (n = 2,410). After answering to the first questionnaire, the respondents were invited to participate in the activity sub-study and for those who returned the informed consent an accelerometer was sent (n = 908). Thereafter, the participants were followed-up annually up to four times in total with an aim to conduct two accelerometer measurements before retirement and two measurements after retirement. The data used in the Study IV was collected between September 2014 and April 2019 and of the consented participants, 562 participants had successfully used the accelerometer at least once before and once after the transition to full-time statutory retirement. Those participants whose all pre-retirement measurement weeks included at least one night shift, were excluded from the study population (n = 47). The final analytical sample included those who in the last measurement prior to retirement had data from at least one night before a working day and one night before a day off and who in the first measurement after retirement had data from at least one night (n = 420). The participants provided data on average from 3.4 (range 2–4) annual accelerometer measurement points around the transition to retirement.

4.2 Assessment of Sleep

Sleep was measured annually around retirement with both self-reports (Studies I-III), and by using accelerometry (Study IV).

4.2.1 Self-Reported Measures

The sleep-related measures used in this study are shown in Table 2. Sleep duration was measured with a question concerning usual sleep duration per 24 hours, as is often done in epidemiological studies (Girschik et al., 2012). The response alternatives ranged from “6 hours or less” to “10 hours or more” with 0.5 hour intervals. A continuous variable of sleep duration was formed by counting the response alternatives as hours with 5.5 hours and 10.5 hours representing the extremes of the scale. Self-reported sleep duration was used as a continuous outcome variable in Studies I and III.

Table 2. The survey questions assessing sleep and tiredness

SLEEP MEASUREMENT (ORIGINAL STUDY IN WHICH USED AS AN OUTCOME)	SURVEY QUESTIONS	RESPONSE SCALE AND CATEGORIZATION USED IN THE ANALYSES
Sleep duration (Studies I and III)	How many hours do you usually sleep per 24 hours?	1) 6 hours or less; 2) 6.5 hours; 3) 7 hours; 4) 7.5 hours; 5) 8 hours; 6) 8.5 hours; 7) 9 hours; 8) 9.5 hours; 9) 10 hours or more Short sleepers: ≤6.5 hours Mid-range sleepers: 7–8.5 hours Long sleepers: ≥9 hours
Sleep difficulties The Jenkins Sleep Problem Scale (Jenkins et al., 1988) (Studies II and III) • Any sleep difficulty • Difficulties falling asleep • Difficulties maintaining sleep during the night • Waking up too early in the morning • Nonrestorative sleep	How often *during the previous four weeks* have you experienced the following symptoms? • Difficulties falling asleep • Waking up several times per night • Having troubles staying asleep (including too early awakening) • Waking up after the usual amount of sleep feeling tired and worn out	1) Never 2) 1–3 nights per month 3) One night per week 4) 2–4 nights per week 5) 5–6 nights per week 6) Nearly every night Sleep difficulties, no: options 1–4 Sleep difficulties, yes: options 5–6
Daytime tiredness (Study III)	Compared to other people of your age, are you usually more tired during the daytime?	1) Yes, almost always 2) Yes, often (at least weekly) 3) No 4) Cannot say Daytime tiredness, no: option 3 Daytime tiredness, yes: options 1–2 Excluded: option 4
Sleep loss due to worry an item from the 12-item version of the General Health Questionnaire (Goldberg 1972; Goldberg et al., 1997) (Study III)	The following question(s) concern your wellbeing during the previous few weeks. Have you recently lost much sleep due to worry?	1) Not at all 2) No more than usual 3) Rather more than usual 4) Much more than usual Sleep loss due to worry, no: options 1–2 Sleep difficulties, yes: options 3–4

Sleep difficulties were assessed using the Jenkins Sleep Problem Scale (Jenkins et al., 1988), a scale for measuring the occurrence of four different types of sleep difficulties: (1) difficulties falling asleep, (2) difficulties maintaining sleep during the night, (3) waking up too early in the morning, and (4) nonrestorative sleep. The frequency of each of these difficulties during the previous four weeks was estimated (never, one–three nights per month, one night per week, two–four nights per week, five–six nights per week, and nearly every night). This scale can be used to measure sleep difficulties in general, that is, the prevalence of any sleep difficulty, or the prevalence of a single type of sleep difficulty. To assess the prevalence of any sleep difficulty, the most frequent symptom the participant reported of the four symptoms was identified. Following a categorization used in previous studies (Salo et al., 2012; Salo et al., 2014), the participant was considered to have sleep difficulties, if the frequency of the most frequent symptoms was higher than four nights per week (i.e. the participant estimated the frequency being either "five–six nights per week" or "nearly every night"). Similar dichotomization was used, when assessing the prevalence of the single types of sleep difficulties. The dichotomized sleep difficulties were used as outcome variables in Study II and Study III.

One of the criteria for insomnia in the current Diagnostic and Statistical Manual of Mental Disorders (DSM-5) is the sleep disturbances to have consequences on daytime functioning, that is, clinically significant distress or impairment in social, occupational, or other important areas of functioning. To assess daytime functioning, an item measuring daytime tiredness was used in Study III. The participants were to compare whether they experienced being more tired during the daytime than the other people of their age (1) "Yes, almost always", 2) "Yes, often (at least weekly)", 3) "No", or 4) "Cannot say". Those answering "Yes, almost always" or "Yes, often (at least weekly)" were indicated experiencing daytime tiredness, while those who could not say were excluded from the analyses.

Another feature of insomnia symptoms is sleep loss due to worry. This measure was used in Study III and was assessed with a single item from the 12-item General Health Questionnaire (Goldberg, 1972). Participants were asked whether they had lost sleep due to worry during the previous few weeks by choosing one of the following response alternatives: 1) "Not at all", 2) "No more than usual", 3) "Rather more than usual", and 4) "Much more than usual". Following categorization used in previous studies, those who responded with options 3 or 4 was considered to have sleep difficulties due to worrying (Lallukka et al., 2011; Salo et al., 2012). This measure of sleep loss due to worry has been found to have rather low sensitivity (37%) compared to the Jenkins Sleep Problem Scale, but a good specificity (87%) in identifying insomnia (Lallukka et al., 2011). It has been suggested to possibly measure a different aspect of disturbed sleep compared with measurements of insomnia symptoms, and to possibly also be more effective in capturing milder sleep disturbances.

4.2.2 Accelerometer Measurements

In addition to self-reported sleep, the aim was to examine changes in sleep around retirement with a more objective measure of sleep. For sleep measurements in Study IV, a triaxial accelerometer was chosen to measure movements during sleep and wakefulness. Two models of the same accelerometer were used, wActiSleep-BT and wGT3X-BT by ActiGraph (Penacola, Florida, USA), as shown in Figure 3a. Based on information provided by the manufacturer, the newer model, wGT3X-BT, is fully backward compatible with the previous model wActiSleep-BT (ActiGraph, 2019).

In each annual measurement wave, the accelerometers were sent to the participants by mail accompanied by instructions on the use of the device, a daily log to be completed during the measurement week, and a postage paid envelope for returning the device. The instructions stated that the accelerometer measures daily activity, such as the amount of physical activity and sleep duration of the participant, and that the aim is to gather information of their activity during a usual week. The accelerometer was initialized to start recording at 5 A.M. on the first Saturday after the participants received the device, and thus, participants were asked to begin the measurement on a Saturday morning and wear the device during the next working week (if still working). If they were not able to start the measurement on the given Saturday due to e.g. being on an annual leave, the participants had an opportunity to start the measurement later, as long as it was within the following two weeks after receiving the device. Participants were asked to wear the device on their non-dominant wrist (Figure 3b) continuously during day and night for seven consecutive days. The accelerometer did not provide any feedback to participants about their activity. The instructions stated that as the device is water-proof, it may be worn during swimming, but advised the device to be removed during sauna to prevent it from overheating. In addition, for each measurement day, the participants were asked to complete a daily log (Appendix 1). This log was used to record the date of the measurement, when the participant woke up and went to bed, whether the day in question was a working day or a day off, and whether the day was different from a normal one in some way. The daily log was completed until the last evening of the measurement week, although the measurement continued until the following morning. The measurements were conducted during all four seasons and at an approximately same time for a single participant as his/her previous measurement(s) to avoid possible seasonal effect affecting the reliability of the measurements. After participating in all four measurement waves, the participants were provided feedback on their physical activity and sleep duration in each measurement point.

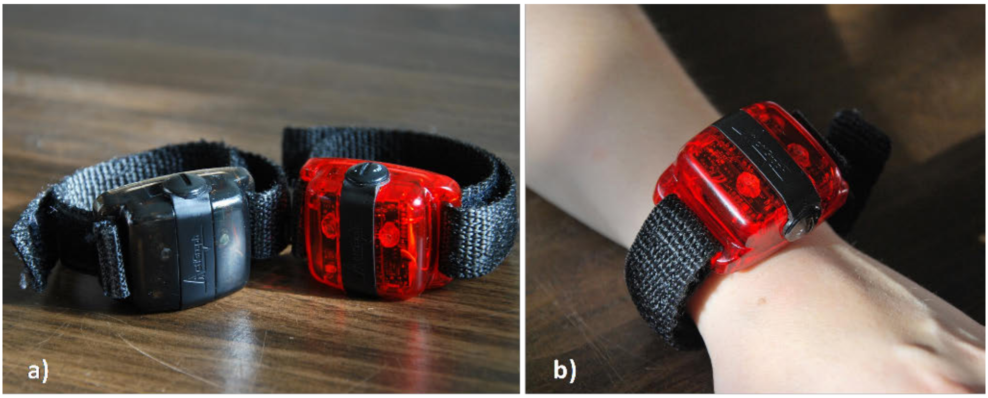

Figure 3. a) The two accelerometer models by ActiGraph used in Study IV, wActiSleep-BT and wGT3X-BT and b) the position of the device on the non-dominant wrist

The raw data from the accelerometers were downloaded to the computer as soon as the device was returned by the participant by mail. Manufacturer's ActiLife software (version 6.13; ActiGraph, Pensacola, Florida, USA) was used to convert the raw data into 60s epochs. The Cole-Kripke algorithm (Cole et al., 1992) was used to define each epoch as sleep or wake, as this algorithm has originally been validated in adult population using wrist-worn accelerometers and has been found to have high sensitivity in detecting sleep (Quante et al., 2018). Choosing the correct algorithm is crucial, as unsuitable algorithms may weaken the validity of the sleep measure (Zinkhan & Kantelhardt, 2016). For detecting the sleep periods and estimating sleep parameters, the ActiGraph algorithm available in the ActiLife software was used (ActiGraph, 2018a; ActiGraph, 2018b). First, the algorithm detects non-wear periods, that is, periods of time the participant does not seem to be wearing the device. Second, it ignores those non-wear periods that are greater than 24 hours and those non-wear periods that have five or more minutes of non-zero counts. Finally, the algorithm defines the remaining non-wear periods as sleep time. Before analyzing the data, the data were systematically checked and cleaned, for example, to prevent actual non-wear time (due to e.g. participant going to sauna) in the evenings and mornings to be scored as sleep. Furthermore, although the algorithm detected some sleep periods during the daytime, these sleep periods were in fact most often non-wear periods during the day, and the algorithm did not seem to detect true daytime sleep periods (for example, when participant reported having taken a daytime nap). Thus, all the sleep periods detected by the algorithm that occurred during daytime, were excluded from the analyses, as they were considered to not reliably represent true daytime sleep periods. In addition, all the measurement weeks during which the participant had at least one night shift, were removed. Detailed description of checking and cleaning of the data is provided in the Study IV (supplementary materials Table S1 in Study IV).

For Study IV, the following sleep parameters were derived from the accelerometer data: *in bed time*, *out bed time*, *time in bed* (i.e. the total time spent in bed from in bed time to out bed time), *sleep duration* (i.e. minutes categorized as sleep by the algorithm during the time spent in bed), and *sleep efficiency* (i.e. the percentage of sleep duration from the time in bed). For each sleep parameter, a mean was calculated for *nights before working days* and *nights before days off*. In addition, these estimates were used to calculate a weighted weekly average for each sleep parameter, referred to as *nights prior to retirement*, by using the following formula: (5 * mean of *nights before working days* + 2 * mean of *nights before days off*) / 7. Finally, a mean for *nights after retirement* was calculated for which all nights of each measurement week were considered. The participants provided data from a median of 4 nights before working days (interquartile range [IQR] 3–5), 1 night before days off (IQR 1–2) in the last measurement point prior to retirement, and from a median of 6 nights after retirement (IQR 6–6) in the first measurement point after retirement.

4.3 Assessment of Retirement

Studies I-IV focused on transition to full-time statutory retirement. The register-linkage available in Studies I and II allowed the information on each participants' retirement to be gathered from the Finnish Centre for Pensions, the coordinator of all earning-related pensions for permanent residents in Finland. In Studies I and II, the start dates for pensions were obtained for each participant from 2000 through 2011 and the survey data was centered around each participant's actual retirement date. The start dates for pensions were also used to calculate a retirement age for each participant. In Study III, the timing of actual retirement was reported by the participants in the questionnaire. The information on retirement date was obtained from the first questionnaire in which the participant indicated being retired full time and was used irrespective of any discrepancies in the later questionnaires. In Study III, the participants retired between 2013 and 2017. In Study IV, information on participants' retirement was based on information gathered from the daily logs completed during the accelerometer measurements. The year of the measurement in which time the participant reported being on a full-time retirement for the first time was set as the year of retirement. In addition, if the participant reported being on an annual leave and reported transitioning directly from the leave into retirement, this measurement was regarded occurring after retirement transition. Some of the participants (n = 19) also reported work days in the measurement waves occurring after reporting being on a full-time retirement, but as these were only temporary work shifts, their original year of retirement was used in the analysis.

4.4 Covariates and Pre-Retirement Factors

For this study, factors that have been associated with sleep during the working years, were used as covariates and as pre-retirement factors to examine how the possible changes in sleep were associated with pre-retirement differences between the participants. For the most part, information on the factors was obtained from the last measurement prior to retirement, and thus, they represent pre-retirement levels of each factor. Only exceptions for this were in Study I, as in that study, for the number of chronic diseases, chronic diseases from all pre-retirement measurements were taken into account and in the case of lifestyle factors (i.e. alcohol use, smoking, and physical activity), a time-dependent form of each factor was used.

4.4.1 Demographic Factors

Information on year of birth, gender, and occupational title was obtained from either the employers' registers (in Study I and Study II) or the pension insurance institute for the municipal sector in Finland (Keva) (in Study III and Study IV). In studies I and II, the start dates for pensions obtained from the Finnish Centre for Pensions were used to calculate a retirement age for each participant. Retirement age was used both as a continuous variable (when it was adjusted for in the analyses) and as categorical variable (when used as a pre-retirement factor) with three categories: less than 60 years, 60–64 years, and more than 64 years. In Study III and Study IV, instead of retirement age, participants' age at the last measurement point before retirement was used as a covariate. In all the original studies, the occupational titles of the last occupation preceding retirement were used to categorize occupational status according to the Standard Classification of Occupations (ISCO) 2001 (Statistics Finland, 2001) into three groups: upper-grade nonmanual workers (ISCO classes 1–2; e.g., teachers, physicians), lower-grade nonmanual workers (ISCO classes 3–4; e.g., registered nurses, technicians), and service and manual workers (ISCO classes 5–9; e.g., cleaners, maintenance workers). Information on marital status was obtained from the questionnaire and used in Studies I and II after being categorized into married (i.e. married or cohabiting) and not married (i.e. other response).

4.4.2 Work-Related Factors

Work-related factors used in the original studies were shift work (in Study I and Study II) and job strain (in Studies I-IV). Shift work was used as a dichotomous variable (yes vs. no) and doing shift work included shift work with or without night shifts, regular night work, and other irregular work. Job strain was assessed with a shorter version of the Job Content Questionnaire (Fransson et al., 2012; Karasek et al., 1998) in which participants evaluated nine items on job control and five items on job demands on a 5-point scale that ranged from 1 (totally agree) to 5 (totally disagree). Job strain was defined as having high demands and low control based on median cut-off points from either the year 2000 FPS survey (Study I and Study II) or the year 2012 FPS survey (Study III and Study IV). For Study III, also a continuous job strain variable was calculated by subtracting the mean of the nine job control scores from the mean of the five job demand scores and higher scores indicated higher job strain. The other work-related stressors used in Study III in addition to job strain were low work time control (with the lowest quartile of the scores indicating exposure to low work time control) (Ala-Mursula et al., 2005), effort-reward imbalance (ratio of effort score and mean score of three reward items with the lowest quartile of the scores indicating exposure to effort-reward imbalance) (Siegrist, 1996; Siegrist et al., 2009; Juvani et al., 2014), and organizational injustice (with the lowest quartile of the means of scores on six items on relational justice and seven items on procedural justice indicating exposure to organizational injustice) (Moorman, 1991; Elovainio et al., 2002). These factors were used as both dichotomous variables as well as continuous variables when used as pre-retirement factors in Study III. In addition, in Study III, a summary variable of all work-related stressors was used as a pre-retirement factor with the participants categorized into having being exposed to “0”, “1”, or “2 or more” work-related stressors before retirement.

Since questions on work-related stressors were not included in the FIREA questionnaires until 2016, only part of the participants in Study III (n = 294) had information available on work-related stress factors. However, as this information was highly valuable for Study III, additional information on all the work-related stressors was used from the FPS surveys. Thus, for those participants who had given permission to link their information from the FPS surveys to the FIREA surveys (n = 1,526), information on work-related stressors for Study III was obtained from the last FPS questionnaire preceding retirement.

4.4.3 Health Risk Behavior and Health-Related Factors

Information on health risk behaviors and health was derived from the questionnaires and all original studies included physical activity, alcohol use, and body mass index. Physical activity was based on reports of average weekly hours of leisure-time physical activity (including commuting) within previous year in walking, brisk walking, jogging, and running, or their equivalent activities and weekly physical activity was expressed in metabolic equivalent hours. Different physical activity categorizations were used in the original studies. In Study I and Study II, four-level categorization was used: inactive (<7 MET hours/week), low (7–14 MET hours/week), medium (14–30 MET hours/week), and high (≥30 MET hours/week). In Study III, a continuous variable of physical activity was used. In Study IV, physical activity was dichotomized into low (<14 MET hours/week) and medium to high active (≥ 14 MET hours/week). Alcohol use was based on habitual frequencies of beer, wine, and spirits consumption and expressed as grams of alcohol per week. In Study I and Study II, alcohol use was categorized into none, moderate, and heavy, and the limit for heavy alcohol use was set as >16 drinks/week for women and >24 drinks/week for men, as these limits correspond to the lower limit for heavy use of alcohol set by the Finnish Ministry of Health and Social Affairs (Halonen et al., 2017). In Study III, a continuous variable of alcohol use was used. In Study IV, a dichotomous variable of heavy alcohol use (yes vs. no) was used based on the previously mentioned limits. Body mass index (BMI) was calculated based on self-reported body weight and height (kg/m^2) and categorized into underweight (<18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25–29.9 kg/m^2), and obesity (BMI ≥30 kg/m^2) in Study I and Study II. In Study III, BMI was used as a continuous variable. In IV, BMI was dichotomized into non-obese (<30 kg/m^2) and obese (≥30 kg/m^2). Smoking was categorized as never, former, or current and used in Study I and Study II. Finally, in Study I, the factors related to health-risk behaviors (alcohol use, smoking, and physical activity) were used as time-dependent factors to also control for their change during the retirement transition in the analyses.

All original studies included self-rated health, assessed with a 5-point scale (1 = good … 5 = poor), and dichotomized into good (options 1 and 2) and suboptimal (options 3–5). All original studies except Study III also included psychological distress as a pre-retirement factor (Study I and Study II) or as a covariate (Study IV). It was measured with a 12-item version of the General Health Questionnaire (Goldberg, 1972; Goldberg et al., 1997) and used as a dichotomous variable (with four or more symptoms indicating psychological distress) and additionally as continuous variable in Study II. Psychological distress was not used in Study III as sleep loss due to worry, one of the items in the General Health Questionnaire, was used as a sleep outcome in that study. In addition, for Studies I and Study II, information on pre-retirement chronic conditions was obtained from national registers: rheumatoid arthritis, diabetes, coronary heart, and asthma disease were based on the Social Insurance Institution of Finland's (SII) Drug Reimbursement Register; depression was based on the Finnish Prescription Register kept by SII (ATC code N06A) and cancer was based on the Finnish Cancer Registry. Information on osteoarthritis was derived from the questionnaires. In Study I, the chronic diseases reported in any of the measurements that were available prior to retirement were taken into account and participants were categorized as having had no chronic diseases, one chronic disease, or two or more diseases prior to retirement. In Study II, dichotomous variables of four chronic conditions (yes vs. no) were separately examined: arthritis (osteoarthritis and rheumatoid arthritis), cardio metabolic diseases (including diabetes and coronary heart disease), asthma, and cancer.

In addition to being the outcome variable in Studies I–III, self-reported sleep duration and sleep difficulties were also used as pre-retirement factors in Study I, Study II (only sleep duration), and Study IV (self-reported sleep duration used only to compare the study sample to the eligible population) with the focus on sleep prior to retirement. In addition, in Study IV, information on sleep apnea (yes vs. no) was derived from the last questionnaire before retirement and used as a pre-retirement factor. For Study I and Study IV, the participants were categorized into short (6.5 hours or less), mid-range (7–8.5. hours), and long sleepers (9 hours or more), whereas in Study II, a continuous variable was used. Self-reported sleep difficulties were used as a dichotomous variable (yes vs. no) in Study I and Study III.

4.5 Statistical Methods

As all the original studies aimed at describing the changes in sleep around the transition to retirement, in each study, the data were centered around the exact timing of retirement with measurements occurring both before and after this time point. In Studies I and II, the interval between each measurement point was approximately 4 to 5 years, whereas in Studies III and IV, this interval was approximately one year.

To study changes in the different sleep parameters around retirement, either linear regression (for continuous sleep outcomes in Studies I, III, and IV) or Poisson regression (for dichotomous sleep outcomes in Studies II and III) analyses with generalized estimating equations (GEE) were used. GEE model is a suitable method when using repeated measurements, as it controls for intra-individual correlation between the measurements (Zeger & Liang, 1986; Diggle et al., 1994). In addition, the GEE model uses an exchangeable correlation structure and is not sensitive to measurements that are missing at random. In this PhD thesis summary, results on the changes in sleep during the transition to retirement are shown from GEE models adjusted for age, gender, and occupational status. Different adjustments were used in the original studies, as described later, but as these adjustments did not markedly change the results, those results will only be described in the original studies. All analyses in the original studies were conducted using the SAS 9.4 Statistical Package (SAS Institute Inc., Cary, North Carolina, USA).

4.5.1 Main Analyses

In Study I, the average self-reported sleep duration in each measurement point around retirement was reported as mean estimates and their 95% confidence intervals (CIs). Mean change of self-reported sleep duration and its 95% CIs was calculated from the last measurement before retirement to the first measurement after retirement (referred to as "the retirement transition period" in Study I). These analyses were adjusted for retirement age, gender, occupational status, shift work, and BMI at the measurement immediately before retirement, number of chronic diseases prior to retirement, and time-dependent alcohol use, smoking, and physical activity. Additional analyses included examining whether pre-retirement socio-demographic, work, health, health behavior, and sleep factors predicted changes in sleep duration during the retirement transition. This was done using the contrast statements in the GEE models while adjusting for retirement age, gender, and occupational status.

In Study II, self-reported sleep difficulties (both any sleep difficulty and the four individual types of sleep difficulties) were assessed by calculating prevalence estimates and their 95% CIs for each measurement point around retirement while adjusting for gender, retirement age, and occupational status. Changes in sleep difficulties during the retirement transition period were calculated by comparing the prevalence estimates in the first measurement after retirement to the last measurement before retirement and the results were reported as risk ratios (RRs) and their 95% CIs. The analyses were conducted in two phases: First, the models were adjusted for gender, retirement age, and occupational status. Second, the models were additionally adjusted for marital status, shift work, job strain, physical activity, alcohol use, smoking, BMI, self-rated health, psychological distress, arthritis, cardiometabolic diseases, asthma, cancer, and sleep duration before retirement. Similarly, RRs and their 95% CIs for the prevalence estimates of any sleep difficulty were calculated for each level of the pre-retirement factors. Interactions between the changes in any sleep difficulty and the pre-retirement characteristics (i.e. time × pre-retirement characteristic interaction) were analyzed. Furthermore, for those pre-retirement factors that statistically significantly predicted changes in any sleep difficulty, it was examined, whether they were associated with changes in the four individual sleep difficulties as well. These analyses were adjusted for gender, retirement age, and occupational status.

In Study III, unadjusted mean estimates and their 95% CIs were calculated for self-reported sleep duration and unadjusted prevalence estimates and their 95% CIs were calculated for sleep difficulties, daytime tiredness, and sleep loss due to worry by 3-month intervals around retirement. This was done to examine the timing of the sleep changes in more detail, and each participant contributed, thus, to approximately every fourth measurement point. For assessing changes in the sleep characteristics during the transition to retirement, each participant's first measurement after retirement was compared to his or her last measurement before retirement and the results were reported as mean change and its 95% CIs for self-reported sleep duration and as RRs and their 95% CIs for all the other sleep characteristics. These analyses were adjusted for: 1) age and gender, and 2) additionally for occupational status, physical activity, alcohol use, BMI, and self-rated health before retirement. As the focus in this study was to examine the role of the removal of work-related stressors, mean change (for sleep duration) and RRs (for other sleep characteristics) and their 95% CIs were calculated for each level of the individual work-related stressors (job strain, low work time control, effort–reward imbalance, and organizational injustice) and the number of work-related stressors. These analyses on the work-related stressors were adjusted for age, gender, occupational status, physical activity, alcohol use, BMI, and self-rated health before retirement. These models also included a "work-related stressor × time (i.e. before or after retirement)" interaction term to assess group differences and the individual work-related stressors were analyzed separately as both dichotomous variables and as continuous variables.

In Study IV, the average levels of each accelerometer-based sleep parameter (in bed time, out bed time, sleep duration, time in bed, and sleep efficiency) were reported as unadjusted mean estimates and their 95% CIs for each measurement point around retirement. The means for each sleep parameter were calculated separately for all "nights before working days" and for all "nights before days off" for the measurements prior to retirement. In addition, a weighted weekly average prior retirement was calculated for each measurement point (referred to as "nights prior to retirement") for each sleep parameter with the following formula: (5 * mean of nights before working days + 2 * mean of nights before days off) / 7. For each measurement after retirement, a mean across all the nights, henceforth referred to as "nights after retirement", was calculated for each sleep parameter. The changes in these sleep parameters during the transition to retirement were examined by comparing each participant's first measurement after retirement to their last measurement before retirement while adjusting for age, gender, and occupational status. Furthermore, latent trajectory analysis was used to identify distinctive groups of individuals with similar developmental trajectories of sleep duration around retirement by modelling the changes from the weighted weekly averages of nights prior to retirement to nights after retirement. Following the two-step procedure by (Nagin, 2005), an increasing number of trajectory groups with cubic polynomial shape were fitted for sleep duration until no improvement in model fit was observed (based on Bayesian information criterion values, Akaike information criterion values, Log-likelihood, and posterior probabilities of trajectory membership) to determine the optimal number of trajectories. After choosing a model in the first step, models with quadratic and linear trajectories were tested for the chosen model. A three trajectory model was chosen with two groups having a cubic order and one a linear order. Finally, pre-retirement factors that best characterize belonging to each trajectory group were identified by calculating odds ratios (OR) and their 95% CIs for each pre-retirement factor while adjusting for age and gender.

4.5.2 Sensitivity Analyses

The original studies included several sensitivity analyses. However, as the results of these sensitivity analyses were highly similar to those of the main analysis and did not influence the interpretation of the results, they will not be reported in this summary, but can be found in the original articles. In Study I, a sensitivity analysis was conducted in which the changes in sleep duration were examined among those who had provided data from all four measurement points (n = 4,356) to examine whether participants with missing data in one or two measurement points biased the results. In Study II, the robustness of the results on the changes in any sleep difficulty was examined by using a lower cut-off point for the occurrence of sleep difficulties, the frequency of at least two nights per week with symptoms indicating the presence of sleep difficulties. Study III included sensitivity analyses in which the changes in the sleep characteristics across groups categorized by number of work-related stressors before retirement were examined among two groups in which effects of the removal of work-stressors could especially be thought to be visible: 1) among those who reported sleeping less than 7 hours per 24 hours in the last measurement before retirement (n = 538), and 2) among those working full-time in the last measurement point before retirement (n = 1,432).

5 Results

5.1 Characteristics of the Study Participants

Pre-retirement characteristics of the participants in Studies I–IV, derived from the last measurement preceding retirement, are shown in Table 3. On average, participants' age at retirement was 61.9 years (SD = 2.0) in Study I and Study II, and age in the last measurement before retirement was 63.2 years (SD = 1.3) in Study III, and 63.3 years (1.1) in Study IV. In all the original studies, majority of the participants were women (ranging from 80% in Study I and II to 87% in Study IV). The percentage of those in service and manual occupations ranged from 33% in Study IV to 37% in Study III. For most part, the study populations in these studies were similar in regard to health- and work-related factors, although Study IV (the accelerometer study) had a slightly lower percentage of those with job strain, suboptimal self-rated health, or psychological distress than the other studies.

Table 3 Characteristics of the study participants before retirement in the Studies I–IV.

CHARACTERISTICS	STUDY I (N = 5,785) N(%) / MEAN (SD)	STUDY II (N = 5,807) N(%) / MEAN (SD)	STUDY III (N = 2,053) N(%) / MEAN (SD)	STUDY IV (N = 420) N(%) / MEAN (SD)
GENDER				
MEN	1,168 (20)	1,162 (20)	342 (17)	54 (13)
WOMEN	4,617 (80)	4,645 (80)	1,711 (83)	366 (87)
AGE[a]	61.9 (2.0)	61.9 (2.0)	63.2 (1.3)	63.3 (1.1)
OCCUPATIONAL STATUS				
UPPER-GRADE NONMANUAL	2,201 (38)	2,205 (38)	669 (33)	159 (38)
LOWER-GRADE NONMANUAL	1,538 (27)	1,551 (27)	611 (30)	119 (29)
SERVICE AND MANUAL	2,017 (35)	2,023 (35)	750 (37)	139 (33)
JOB STRAIN[b]				
NO	4,299 (75)	4,314 (75)	1,459 (80)	157 (82)
YES	1,406 (25)	1,413 (25)	355 (24)	34 (18)
PHYSICAL ACTIVITY				
INACTIVE	1,126 (20)	1,130 (20)	384 (19)	68 (17)
LOW	1,293 (23)	1,304 (23)	410 (20)	82 (20)
MEDIUM	1,681 (29)	1,691 (29)	599 (29)	117 (29)
HIGH	1,647 (29)	1,646 (29)	645 (32)	142 (35)
ALCOHOL USE				
NONE	915 (16)	918 (16)	339 (17)	62 (15)
MODERATE	4,399 (77)	4,416 (77)	1,538 (75)	319 (78)
HEAVY	435 (8)	437 (8)	166 (8)	28 (7)
SELF-RATED HEALTH				
GOOD	3,637 (63)	3,647 (63)	1,521 (74)	316 (77)
SUBOPTIMAL	2,117 (37)	2,126 (37)	529 (26)	94 (23)
BODY MASS INDEX				
UNDERWEIGHT	26 (0.5)	25 (0.5)	7 (0.4)	3 (0.8)
NORMAL WEIGHT	2,373 (43)	2,382 (43)	772 (38)	154 (38)
OVERWEIGHT	2,277 (41)	2,279 (41)	818 (41)	170 (42)
OBESE	892 (16)	898 (16)	422 (21)	75 (19)
PSYCHOLOGICAL DISTRESS			not used	
NO	4,399 (76)	4,419 (76)		366 (89)
YES	1,361 (24)	1,364 (24)		43 (11)

[a] This represents either retirement age (Study I and Study II) or age in the last measurement before retirement (Study III and Study IV)
[b] Missing information in Study IV

5.2 Changes in Sleep Duration during the Transition to Retirement

Sleep duration increased in a similar manner based on both self-reported and accelerometer-based measures over longer and shorter measurement intervals around the transition to retirement (Figure 4). In the last measurement prior to retirement, which occurred approximately 1.6 years (SD = 1.6 years) before the retirement date in the FPS study (Study I), average self-reported sleep duration was 7 hours and 5 minutes (95% confidence interval [CI] 7 hours 3 minutes – 7 hours 6 minutes) (Table 4). In the FIREA study (Study III), the average sleep duration was 7 hours 7 minutes (95% CI 7 hours 4 minutes – 7 hours 10 minutes) in the last measurement prior to retirement, which occurred approximately 6 months (SD= 3 months) before the retirement date. Based on the accelerometer measurements (Study IV), average sleep duration on nights before working days was 6 hours 26 minutes (95% CI 6 hours 18 minutes – 6 hours 34 minutes) and on nights before days off 7 hours 19 minutes (95% CI 7 hours 9 minutes – 7 hours 29 minutes) in the last measurement before retirement, which occurred between 0 and 12 months before the retirement date. When both nights before working days and nights before days off were taken into account in the weighted weekly average, accelerometer-based sleep duration before retirement was 6 hours 41 minutes (95% CI 6 hours 33 minutes – 6 hours 49 minutes).

Self-reported sleep duration was observed to increase by 22 minutes (95% CI 20 minutes – 23 minutes) during the approximately 4-year retirement transition in the FPS study (Study I) (Table 4). When self-reported sleep duration was examined during a shorter, approximately 1 year interval around the transition to retirement in the FIREA study (Study III), sleep duration was observed to increase by 19 minutes (95% CI 17 minutes – 20 minutes). Accelerometer based sleep duration increased from nights before working days by 41 minutes (95% CI 35 minutes – 46 minutes), but decreased from nights before days off by 16 minutes (95% CI -20 minutes – -6 minutes) during the 1-year retirement transition, resulting in the weighted weekly average of accelerometer-based sleep duration increasing by 25 minutes (95% CI 20 minutes – 30 minutes) during the retirement transition (Study IV).

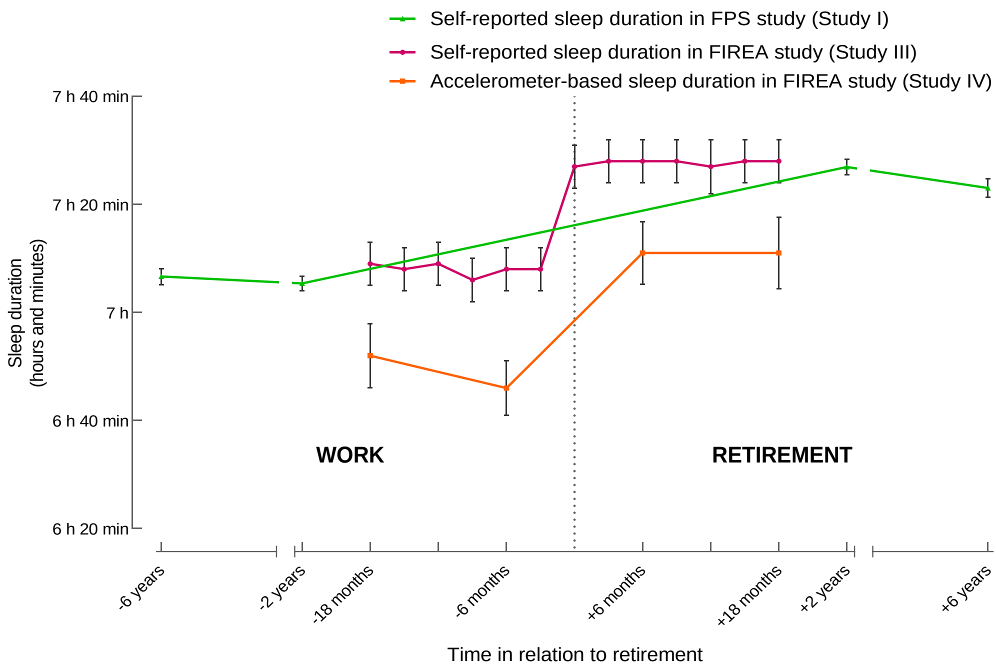

Figure 4. Unadjusted average self-reported and accelerometer-based sleep duration and their 95% confidence intervals in relation to retirement in the FPS (Study I) and FIREA (Study III and IV) studies. Time points from -6 years to -6 months refer to measurements before retirement and time points from +6 months to +6 years to measurement after retirement.

When the changes in self-reported sleep duration were examined across groups characterized by different pre-retirement factors, greatest increases in sleep duration were observed among those with pre-retirement heavy alcohol use, short self-reported sleep duration (6.5 hours or less), and sleep difficulties (Table 2 in the original Study I). Greater increases in self-reported sleep duration were also observed among men, those retiring at the age of 60–64 years (vs. those retiring at 60 years or younger), those who were married, had an upper grade nonmanual occupation (vs. manual occupation), job strain, or psychological distress before retirement. During the 4-year transition to retirement, self-reported sleep duration was observed to decrease only among those with self-reported sleep duration of over 9 hours before retirement. Associations of individual work-related stressors and number of stressors with changes in self-reported sleep duration during the retirement transition were examined in Study III and none of the work-related stressors were observed to predict changes in sleep duration during retirement transition (Table 3 in the original Study III).

Table 4. Changes in self-reported and accelerometer-based sleep duration during the transition to retirement adjusted for age, gender, and occupational status.

SLEEP DURATION	LAST MEASUREMENT POINT BEFORE RETIREMENT			RETIREMENT TRANSITION[d]		
	MEAN ESTIMATE (MINUTES)	95% CI		MEAN CHANGE (MINUTES)	95% CI	
SELF-REPORTED SLEEP DURATION						
FPS STUDY (STUDY I)[a]	425	423	426	22	20	23
FIREA STUDY (STUDY III)[b]	427	424	430	19	17	20
ACCELEROMETER-BASED SLEEP DURATION (STUDY IV)[c]						
NIGHTS BEFORE WORKING DAYS	386	378	394	41	35	46
NIGHTS BEFORE DAYS OFF	439	429	449	-13	-20	-6
WEIGHTED WEEKLY AVERAGE	401	393	409	25	20	30

[a] In the FPS study, the last measurement before retirement was on average 1.6 years (SD = 1.6) before retirement, and the retirement transition is approximately 4 years

[b] In the FIREA study, the last measurement before retirement was approximately 6 months (SD= 3) before retirement, and the retirement transition is approximately 1 year.

[c] In the FIREA accelerometer study, the last measurement before retirement is 0 to 12 months before retirement, and the retirement transition is approximately 1 year.

[d] The retirement transition period refers to comparison of the mean estimates in the first measurement after retirement to those of the last measurement before retirement.

5.2.1 Latent Trajectories of Accelerometer-Based Sleep Duration

Latent trajectory analysis was used to identify distinctive groups of individuals showing similar trajectories of accelerometer-based sleep duration around the transition to retirement in Study IV. Three trajectories of sleep duration around the transition to retirement were identified: 1) Shorter mid-range sleep duration with increase at retirement (comprising 54% of the participants), 2) Longer mid-range sleep duration with increase at retirement (33% of the participants), and 3) Constantly short sleep duration (13% of the participants) (Figure 4 in Study IV). Among those in the first two trajectories, a similar increase in sleep duration was observed after retirement and they differed mainly in the level of sleep duration: sleep duration in the last measurement before retirement was approximately 6 hours and 37 minutes among those in the shorter mid-range trajectory group and 7 hours and 37 minutes among those in the longer mid-range trajectory group. Among the participants in the third trajectory, sleep duration was less than 6 hours throughout the measurements around retirement and no change was observed during the transition to retirement.

Participants belonging to each trajectory differed in their sleep efficiency, with those belonging to the "Longer mid-range sleep duration with increase at retirement" having the highest sleep efficiency before retirement (90.9%, 95% CI 90.2% – 91.7%) and those in the "Constantly short sleep duration" having the lowest sleep efficiency before retirement (84.9%, 95% CI 83.8% – 85.9%) after adjusting for age and gender. Those belonging to the "Constantly short sleep duration" trajectory were more often male, had a non-manual occupation, and were more often obese and those belonging to the belonging to the "Longer mid-range sleep duration with increase at retirement" trajectory were more likely to report job strain than those belonging to the "Shorter mid-range sleep duration with increase at retirement" trajectory. Those belonging to the "Longer mid-range sleep duration with increase at retirement" group were more often female and less often obese than those belonging to the "Constantly short sleep duration" trajectory.

5.3 Changes in Sleep Difficulties during the Transition to Retirement

The prevalence of any sleep difficulties was 30% (95% CI 29% – 31%) in the last measurement before retirement in Study II (Table 5) and 26% (95% CI 24% – 29%) in Study III. A similar decrease in the prevalence of any sleep difficulty was observed in the FPS study during the approximately 4-year retirement transition and in the FIREA study during the approximately 1-year retirement transition (Figure 5). In the FPS study, the risk ratio (RR) for any sleep difficulty was 0.88 (95% CI 0.85 – 0.92) in the first measurement after retirement compared to the last measurement before retirement (Table 5). In the FIREA study, the corresponding RR was 0.91 (95% CI 0.84 – 0.97).

When the specific types of sleep difficulties were examined, the prevalence estimates before retirement and changes during transition to retirement varied between different types of sleep difficulties (Figure 5). However, the trends of each specific type of sleep difficulty were observed to be rather similar between the individual studies (Study II and Study III), which varied in terms of the measurement interval. In both the FPS study (Study II) and the FIREA study, difficulties maintaining sleep were observed to be the most prevalent sleep difficulty and difficulties falling asleep the least prevalent sleep difficulty in the last measurement before retirement (Table 5). Furthermore, 17% of the participants reported daytime tiredness and 14% reported sleep loss due to worry before retirement in the FIREA study.

Table 5. Changes in self-reported sleep difficulties during the transition to retirement adjusted for age, gender, and occupational status.

SELF-REPORTED SLEEP DIFFICULTIES	LAST MEASUREMENT POINT BEFORE RETIREMENT: PREVALENCE ESTIMATE (%)	95% CI		RETIREMENT TRANSITION[c]: RR	95% CI	
FPS STUDY (STUDY II)[a]						
ANY SLEEP DIFFICULTY	30	29	31	0.88	0.85	0.92
DIFFICULTIES FALLING ASLEEP	5	4	6	0.91	0.80	1.03
DIFFICULTIES MAINTAINING SLEEP	25	24	26	0.97	0.92	1.02
WAKING UP TOO EARLY IN THE MORNING	13	12	14	0.75	0.69	0.81
NONRESTORATIVE SLEEP	11	10	12	0.46	0.41	0.52
FIREA STUDY (STUDY III)[b]						
ANY SLEEP DIFFICULTY	26	24	29	0.91	0.84	0.97
DIFFICULTIES FALLING ASLEEP	4	3	5	0.88	0.72	1.08
DIFFICULTIES MAINTAINING SLEEP	25	21	26	0.94	0.87	1.02
WAKING UP TOO EARLY IN THE MORNING	12	10	14	0.77	0.68	0.88
NONRESTORATIVE SLEEP	7	6	9	0.70	0.58	0.84
DAYTIME TIREDNESS	17	15	20	0.68	0.61	0.76
SLEEP LOSS DUE TO WORRY	14	12	16	0.74	0.65	0.85

[a] In the FPS study, the last measurement before retirement was on average 1.6 years (SD = 1.6) before retirement, and the retirement transition period is approximately 4 years.
[b] In the FIREA study, the last measurement before retirement was approximately 6 months (SD = 3) before retirement, and the retirement transition is approximately 1 year.
[c] The retirement transition period refers to comparison of the prevalence estimates in the first measurement after retirement to those of the last measurement before retirement.

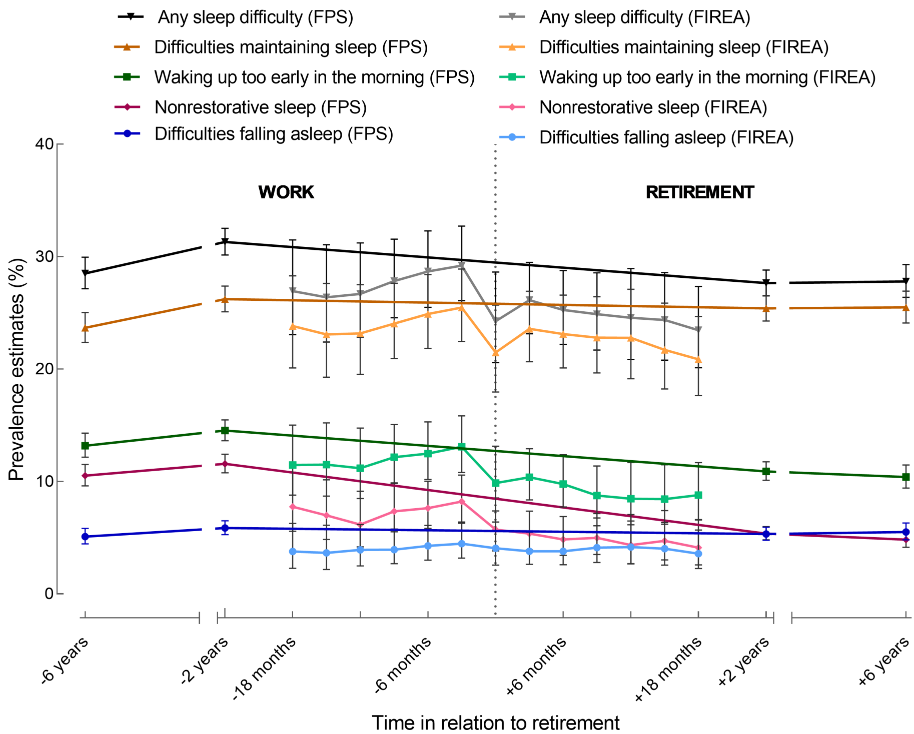

Figure 5. Unadjusted prevalence estimates of specific types of self-reported sleep difficulties and their 95% confidence intervals in relation to retirement in FPS (Study II) and FIREA (Study III) studies. Time points from -6years to -6months refer to measurements before retirement and time points from +6months to +6years to measurement after retirement.

The prevalence estimates of waking up too early in the morning and nonrestorative sleep were observed to decrease during both the 4-year retirement transition in the FPS study (Study II) and the 1-year retirement transition in the FIREA study (Study III). In the FPS study, the RR for waking up too early in the morning was 0.75 (95% CI 0.69 – 0.81) and the RR for nonrestorative sleep was 0.46 (95% CI 0.41 – 0.52) in the first measurement after retirement compared to the last measurement before retirement. In the FIREA study, the corresponding RRs were 0.77 (95% CI 0.68 – 0.88) for waking up too early in the morning and 0.70 (95% CI 0.58 – 0.84) for nonrestorative sleep. Neither the FPS nor the FIREA study showed changes in difficulties falling asleep and difficulties maintaining sleep. Finally, in the FIREA study, both daytime tiredness and sleep loss due to worry were observed to decrease during the 1-year retirement transition: the RR for daytime tiredness was 0.68 (95% CI 0.61 – 0.76) and the RR for sleep loss due to worry was 0.74 (95% CI 0.65 – 0.85).

When association between different work-related stressors and changes in the specific types of sleep difficulties during the retirement transition were examined in more detail in Study III, no systematic associations were observed. Differences in the sleep changes were only observed with two stressors: 1) participants reporting effort-reward imbalance had a greater decrease in nonrestorative sleep compared with those not reporting effort-reward imbalance and 2) those reporting job strain before retirement had a greater decrease in difficulties maintaining sleep than those without job strain (Table 3 in original Study III). When the sleep changes were compared across those reporting different numbers of work-related stressors, the only difference was observed between those not reporting experiencing any work-related stressors and those exposed to one work-related stressors (but not those exposed to 2 or more stressors), with the former having greater decrease in difficulties falling asleep than the latter (Table 4 in original Study III).

5.4 Changes in Other Sleep Characteristics during the Transition to Retirement

Sleep data from accelerometer measurements were used to assess changes in timing of sleep (in bed times and out bed times), time in bed, and sleep efficiency in Study IV. In the last measurement prior to retirement, the average in bed time was 10:18 PM (95% CI 10:12–10:24 PM) on nights before working days and 10:52 PM (95% CI 10:44–11:00 PM) on nights before days off (Figure 6). In the first measurement after retirement, the average in bed time was 11:01 PM (95% CI 10:55–11:07 PM). After adjusting for age, gender, and occupational status, in bed time after retirement was observed to be on average 42 minutes (95% CI 37 – 48 minutes) later than on nights before working days and 9 minutes (95% CI 2 – 15 minutes) later than on nights before days off. The average out bed time was 5:37 AM (95% CI 5:30–5:43 AM) on working days and 7:12 AM (95% CI 7:04–7:20 AM) on days off in the last measurement before retirement and 7:07 AM (95% CI 7:00 – 7:13 AM) in the first measurement after retirement (Figure 6). After adjusting for age, gender, and occupational status, out bed time after retirement was observed to be on average 1 hour and 30 minutes later (95% CI 1 hour 23 minutes – 1 hour 36 minutes) than on working days prior to retirement, but not statistically significantly different from out bed time on days off prior to retirement (-5 minutes, 95% CI -12 minutes – 2 minutes).

Average time in bed on nights before working days was 7 hours 12 minutes (95% CI 7 hours 4 minutes – 7 hours 20 minutes) and on nights before days off 8 hours 19 minutes (95% CI 8 hours 3 minutes – 8 hours 25 minutes) in the last measurement before retirement. When both nights before working days and nights before days off were taken into account in the weighted weekly average, time in bed before retirement was 7 hours 30 minutes (95% CI 7 hours 22 minutes – 7 hours 38 minutes). In the first measurement after retirement, the average time in bed was 7 hours 59 minutes (95% CI 7 hours 51 minutes – 8 hours 8 minutes), and thus, time in bed increased by 47 minutes (95% CI 41–53 minutes) from pre-retirement nights before working days and decreased by 14 minutes (95% CI -22 – -6 minutes) from nights before days off after adjusting for age, gender, and occupational status. The weighted weekly average of time in bed was observed to increase by 30 minutes (95% CI 24 minutes – 35 minutes) during the retirement transition.

Average sleep efficiency on nights before working days was 89% (95% CI 89% – 90%) and on nights before days off 89% (95% CI 88% – 90%) in the last measurement before retirement. The weighted weekly average of sleep efficiency was 89% (95% CI 89% – 90%). In the first measurement after retirement, average sleep efficiency was 89% (95% CI 88% – 89%). No changes in sleep efficiency were observed from nights before days off when compared to nights after retirement, whereas a borderline significant decrease of 0.38 percentage points (95% CI -0.75 – -0.02) was observed from nights before working days (Table 2 in Study IV). Similarly, the weighted weekly average of sleep efficiency was observed have a borderline significant decrease of 0.35 percentage points (95% CI -0.68 – -0.02) after retirement.

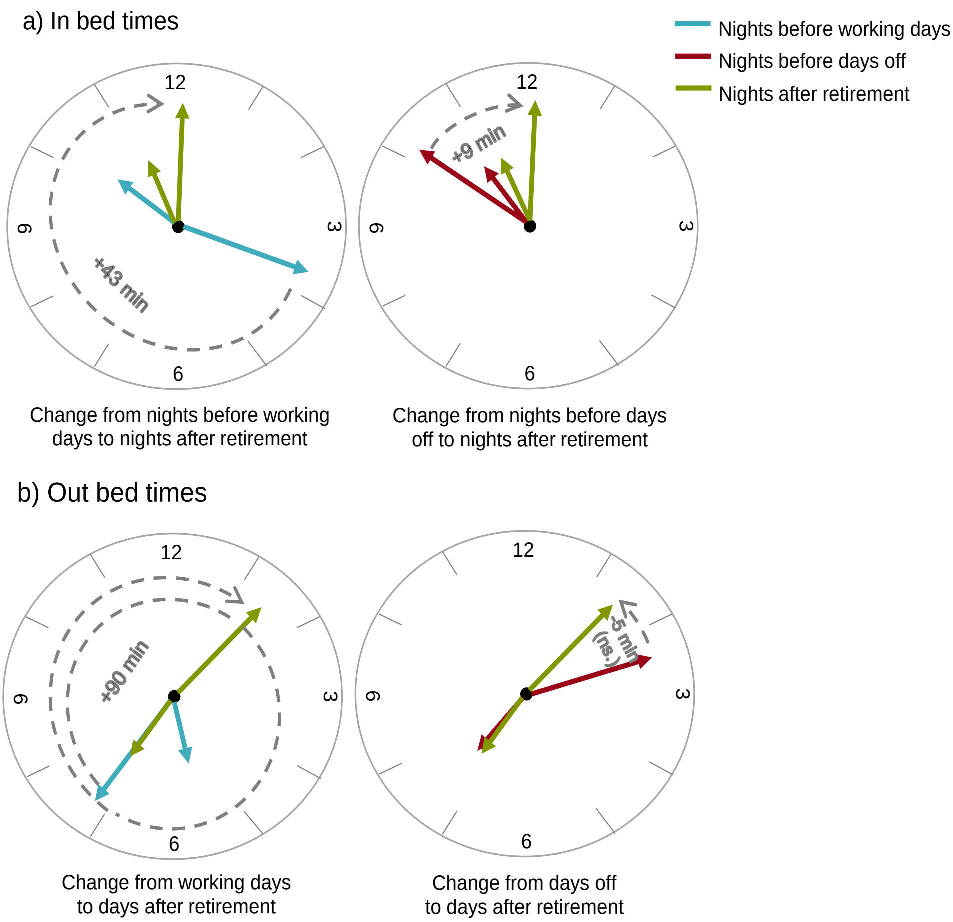

Figure 6. Changes in accelerometer-based observed average a) in bed times and b) out bed times during the transition to retirement shown on clock faces

6 Discussion

During the transition to full-time, statutory retirement, both self-reported and accelerometer-based sleep duration were observed to increase. Retirement was also associated with decreases in self-reported difficulties in waking up too early in the morning, nonrestorative sleep, daytime tiredness and sleep loss due to worry. After retirement, both in bed times and out bed times were delayed, and the timing and duration of sleep resembled those of pre-retirement nights before non-working days. These results, thus, suggest that the possibility to sleep longer in the morning with no working hours determining the timing of sleep, might be one of the main reasons for changes in sleep during the retirement transition. This study was the first to examine changes in sleep during the retirement transition by measuring sleep repeatedly with both self-reports and accelerometer measurements before and after retirement.

6.1 Retirement and Sleep Duration

6.1.1 Sleep Duration Increases during the Transition to Retirement

Similar changes in sleep duration around the retirement transition were observed based on both self-reported and accelerometer measurements. All studies showed an increase in sleep duration approximately by 22 minutes (the observed changes ranging from 19 minutes to 25 minutes) during the transition to retirement despite the different measures and measurement intervals that were used. Furthermore, this increase in sleep duration seems to occur for the majority of retirees, with only few pre-retirement characteristics associated with no changes or a decrease in sleep duration during the retirement transition. This study, thus, implies that the increase in sleep duration is an overarching characteristic of the sleep changes associated with retirement.

Before Study I was conducted, only one longitudinal cohort study, the REST study, had examined changes in self-reported sleep duration after retirement (Hagen et al., 2016). The current study expands this previous knowledge on the changes of self-reported sleep duration during the retirement transition by following aging workers for a longer period, up to 12 years around the retirement transition (Study I), as well as by examining these changes with shorter intervals around the transition to retirement (Study III). This study showed highly similar estimates of the increases in self-reported sleep duration as those found by Hagen et al. (2016) They observed that retirees reported 15, 16, and 22 min longer overall sleep durations 1, 2, and 3 years postretirement, respectively, compared to those who continued working full-time during the same time period. Correspondingly, this study observed self-reported sleep duration to increase by 22 minutes during the approximately 4-year retirement transition in the FPS study (Study I). Furthermore, this study observed that after the increase during the retirement transition, sleep duration was remained at approximately the same level throughout the post-retirement period for up to 8 years after the retirement transition. One possibility for this could be that retirees reach their preferred sleep duration soon after retirement and continue to sleep according to this preference during the subsequent retirement years.

In fact, these results in addition to those of Hagen et al. (2016) seem to suggest that the increase in sleep duration occurs shortly after retirement. In the FIREA study, the increase was observed to be 19 minutes during the shorter, approximately 1 year interval around the retirement transition (Study III). Further support for the changes in sleep duration to occur shortly after the transition to retirement is given by an Australian study on the changes of daily use of time across the transition to retirement (Sprod et al., 2017). They observed an increase of 32 minutes in the time used for sleeping already 3 months postretirement. Similarly, in the current study (Study III), the increase in sleep duration was already visible among those who completed the questionnaire approximately at the time of the exact retirement date with an accuracy of 90 days, suggesting that the increase in sleep duration occurs immediately after retirement. However, this time point is somewhat problematic, as it may comprise of both those participants, who have completed the last questionnaire before retirement near their exact retirement date and of those, who have completed the first questionnaire following retirement near their exact retirement date. Consequently, in the time point 0, there are those who are still working, those who are recently retired, and also those on annual holiday, which they take before moving into retirement. Nevertheless, findings from this study along with the previous studies suggest the increases in sleep duration to occur immediately or at least very shortly after retirement.

This was the first study to longitudinally examine changes in accelerometer-based sleep duration during the transition to retirement (Study IV). The results on the accelerometer-based sleep duration support the findings of increased self-reported sleep duration after retirement. When all nights prior to retirement (combining nights before working days and nights before days off) were considered, accelerometer-based sleep duration was observed to increase approximately by 25 minutes, which is highly similar to the estimates provided by self-reports.

The accelerometer study also expands the findings on sleep duration by comparing pre-retirement nights before working days and nights before days off. Whereas Study I and Study III only examined changes in usual sleep duration, in Study IV, it was possible to observe that these changes were different when nights after retirement were compared to nights before working days and to nights before days off based on the accelerometer measurements. Firstly, accelerometer-based sleep duration differed between these nights already prior to retirement, as sleep duration on nights before days off was approximately 50 minutes longer than on nights before working days. This finding is consistent with previous research that has shown people to sleep more on non-working days, such as weekends and other leisure days, than on working days (Basner et al., 2014; Polo-Kantola et al., 2016; Aili et al., 2017). Secondly, after retirement, sleep duration was observed to increase by approximately 41 minutes from nights before working days, but to decrease by approximately 13 minutes from nights before days off. Similarly, Hagen et al. (2016) have previously observed a greater increases in self-reported sleep duration from week/work nights than from weekend nights. Similar finding was also observed in the accelerometer case study by Borbély et al. (2017). After retirement, all days are "days off". Thus, there may not anymore be a similar need to compensate for possible sleep debt that may have accumulated during the working days with extended sleep on free days, often referred to as "catch-up sleep". In this way, the sleep after retirement might also represent preferred sleep duration: sleep duration is longer than on nights before working days, but not as long as on pre-retirement nights before days off.

Although the accelerometer-based estimates on sleep duration were lower throughout the follow-up period, the self-reports and accelerometer measurements provided similar results in terms of changes in sleep duration during the retirement transition. The differences in the level of sleep duration may be due to differences between the methods in how they measure sleep duration or differences between those participating in the surveys and those participating in the accelerometer measurements. With accelerometers, only night-time sleep was measured, whereas the questionnaires assessed usual sleep duration per 24 hours, which may include daytime naps for some participants. Furthermore, self-reported sleep duration has been shown to only moderately correlate with sleep duration measured with an accelerometer (Girschik et al., 2012; Lauderdale et al., 2008). Self-reports of habitual sleep have been generally shown to overestimate sleep duration compared to accelerometry (Lauderdale et al., 2008). Opposite findings have also been reported (Zinkhan et al., 2014), and for example, those with insomnia have been observed to systematically underestimate their sleep duration (Means et al., 2003; Van Den Berg et al., 2008; Harvey & Tang, 2012). Nevertheless, despite providing different estimates of the level of sleep duration, self-reports and accelerometer measurements provided highly similar estimates for the change in sleep duration during the retirement transition, and thus, mutually strengthen these findings.

These results of this study highlight the importance of promoting the sleep health of older employees. Before retirement, the average sleep duration of the participants was on average just inside the optimal range of sleep duration (7–8 hours per night) when based on self-reports, but below this recommendation, when based on accelerometer measurements. Furthermore, in the FPS study (Studies I and II) a third of the participants were observed to sleep 6.5 hours or less per 24 hours. What these results indicate is that during the working years, many employees of the public sector in Finland do not sleep according to the recommendations. Whether this is due to the sleep hours being traded off for working or work-related activities, such as commuting, is not clear, but support for this is given by the longer sleep durations and later awakening times observed on both pre-retirement non-working days off and after retirement.

6.1.2 Increase in Sleep Duration Is Experienced by Most Retirees

It is remarkable, that the increase in sleep duration seems to apply to a majority of the retirees almost regardless of their pre-retirement characteristics. As seen in the original studies of this thesis, the estimates of the sleep duration changes did not greatly alter after controlling for various pre-retirement sociodemographic, health, and work factors. Furthermore, when the changes in self-reported sleep duration in Studies I and III were examined in groups categorized by different pre-retirement factors, the only groups among which sleep duration did not increase were those who were underweight (BMI < 18.5 kg/m^2, 0.5% participants) and those who had long sleep duration (≥9 hours/24 hours, 3% participants) before retirement. However, these groups consisted only of a small proportion of the participants.

The possibility to sleep more after retirement, as the work related factors are removed from the daily schedule, seems to be used by most retirees, as the great majority of people show increases in both self-reported and accelerometer-based sleep duration after retirement. Based on the latent trajectory analysis in Study IV, only 13% of the participants had constantly short sleep duration throughout the measurements and showed no increase in sleep duration at retirement. Participants belonging to this group were more often male, in a nonmanual occupation, obese, and had lower sleep efficiency than those whose sleep duration increased at retirement. It is possible that those with either a naturally short (preferred) sleep duration or conditions affecting their sleep duration and quality, such as primary sleep disorders (e.g. sleep disordered breathing), may not experience an increase in sleep duration at retirement.

6.2 Retirement and Sleep Difficulties

6.2.1 Retirement Is Associated with a General Decrease in Sleep Difficulties

Significant decreases in both self-reported sleep difficulties in general and in some specific types of sleep difficulties during the transition to statutory retirement were observed in the Study II and Study III. Both studies showed similar changes in sleep difficulties during the retirement transition with a similar level of prevalence estimates observed in both studies before and after the transition to retirement. This finding was expected, as the FPS and FIREA studies have similar study populations of public sector employees. Decreases were observed in waking up too early in the morning and nonrestorative sleep, as well as in daytime tiredness and sleep loss due to worry. These changes were shown to occur shortly or even immediately after the transition to retirement. Furthermore, the level in the prevalence of sleep difficulties seems to be maintained during the following months and years in retirement, thus, suggesting a rather sustained change in sleep difficulties following retirement. However, the decreases in sleep difficulties were observed to be prevalent in some, but not all groups characterized by pre-retirement factors. In regard to improvements in sleep, retirement seems to be the most beneficial for those experiencing suboptimal self-rated health, psychological distress, and short sleep duration before retirement.

The study expands previous knowledge (Vahtera et al 2009; Marquié et al., 2012) on the changes of self-reported sleep difficulties after retirement by examining the changes in different types of sleep difficulties during a both longer and shorter retirement transition window around retirement. Firstly, a substantial decrease in self-reported sleep difficulties in general, referred to as *any sleep difficulty,* was observed during the approximately 4-year transition to retirement. The risk for any sleep difficulty being 12% smaller in Study II and 9% smaller in Study III in the measurement after retirement compared to the measurement prior to retirement. Highly similar results were observed in the GAZEL study (Vahtera et al., 2009), although they observed a somewhat greater decrease in general sleep difficulties. This might be explained by differences in the study populations: the participants in the GAZEL cohort were men (80% compared to 20% in this study) and they retired at a fairly young age (55 years, on average) and with a fairly generous retirement scheme (80% of their salary) paid by the company. The finding of decreases in self-reported sleep difficulties has also later been replicated in a general working population in Sweden (van de Straat et al., 2019).

Secondly, this study expand previous knowledge by showing how much and what type of sleep difficulties the employees experienced while at work and particularly by showing which sleep difficulties diminish after retirement. Previously another French study, the VISAT study, showed that from different types of sleep difficulties, the prevalence of premature awakenings in particular was observed to be lower following retirement (Marquié et al., 2012). In this study, a third of the public sector employees reported some difficulties with their sleep before retirement, and a quarter of the employees reported experiencing difficulties in maintaining sleep during the night. In addition, prior to retirement, approximately 4–5% reported difficulties falling asleep, 12–13% reported waking up too early in the morning, 7–11% reported nonrestorative sleep, 17% reported daytime tiredness, and 14% reported sleep loss due to worry. During the approximately 4-year retirement transition in Study II, the prevalence estimates of waking up too early in the morning and nonrestorative sleep were observed to decrease. Using a shorter measurement interval around retirement, the finding from Study I was replicated in Study III while also showing that these decreases take place shortly or even immediately after retirement. Furthermore, the Study III also showed for the first time that also daytime tiredness and sleep loss due to worry decrease shortly after the transition to retirement.

One explanation for these improvements in some of the sleep difficulties could be that retirement allows people to sleep longer in the mornings, as working hours no longer dominate the wake up times, thus, providing more possibilities to compensate for possible sleep loss during the night and to acquire more restorative sleep, which may in turn have positive effects in regard to daytime tiredness. However, the increased opportunities for sleeping might have different effects for different individuals. For example, for those with insomnia, the opportunity to sleep longer might even perpetuate their sleep difficulties, as it might lead to decreased sleep efficiency (Perlis et al., 1997; Riemann et al., 2010). As a result, those with insomnia may associate the bed with arousal and wakefulness rather than sleep. In fact, restricting time in bed is a key intervention in cognitive behavioral therapy for chronic insomnia (Spielman et al., 1987; Miller et al., 2014; Maurer et al., 2018). On the other hand, for other individuals, the increased opportunities for sleeping might decrease the worry over whether they will have enough time to sleep, and in this way, help them to fall asleep.

Retirement was not associated with decreases in all types of sleep difficulties, as no changes were observed in difficulties maintaining sleep and difficulties falling asleep when all participants were considered. Throughout the follow-up periods in Study II and Study III, the prevalence estimates for difficulties maintaining sleep were observed to be the highest of the different types of sleep difficulties and no changes were observed in difficulties maintaining sleep during the retirement transition. This could reflect the age-related decrease in the ability to sleep and the increasing fragmentation of sleep with age (Cooke & Ancoli-Israel, 2011). Difficulties falling asleep, on the other hand, had a low prevalence throughout the follow-up periods in both studies, and could be associated with personality characteristics, such as tendency to rumination (Zoccola et al., 2009), which retirement might not greatly affect. Rumination may increase physiological and cognitive activation, and as a result, those prone to worrying and rumination at bedtime may experience more difficulties with falling asleep (Zoccola et al., 2009; Kompier et al., 2012).

6.2.2 Factors Associated with Decreases in Sleep Difficulties

The reasons behind the decrease in sleep difficulties following retirement are not known. Insight into the reasons behind these changes might be given by examining how the changes observed in sleep difficulties vary between different groups, and who especially benefits from retirement. The findings from the current study were somewhat in contrast with the previous findings in regard to who especially benefits from retirement. Previously, the GAZEL study showed the decrease in sleep difficulties to be more pronounced among women than men (Vahtera et al., 2009), and this finding was later repeated by van de Straat et al. (2019). In the GAZEL study (Vahtera et al., 2009), more pronounced improvement in sleep difficulties was observed among higher-grade workers than lower-grade workers and among those doing night/shift work. In contrast to those findings, the present study (Study II) observed no differences in regard to gender, occupational status or shift work status. However, comparing these findings to those of the previous studies is somewhat challenging, as the study populations distribute differently by gender and different occupations. The incongruent finding in relation to shift work status in the present study might be explained by differences in the retirement ages between the studies. In the current study, the public sector employees' retirement age was on average 62–63 years, whereas in the GAZEL study (Vahtera et al., 2009), the employees were able to retire at an earlier age, the average retirement age being 55 years. Those individuals who have been able to continue doing shift work until retirement at the public sector in Finland are a highly selected group, as it is highly likely that those shift workers who had had health problems or sleep difficulties due to shift work have changed to day work already years before retiring (Linton et al., 2015).

Removal of adverse work characteristics has been suggested as one of the key factors driving the changes in sleep after retirement (Vahtera et al., 2009). Previous findings have indicated the most pronounced decreases in sleep difficulties following retirement to occur among those who report high psychological demands, mental fatigue, and depression before retirement (Vahtera et al., 2009; van de Straat et al., 2019). Accordingly, in Study II, those reporting job strain (high demands and low control at work) and psychological distress were observed to be among those with the most pronounced decreases in any sleep difficulty, and in fact, among those with psychological distress, all the specific sleep difficulties were observed to decrease during the retirement transition.

However, somewhat contradictory findings were observed in Study III that focused on more closely examining the role of the removal of work-related stressors on the changes in sleep difficulties during the retirement transition. In Study III, no systematic associations were observed across the individual work-related stressors, including job strain, low work time control, effort-reward imbalance, and organizational injustice, or the amount of stressors the person was exposed to and changes in sleep characteristics. This means that similar trends in sleep difficulties were observed almost regardless of whether the participants were exposed to work-stressors prior to retirement or not. Only high pre-retirement job strain and effort-reward imbalance were associated with greater decreases only in difficulties maintaining sleep and nonrestorative sleep, respectively, but not with any other sleep changes. Furthermore, no differences in sleep loss due to worry, a characteristic of sleep that could especially be thought to be associated with work-related stressors, were observed in relation to the amount of work stress or the individual work-related stressors the participants were exposed to. These discrepant findings on the association between pre-retirement work-related stressors and changes in sleep might rise from differences in how the pre-retirement work factors have been measured. For example, the GAZEL study assessed mental fatigue, which might be challenging for the individuals to separate from fatigue induced by sleep difficulties, and thus, the two measures might be highly interconnected. On the other hand, it is not clear whether the measures of work-related stressors, such as those used in the current study, in fact capture those aspects of work that the employees themselves experience causing stress.

Nevertheless, results from this study, raise the question of whether there are in fact some other factors than the removal of work-related stressors that drive the decrease in sleep difficulties following retirement. Findings from this study along with previous ones (Vahtera et al., 2009) indicate that retirement might be especially beneficial to sleep for those with a poorer mental and physical health prior to retirement. Self-rated health, as well as mental and physical fatigue and depressive symptoms have been observed to improve following retirement (Westerlund et al., 2009; Westerlund et al., 2010), and these improvements in health in general after retirement might also lead to improvements in sleep. This study did not examine how depressive symptoms prior to retirement are associated with changes in sleep after retirement, and further research is needed on whether improvements in depressive symptoms explain the changes in sleep difficulties after retirement. Another possible reason for improvements in sleep after retirement might be that retirement reduces or ends the conflicts between work and family, as there is a strong association between work–family conflicts and sleep complaints (Lallukka et al., 2010; Crain et al., 2014). Future studies should more closely examine these and other possible reasons for the changes in sleep during the retirement transition to better understand what factors in retirement make it such beneficial for sleep.

6.3 Retirement and Other Sleep Characteristics

Along with increases in sleep duration and decreases in sleep difficulties, the Study IV observed retirement to be associated with changes in other sleep characteristics as well. Based on accelerometer measurements, a shift toward a later sleep-wake rhythm was observed, which was seen as later in bed times and out bed times after retirement. Especially the out bed times were delayed after retirement, and as a result also the weekly average of time in bed increased during the retirement transition. No major changes in sleep efficiency were observed during the transition to retirement.

This study showed retirement being associated with delayed in bed times and out bed times when measured with accelerometers, as has been previously shown using self-reports of usual sleep timings (Hagen et al., 2016). Prior to retirement, both the in bed times and the out bed times were later on nights before days off than on nights before working days. After retirement, in bed times were delayed from both nights before working days and nights before days off. Out bed times, on the other hand, were observed to be on average 1 h 30 minutes later after retirement than on working days, but no differences were observed to days off when still in working life. Thus, after retirement, the timing of sleep begins to resemble that of the pre-retirement nights before days off, that is weekend nights and other free nights. Increase in sleep duration seems to occur at the end point of night so that the retirees get up later than while they were working. Having no work hours that may possible dominate the timing of sleep is a common feature for nights before days off and nights after retirement. Thus, not needing to get up early for work appears to be one of the main reasons for the changes in timing of sleep, and as a result, for the increased sleep duration after retirement, also suggested by Hagen et al. (2016).

Previous studies on the association between retirement and sleep have not examined changes in sleep efficiency and time in bed during the transition to retirement, as these sleep characteristics rely on accelerometer measurements. Assessing the changes in sleep efficiency in particular is important, as it provides a more objective estimate of how retirement is associated with the quality of sleep.

Sleep efficiency refers to how the proportion of how long the person has been asleep from the time they have spent in bed. Sleep efficiency was not observed to differ on nights before working days and nights before days off prior to retirement, and only a minor, borderline significant decrease in sleep efficiency was observed from nights before working days into nights after retirement. This result was expected, as the changes in time in bed around retirement closely resembled that of sleep duration. This result is also in line with a previous one showing no significant differences in sleep efficiency between nights before working days and non-working days (Aili et al., 2017). However, this finding in somewhat surprising, as it does not reflect the changes observed in self-reported sleep difficulties. It is possible that the wrist-worn accelerometer does not detect wakefulness adequately enough, and thus, some immobile periods of wakefulness during the night are scored as sleep (Quante et al., 2018). This could explain why sleep efficiency was rather high (approximately 89%) throughout the follow-up period. However, it is unlikely that the accelerometer would estimate sleep efficiency in different ways before and after retirement, and thus, the overestimation of sleep efficiency is not a likely explanation for why no changes being observed in sleep efficiency during the retirement transition.

6.4 Methodolocigal Considerations

6.4.1 Study Population

The study populations of the FPS and the FIREA studies consisted of relatively healthy public sector employees in Finland. The participants of the study samples came from various occupations of the public sector, and the three levels of occupational status were relatively evenly distributed among the study participants in each original study. Comparisons to eligible populations were also made in Study II (with mainly the same participants as in Study I), Study III, and Study IV, and these comparisons indicated that the final study samples represented the eligible populations for the most part. However, the generalizability of these findings to the general working-age population in Finland or in other countries may be limited. Firstly, the Finnish public sector is a highly female-dominated working sector, and therefore, majority of the study participants in each study were women. As gender differences have been observed in sleep need, sleep duration and sleep quality (van de Straat & Bracke, 2015; Polo-Kantola et al., 2016), it is possible that the results of this study are affected by the female-dominated sample. However, similar findings in relation to changes in sleep difficulties during the retirement transition have been observed in a highly male-dominated sample in the GAZEL study (Vahtera et al., 2009), suggesting that results on the changes in sleep at retirement are generalizable to different populations. Secondly, the generalizability of the results to the private sector or the self-employed, or to working population in other countries than Finland is unknown. For example, self-employed have more autonomy in deciding when they work (Hyytinen & Ruuskanen, 2007), which could allow them to more easily regulate their working hours so that they would able to sleep adequately and at a suitable time for them (e.g. those with an evening preference could start the work day later in the mornings and work longer in the evenings). In fact, self-employed individuals have been observed to sleep more and to wake up later on weekdays than private sector or government employees in the United States (Basner et al., 2014), and consequently, it could be hypothesized that they would not experience as great changes in their sleep duration and sleep timing after retirement. However, self-employed have also been found to work more in the evenings, on weekends and on holidays than those employed by an organization (Hyytinen & Ruuskanen, 2007; Basner et al., 2014), which might impact how much they sleep overall. It would be, thus, important to examine in the future, whether similar changes in sleep after retirement are observed for retirement from different types of employments and working sectors. Furthermore, as the retirement pension schemes, the pension benefits and the statutory retirement ages vary between countries and are also in a continual change, more research on the changes in sleep during the retirement transition is needed for examining whether the findings are generalizable to other countries.

It needs to be taken into account that there may have been some selection into the study samples in this study. For example, it is possible that especially those participating in the accelerometer measurements in Study IV are more interested in following and recording their health-related behaviors and sleep. In the activity sub-study, there were slightly more women and non-manual employees and those who reported less obesity, psychological distress and suboptimal health than in the eligible population for that study. Participating in the accelerometer measurements may also be experienced as more cumbersome than participating in a survey, and thus, those with a more stressful or busy life situation may have chosen to not take part in the accelerometer study, if having considered it as too much of a burden.

A major strength of the present study is the relatively large sample sizes in both the surveys (Studies I–III) and in the accelerometer measurements (Study IV). The response rates in the FPS and FIREA studies have in general been relatively good. In the activity sub-study (Study IV) the drop-out rate in the repeated accelerometer measurements ranged from only 1.6% to 2.8%. Thus, only a considerably small number of participants dropped out from the accelerometer measurement, although taking part in the measurements requires more engagement than taking part in the surveys. The large study samples have allowed the changes in sleep to be compared in smaller groups categorized by pre-retirement factors. In addition, in each of the original studies, each participant contributed to at least two consecutive measurements around the retirement transition, one before and one after retirement, which enabled the comparisons in sleep before and after retirement to be made among the same individuals. This is important, as it prevents the differences in sleep before and after retirement being due to differences in other characteristics between those who are working and those who have retired, which may be the case in cross-sectional studies. In addition, the participants provided data on sleep on average from 3.6 measurements around retirement, and thus, wider changes in sleep around the retirement transition could be examined, which would not have been possible with only two measurements around retirement.

6.4.2 Self-Reported Sleep

The present study included survey questions for assessing sleep duration, different types of sleep difficulties, daytime tiredness, and sleep loss due to worry. These self-reports of sleep were repeatedly collected before and after retirement. The assessment of sleep duration and sleep difficulties was identical in the FPS and FIREA questionnaires, which allowed the results being compared across the studies. Self-reported sleep duration was on average 7 hours and 25 minutes after retirement, and thus, it corresponds well with the mean self-reports on sleep duration among people aged 60–69 in Finland from 2017, which were 7 hours and 36 minutes among women and 7 hours and 18 minutes among men (Koponen et al., 2018).

Self-reports are a highly practical and cost-effective method to assess sleep in large samples, such as the ones in the present study. They also provide highly important information on participants' own evaluations of how they sleep. However, there are some challenges in the use of self-reports to measure sleep. Firstly, self-reports are susceptible to inaccuracies due to bias related to perception and estimation of sleep. Individuals may find it difficult to estimate their usual sleep duration, for example, if their sleep varies according to the day or season (Girschik et al., 2012). Participants may also answer based on what they think would be a good sleep duration, if they find it challenging to estimate how much they usually sleep (Lauderdale et al., 2016). Furthermore, how much and how well the individuals actually sleep may have an impact on how they estimate their sleep duration and quality. For example, those with subjective sleep disturbances and insomnia have been found to underestimate their sleep duration, when compared to objectively measured sleep duration (Means et al., 2003; Van Den Berg et al., 2008; Harvey & Tang, 2012). However, it is not known, whether this actually reflects people's misperception of their sleep duration or the inaccuracy of the objective measures to assess sleep duration (Van Den Berg et al., 2008). Finally, it has been suggested, that perceived sleep quality is something different from objective quality of sleep and that different aspects of sleep may be captured with objective and subjective estimates on sleep quality, particularly among older adults (Jackowska et al., 2011; Landry et al., 2015; Aili et al., 2017)

The present study assessed sleep duration with a single question concerning usual sleep duration per 24 hours, which is very common way to measure sleep in epidemiological studies (Lauderdale et al., 2008; Girschik et al., 2012). However, this type of question may produce some challenges in the interpretation of the results. Firstly, it is relevant to point out that as this question concerns usual sleep duration per 24 hours, depending on their view point, the participants may count only their usual sleep duration during the night (i.e. the main sleep period) or they me also include daytime naps into this estimate. However, it is not known whether the frequency of daytime naps increases after retirement. Secondly, in the present study, to answer this question, the participants were given options ranging from "6 hours or less" to "10 hours or more" with 30 minute intervals. Thus, as the question was not open-ended, participants may have had difficulties in choosing the most accurate option in regard to their usual sleep duration.

The use of the same method to asses sleep difficulties, namely the Jenkins Sleep Problem Scale (Jenkins et al., 1988), allowed the prevalence estimates to be compared between the FPS study (Study II) and the FIREA study (Study III). However, choosing a suitable cut-off point to indicate the presence of sleep difficulties was somewhat challenging. One of the diagnostic criteria for an insomnia disorder in the current Diagnostic and Statistical Manual of Mental Disorders (DSM-5) is the cut-off point of sleep disturbances occurring at least three times per week (American Psychiatric Association, 2013), and thus, choosing a cut-off point corresponding to this criterion would be reasonable. However, the cut-off point of three nights per week falls between the response alternatives available in the surveys with one of the alternatives being "two–four nights per week". On the grounds of previous studies, the higher response alternative (≥5 nights per week) was chosen to indicate sleep difficulties (Salo et al., 2012; Salo et al., 2014). In addition, a lower cut-off point (≥2 nights per week) was also used in the sensitivity analyses (Study II), and the results showed a difference only in the prevalence of but not the changes in sleep difficulties around retirement.

6.4.3 Accelerometer Measurements

Examining changes in accelerometer-measured sleep around retirement along with self-reports was reasonable, as these different methods used to assess sleep have been shown to only moderately correlate with each other (Lauderdale et al., 2008) and to possibly capture altogether different dimensions of sleep (Aili et al., 2017; Landry et al., 2015). Accelerometry has been regarded as a valid measuring tool for assessing the average total sleep time and sleep efficiency on a population level when used with the current algorithms (Zinkhan et al., 2014; Slater et al., 2015; Quante et al., 2018). As the year-to-year variation in sleep measured with accelerometry seems to be much smaller than day-to-day variation, accelerometry should correctly reflect average levels of individual's sleep when using average sleep parameters from multiple day accelerometer measurement (Knutson et al., 2007). Two models of the same triaxial accelerometer were used in this study: wActiSleep-BT and wGT3X-BT by ActiGraph (Penacola, Florida, USA). Although the newer model, wGT3X-BT should be fully backward compatible with the previous model, each annual measurement of a single participant was conducted with the same accelerometer model, mainly to improve the reliability of the repeated measurements and to avoid confusion among participants in regard to the appearance of the accelerometer.

The accelerometer measurements and sleep scoring were pursued to be conducted in a similar fashion in each measurement point and at an approximately same time of the year for a single participant as his/her previous measurement(s) to improve the reliability of the repeated measurements and avoid seasonal effect on the measurement. Also the sleep scoring was conducted following the same principles in each measurement point. However, it cannot be ruled out that the weeks when the accelerometer sleep measurements were conducted did not possibly represent a normal week for the participant in regard to their sleep. On the other hand, as only little year-to-year variation has been shown to occur in accelerometer-based sleep, average sleep parameters from multiple day accelerometer measurement should reflect average level of individual's sleep (Knutson et al., 2007).

The accelerometer used in the FIREA study can be worn either on hip or on wrist, with the hip placement used more often in physical activity research and the wrist placement in sleep research (Slater et al., 2015). The algorithms currently available to estimate sleep are mainly suitable for the devices worn on wrist, and thus, the device was chosen to be worn on the non-dominant wrist. Furthermore, the placement of the device on wrist has been found to be optimal in comparison to hip in regard to measure of sleep parameters (Zinkhan et al., 2014; Slater et al., 2015; Full et al., 2018), mainly due to the unsuitability of the algorithms for assessing sleep from hip (Zinkhan & Kantelhardt, 2016). The non-dominant wrist was chosen as the placement of the accelerometer, as it is more commonly accepted and used placement in research measuring sleep and physical activity with accelerometers (Troiano et al., 2014; Ancoli-Israel et al., 2015).

Choosing the proper algorithms to analyze the raw accelerometer data is crucial, as unsuitable algorithms may weaken the validity of the sleep measure (Zinkhan & Kantelhardt, 2016). As was pointed out by Zinkhan and Kantelhardt in their narrative review of sleep assessment with accelerometers in large cohort studies, more up-to-date algorithms are needed to match with the recent high-resolution 3-axis accelerometers to correctly estimate the sleep characteristics. Two algorithms were used in this study: the Cole-Kripke algorithm (Cole et al., 1992) was used to define each epoch as sleep or wake, and the ActiGraph algorithm (ActiGraph, 2018a; ActiGraph, 2018b) to detect the sleep periods and to estimate sleep parameters. The Cole-Kripke algorithm was chosen, as it has been validated in adult population using particularly wrist-worn accelerometers. Recently, Quante et al. (2018) examined the validity of the Cole-Kripke algorithm when using a similar accelerometer, and observed that this algorithm provided comparable and accurate data compared to polysomnography in regard to sleep (i.e. had a high sensitivity), but poorly identified wake episodes (i.e., had low specificity). This means that the algorithm may slightly overestimate sleep, for example, by scoring immobile periods of wakefulness as sleep. Thus, for this reason, although the ActiGraph algorithm would have provided estimates also on, for example, sleep onset latency, wake after sleep onset, and the number of awakenings, these sleep parameters were chosen not to be included in the analyses (Slater et al., 2015; Quante et al., 2018). Furthermore, it is challenging to correctly detect the timing of the sleep onset, as the individual may be motionless, yet awake, for a while before falling into sleep, which often leads to the accelerometers underestimate sleep onset latency (Slater et al., 2015).

Finally, one of the limitations of the present study is that with the current algorithms, it was not possible to detect sleep periods outside the main sleep period, and, thus to examine whether retirement is associated with changes in the duration and frequency of daytime sleep. Although the algorithms seemed to detect sleep periods during daytime, these were almost exclusively observed to be non-wear time that was scored as sleep by the algorithm. On the other hand, it seemed that the algorithms were not able to detect true daytime sleep periods, which means that they did not detect sleep during daytime when a participant had reported having taken a daytime nap. For this reason, all the daytime sleep periods were chosen to be excluded and the examination focused on nighttime sleep only.

6.4.4 Retirement

In the present study, information on the timing of retirement was based on information from the registers, namely the Finnish Centre for Pensions (in Study I and Study II), information provided by the participants in the surveys (Studies III), or in the daily log they completed during the accelerometer measurements (Study IV). Retirement was, thus, defined as either receiving a pension for statutory retirement (in Study I and Study II), as reporting being on retirement full-time (Study III), or as reporting being on retirement full-time and having no work days (during the measurement week) (Study IV).

Naturally, these measures and definitions of retirement are not always exact and may have an impact on the results. For example, in Studies I and II, participants may have been working while also receiving a pension, as receiving a pension does not indicate complete withdrawal from the work force. On the other hand, when the timing of retirement is based on self-reports, the participants may provide inconsistent answers: for example, a participant may report being on retirement full-time in one questionnaire and then report being on retirement only part-time or working full-time in the following questionnaire. In Studies III and IV, the first mention of being on full-time retirement was set as the timing of retirement regardless of the answers in the following surveys. Furthermore, in the accelerometer measurements (Study IV), the participants were classified as retired only when they reported being on full-time retirement (or on annual leave right before retirement) and did not have any work days during their measurement week.

6.5 Implications and Future Directions

Retirement transition signifies a shift towards longer sleep duration for the majority of the employees. Retirement is also associated with an improved sleep quality for many, by showing reduced prevalence estimates especially in waking up too early in the morning and nonrestorative sleep. Although the reasons behind these improvements in sleep after retirement are not fully understood, the removal of work, both in relation to its characteristics and the time it takes, seems to play a key role. As aging has been mainly associated with changes toward shorter, more fragmented sleep (Ohayon et al., 2004; Cooke & Ancoli-Israel, 2011), retirement seems to bring a slight exception to this trend. What these results also indicate is that sleep is worse during the final working years compared to years after retirement for many people. This is an important notion in relation to extending working careers by postponing retirement ages: workers may experience sleep problems in increasing amounts if the retirement ages are postponed. These results, thus, highlight the importance of improving sleep of older employees.

What this study also implies is that inadequate sleep and some sleep difficulties of the older employees can be modified and sleep can be improved. Thus, it is important to identify those aspects in retirement that drive these improvements in sleep. By easing the demands of work, providing possibilities for part-time employment, and for flexibility in terms of workings hours and the timing of work sleep could potentially be improved already during the working years. For example, some of these aspects could be. The findings of sleep duration increasing especially due to sleeping longer in the mornings (a phenomenon that can be seen also during pre-retirement non-working days) seems to point to working hours having a key role in reducing sleep. In addition, lower psychological distress and higher work time control have been found to be key factors in extending employment into older ages (Virtanen et al., 2014) and could potentially also be associated with improved sleep for some employees (Kubo et al., 2016; Salo et al., 2014). As the findings on the association of work-related stressors with the sleep changes in retirement were not conclusive in this study, more research is needed.

It is not known, however, how changes in sleep are associated with health outcomes in later life and this presents a need for further research. Increase of sleep duration from 7 to 8 hours among those aged 35 to 55 was associated subsequently with poorer cognitive function (Ferrie et al., 2011) and all-cause mortality (Ferrie et al., 2007) in studies from the British Whitehall II cohort. However, as the changes observed in sleep duration after retirement seem to be towards the range of recommended sleep duration (i.e. 7 to 8 hours), rather than towards long sleep (i.e. more than 8 hours), these changes could be hypothesized to instead have protective effects in relation to morbidity and mortality in later life. For example, those who sleep between 7 and 8.5 hours and report no sleep difficulties between ages 50 to 75 have recently been observed to have longer healthy and chronic disease free life expectancy (Stenholm et al., 2019).

The findings on decreases in sleep difficulties also seem to point to retirement being a rather positive transition in relation to sleep. On the other hand, studies have observed that retirement seems to be associated more with positive changes in mental health (Westerlund et al., 2010; Oksanen et al., 2011) rather than changes in physical health, such as risk of major chronic diseases (Westerlund et al., 2010). Future studies are, thus, needed to examine how the changes observed in sleep after retirement affect subsequent mental and physical health. This could be done, for example, by prospectively comparing the health outcomes of those who experience changes in sleep duration and sleep difficulties during the retirement transition and those who do not.

Future studies on the association of retirement and sleep could benefit from sleep duration and sleep quality being examined simultaneously, preferably using both self-reports and more objective measures of sleep. The impact of the sleep changes associated with retirement on subsequent health could depend on whether changes are observed in both, sleep duration and sleep quality, or only in one of them. Both short and long sleepers report poorer quality of sleep than mid-range sleepers (Grandner & Kripke, 2004). The most pronounced health risks have been found among those with both short sleep duration and poor sleep quality, often characterized as insomnia (Fernandez-Mendoza et al., 2010; Vgontzas et al., 2009). However, poor sleep quality seems to be associated with poorer health functioning, including physical, emotional, and social functioning, regardless of sleep duration (Lallukka et al., 2018). It has, therefore, been suggested that possibly the adverse health outcomes associated with both short and long sleep duration might in fact be related to poor sleep quality rather than sleep duration (Lallukka et al., 2018). Furthermore, when considering the effects of changes in sleep for subsequent health, all the different characteristics of sleep, including the timing and variability of sleep, should be considered both simultaneously and separately (Matricciani et al., 2018).

The present study provides information on the association of retirement with changes in one aspect of daily activities, the nighttime sleep. However, nighttime sleep is not the only daily activity that is associated with health (Matricciani et al., 2018), nor is it the only manifestation of sleep either, as daytime sleep may also be related to health. It would, thus, be important to examine the changes in sleep following retirement as a part of the entire 24 hours. Firstly, it would be important to examine changes in daytime napping during the retirement transition. Based on a narrative review by Milner and Cote (2009), napping is more frequent among older than younger adults and is beneficial for well-being and cognitive performance of healthy older adults, whether they nap for restorative reasons (e.g. to feel less sleepy) or for enjoyment. The authors also point out that retirement provides more opportunities for napping. However, it is not known, whether retirement is in fact associated with changes in the duration and frequency of daytime sleep. Examining changes in sleep duration of the entire 24 hours, that is, including both daytime and nighttime sleep, would provide a more holistic view of the changes in sleep duration following retirement. For examining this, more advanced algorithms may be required to detect the daytime sleep periods from accelerometer data, as these sleep periods are usually much shorter, ranging from only minutes to few hours. Moreover, in the future, easy-to-use, ambulatory home polysomnography could potentially provide a solution for registering daytime sleep.

Secondly, it would be useful and important to examine the changes in sleep following retirement along with the other components of the 24 hours, that is, physical activity and sedentary time (Matricciani et al., 2018). The 24-hour movement behavior approach has gained increasing interest among researchers, because accelerometer measurements conducted over the entire 24 hours enable identification of sleep, sedentary time and physical activity. It has been suggested that effects of daily activities, such as sleep, on health depend on the overall time allocation across all the domains rather than one domain that is analyzed in isolation from the others (Dumuid et al., 2018). Thus, the effects of the sleep changes during retirement on health might depend on how the other components of the 24 hours change at the same time

The future research on the association of retirement with sleep could benefit from wider use of accelerometers. Along with examining the changes in sleep in the context of the entire 24 hours, accelerometers could be used to provide information on circadian preference of the participants as well. This would make it possible to examine the changes in sleep duration and the timing of sleep in relation to circadian preference, and thus, to compare whether these changes differ between those with a morning and those with an evening preference. Retirement could be especially beneficial for those with an evening preference, as this group is more likely to sleep against their preferred sleep timings due to typical office hours that often make those with an evening preference to wake up earlier than would be natural to them. Using self-reported circadian preference, it has in fact been already shown that the extension in wake time after retirement is much greater for those with an evening preference compared to those with a morning preference (Hagen et al., 2016). As the present study was the first to examine changes in sleep during the retirement transition using both self-reports and accelerometers to measure sleep, more studies are needed to corroborate these findings.

Finally, some factors that could potentially impact the changes in sleep during the retirement transition could not be examined in this study, and thus, further research on this topic is needed. Firstly, this study did not have sufficient information on the use hypnotics and could not examine how the use of hypnotics changes during the retirement transition and how it is associated with changes in the different sleep characteristics. Another aspect that could potentially affect the changes in sleep at retirement that this study did not have information on is chronic pain. Pain has been independently associated with subsequent disability retirement, especially when co-morbid with insomnia (Lallukka et al., 2014), but it is not clear what role it plays in the changes of sleep during the transition to statutory retirement. Furthermore, although this study included some measures of mental health, namely psychological distress, it did not include information on depressive symptoms or the use of antidepressants, and it would be important to examine whether pre-retirement depressive symptoms or potential changes in those symptoms have an impact on the sleep changes after retirement.

7 Conclusions

In this thesis, the changes in sleep during the transition to full-time retirement were examined using both repeated self-reports and accelerometer measurements. Furthermore, it was examined how the pre-retirement characteristics of the participants were associated with the changes in sleep following retirement. The main conclusions of the thesis were the following:

1. Both self-reports and accelerometer measurements showed an increase in sleep duration during the retirement transition shortly or even immediately after the retirement transition. Thus, for the majority of retirees, retirement was associated with an increase towards recommended range (7-8 hours per night) of sleep duration. One of the main reasons for the increase in sleep duration after retirement could be that working hours no longer require to wake up at a certain time in the morning, as longer sleep durations are observed on both pre-retirement nights before non-working days and on nights after retirement than on nights before working days.

2. The prevalence of sleep difficulties in general decreased during the transition to retirement. In particular, transition to retirement was associated with decreases in waking up too early in the morning, nonrestorative sleep, daytime tiredness, and sleep loss due to worry, whereas difficulties falling asleep and difficulties maintaining sleep did not change during the retirement transition. Greatest increases in sleep difficulties were experienced among those with suboptimal self-rated health, psychological distress, and short sleep duration before retirement. The mechanisms driving these changes are still unclear, as the removal of work-related stressors does not seem to explain all the decreases in sleep difficulties. All in all, sleep seems to be significantly worse in some groups during the last years of working career compared to after retirement. These data, thus, emphasize the importance of promoting good quality sleep of older employees.

3. The transition to retirement is associated with both later in bed times and later out bed times than before working days prior to retirement. After retirement, the timing of sleep begins to resemble that of nights before non-working days prior to retirement. Thus, especially the possibility to sleep longer, as working hours no longer determine the sleep timings, seems to be used after the transition to retirement. In addition, also the time spent in bed seems to increase after the transition to retirement, whereas retirement is not associated with major changes in sleep efficiency. More repeated objective measurements of sleep characteristics before and after retirement are needed, as this was the first cohort study, to examine these changes with a method other than self-reports.

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You don't know

You don't know nothing yet

About the dreams I have

I will make you sleep

AMORPHIS – HOUSE OF SLEEP (NUCLEAR BLAST, 2006)

Thank you,

In Turku, 14 February 2020

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Appendices

Appendix 1. Daily log used in Study IV.

	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7	
Day of the week														
Date														
I woke up at														
On a scale of 0–10, how well rested did you feel when you woke up?	0 (not rested) – 10 (fully rested)													
Possible daytime nap at														
I went to bed at														
If you are still in working life, please mark whether it was a work day or not and your working hours	Work hours	Not working	Work hours	Not working	Work hours	Not working	Work hours	Not working	Work hours	Not working	Work hours	Not working	Work hours	Not working
Mode and duration of commuting (return trip, in minutes)	Mode	Duration	Mode	Duration	Mode	Duration	Mode	Duration	Mode	Duration	Mode	Duration	Mode	Duration
Exceptional day	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
If yes, please explain														

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