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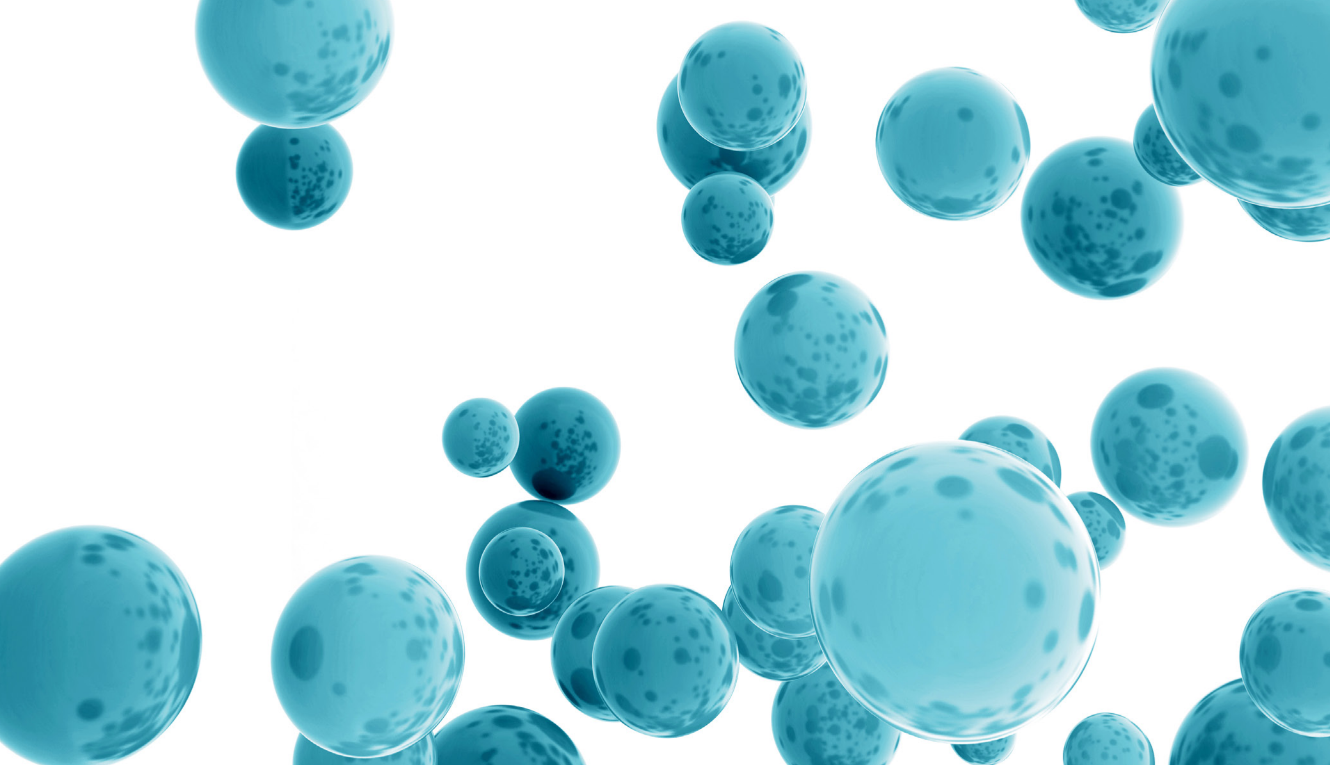
A 28-year follow up of Finnish municipal employees



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ACADEMIC DISSERTATION
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UNIVERSITY OF TAMPERE

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University of Tampere, Faculty of Social Sciences
Finland

Supervised by
Professor Clas-Håkan Nygård
University of Tampere
Finland
Docent Subas Neupane
University of Eastern Finland
Finland

Reviewed by
Docent Minna Mänty
University of Helsinki
Finland
Professor Jussi Vahtera
University of Turku
Finland

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Abstract

Work related exposures during adult life may have long-term effects and subsequently increase the risk of musculoskeletal disease (MSDs), which in turn results in mobility decline leading to significant physical disability in later life. There are consistent findings worldwide regarding the detrimental effects of work-related hazards and exposures on the overall health of the workers. However, the evidence on the effect of these midlife exposures on health in old age is limited. In addition, it is crucial to know those effects from the perspective of public health due to global population aging. Adequate functioning in activities of daily living (ADL) is needed for independent living in old age and those activities could be compromised due to the MSDs and physical limitations associated with work-related exposures. In general, the degradation of musculoskeletal health triggers limitations in the functioning of basic and instrumental ADL, thereby imposing a huge socioeconomic burden throughout the world. This dissertation aimed to investigate the associations between work-related exposures in midlife and musculoskeletal diseases, mobility limitations and disabilities in old age through a longitudinal study of Finnish municipal employees followed up for almost three decades. The exposures used were job strain, biomechanical exposure, shift work (work schedule) and detailed job analysis from midlife. The outcomes were related to musculoskeletal health such as MSDs, mobility limitations (MLs) and disability. In addition to separate associations, the joint associations of different work-related exposures in predicting MSDs and disability were studied. This study also took the opportunity to investigate the developmental pathways of MLs separately for those retired on statutory pensions (SP) and on disability pensions (DP).

The data from Finnish Longitudinal Study on Aging Municipal Employees (FLAME) was used in the study. A total of 6257 (response rate 85%) public sector employees aged 44-58 years from various Finnish municipalities participated in the FLAME study in 1981. They were followed up for the next 28 years at four different time points in 1985 (N=5,556), 1992 (N=4,534), 1997 (N=3,815) and in the year 2009 (N=3,093). The exposures used in this study were from baseline and the outcomes were mostly from the last follow-up. All survey waves were considered to investigate the developmental pathways of MLs. The detailed job analysis and job demand control concept (Karasek model) was used to formulate the exposures and international classification of functioning (ICF) by the World Health Organization (WHO) and ADL and IADL items (Katz model) were used to construct the outcomes. The unique personal identification number was used to link the national pension and mortality registers with the survey data. The association of work-related exposures with MSDS and MLs was investigated using binary and multinomial regression and the developmental pathways of MLs were identified using latent class analysis through growth mixture modelling. The negative binomial regression was used to quantify the association of work-related exposures and disability in later life and joint effects of the exposures were quantified by calculating relative excessive risk due to interaction (RERI).

The higher the level of work-related biomechanical exposure and job strain the higher was the risk of back and degenerative MSDs among both women and men. The interaction of high job strain and high biomechanical exposures also predicted MSDs among both genders mostly around and after retirement, but not in old age. The presence of statistical interactions among the exposures served to increase the risk of back and degenerative MSDs after retirement. Similarly, four trajectories of MLs, namely low persistent, low increasing, high decreasing and high persistent were identified. Shift work with night shifts characterized increased risk of high persistent MLs among the SP recipients. Being physically inactive likewise appeared to contribute to increased risk of high persistent MLs among both SP and DP recipients. Job profile in midlife with higher musculoskeletal load strongly predicted the severity of ADL disability in later life among both genders. Physically less demanding office job profile among women and technical

supervision among men were also a high risk group for increased severity of disability. Furthermore, the increased severity of disability in later life was associated with high biomechanical and high job strain exposure in midlife among both genders.

In conclusion, the level of work-related exposures and their interactions in midlife strongly predict musculoskeletal diseases, mobility limitations and disability in old age among both women and men. The effect of the interaction of two co-occurring work related exposures is equally important to consider when people are still in their working life. The work place could also serve as an arena to prevent and reduce the deterioration of musculoskeletal health in later life. There is still a need for more evidence from intervention studies to establish the causal inference in such associations.

Key Words: Work, Musculoskeletal health, work-related exposures, work schedule, musculoskeletal diseases, ADL/ IADL, mobility limitations, disability, longitudinal study, occupational epidemiology

Tiivistelmä

Aikuisiän työperäisillä altistuksilla voi olla pitkäaikaisia vaikutuksia ja ne voivat näin ollen lisätä tuki- ja liikuntaelinten sairauksien riskiä, mikä puolestaan johtaa liikkuvuuden vähenemiseen ja tästä seuraavaan merkittävään fyysiseen vammautumiseen myöhemmällä iällä. Maailmanlaajuisesti on tarjolla yhtenevää tutkimustietoa työhön liittyvien vaarojen ja altistusten haitallisista vaikutuksista työntekijöiden kokonaisterveydentilalle. Tästä huolimatta tutkimustietoa keski-iän altistusten vaikutuksista vanhuuden ajan terveydelle on rajallisesti. Lisäksi on olennaisen tärkeää tunnistaa nämä vaikutukset kansanterveyden näkökulmasta johtuen maailmanlaajuisesta väestön vanhenemisesta. Riittävää arjen toimintakykyä tarvitaan itsenäiseen elämään vanhuudessa ja siihen kuuluvia toimintoja voivat haitata tuki- ja liikuntaelinten sairaudet ja fyysiset rajoitteet, jotka liittyvät työperäisiin altistuksiin. Yleisesti ottaen tuki- ja liikuntaelinten terveyden rappeutuminen saa aikaan arjen perus- ja olennaisten toimien rajoitteita ja näin aiheuttaa valtavan maailmanlaajuisen sosioekonomisen rasitteen. Tämän väitöksen tarkoitus oli tutkia yhteyksiä keski-iän työperäisten altistusten ja vanhuuden tuki-ja liikuntaelinsairauksien, liikunta- ja toimintarajoitteisuuden välillä hyödyntäen pitkittäistutkimusta, joka seurasi suomalaisia kuntatyöntekijöitä lähes kolmen vuosikymmenen ajan. Altistuksista käytettiin tässä tutkimuksessa työn koettua kuormittavuutta, tuki- ja liikuntaelinten (biomekaanista) kuormitusta, vuorotyötä sekä yksityiskohtaista keski-iän työkuvausta ja lopputulemat suhteutettiin tuki- ja liikuntaelinten terveyteen, kuten tuki- ja liikuntaelinsairauksiin, liikunta- ja toimintarajoitteisiin. Erillisvaikutusten lisäksi tutkittiin erilaisten työperäisten altistusten yhteisvaikutuksia tuki-ja liikuntaelinsairauksien vammautuneisuuteen. Tämän lisäksi tarkasteltiin liikuntarajoitteiden kehitystä erikseen lakisääteistä vanhuuseläkettä ja työkyvyttömyyseläkettä nauttivien kohdalla.

Tutkimusaineistona käytettiin FLAME pitkittäistutkimusta kunnallisista työntekijöistä Suomessa. Yhteensä 6257 (vastausaste 85%) julkisen sektorin 44-58-vuotiasta työntekijää useista Suomen kunnista osallistui FLAME-kyselyyn vuonna 1981. Heitä seurattiin 28 vuoden ajan neljänä eri ajankohtana, vuosina 1985 (N=5556), 1992 (N=4534), 1997 (N=3815) ja vuonna 2009 (N=3093). Tässä tutkimuksessa käytetyt työn altistukset ovat peräisin lähtötilanteesta vuonna 1981 ja tulokset suurimmalta osin seurannasta. Kaikki tutkimusaallot huomioitiin, jotta voitiin tutkia liikuntarajoitteiden kehityspolkuja. Yksityiskohtaista työanalyysia ja työn vaatimuksen ja hallinnan käsitettä (Karasekin malli) käyttäen muodostettiin altistukset. Maailman terveysjärjestö WHO:n kansainvälistä toimintakyvyn, toimintarajoitteiden ja terveyden luokitusta (*ICF*) sekä ADL- ja IADL-mittareita (Katzin indeksi) käytettiin muodostettaessa tuloksia. Henkilöturvatunnusten avulla linkitettiin tutkimusaineistokansaneläke- ja kuolin rekistereihin. Työperäisten altistusten yhteyttä tuki- ja liikuntaelinsairauksiin ja liikuntarajoitteisiin tutkittiin käyttäen binääristä- ja multinomiaalista logistista regressiota ja liikuntarajoitteiden kehityspolut tunnistettiin käyttäen latenttia luokka-analyysia kasvukäyrämallinnuksen (GMM) kautta. Negatiivista binomista regressiota käytettiin mittaamaan yhteyttä työperäisten altistusten ja vanhuuden toimintarajoitteisuuden välillä. Altistusten yhteisvaikutuksia mitattiin laskemalla yhteisvaikutuksesta johtuva suhteellinen lisäriski (RERI).

Mitä korkeampi oli biomekaanisen työperäisen altistuksen ja työrasituksen aste, sitä korkeampi oli selän ja rappeuttavien tuki- ja liikuntaelinsairauksien riski sekä miehillä että naisilla. Myös korkeat työkuormituksen ja biomekaanisen altistuksen tasot ennustivat tuki- ja liikuntaelinsairauksia molemmilla sukupuolilla useimmiten lähellä eläkeikää tai sen jälkeen, mutta eivät vanhemmalla iällä. Korkean koetun kuormittavuuden ja korkean biomekaanisen kuormituksen tilastollinen yhdysvaikutus lisäsi selän ja rappeuttavien tuki- ja liikuntaelinsairauksien riskiä eläkkeelle jäämisen jälkeen. Vastaavasti tunnistettiin neljä liikuntarajoitteiden kehityskaarta, tarkemmin sanoen matala pysyvä), matala nouseva, korkea nouseva ja korkea pysyvä. Iltapainotteinen vuorotyö luonnehti korkean jatkuvan kehityskaaren liikuntarajoitteiden kohonnutta riskiä vanhuuseläkettä nauttivien keskuudessa. Vähäinen liikunnan määrä niin ikään vaikutti lisäävän korkean kehityskaaren tuki- ja liikuntaelinsairauksien riskiä sekä vanhuus- että työkyvyttömyyseläkettä nauttivien keskuudessa. Keski-iän työprofiili, jota luonnehti suurempi tuki- ja liikuntaelimiin kohdistuva rasitus ennusti vahvasti arjen toimien rajoitteisuutta myöhemmällä iällä kummallakin sukupuolella. Lisääntyneen toimintarajoittuneisuuden korkean riskin ryhmään kuuluivat myös työprofiilit, joita naisilla luonnehti fyysisesti vähemmän vaativa toimistotyö ja miehillä esimiestyö teknisissä ammateissa. Lisäksi lisääntynyt toimintarajoitteisuus myöhemmällä iällä oli yhteydessä keski-iän korkean biomekaanisen- ja työkuormitusaltistuksen kanssa kummallakin sukupuolella.

Päätelmänä voidaan todeta, että työperäisten altistusten taso ja altistusten yhteisvaikutukset keski-iässä ennustavat vahvasti tuki- ja liikuntaelinsairauksia, liikunta– ja toimintarajoitteisuutta vanhuudessa, sekä miehillä että naisilla. Kahden samanaikaisen työperäisen altistuksen yhteisvaikutus on niin ikään tärkeää huomioida ihmisten ollessa yhä työelämässä. Työpaikka voisi myös toimia myöhemmän elämän tuki- ja liikuntaelinterveyden rappeutumisen vähentämisen ja ehkäisemisen areenana. Tarvitaan edelleen lisää näyttöä seurantatutkimuksista, jotta kyseisten yhteyksien syy-seurauspäätelmät voidaan todentaa.

Avainsanat: työ; tuki- ja liikuntaelinten terveys; työperäiset altistukset; tuki- ja liikuntaelinsairaudet; liikuntarajoitteet; toimintarajoitteet; pitkittäistutkimus; työepidemiologia

Abbreviations

ADL	Activities of Daily Living
AET	Arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitanalyse
AIC	Akaike Information Criterion
ANOVA	Analysis of Variance
BIC	Bayesian Information Criterion
BMI	Body Mass Index
CCOSH	Canadian Centre for Occupational Health and Safety
CI	Confidence Interval
DALYs	Disability-Adjusted Life Years
DP	Disability Pension
FIOH	Finnish Institute of Occupational Health
FLAME	Finnish Longitudinal study on Aging Municipal Employees
GAZEL	Gaz et Électricité
GBD	Global Burden of Disease
GMM	Growth Mixture Modelling
HALE	Healthy Life Expectancy
ICF	International Classification of Functioning, disability and health
ICIDH	International Classification of Impairments, Disabilities, and Handicaps
ILO	International Labour Organization
IOM	Institute of Medicine
IOSH	Institute of Occupational Safety and Health
IADL	Instrumental Activities of Daily Living
IRR	Incidence Rate Ratio
LBP	Low Back Pain
LMR	Leo-Mendell-Rubin
LTPA	Leisure Time Physical Activities
MLs	Mobility Limitations
MSDs	Musculoskeletal Diseases
OR	Odds Ratio
PR	Prevalence Proportion Ratio

RERI	Relative Excessive Risk due to Interaction
RR	Risk Ratio
SP	Statutory Pension
WAI	Work Ability Index
YLD	Years Lived with Disability

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II. Prakash, K. C., Neupane, S., Leino-Arjas, P., Härmä, M., von Bonsdorff, M. B., Rantanen, T., von Bonsdorff, M. E., Hinrichs, T., Seitsamo, J., Ilmarinen, J., & Nygård, C-H. (2017). Trajectories of mobility limitations over 24 years and their characterization by shift work/work schedules and leisure time physical activity in midlife. *(Submitted)*

III. Prakash, K. C., Neupane, S., Leino-Arjas, P., von Bonsdorff, M. B., Rantanen, T., von Bonsdorff, M. E., Seitsamo, J., Ilmarinen, J., Nygård, C-H. (2017). Work-related biomechanical exposure and job strain as separate and joint predictors of musculoskeletal diseases: A 28-year prospective follow-up study. *Am J Epidemiol*, 186(11), 1256–1267.

IV. Prakash, K. C., Neupane, S., Leino-Arjas, P., von Bonsdorff, M. B., Rantanen, T., von Bonsdorff, M. E., Seitsamo, J., Ilmarinen, J., & Nygård, C-H. (2017). Work-related biomechanical exposure and job strain in midlife separately and jointly predict disability after 28 years: results from Finnish Longitudinal study on Aging Municipal Employees (FLAME). *Scand J Work Environ Health,* 43(5), 405–414.

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1 Introduction

Musculoskeletal diseases (MSDs) are one of the most common causes of disability around the globe, neck pain and low back pain (LBP) being the key contributors. There is a swift rise in the prevalence of MSDs coinciding with the larger proportion (21.3%) of years lived with disability (YLDs) worldwide and there is an elevation in rates of YLDs due to MSDs with increasing age (Murray et al., 2013; Murray et al., 2015). In Finland, 13% of the total retirement in 2016 was accounted for partial disability pensions. The diseases of the musculoskeletal system coincided with 27% of those disability retirements and was the second leading factor followed by behavioural disorders (Statistics Finland, 2017). MSDs account for a huge proportion in the global burden of disease with an increase in the old aged population. Musculoskeletal disorders are the most common disorders associated with loss of physical functioning and progressing to physical disability. Disorders in musculoskeletal health comprise more than 150 diseases of the upper and lower extremities (WHO, 2003).

Epidemiological investigations reveal a trend toward a swift rise of MSDs in every parts of the world. There is a need for some lifestyle interventions and preventive strategies during the earlier period of life as many midlife factors such as work and lifestyle related factors are associated with MSDs (Mody & Brooks, 2012). Earlier detection and management of MSDs could play a vital role in maintaining the health of an aging population by markedly reducing the global burden of MSDs. A holistic public health approach is needed to prevent the MSDs and ultimately promote lifelong musculoskeletal health (Leveille, 2004) and in addition alleviate the huge economic burden on society (Clark & Ellis, 2014). Hence, prevention of the MSDs should be started during working life as most of these MSDs (LBP, neck pain, osteoarthritis etc.) start to accumulate through midlife and are associated with work and work-related exposures (Eriksen, Bruusgaard & Knardahl, 2004; Nordander et al., 2009; Ahacic & Kåreholt, 2010; da Costa & Viera, 2010; Wahrendorf et al., 2012; Taylor et al., 2014).

The wide ranges of occupational factors such as heavy work load and high physical exposures during midlife are harmful to musculoskeletal health, and may result in different types of MSDs and ultimately impair musculoskeletal aging. In addition, pain and MSDs lead to mobility limitations (MLs) that could ultimately end up as or prominently predict physical disabilities in old age (Guralnik et al., 1995; Fried & Guralnik. 1997; Guralnik et al., 2000; Fried et al., 2001; Heiland et al., 2016). Similarly, most such mobility decline resulted by deteriorated musculoskeletal health could possibly end up as preclinical physical disability (Fried et al., 2001). The same applies to the rise in the prevalence of MSDs with increasing age has a negative effect on people's working life, making working lives shorter in many localities (March et al., 2014). Work disability is an integral facet in understanding disability. One should clearly describe it as a vital sub-dimension, while explaining the concepts of progression and onset of disability (Verbrugge & Jette, 1994). Disability could be described in terms of one's ability for environmental accommodation of an impairment, which could be clarified, by the fact that two individuals with the same kind of impairment may not be similarly disabled or share the same perception of the impairment (Mathiowetz, 2000). The disabilities related to work are regarded as the output of the combination of societal, environmental and individual causes and this multifactorial aetiology makes the concept of work-related disability a broad phenomenon with broader spectrums of related factors (Ilmarinen, 2006; Ilmarinen et al., 2008). Likewise, it is vital to perform activities of daily living (ADL) without any difficulties in order to sustain independent living in old age. In order to tackle the challenges resulting from the growing number of population with disabilities, more needs to be known about the potentially modifiable determinants of the variation in ADL disability in old age (Maenner et al., 2013). The relationship between low socio-economic position and ADL disability is evident (Picavet & Hoeymans, 2002) and there is need to investigate other related causes. Promoting work ability is crucial to prevent disability (Tuomi et al., 2001). A holistic approach is significant in promoting work ability, and should comprise a package of factors related to work and working, the external environment and the resources of the individual (Ilmarinen, 2006). Working life studies have additionally reported a need to assess the impact of work-related factors in later life, especially around retirement and after retirement in old age. Moreover, work-related studies have separately addressed working life and life in old age after retirement and there are very few longitudinal studies on these areas (Westerlund et al., 2009).

The present study was inspired by the gaps in the research so far on the association of midlife work exposures and old age health outcomes (such as MSDs, MLs and disability) and the inherent glitches in the attempts to fill them. Therefore there was a need for further exploration using longitudinal evidence to ascertain the possible effects of midlife work exposures so as to reduce and prevent future MSDs, MLs and disability in society. This study aimed to investigate how work-related exposures (job profiles, shift work, biomechanical and psychosocial) in midlife predict MSDs, MLs and disability in old age among the Finnish municipal employees using a long follow-up of almost three decades.

2 Literature review

2.1 Conceptual framework

This study is based on the perspectives of the disablement process shown in the conceptual framework in **Figure 1,** which is partly adapted from Verbrugge & Jette (1994). The model conceptualizes the fact that the onset of disability initiates in midlife due to several demographic, socio-economic and intra-individual life style factors. The conceptual framework is almost parallel to that of Nagi (1965) and also WHO (1980). The WHO framework on the international classification of impairments, disabilities, and handicaps (ICIDH) and the Nagi disablement model coincide on their concepts of disability and its consequences. Furthermore, in this study work-related factors are emphasized as the vitally associated ones (Nagi, 1965; WHO, 1980). In addition, socio-economic, demographic and life style factors are inseparable in the study of the association of midlife factors with later life outcomes. Most of these factors were considered as confounders masking the association between exposure and outcome.

The occupations carried out in midlife, be they white collar, upper blue collar or blue collar, all involve the risk of being exposed to physical, biomechanical, job strain (psychosocial), and other work schedule related exposures. However, the extent of these exposure depends particularly on the nature of the job done, which was investigated through the very first objective in terms of musculoskeletal load and other kind of loads in thirteen different job profiles (cluster of 88 different municipal occupations) and their predictability for disability in old age. Work schedules (termed shift work in this study) were used in the second objective along with leisure time physical activity (LTPA) as the predictors of mobility limitations (MLs) in later life. The job demand-control concept was used to derive work-related psychosocial exposure used in the third and the fourth objective. The association of biomechanical exposures in midlife with musculoskeletal diseases (MSDs) and disability in old age was likewise checked respectively in the third and the fourth objectives.

In the main pathway of the disablement process, MSDs come first, followed by MLs and disability (depending upon the severity/degree of deterioration of musculoskeletal health).

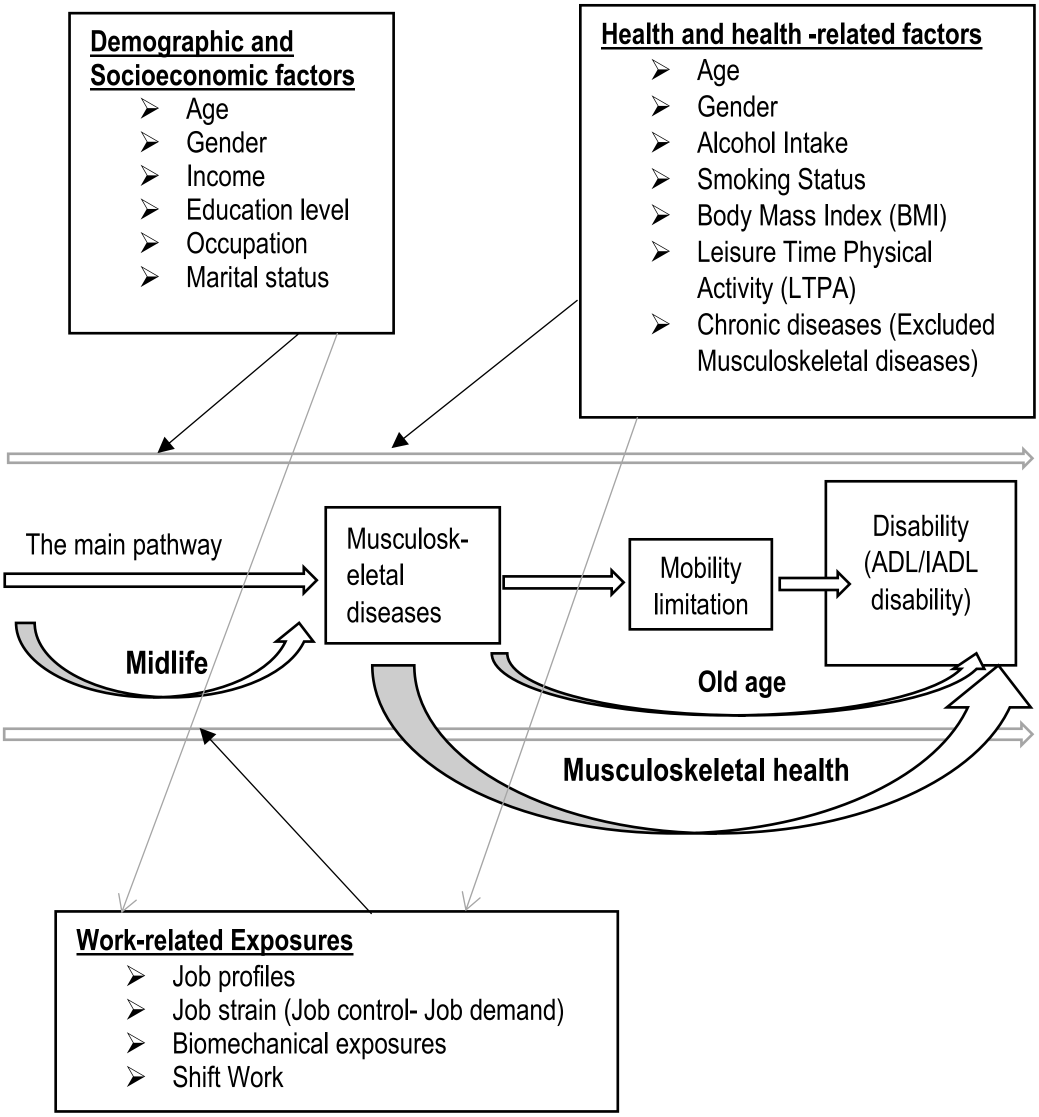

Figure 1: The disablement process from midlife to old age, partly adapted and modified from Verbrugge & Jette, (1994)

2.2 Concepts and definitions

2.2.1 Musculoskeletal Diseases

The conditions that affect muscles, nerves and tendons along with the supportive structure of the body like the discs on the back could be termed musculoskeletal diseases (MSDs). The most prominent MSDs are low back disorders, arthritis and other joint related disorders. MSDs are mostly associated with adverse working conditions and environments (CCOHS, 2017; IOSH, 2017). MSDs are highly prevalent among general population (Woolf & Pfleger, 2003; Palazzo, et al., 2014) and are regarded as a cause of suffering among working populations with a higher prevalence among older workers (Tsang et al., 2008; Halderman, Carroll & Cassidy, 2010). Furthermore, MSDs could be attributed to multisite musculoskeletal pain (MSP) in the body. Pain, ache or discomfort with unpleasant sensory and emotional experience that occurs with or without the presence of actual or potential tissue damage in multiple anatomical sites of the body is regarded as MSP (Wolfe et al., 1990). Additionally MSP may occur with chronic widespread pain in the axial skeleton on left and right, above and below the waist. MSP is reported to be very common among working population and general population and is associated with decline in work ability (Neupane, et al. 2011; Haukka et al., 2015) and may lead to medically certified disability retirement (Haukka, et al. 2015). Previous studies have also reported that the higher the number of pain sites in the body the higher was the likelihood of deterioration in work ability in future and possible musculoskeletal disability (Neupane et al., 2011; Haukka et al., 2015). Likewise, a recent study on developmental pathways of MSP among food industry workers in Finland by Neupane, et al., (2017) reported that 29% of the employees had persistent MSP and this was mostly associated with adverse working conditions. The aetiology of MSDs has many complexities due to the significant masking of day-to-day activities, life style related factors and several sociodemographic and health related conditions (Bugajska et al., 2013).

The burden of MSDs is common problem in developing and developed parts of the world (Murray et al., 2012). A study in France among a whole non-institutionalized population reported MSDs to be highly prevalent (27.7%) amounting to 17.3 million people. Low back pain was highly prevalent (12.5%), followed by osteoarthritis (12.3%) among the middle aged population (Palazzo et al., 2014). Likewise, a study on construction workers in the United States reported them to be at the higher risk group of work-related MSDs and that 40% of those MSDs were due to back related injuries among the workers (Wang et al., 2017) and the rate of MSDs due to construction work was less among the people aged 65 and above than among their younger counterparts. Similarly, a cross-sectional study among rubber tappers in Sri Lanka reported that around 66% of the respondents had experienced MSDs (Stankevitz et al., 2016). The same study reported that back related problems were highly prevalent among rubber tappers. Likewise, a cross-sectional study among sonographers in China reported 12-month period prevalence of 98.3% for MSDs among the respondents (Feng et al., 2016) and neck disorders had the highest prevalence among the sonographers. In contrast, a study in Canada reported a decline in non-traumatic MSDs throughout the past decade (Mustard et al., 2015). Nonetheless, WHO has reported that deterioration in musculoskeletal health encompasses more than 150 MSDs in the extremities that could lead to lifelong disability (WHO, 2003). Therefore, the prevention of MSDs is better than curing lifelong limitations in musculoskeletal health.

2.2.2 Mobility limitations

The key components of mobility are the bodily functions related to the physical capacity of an individual such as moving around, using transportation, walking, using stairs, changing and maintaining body positions along with moving, handling and carrying objects. The difficulties and limitations in adequately performing these mobility tasks could be considered to be mobility limitations (WHO, 2001) and are the most prominent cause of disablement among old people (Guralnik et al., 1993; Brown & Flood, 2013; Hinirichs et al., 2014; Heiland et al., 2016). Both women and men have an increased risk of MLs with increasing age and the number of chronic conditions diagnosed in midlife (Guralnik et al., 1993) which are mostly due to MSDs and are often work-related. An objective assessment of mobility functions among 1,122 subjects by Guralnik and colleagues (1995) showed that those who had poor mobility functions were highly likely to have disability compared to those with good mobility (Guralnik et al., 1995). Likewise, another study by Guralnik and colleagues (2000) was able to replicate the findings by re-establishing the association of mobility functions of the lower extremities and incident disability. Mobility functions were regarded as precise predictors of disability in old age among a variety of populations (Guralnik et al., 2000).

Numerous risk factors of MLs, behavioural, environmental, lifestyle-related and socio-economic (Guralnik et al., 1993; Shumway-Cook et al., 2005; von Bonsdorff et al., 2006; Brown & Flood, 2013) start to accumulate from midlife, but there is limited evidence on the association of MLs and work-related exposures in midlife. Work history plays an important role in the process of disablement (Verbrugge & Jette, 1994), therefore, it is crucial to investigate the link between midlife work-related exposures and later life MLs. Occupations entailing high physical activity and high physical demands (Hinrichs et al., 2014), and higher work-related stress (Kulmala et al., 2014) in midlife carry higher risk of MLs in old age. Likewise, poor work ability in midlife is also associated with increased MLs in old age (von Bonsdorff et al., 2016).

2.2.3 Disability

Several definitions of disability have been proposed and most of them describe disability as a consequence of a health related condition on the body, activities and participation of a person in general. The international classification of functioning, disability and health (ICF) framework of the World Health Organization (WHO) has been endorsed by Jette (2006) as a standard model for disability. The author states that the model is fit for common disablement language as it focuses on how people survive with their conditions beyond chronic diseases (Jette, 2006). However, Schuntermann (2005) has reported the international classification of impairments, disabilities and handicaps

(ICIDH) framework as more popular and helpful than the ICF, giving as a reason that the ICF models are comprised of neutral terms only. Likewise, Masala & Petretto (2008) indicated that the ICF model is preferable to other contemporary conceptual models of disability, but they have recommended re-considerations of the ICF model regarding the aspects of rehabilitation and the process of enablement. In addition, Masala & Petretto (2008) have reported that a complete model should have all three dimensions namely; environment, individual and interaction between environment and individual, which they suggest, are provided in Nagi's 1991 model of disability and Brandt and Pope's Institute of Medicine model of 1997.

The level of difficulty in performing activities of daily living (ADL) and instrumental activities of daily living (IADL) is often used to assess disability (Katz, 1983). Adequate performance and functioning of ADL and IADL is crucial for independent living throughout life (Tas et al., 2007; Chan et al., 2012; Maenner et al., 2013). *"Disability is the expression of a physical or a mental limitation in a social context"* as it is explained in the sociologist Saad Nagi's theory of disability (Nagi, 1965). Disability is often considered as a vital adverse health outcome related to aging (Fried & Guralnik, 1997). The severity of disability in later life or old age mostly depends on various factors related to midlife. The severity depends mostly on personal level or behavioural risk factors. Most of the risk factors start to accumulate at a young age. Socioeconomic differences, differences in immunity on a personal level and the most important ones are work-related factors, as most of the changes start to manifest during midlife. If we want to understand these changes and meet the needs of people at this age, research among the elderly is warranted (The Lancet editorial, 1993). The current body of literature includes ample proof of an association of midlife socioeconomic position (Picavet & Hoeymans, 2002), lifestyle factors (Backholer et al., 2012; Klijs, Mackenbach, & Kunst, 2012; Tak et al., 2013; Van Oyen et al., 2014) and other health related conditions (Hung et al., 2012) with disability in later life. In addition, most of these personal factors play a vital role in the onset of disability from middle to old age (Kuh et al., 2014).

Disability occurs due to a loss of balance between the demands posed by the physical environment and one's physical capabilities to cope those demands (Nagi, 1965; Institute of Medicine, 1997; Schillerstrom, Royall, & Palmer, 2008). MSDs are reported to be the major cause of MLS and disability in general (Badley, Webster, & Rasooly, 1995; Melhorn, 1998; Guralnik et al., 2000; Fried et al., 2001; Escorpizo, 2014; Heiland et al., 2016). Likewise, the earlier research has also reported a higher likelihood of IADL impairment among individuals with low back pain (Di Iorio et al., 2007) and of ADL impairment among those with arthritis (Covinsky et al., 2008). Furthermore, the mobility functions that are limited (MLs) due to inadequate physical functionings of the body (mostly pain and MSDs) are the most prominent predictors of disability in old age (Guralnik et al., 1995; Fried & Gurlanik. 1997; Guralnik et al., 2000; Fried et al., 2001; Palazzo et al., 2014 ; Heiland et al., 2016). Therefore, *theoretically MSDs result in MLs that end up as disability in old age*.

2.2.4 Job-profile

The AET method analyses physical, psychosocial and mental demands at work through the detailed job analysis of different individual job titles. The matched titles come together in a profile through cluster analysis and that profile is known as job profile (Landau, Luczak, & Rohmert, 1976; Rohmert & Landau, 1983). The method is used to describe work exposure for different occupations internationally, and has been used, for example, by Ilmarinen, et al., (1991) in their study to describe work load and exposures among Finnish municipal employees. The detailed job and cluster analysis from several occupational titles resulted in 13 different job profiles in that study (Ilmarinen et al., 1991).

In job analysis, items like work demands (perception, decision-making, education and physical load), work tasks, and work system (work objects, equipment and environment) were used and coded from zero to five (0-5) depending upon their frequency and duration. The names of the emerging 13-job profile groups along with their respective stress factors are presented in **Table 1**.

Table 1: Work-related exposures and conditions used for AET analysis to generate 13 profile groups (adapted from Ilmarinen, et al., 1991)

Job profile groups	Stress factors (exposures and conditions)
Auxiliary	Poor work postures, dynamic muscle work, proprioceptive information input, climatic conditions, dangerous environment
Installation	Coordinated body movements, strength in dynamic and static work, sensory perception
Home care	Dynamic muscle work, use of strength in dynamic and static work, possible conflicts with patients, responsibility for safety
Transport	Visual information, accuracy, coordination of body movements, static muscle work
Dump	Walking, outdoor environment (dirty and wet), climate
Office	Accuracy, visual information, need for knowledge, static muscle work
Nursing	Dynamic muscle work (walking), working postures, accuracy in information input, complex and time-pressured decision-making
Technical supervision	Contacts with subordinates, need for special knowledge, decision-making, visual perception
Kitchen supervision	Information input and processing (smell, taste), contacts with subordinates, time-pressured decision-making
Dentist	Visual reception of information, contacts with subordinates, co-ordination of body movements, complex decision-making, responsibility for patients
Physician	Complex and time-pressured decision making, accuracy in sensory perception, contacts with colleagues, demands for professional training
Teaching	Responsibility for and contacts with pupils, complex decision-making, advanced professional training
Administrative	Processing of information, complex and time-pressured decision-making, accuracy, social environment

2.2.5 Biomechanical exposure

The study of the effects on the body, tissues and fluids due to forces generated within the body and forces acting externally on the body could be generally called biomechanics. The exposure of the body to external physical stressors like force, motion, vibration and overall physical loads is known as biomechanical exposure when considering work-related external exposures. Kinetic, kinematic and oscillatory measurements are used to measure the extent of the exposure in an objective way. There is a biomechanical pathway in the onset of MSDs due to occupational physical demands. The key to the concept is when an individual is exposed to external physical loading that the tolerance of that load mechanically with appropriate physiological response avoids any impact on musculoskeletal health. However, if the body fails to tolerate it then the load may impair the musculoskeletal health of the individual resulting in pain in the extremities, which, in turn may progress to MSDs and impairments depending upon the extent (magnitude), repetition and duration of the exposure. The biomechanical model is shown in detail in **Figure 2.** The specific metrics that are quantifiable and informative in the context of biomechanical properties are specifically required to understand biomechanical loading due to occupational exposures and their association with musculoskeletal health. (National Research Council & Institute of Medicine, 2001)

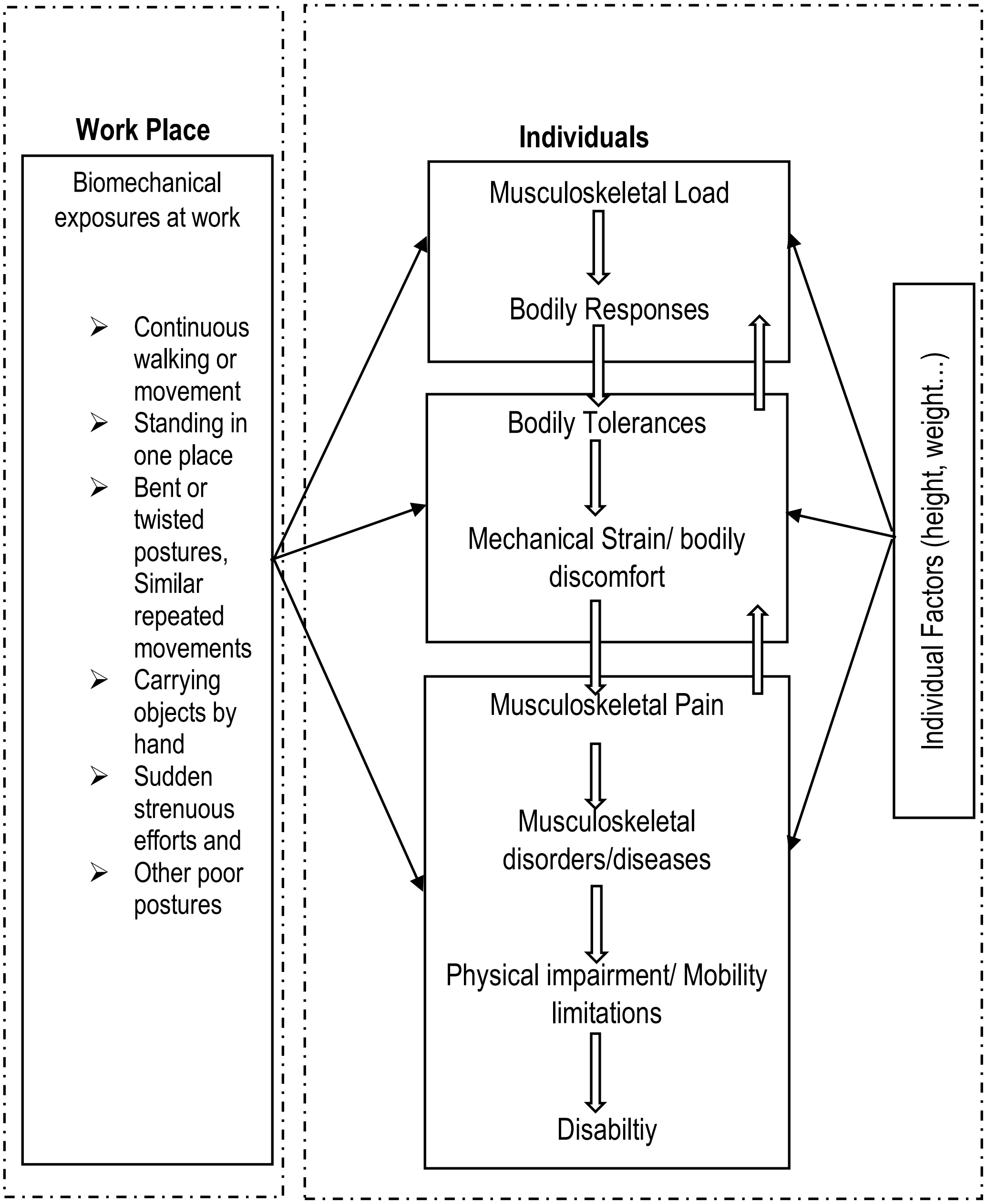

Figure 2: Biomechanical exposure and outcomes (partly adapted and modified from the National Research Council & Institute of Medicine, 2001)

2.2.6 Job strain

We adapted Karasek's concept on job demands and controls to construct the job strain model which is shown in **Figure 3**. Job strain is defined in four categories:- if subjects are exposed to high demand and low control at work they are deemed to have high job strain or higher degree of psychosocial exposures. Likewise, low demands and high control are regarded as low strain (group relieved from psychological distress) and low control/low demand as the passive and high control/high demands as the active group. The job demand control model uses more focused and multi-faceted concepts of both job control and job demands in order to make the concepts from the model more suitable and significant to the occupational settings of today's world. Karasek's model theorizes and emphasizes the idea that control over individuals' working environments plays a crucial role in determining their health. Furthermore, this may also play a significant role in determining one's learning capabilities and active behaviour. The job strain hypothesis suggests that a combination of lack of control and high demands in the job could play a negative role in terms of workers' health status and such a combination was termed as high strain. Likewise, the jobs where the worker has high control, but the demand is also higher could somehow help the workers in dealing with and facing the existing and upcoming challenges at work and such phenomena were termed active jobs. In addition, it provides the space for actively learning and mastering new ideas at work and will help in upgrading self-efficacy at work. Likewise, when someone has relatively low control and lower demand at work there is passivity towards new learning and inability to actively participate in decision-making and mastering the ideas. However, these jobs involve less strain and workers may feel much relief. Such a combination was theorized to be a passive job in the job demand control model. Furthermore, the model suggests that having high control and similarly low demands at work could provide the worker with active learning opportunities, actively meeting the challenges, higher-decision making context, low pressure at work and controlling one's own work environment. In addition, these combinations could provide a wider and better context for a worker in terms of health and wellbeing and this was termed low strain in the job strain hypothesis (Karasek, 1979; Karasek & Theorell 1990). Occupations such as those of natural scientists, architect, foreman, etc., fall into the low strain category. Nurse, clerk, bank employee, farmer, physician etc., fall into the active category and watchman, janitor, miner, dispatcher, etc., fall into the passive category followed by keypuncher, gas station attendant, waitress, nurse's aides, etc., who fall into the group with high strain. (Karasek & Theorell 1990).

A recent study by Santos, et al. 2017 used the latent class model in order to investigate the dimensional structure of the job content questionnaire in different occupational profiles and confirmed the adequacy of the instrument. The four job types namely low strain, passive, active and high strain, projected by the job strain model using the job content questionnaire were derived from among the workers in the petroleum industry along with those working in healthcare. The authors were able to identify the most pertinent items of job content scale for job profile groups such as urban workers, teachers, petroleum workers and healthcare workers and the use of the latent class model made the task more feasible in the study (Santos et al., 2017).

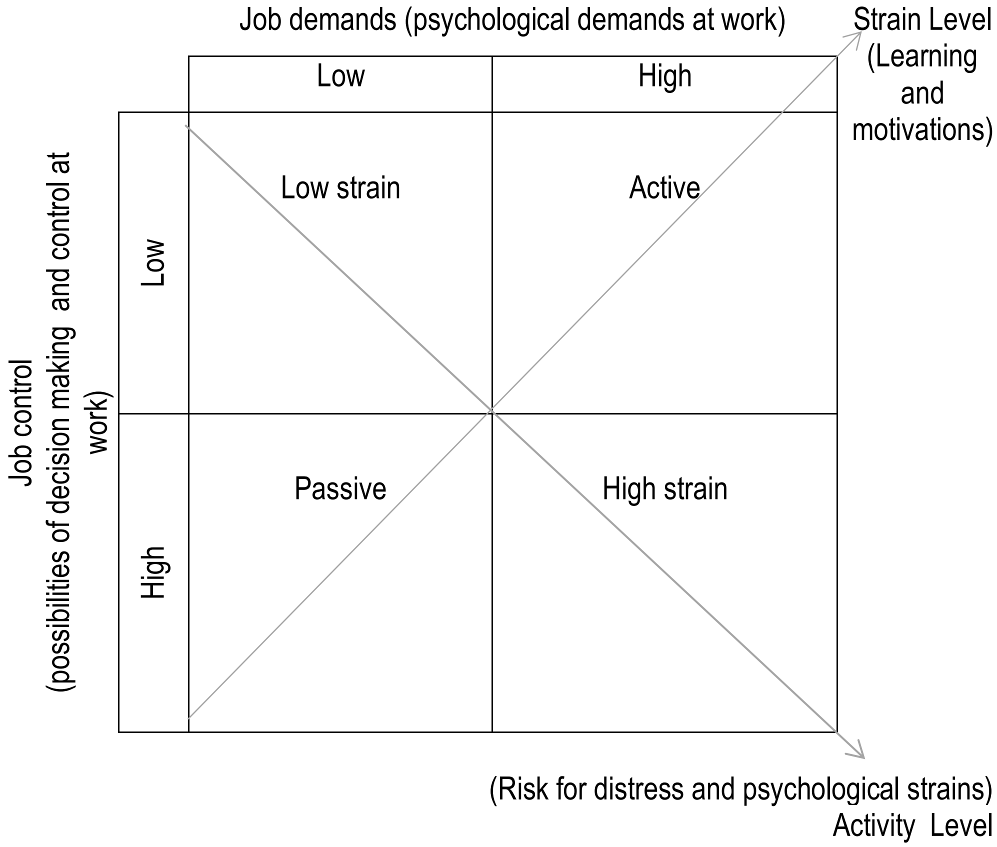

Figure 3: Job demand-control concept (Karasek model, Adapted from: Karasek, 1979)

2.2.7 Shift work

A method of organizing the working hours in a workplace in which one worker succeeds another in order to continue operations for longer hours than the time allocated for individual workers can be regarded as shift work (ILO, 2004). There are distinctive types of shift work namely rotating and fixed shift systems. In rotating shifts, the working shifts rotate around the clock and often vary with time. However, the fixed shift is involves three shifts, namely early (morning early afternoon), late/evening (late afternoon and evening) and night shifts (during night time). (ILO, 2004)

The work schedule has five key components which are the format of the shift schedule (rotating or fixed), length of shift, work patterns (on-off), policies on shift schedules and overtime (Shiftwork Solutions, 2017). Occupational classes like transportation, mining and blue-collar manufacturing are often understood to be shift workers, but the workers in occupational sectors such as hospitals, emergency response services, monitoring and support centres, hotels, casinos and utilities may also be the shift-workers, depending on the requirements of the organizations. In addition, there is a rising trend for extended operating hours around the globe (Shiftwork Solutions, 2017).

2.3 Midlife job profiles and disability

Occupational physical activity being an inseparable part of the day-to-day life of most adults plays a crucial role throughout life, but studies on the association of detailed occupational loading and disability in later life are limited. Earlier studies have used occupational titles and specific occupations as exposures of interest. There is a need of detailed job analysis of different occupational tasks, which should give a clearer picture of the effects of physical load. A nested case-control study conducted in Taiwan by Li et al. (2000) among 2,198 subjects investigated the association between longest held occupation and disability in later life and resulted in a significantly higher risk of disability among agricultural, forestry, crafts and animal husbandry workers. In addition, other unskilled blue-collar workers were also highly likely to suffer from disability in later life when lifestyle, sociodemographic and other health related factors were controlled for. Similarly, McCarthy et al. (2013) in their study of 328 respondents in Ireland also found that those with disability in later life (70-80 years) had a physically demanding work history. Furthermore, manual and physical heavy work was associated with elevated rates of disability pension as it increased the burden of disability and also more years lost due to disability and more working life lost in a study among the Swedish construction workers from1980 to 2008 (Järvholm et al., 2014). The risk of labour market exit was associated with number of work-related exposures in midlife in a full-panel prospective study in Norway in which, heavy workload was predisposed to (HR 1.93, 95% CI 1.39-

2.68) disability retirement (Emberland, Nielsen, & Knardahl, 2017). Likewise, a municipality level study of 25-62 year old subjects in Finland reported the results similar to those of the aforementioned study. Disability retirement due to MSDs was highest in the municipality with the highest proportion of manual workers (Laaksonen & Gould, 2014). Likewise, women involved in manual occupations in midlife had higher likelihood of belonging to the most disabled trajectory in later life in the UK as reported by Newcastle 85+ study. However, those in managerial and less physically loading occupations were less likely to be in the least disabled trajectory in both genders. This study provides additional evidence on the association of midlife socioeconomic status and severity of disability in later life (Kingston et al., 2015).

Furthermore, a Finnish study on the employees of city of Helsinki reported that women working in a routine non-manual occupation had an increased risk (HR 2.75, 95% CI 2.56, 2.95) of disability retirement after hospitalization due to MSDs (Pietiläinen et al., 2017) . The same study further added that men in the manual occupational class had the highest risk (HR 2.40, 95% CI 2.18, 2.65) compared to others. A population based study of Swedes aged 40-70 years reported the risk of disability pension due to knee osteoarthritis among men in job sectors like construction, transportation and metalwork, which was also compared to the business/administrative job sector (Hubertsson et al., 2017). Another study by Mäntyniemi et al. (2012) with a follow up time of 4.6 years reported manual occupations as a risk factor for disability pension among both men and women. Baruth and colleagues (2013) in their randomized controlled trial of adults with arthritis reported men to be less vulnerable to major disability than women and the higher the age the higher was the likelihood of greater disability. In another cross sectional study in the USA among people aged 65 and older vigorous occupational physical activity in midlife had a deleterious effect on the performance of ADL, but the results reported indicated the protectiveness of midlife optimal level of occupational physical activities (Missikpode, Michael, & Wallace, 2016). The results reported by the aforementioned study corroborated the hazardous effects on physical functioning in later life of physically demanding occupations in midlife. Similar findings, in addition to the protective effect of midlife high level of LTPA, were reported by another study on 1,260 people aged 60-79 years (Kulmala et al., 2016). The same study further reported lower socioeconomic status in midlife was associated with later life disability rather than socioeconomic status at a young age. Another systematic review on the behavioural risk factors of midlife for different later life outcomes like disability and frailty reported largely similar findings. They reported that later life disability could be prevented by the promotion of physical activities during midlife (Lafortune et al., 2016). Furthermore, lack of LTPA, heavy drinking and smoking during midlife were found to be associated with the risk of disability in later life (cohort above 54 years) which persisted after adjusting for a possible range of covariates in the Whitehall II cohort study with a follow up of more than two decades (Artaud et al., 2016). Limitations in mobility, ADL and IADL were taken to constitute disability in that study. In a validation study of the prediction model for incident disability using two British cohorts low LTPA profoundly predicted the disability after several years (Nüesch et al., 2015). In a study on modifiable midlife risk factors for physical disability in later life among an Australian cohort, smoking was strongly associated with the risk of physical disability (OR 1.81, 95% CI 1.18-2.78) and the higher the body mass index in midlife the higher was the likelihood of being physically disabled in later life (Wong et al., 2015). Unlike most studies, a study of 1,804 Swedes aged 72 and above by Rydwik, et al. (2013), reported that occupational physical activity in midlife does not predict disability in later life. The same study reported that moderate level of occupational physical activity is protective against disability in old age.

However, the trend of limitations in ADL and IADL and difficulty in performing those physical functions was reported to be more marked in the middle aged to early old aged population and women were more prone to limitations than men (Martin & Schoeni, 2014). A systematic review investigating the risk factors for later life ADL disability among old people (≥75 years) reported higher age and female gender to be likelier to result in limitations in ADL in old age (van der Vorst et al., 2016). Similarly, age and gender significantly characterized the trajectories of limitations in ADL among older adults after the age of 60 years, and increase in age increased the ADL score and being female predicted higher ADL score in a Mexican study with 11year follow up

(Díaz-Venegas & Wong, 2016). Likewise, the likelihood of physical disability among women was higher than in men in a result reported among the Australian cohort (Wong et al., 2015). Demographic and socioeconomic factors play an independent role in the whole process of disablement. There are also many intra-individual factors playing their own part in the whole process. For instance, alcohol intake and smoking status have been found to aggravate the situation while being highly physically active during leisure time has been shown to have protective effect. Job history data and information on different work-related conditions, frequently self-reported, are valuable tools for experts in the assessment of the occupational exposures. The results of studies on the validity and consistency of self-reported instruments and techniques reveal the similarities with study types other than case-control (Teschke et al., 2002). Reducing high occupational physical activity at work among the old aged work force could raise the rate of labour force participation among them and these strategies are equally important in reducing burdens due to disability. In most of the research so far, occupational titles have been used to describe the jobs, but a person's perception of his or her work may change with the decline in functional capacities and this should be considered to avoid bias in results when the respondents are older workers. There are limited longitudinal studies on the association of later life disability with midlife occupations. Additionally, there is the lack of use of detailed job analysis.

2.4 Shift work and mobility limitations

Numerous risk factors of MLs in later life, like behavioural, environmental, lifestyle-related and socio-economic factors start to accumulate from early midlife (Guralnik et al., 1993; von Bonsdorff et al., 2006; Shumway-Cook et al., 2005; Brown & Flood, 2013), but little is known about the relationship between work-related exposure including, work-history in midlife and MLs in old age. However, the earlier studies suggest that there was an emphasis on the health of shift workers, especially those working night shifts, through services which were preventive rather than rehabilitative (Koller, 1996). Furthermore, work history, like shift work, is being recognized increasingly as a risk factor for sleep disturbances and numerous chronic diseases (Fujino et al., 2006; Virkkunen et al., 2006; Kecklund & Axelsson, 2016), as well as mortality (Jørgensen et al., 2017). There were adverse effect of night shift work on sleep that affected performance of day to day life (Åkerstedt & Wright, 2009) and shift work have been an integral part of today's working life. Sleep disturbances (Bonvanie et al., 2016) and shift work (Lipscomb et al., 2002; Takahashi et al., 2015; Del Campto et al., 2017; Kärkkäinen et al., 2017) predict musculoskeletal disorders and pain in different body sites. There was a less likelihood of disability retirement due to MSDs among employees with high work-time control than among those with low work-time control as reported by Vahtera et al. (2010) in their study of disability retirement among the Finnish employees. The night work schedule highly described the higher risk of MSDs among registered nurses (Lipscomb et al., 2002). Likewise, the adverse effects of night work schedules was reported across most of the occupational sectors (Dall'Ora et al., 2016). A prospective cohort study of Finnish public sector employees with 3.3 year follow up reported an increased risk of MSDs related work disability (HR 1.6, 95% CI 1.4-1.8) due to severe sleep disturbances (Salo et al., 2010). In a Danish study with 15 years of follow-up, shiftwork moderately predicted going on disability pension among women, but the association did not exist among men (Tüchsen, Christensen, & Lund, 2008). The HUNT-2 historical cohort study reported insomnia as a robust risk factor (OR 1.75, 95% CI 1.40-2.20) of work disability and the work schedule had some confounding effects on the association (Sivertsen et al., 2006). The findings from another study of the same cohort endorsed sleep disturbance as a more common cause for going on disability pension than other common causes like depression (Overland, Glozier, & Sivertsen, 2008).

Work schedule was reported to be associated with MSDs of upper extremities in a cross-sectional study of clerical workers in Los Angeles. This study demonstrated the need for adjustable workstations (Delp & Wang, 2013). Shift work with night shifts together with sleep problems carried an increased risk of disability due to low back pain with adjusted odds of 1.78 (95% CI 1.13-2.80) and even day work with sleep disturbance strongly predicted disabling low back pain (Takahashi, Mastudaira, & Shimazu, 2015) in a study in Japan. In a prospective study of Maastricht cohort, shift work with night shifts and irregular work schedules among old aged workers was associated with risk of future disability (Gommans et al., 2015). Furthermore, among the working population of the United States that participated in a national health and examination survey, the highest prevalence of sleep problems was found among shift workers with night shifts and the same working group were more prone to disturbed ADL (Yong, Li, & Calvert, 2017). Shift work with night shifts was not associated with low back pain among nursing home care workers, but sufficient sleep was more protective against MSDs than was short sleep (Takahashi, Iwakiri, & Sotoyama, 2009). A review by Caruso & Waters (2008) suggested a gap in methods and priorities in the research on shiftwork and MSDs (Caruso & Waters, 2008). Similarly, epidemiological evidences on the association of shift work with adverse chronic health outcomes is not consistent with their findings and are quite unmatched on the use of methods (Caruso & Waters, 2008; Härmä et al., 2015). On the other hand, the associations may be conditional and masked by confounders like lack of sleep and further examination of those pathways was warranted by a previous study (Bonvanie et al., 2016). However, we are not aware of earlier longitudinal studies examining the link between shift work and the developmental pathways of MLs in a longitudinal study with a long follow-up.

2.5 Leisure time physical activity and mobility limitations

It is well documented that being physically active in leisure-time is protective against limitations in physical functioning in later life (Leino-Arjas et al., 2004; Gretebeck et al., 2012; Hinrichs et al., 2014; Artaud et al., 2016; Portegijs et al., 2017). In a single blinded randomized trial among men and women aged 70 to 89 years in the United States, the risk of mobility disability was reduced by a physical activity programme more than by a health education programme (Pahor et al., 2014). Another study on same trial reported an established dose-response relationship between structured physical activity program and major mobility disability. More mobility disability episodes along with the onset of disability were prevented and reduced through the structured physical activity programme (Gill et al., 2016). In a study of 1,635 men and women aged 70-89 years the risk of mobility disability was reduced by the moderate level of physical activity program, however, the program did not show any response to the risk of disability in performing basic ADL. The physical activity program in that study comprised the ability of balance, flexibility, strength and walking at a moderate intensity (Manini et al., 2017). Persistent decline in leisure time physical activity predicted higher risk of disability among a cohort aged 54-84 years in the Whitehall II study that suggested that being physically active in midlife could prevent disability in later life (Artaud et al., 2016). In a study by Pinto et al. (2014) subjects involved in moderate and vigorous level of physical activity had a less chance of being disabled than did those with sedentary life styles. Likewise, lack of LTPA contributed to the characterization of trajectories of disability ranging from rapid to severe in a multi-round prospective study in the Netherlands (Nusselder, Looman, & Mackenbach, 2005). Hinrichs et al., (2014) in the study of a cohort in Finland reported that vigorous LTPA in midlife is protective against MLs in later life, but vigorous occupational physical activity in midlife predicted high MLs rate in later life. The level of physical activity plays a vital role in the determination of mobility (Morie et al., 2010) and active involvement in LTPA helps in the prevention of physical decline in mobility regardless of the type of work and high workload at work (Mänty et al., 2014). The lower level of habitual physical activity in midlife played a significant role in the onset of disability among elderly persons (Morie et al., 2010) and active involvement in LTPA helped in the prevention of physical decline (Mänty et al., 2014). Along with LTPA various other lifestyle and biological factors may play a role in limiting mobility functions in old age (Lin et al., 2011; Murphy et al., 2014).

2.6 Work-related biomechanical exposures and musculoskeletal diseases and disability

There are several work-related risk factors of MSDs, such as heavy lifting, uncomfortable working positions, repetitive tasks, and long working hours, bending and twisting as reported by numerous studies. Most of the risk factors of MSDs are reported to be related to work. In addition, MSDs are reportedly associated with adverse working environment (such as vibration, too cold and hot). (CCOHS, 2017; IOSH, 2017). Heavy weight lifting during work was associated with incidence of low back pain in a longitudinal study by Chaffin and Park in 1973, and this study was the very first of its kind to explore these associations (Chaffin & Park, 1973). There are already numerous studies establishing the association of biomechanical exposures with disorders in both upper and lower extremities, which provides evidence of work-related MSDs due to biomechanical exposures and warrants further investigations. Interventions such as amplification in physical variations could be beneficial in order to prevent MSDs in work involving more repetitive operations and long-lasting loads (Mathiassen, 2006).

There is also some earlier evidence establishing a strong association of work-related biomechanical exposures with disabling back-related MSDs (Rijs et al., 2014; Sterud & Tynes, 2013; Taylor et al., 2014; Nolet et al., 2016), which have added to the importance of further investigations into these associations. Similarly, the symptoms of work-related limb and neck MSDs have many predictors, like physical and behavioural factors at work, but the most significant one is behavioural aspects, such as work style (Bongers et al., 2006). Repetitive upper limb related work like constant mouse use predicted upper limb MSDs in a cohort study of 1,283 computer users (Tornqvist et al., 2009). Health related quality of life could be potentially impaired due to MSDs related to the upper extremities such as the neck and shoulder, which are strongly associated with work-related biomechanical exposures in midlife (Pope et al., 2001; Andersen et al., 2002; Sim, Lacey, & Lewis, 2006; Andersen, Haahr, & Frost, 2007; Miranda et al., 2008). A cross-sectional survey of 775 manual workers in the UK found an association between disabling shoulder pain and work-related biomechanical exposure like duration of lifting with one hand and working above shoulder level (Pope et al., 2001). Similarly, upper limb disorders were reported to be predicted by repetitive work in a cross sectional study among industrial workers and such discomforts in wrist, fingers and hands were associated with other work-related physical stressors (Latko et al., 1999). A cross-sectional study among German nurses by Heiden et al., (2013) reported the likelihood of MSDs (back and other degenerative) due to high physical demands, but the likelihood was only consistent for subjects aged 35-44 years when the estimates were adjusted for duration of working in the profession, gender, exercise, BMI and smoking status.

An Italian longitudinal study reported an association between biomechanical exposures like heavy workload and hand-transmitted vibration and MSDs in the neck and upper limbs in a three-year follow-up (Bovenzi, Prodi, & Mauro, 2016). Similarly, a prospective population based cohort study of 1,953 subjects aged 18-65 years in the UK suggested that the onset of symptoms of MSDs related to the forearm was predicted by repetitive movements of arms (RR 4.1, 95% CI 1.7-10.0) and wrists (RR 3.4, 95% CI 1.3-8.7) at work (Macfarlane, Hunt, & Silman, 2000). In a study by Roquelaure et al., (2006) the MSDs of the upper extremities were mostly work-related among both women and men and the prevalence of those MSDs varied across different occupations and was mostly dependent on several occupational activities. It was moreover reported that MSDs increase with age. In a population-based cohort study in Finland heavy physical load related to work was reported to be a significant risk factor of physician diagnosed chronic shoulder disorder in old age. Work-related biomechanical exposures such as repetitive movements (OR 2.3, 1.3-4.1) and vibration (2.5, 1.2-5.2) were highly likely to increase the risk of MSDs related to the upper extremities (Miranda et al., 2008). Degenerative MSDs like knee and hip osteoarthritis were reported to be the main reason for disability pension among Swedish women in occupational sectors like childcare, health care and cleaning in associations adjusted for age and education and the results were compared to women in business/administrative occupational sectors (Hubertsson et al., 2017). In a study related to disability retirement in Finland from the perspectives of socioeconomic inequalities, manual work was found to be highly hazardous for all-cause disability retirement among both women and men. The role of physical working conditions was more prominent among subjects aged ≥50 years and these conditions were highly predictive of MSDs (Polvinen et al., 2013). Sommer, Svendsen, & Frost. (2016) reported that high mechanical exposure at work increases the risk of work disability (HR 4.59, 95% CI 2.36-8.94). Furthermore, biomechanical exposures like repetitive work, strenuous work and working in awkward body postures at work carried an increased risk of disability retirement among Finnish men aged 42-60 years. The four-year follow up showed a strong association of incident disability retirement with poor workplace factors and conditions (Kirause et al., 1997). In a cohort study of public sector employees in Finland low adult socioeconomic status was found to be a major risk factor for MSDs (HR 2.38, 95% CI 2.14-2.64). Low socioeconomic status signifies low occupational positions like manual work and clerical services (Halonen et al., 2017).

The best way to manage disorders due to repetitive strain related to work is to start prevention already in working life, as the definite dose-response relationship is still not clear in these cases (Melhorn, 1998). Most neck and upper limb MSDs are work-related, thus preventive actions should already be started in active working life (Buckle & Devereux, 2002). A systematic review of causal associations between work-related lifting and low back pain reported moderate evidence of this relationship (Wai et al., 2010). Another systematic review investigated the causal association between work-related biomechanical exposures and knee osteoarthritis and concluded that work-related biomechanical exposures are risk factors for knee osteoarthritis, but there was not sufficient evidence of a dose-response relationship (Jensen, 2008). However, a field study of vineyard workers reported that the workers were prone to biomechanical exposures like bending forward along with rotating trunk, but the duration of these exposures was not associated with MSDs. This study had the limitation of very small sample size for the generalizability of the results to other working groups (Balaguier et al., 2017). Similarly, in an objective assessment of female workers, prevalence of neck and upper limb disorders was associated with physical workloads like repetitive wrist movements, but the results were not sufficiently consistent and conclusive (Hansoon et al., 2000). Coggon and colleagues (2013) in their multi-country study of musculoskeletal pain among 47 different occupational groups found an association of awareness of pain and onset of pain among the workforce because of the nocebo effect, but the effect was relatively minimal and did not affect prevalence. The inconsistencies in earlier findings warrant further investigations.

2.7 Job strain and musculoskeletal diseases and disability

Work-related psychosocial factors such as low job control and high job demands have been reported to be important risk factors of MSDs in number of studies (CCOHS, 2017; IOSH, 2017). The importance of the role of work-related psychosocial factors in the onset of MSDs has been elevated since 1990s and has gained a lot of attention ever since (Karasek & Theorell, 1990; Bongers et al., 1993; Hoogendoorn et al., 2000; Häkkänen, Viikari-Juntura & Martikainen, 2001). Since then, work-related psychosocial exposures have been increasingly used in scientific studies in recent times as they have been found to be interrelated to both mental and physical illness (Kivimäki et al., 2006). The existing evidence suggests an interplay of various factors including psychosocial risk factors at work that prominently predict disabling back related MSDs (da Costa & Vieira, 2010; Roffey et al., 2010; Sterud & Tynes, 2013; Rijs et al., 2014; Taylor et al., 2014; Nolet et al., 2016). Health related quality of life could be potentially impaired due to MSDs related to the upper extremities like the neck and shoulder, which are strongly associated with work-related psychosocial exposures in midlife (Pope et al., 2001; Andersen et al., 2002; Sim, Lacey, & Lewis, 2006; Andersen, Haahr, & Frost, 2007; Miranda et al., 2008; Bugajska et al., 2013). A cross-sectional survey of 775 manual workers in the UK found an association between disabling shoulder pain and psychosocial exposures (work stress) (Pope et al., 2001). Another prospective population based cohort study of 1,953 subjects aged 18-65 years in the UK suggested that the onset of symptoms of MSDs related to the upper limbs (forearm) was associated with psychosocial risk factors at work (RR 4.7, 95% CI 2.2-10.0) (Macfarlane, Hunt, & Silman, 2000). A study of Chinese teachers and miners using the Nordic questionnaire reported an association of work-related psychosocial exposures and MSDs. The study reported a similar prevalence of MSDs among miners and teachers. High job satisfaction was protective against MSDs of the upper and lower limbs and neck and shoulder among teachers, while low job demands was protective against those MSDs among miners (Yue et al., 2014). In a study of 12,195 workers from 18 different countries, generalized neck/shoulder disorder was characterized by low job control and high job demands when the two disorders were analysed together. However, the separate analysis of neck and shoulder disorders did not show any kind of significant association except for the prognosis of the disability (Sarquis et al., 2016). The results from the GAZEL (Gaz et Électricité France) cohort suggest that work-related exposures in midlife predict functional health in midlife and play an equally significant role in the prediction of health and functioning in old age after retirement (Warhrendorf et al., 2012; Platts et al., 2013). Similarly, low job control and high efforts in the job were strongly associated with early labour market exit in the English longitudinal Study of Ageing (Hints et al., 2015).

A study of Japanese hospital workers reported that the workplace could serve as an arena for the prevention of low back pain related disability among the workers. The study suggested that the consideration of workplace psychosocial factors like interpersonal stress at work could be beneficial in reducing the burden of disability related to pain in the lower extremities (Yoshimoto et al., 2017). A longitudinal study on 25,292 Danish people reported that the presence of pain in the upper and lower part of the body at work increased the risk of permanent work disability. The pain was further associated with low social support at work (HR 2.19; 95% CI 1.41-3.41), but the job strain was moderately associated compared to other work-related exposures (Sommer, Svendsen, & Frost, 2016). Job strain with high demands and low decision-making was a risk factor for symptoms of neck MSDs in a prospective cohort study of 1,283 computer users in Sweden (Tornqvist et al., 2009). The history of psychological exposures like high job demands among office workers in Thailand was found to be a robust predictor of low back pain related disability (Janwantanakul, Sihawong, & Sitthipornvorakul, 2015). Disability pension due to MSDs was predicted by high individual-level effort-reward imbalance (HR 1.32, 95% CI 1.13-1.53) among Finnish public sector employees followed up for 8.9 years and the risk was also higher for work unit effort-reward imbalance (Juvani et al., 2014). The risk for early labour market exit was associated with a number of work-related exposures in midlife in a full-panel prospective study in Norway, which reported job control to be protective (HR0.62, 95% CI 0.47-0.82) against disability retirement (Emberland, Nielsen, & Knardahl, 2017). Another study by Mäntyniemi et al. (2012) with a follow up time of 4.6 yearsin Finland reported job strain as another risk factor for disability pension due to MSDs among both men and women and those in manual occupations.

Among a cohort of blue-collar manufacturing workers in the USA, psychosocial work-related exposures were associated with injury and MSDs (Cantley et al., 2016). The study used work-related exposures rated by experts and noted that it was crucial to monitor psychological exposures along with the mechanical exposures to ensure the promotion of the workers' health and safety by preventing work-related MSDs. A longitudinal study of 1,522 Dutch workers reported that low job demands and other favourable work-related conditions were protective against work-related MSDs (Joling et al., 2008). In Michigan study of women's health, late middle-aged women were more prone to disability with a subsequently higher prevalence. Degenerative MSDs like knee osteoarthritis were significantly associated with MLs related disability (Karvonen-Gutierrez & Ylitalo, 2013). A population-based study of adults aged 65 and above in the USA found that psychosocial factors like social engagement could enhance disability-free later life. The onset and progression of disability was less likely among those who were engaged in social activities (Mendes de Leon & Rajan, 2014). However, in an objective assessment of female workers in Sweden, prevalence of neck and upper limb disorders was not associated with psychosocial working conditions (Hansoon et al., 2000).

There is still a need for intervention studies designed to study the associations of psychosocial factors at work and several disease endpoints already reported and observed by existing studies and experimental studies will serve to complement the observational evidence (Kivimäki et al., 2015). A cross-sectional study using data from a randomized clinical trial in the Netherlands provided evidence of the validity of self-reported measures of MLs based on activity limitations and participation restrictions. The majority of the subjects who were clinically diagnosed with generalized osteoarthritis had moderate to severe limitations in performing ADL. Almost 50% of the subjects reported great difficulty in basic daily activities for living and most of them reported MLs in walking (Cuperus et al., 2015). However, there are a limited number of longitudinal studies on the association of old age MSDs and disability with midlife occupational exposures.

2.7.1 Gender specific variations

Gender differences have frequently been reported among the associations between work-related exposures and MSDs. A cross section study of female industrial workers in Sweden reported repetitive work to be associated with increased prevalence of neck and upper limb disorders (Ohlsson et al., 1995). A cohort study by Hooftman, et al., (2009) reported a gender difference in the association of work-related exposures and the symptoms of MSDs. In general, the effect of work-related exposures has been reported to be more prominent among women, but the aforementioned study reported greater vulnerability among men than among women. In a study of 3,141 workers in 31 different occupational subgroups (24 women, 9 men) using the Nordic questionnaire, work-related biomechanical along with psychosocial exposures were associated with increased prevalence of MSDs (neck and shoulder). Women had a slightly higher prevalence of MSDs than men (Nordander et al., 2016). Vingård, et al., (2000) in their intervention study of 2,118 general working population reported that work-related physical and psychosocial exposures separately and jointly predict symptoms of back MSDs after controlling for other physical loads and lifestyle factors. The aforementioned study also reported a gender difference in the effect of the exposures on MSDs.

A prospective population based study of a nationally representative sample in Finland reported that physical workload accelerates the onset of physician diagnosed MSDs in the shoulder and the effect has long-term persistence. In the same study, biomechanical exposures like awkward body posture and heavy lifting at work in midlife were found to be deleterious among women. However, among men repetitive movements and exposures to vibration at work in midlife affected the musculoskeletal health related to the shoulder in later life (Miranda et al., 2008). Women had higher rates of disability pension compared to men in a study of Swedish population, which reported that disability pension due to MSDs was significantly predicted by low job control and high physical strain regardless of the distribution of MSDs at different body sites and different levels of severity (Falkstedt et al., 2014). In a Swedish community-based longitudinal study, there was a significant increase in the incidence rate of disability with increasing age among women compared to almost indistinguishable rates among men in different age groups (Sjölund et al., 2015). Likewise, a study of initially MLs free Danish middle-aged subjects reported a higher likelihood of incident MLs among men with high job demands at work, but there was an inverse association of high job demands and incident MLs among women (Hansen et al., 2014). On the other hand, some studies have shown a marked effect of work-related exposures in both genders. Low job control and high job demands strongly predicted disability pensions independently and high job strain was associated with disability pension among both men and women in a 12-year follow-up study of middle-aged Swedish workers (Canivet et al., 2013). In another study of a Swedish cohort disability pension among women and men was largely attributable to MSDs due to long-term biomechanical exposure like physically heavy work load in midlife (Kjellberg et al., 2016). Self-reported measures of disability should be used with caution in gender-stratified studies. These measures should not be regarded as interchangeable with objective measurements in either research or clinical application and should be taken as a complementary method to proper field measurements (Botoseneanu et al., 2016).

2.7.2 Interaction of biomechanical exposure and job strain

Research on the association of interaction of work-related exposure and health functioning outcomes is equally important in addition to the study of the independent effects of the exposures. There is evidence to support the significance of studying the epidemiological interactions of these work-related exposures in predictions of MSDs (Huang, Feuerstein, & Sauter, 2002; Marras et al., 2009; Vandergrift et al., 2012). Some earlier studies have reported increased risk of MSDs (Vingård et al., 2000; Pope et al., 2001; da Costa & Vieira, 2010; Roffey et al., 2010; Waters, Dick, & Krieg, 2011) and future disabilities (Sabbath et al., 2013) due to the interaction of work-related biomechanical and psychosocial exposures. The study on GAZEL cohort by Sabbath et al., (2013) also reported gender-specific variations in the combined effects of the exposures. Clausen, Burr & Borg., (2014) in their study of 40,554 Danish populations reported that psychosocial exposures like job control and demand jointly predict disability pensions and reported the importance of joint work-related exposure for health functioning outcomes. A cross-sectional study of 891 workers in the UK found that joint work-related exposures were strongly predictive of MSD symptoms than the separate exposures (Devereux, Vlachonikolis, & Buckle, 2002). High physical and high psychosocial work-related exposures jointly predicted (OR, 5.42; 95% CI 3.30-8.89) low back MSD symptoms among Indonesian coal miners (Widanarko et al., 2015a). In another study among the same respondents joint exposures strongly predicted (OR 4.83, 95% CI 2.43-9.58) neck and shoulder symptoms (Widanarko et al., 2015b). Although the additive effect of interaction of work-related biomechanical and psychosocial exposures has been highlighted in earlier research, there is still a need for more epidemiological evidence on the association of joint exposures in midlife and musculoskeletal health in later life.

2.8 Summary of the literature review

Work-related exposure in midlife plays a crucial role in the prediction of overall functional health in midlife and is equally crucial in the prediction of health and functioning in old age after retirement. A higher level of occupational physical activity and strain in midlife may have an adverse effect on overall musculoskeletal health in old age, but leisure time physical activity may have protective effects on musculoskeletal health and lead to better physical functioning and better mobility in old age. Shift work in midlife has been reported to be associated with a higher risk of MSDs and various pain symptoms. Similarly, the adverse effect of sleep disturbances on musculoskeletal health has been widely studied among working populations, but studies on the long-term effects of shift work and sleep disturbances were scarce.

Earlier research has reported a dose-response relation between work-related physical and psychosocial exposures in midlife and back and neck-shoulder related MSDs and pain in working life and around retirement. Physically heavy work was reported to be associated with disabling back and neck-shoulder pain. Psychosocial work-related exposures like high job demands and low job control were also reported to be a risk factor of MSDs, MLs and disability. Most of the earlier research also reported gender differences in these associations. The effect of psychosocial exposures was reported to be more marked among women and the effect of physical exposure among men.

Earlier evidence points towards the importance of interaction between work-related physical and psychosocial exposures in predictions of different chronic outcomes and indicated a need for further studies. The body of existing literature was rich in studies on the effects of midlife work-related physical and psychosocial exposures separately, but studies on the association of the interaction of work-related exposures in midlife with outcomes such as MSDs and disability in old age were scarce. Furthermore, there were limited longitudinal studies with long follow-ups investigating the aforementioned associations and these lacked the consistency. Research on the role of physically heavy occupations in midlife on the functioning of overall musculoskeletal health began in the 1970's. Work-related psychosocial exposures likewise began to attract attention as risk factors of different chronic health outcomes around the beginning of the 21st century, and there was a rapid proliferation of working life studies. Technological progress has resulted in improved working conditions depending along with the increase in various occupational exposures. Therefore, more investigation is required to ensure better health of workers during working life and in old age after retirement. In addition, there is a need for long-term studies with follow-up from working life to very old age.

3 Aims of the study

The main purpose of the FLAME study in 1981 was to investigate the reasons behind the increasing rate of early retirement among public sector employees at that time (Ilmarinen et al., 1991).

3.1 Main aim

The major alternative hypothesis for this study was that work-related exposures in midlife characterize musculoskeletal health in old age. The higher the work-related exposures (musculoskeletal load, biomechanical and psychosocial exposures and shift work) in midlife the higher is the deterioration of musculoskeletal health in old age in terms of musculoskeletal diseases, mobility limitations and disability. The general aim of this study was to investigate the long-term associations of midlife work exposures with musculoskeletal diseases, mobility limitations and disability in old age.

3.2 Specific aims

1. To examine the effect of job profiles (detailed analysis of occupational titles) in midlife on the severity of disability in old age among women and men **(***Paper I)*
2. To identify the developmental pathways (trajectories) of mobility limitations and to investigate the association of shiftwork and leisure time physical activity with the developmental pathways of mobility limitations separately among respondents retired on disability and those retired on old age pensions. *(Paper II)*
3. To study the separate and joint effects of work-related biomechanical exposure and job strain in midlife on the onset of musculoskeletal diseases among women and men around retirement and in old age. *(Paper III)*

4. To investigate the separate and joint associations of work-related biomechanical exposure and job strain in midlife with the severity of disability after 28 years among women and men. *(Paper IV)*

4 Materials and methods

4.1 Study design and subjects

This study is based on the Finnish Longitudinal Study on Aging Municipal Employees (FLAME). FLAME was a prospective cohort study of public-sector employees from different municipalities in Finland conducted by the Finnish Institute of Occupational Health (FIOH) (Ilmarinen et al., 1991). In 1981 postal questionnaires were send to 7,344 public sector employees aged 44-58 years. With a response rate of 85.2% a total of 6,257 out of 7,344 employees replied to the baseline questionnaire. The follow-up questionnaires were sent in four waves in 1985, 1992, 1997 and in 2009. The detailed follow-up and loss to follow-up processes are presented in **Figure 4**. In 2009 the follow-up was conducted by FIOH in collaboration with the University of Jyväskylä in the city of Jyväskylä, Finland (von Bonsdorff et al., 2012; Kulmala et al., 2014).

The FLAME data was collated with information from the pension and mortality registers until 2009. The unique identification code of each person was used to collate the data. The participation rate was 88.8% in the second follow-up in 1985. In the follow-up, change in occupation, workload indicators, other individual factors and several stress factors associated with disability and mortality were studied. By 1985, 1% of all subjects had died, 9% were disabled, and around 5% had changed their occupation (Tuomi et al., 1991). According to the mortality data (January 1981 to July 2009) from the Finnish National Population Register, 2,096 (33.5%) of the baseline respondents died during the 28-year follow-up period. The FLAME study was approved by the ethics committee of the FIOH and the national Data Protection Ombudsman provided the ethical clearance for using and collating the pension and mortality registers.

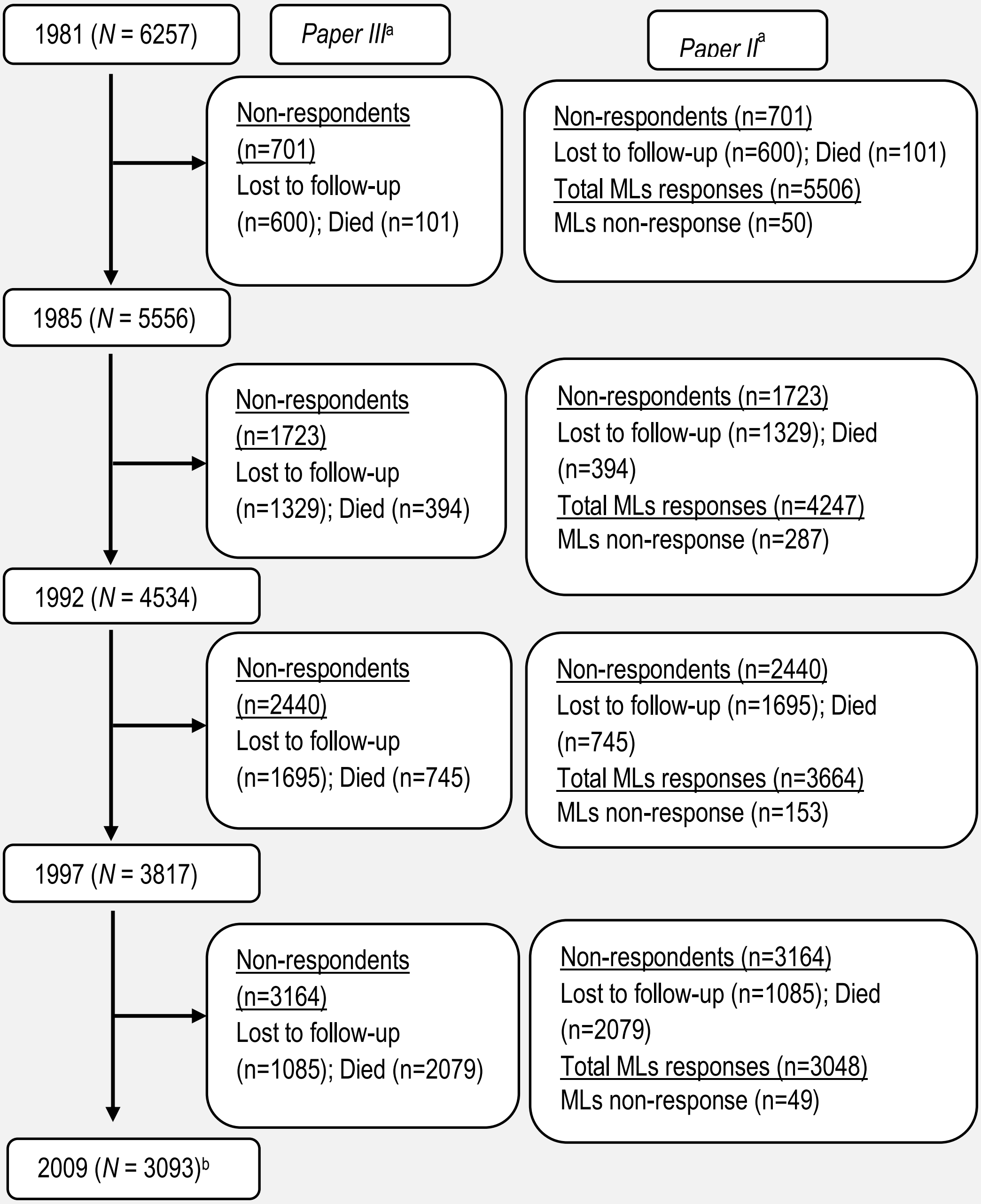

Figure 4: Follow-up of study subjects, Finnish Longitudinal study on Aging Municipal Employees (FLAME) 1981-2009; [a]Total number of Non-respondents (loss to follow-up and died) presented after each wave are cumulative; [b]The baseline survey was used for exposure and the last follow-up was used for outcome in *Paper I* and *Paper IV*

4.2 Outcomes

4.2.1 Musculoskeletal diseases in old age

Information on six musculoskeletal diseases (MSDs) diagnoses was available in our dataset, namely the diagnoses of cervical spine, lower back, sciatica, hands and/or feet, rheumatoid arthritis, or others. The available information was reported by respondents based on diagnosis by a physician. The responses on MSDs diagnosis were binary and coded as "0" no disease and "1" presence of disease. We created and used two forms of MSDs in this study by merging the MSDs diagnoses of different nature and body parts.

- Back MSDs: any of the three back related MSDs namely osteoarthritis of the cervical spine, osteoarthritis of the lower back and sciatica
- Degenerative MSDs: any of the four degenerative MSDs namely osteoarthritis of the cervical spine, osteoarthritis of the lower back, sciatica and osteoarthritis of the limbs

4.2.2 Mobility limitations in old age

We used the concepts of the International Classification of Functioning, disability and health (ICF) framework of the World Health Organization (WHO) to construct MLs (WHO, 2001). The information on MLs items was collected using the self-reported questionnaires in the study waves in 1985, 1992, 1997 and 2009. The 'mobility' domain (*d4*) on component *d* termed 'activities and participation' of the ICF was used to code the outcome variable MLs. The domain *d4* of ICF comprises four main categories, namely changing and maintaining body position (*d410–d429*), carrying, moving, and handling objects (*d430–d449*), walking (*d450*) and moving around (*d455*). In order to cover these categories of ICF we used the nine items available in our questionnaire, which are classified in detail in **Table 2**. Out of nine components, eight were assessed on four levels of difficulty (manage without difficulties, manage with little difficulties, manage with lots of difficulties and cannot manage) and only walking 2 km was assessed on five levels (no difficulty – cannot manage with the help of others as well).

The assessment scale of all nine components was dichotomized (no difficulty "0" vs. at least some difficulty "1"). These, were then summed up to get a summary score "0–9" in the present study. A score of '0' represented no limitations in carrying out any of the nine tasks and a score of '1-9' represented having at least some limitations in carrying out one or more of the nine tasks depending on the number of tasks entailing limitations. (Hinirichs et al., 2014; Kulmala et al., 2014; von Bonsdorff et al., 2016).

Table 2: International Classification of Functioning (ICF), disability and health categories (in **d** Activities and Participation: component **d4** Mobility) used to create Mobility Limitation (0-9)

d4: Mobility	Category	Questionnaire: Any difficulties in……
d410-d429: Changing and maintaining body position	d410: Changing basic body position	Squatting and standing up again? Bending down deep?
	d415: Maintaining a body position	Maintaining body position/sitting still for 2 hours?
d430-d449: Carrying moving and handling objects	d430: Lifting and carrying objects	Lifting and carrying more than 10 Kg?
	d440: Fine hand use	Precise movements of hands?
	d445: Hand and arm use	Lifting hands over the head?
d450-d469: Walking and moving	d450: Walking	Walking 2 kilometres?
	d455: Moving around	Running 100 metres? Climbing three floors/sets of stairs?

4.2.3 Disability in old age

The ability to perform the activities of daily living (ADL) and instrumental activities of daily living (IADL) was used to assess the severity of disability and the information on ADL and IADL tasks was collected using the self-reported questionnaires in 2009. The age of our respondents in 2009 was 72-86 years, so the ability to perform these tasks was used to measure the disability, as they are generally used and established measures of severity of disability among the old people (Spector & Fleishman, 1998; Jagger et al., 2007; Chan et al., 2012; Kulmala et al., 2013). We used the information available on five ADL tasks (eating, dressing, going to bed, toileting and bathing) and seven IADL tasks (doing laundry, preparing meals, doing light domestic work, shopping, using the phone, management of personal finances and dosing/taking medicine) which were partly adapted from Katz ADL index (Katz, 1983).

The scale of assessment of ADL and IADL tasks and the dichotomization of the responses of the items in ADL and IADL task are described in detail in **Table 3.** The dichotomized responses of 12 tasks related to daily living (5 ADL & 7 IADL) were summed to obtain the severity of disability score "0-12". A score of '0' represented those who could perform all the tasks without any difficulty (classified as non-disabled in this study) and those who had at least some difficulty in performing one or more of the 12 tasks scored '1-12' depending on the number of tasks entailing difficulties (classified as disabled in this study). The higher the score the more severe the disability.

Table 3: Classification of Activities of Daily Living (ADL) and Instrumental ADL (IADL) items used to create Disability (0-12)

Activities	Questionnaire: Any difficulties in……	Level of difficulty	Recoded level
ADL tasks	*Eating*	Manage without difficulties	Coded as '0'
	Going to bed	Manage with little difficulties	Coded as '1'
	Dressing	Manage with lots of difficulties	
	Bathing	Cannot manage without help from others	
	Toileting	Cannot manage with help as well	
IADL tasks	*Preparing meals*	Manage without difficulties,	Coded as '0'
	Doing laundry	Manage with little difficulties	Coded as '1'
	Doing light domestic work	Manage with lots of difficulties	
	Dosing/taking medicine	Cannot manage without help from others	
	Shopping	Cannot manage with help as well	
	Using phone		
	Management of personal finances		

4.3 Exposures

4.3.1 Midlife job profiles

The job analysis has been described in detail elsewhere (Ilmarinen et al., 1991). The AET method was used to analyse psychosocial, physical and mental demands at work (Landau, Luczak, & Rohmert, 1976; Rohmert & Landau, 1983). A separate job analysis was used to determine the characteristics of the employees' jobs using the self-reported interviews and the experts' field observations at the work places. A job profile with 13 groups emerged in a cluster analysis of the contents and demands (216 items) of the 88 individual job titles (Ilmarinen et al., 1991). The jobs of 133 different workers all over Finland was considered for the job analysis in 1981 (Ilmarinen et al., 1991), and this was repeated in 1993 (Nygård et al., 1999).The variation in contents and demands including other characteristics among the occupations was greater than within one occupation. The employees' work demands did not greatly change between 1981 and 1993.

The different individual job titles were clustered to form different job profiles. For example, the "Office work" job profile was a cluster of five different job titles (clerk, draftsman, map drawer, secretary and typist) and the "Nursing" job profile was a cluster of five titles (childcare worker, mental health nurse, nurse, practical nurse and specialized nurse). Likewise, the "Homecare" job profile was a cluster of three titles namely bather, domestic helper and housekeeper. The lowest physical load was found in the "Administrative" job profile, which was a cluster of department, bureau, or office supervisor, head nurse, social secretary, social worker and fire chief (Nygård et al., 1987).

4.3.2 Work Schedules

The information on work schedules (used as *shift work* in this study) was collected by using the question "At what time of day do you carry out your main work?" in 1981, 1985, 1992 and 1997. The response alternatives were fixed day work, fixed evening work, fixed night work, 2-shift work (day and evening), 3-shift work (day, evening and night) and other work schedules. In this study we used a work schedule by forming three groups of work shifts namely "*day work*", "*shift work without night shifts*" (those in 2-shift work or in fixed evening work) and "*shift work with night shifts*" (those in 3-shift work or in fixed night work). The construction of the work shift groups was partly adapted from Huslegge et al., (2017).

4.3.3 Work-related biomechanical exposure

Work-related biomechanical exposure was assessed using the self-reported responses to the exposures related to biomechanical hazards at baseline (1981). The seven self-reported items were (a) continuous walking or movement, (b) standing in one place, (c) bent or twisted postures, (d) similar repeated movements, (e) carrying objects in the hands, (f) sudden strenuous efforts and (g) other poor posture. All the items were answered on a scale '0=not at all', '1=a little', '2=somewhat', '3=often', and '4=quite often', except item (g) other poor posture which was answered on '0=not at all', '1= a little', '2=somewhat' or '3=often'. The summary score (Cronbach's α=0.84) was dichotomized into low and high biomechanical exposure using the median value. (Partly adapted from Sabbath et al., (2013)).

4.3.4 Job strain in midlife

4.3.4.1 Job control

Job control was assessed using self-reported responses to the questions related to respondents' possibilities/opportunities for control, guidance and exerting influence in the job at baseline (1981). The ten self-reported items namely: possibility/opportunity for (a) guidance in the job, (b) participating in planning the work, (c) gaining promotion, (d) chances for further training in professional skills, (e) gaining recognition and respect, (f) influencing the work environment, (g) chances to use own abilities and talents, (h) aptitude to learn new things, (i) communicate and work with co-workers and (j) seeing the meaning of the work were answered on a scale from '0=not at all', '1= a little', '2=somewhat' or '3=a lot'. The summary score (Cronbach's α= 0.86) ranging from "0-30" was dichotomized into low (summary score=0–16) and high (summary score=17–30) job control using the median value '16'. (von Bonsdorff et al., 2012).

4.3.4.2 Job demands

Job demands was assessed using self-reported responses to questions about pressure and demands related to the job at baseline (1981). The eight self-reported items were namely: (a) tight time schedule, (b) hectic pace of work, (c) taking responsibility, (d) pressure and interference from supervisor, (e) conflicting demands regarding work tasks and responsibility, (f) pressure of possible failure or making mistakes, (g) isolation or loneliness, and (h) monotonous work, which were answered on a scale from '0=not at all', '1= a little', '2=somewhat' or '3=a lot'. The summary score (Cronbach's α= 0.77) ranging from "0-24" was dichotomized into low (summary score=0–6) and high (summary score=7–24) job demands using the median value '6'. (von Bonsdorff et al., 2012).

4.3.4.3 Job strain

The Karasek model of job demand-control was used to create job strain levels (Karasek, 1979). The dichotomized values of job demands and control were used to construct the four levels of job strain:

- Low strain (high control and low demands)
- Passive job (low control and low demands)
- Active job (high control and high demands) and
- High strain (low control and high demands)

4.3.5 Leisure-time physical activity

Information on Leisure Time Physical Activity (LTPA) during the previous year was assessed using a self-reported questionnaire at baseline. Respondents were asked about their average involvement in LTPA during the previous year with five possible responses ("0: brisk exercise at least twice a week", "1: brisk exercise at least once a week", "2: some form of exercise once a week", "3: some form of exercise less than once a week" or "4: not engaging in exercise"). In the present study LTPA was categorized into three groups (vigorous: 0–1; moderate: 2–3; and inactive: 4) (Hinrichs et al., 2014).

4.4 Background variables

4.4.1 Socio-demographic characteristics

Age of the respondents at baseline ranged from 44 to 58 years. Marital status was elicited with the response options "unmarried" "married/co-habiting", "separated", "widowed" and categorized as "unmarried", "married/co-habiting", "separated and widowed" in this study. Similarly, basic education was elicited with the response options as "elementary school incomplete or no schooling (1)", "elementary school or middle school incomplete (2)", "middle school or high school incomplete (3)" and "high school completed (4)" and it was classified in this study as low (1), intermediate (2), and high (3-4). The total household income per month was collected in eight categories; "less than 2200", "2201-2800", "2801-3400", "3401-4000", "4001-4600", "4601-5200", "5201-5800", "more than 5800" (all in Finnish Marks) and it was classified in this study as low (less than 2200 Finnish Marks/month), intermediate (2201-5800 Finnish Marks/month) or high (more than 5800 Finnish Marks/month), [One Finnish Mark at the time of the study was equivalent to 0.17 Euro]. Two occupational groups namely white-collar (example: administrative, physician) and blue-collar (example: auxiliary, transport worker) were created based on 13 job profiles clustered from 133 different job titles. The tenure period used in this study was occupationally active years between the baseline of this study and retirement. All the socio-demographic characteristics were measured at baseline in 1981.

4.4.2 Type of Pension

The data on the type of pensions, primary diagnosis for Disability Pension (DP) and the dates of pensions being granted were obtained from the Finnish Centre for Pensions. The unique personal identification number was used to cross-link the data obtained to the survey. All our study subjects were retired by July 2000. The official age for old age pension through statutory retirement was 63 years for most of the public sector employees. Retirement was categorized in the following way in this study (von Bonsdorff et al., 2016):-

(i) Statutory Pension (SP): non-disability, part-time, early voluntary and others

(ii) Disability Pension (DP): retirement due to a medically diagnosed illness before the statutory retirement age

4.4.3 Lifestyle related characteristics

Lifestyle related details were also collected by using the questionnaire. Current smoking status was collected as cigarettes/day which was later dichotomized; non-smokers (0 cigarettes /day) and smokers (at least a cigarette /day). Information on alcohol intake was elicited as “never”, “not so often”, “once a month”, “twice a month”, “once a week”, “twice a week”, “daily” and categorized into none, at most two drinks a month and at least one drink a week being based on the seven original categories. Body mass index (BMI) was calculated using the information on height (M^2) and weight (Kg) of the employees.

4.4.4 Health related characteristics

The work ability used in this study was one item of the Work Ability Index (WAI) measured in a scale of 0-10 and for this study it was categorized into poor (0-6), moderate (7-8) or excellent (9-10) (Ilmarinen, et al., 1991; Ilmarinen, et al., 2008). Information on chronic diseases was based on self-reported physician diagnoses and classified as "disease present" or "no disease" and was one of the item in the WAI. Diagnoses of accident or injury, musculoskeletal disorders, cardiovascular disorder, respiratory disorder, mental disorder, nervous/sensory disorder, urinary disorder, skin disorder and digestive disorder were used for this study.

4.5 Statistical analysis

4.5.1 Basic analysis

The basic characteristics of the study participants were described using the frequencies and percentages for categorical variables and means and standard deviations for continuous variables. Cross-tabulation was done to report the proportions and in addition, Pearson's chi-square test or analysis of variance (ANOVA) was used to report the power of the distributions depending upon the nature of the variables in all the four papers. The paper specific statistical analysis are described below:-

Paper I: The outcome variable disability was not normally distributed (more skewed) so negative binomial regression was used to report incidence rate ratios (IRR) and their 95% confidence intervals (CIs). The variance was much higher than the mean described in **Figure 5**. In this case, we used the prevalence of disability so, IRR was reported as prevalence rate ratios regardless of the analysis of the study. The musculoskeletal load score was also calculated for the exposure variable (for each of the 13 job profiles) which is described in detail in **Table 4**. The 'administrative' job profile was used as the reference category in the regression analysis because of the lowest physical load among the 13 job profiles (Nygård et al., 1987). Two models were fitted. Model I was age-adjusted and model II was further adjusted for BMI, smoking status, alcohol intake, and physical exercise, chronic disease/disorders, perceived work ability, basic education, marital status and total household income. The regression coefficients for some of the job profiles among women and men were not presented because of no or few cases. The analysis was done with SPSS version 21.0 and STATA 13.0.

Table 4: Contents of the items of physical demands in the AET method (partly adapted from Nygård et al., (1987))

Physical demands	Description of Characteristics	Assessment Scale	Range of sum scores for demands	musculoskeletal load among individuals in %
Work Posture[a]	Sitting normally	0-5*0.11[c]	5-8	assessed score/maximum score*100
	Sitting bent	0-5*0.26[c]		
	Standing normally	0-5*0.27[c]		
	Standing stopped, kneeling, crouching	0-5*0.50[c]		
	Standing extremely stopped	0-5*1.00[c]		
Static Work[a]	Finger-hand-forearm	0-5	0-11	assessed score/maximum score*100
	Arm-shoulder-back	0-5		
	Leg-foot	0-5		
Heavy, dynamic work[a]	Both arms	0-5	0-8	assessed score/maximum score*100
	Both legs	0-5		
Active, light (repetitive work)[a]	Finger-hand system	0-5	0-5	assessed score/maximum score*100
	Hand-arm system	0-5		
	Foot-leg system	0-5		
Application of forces and frequency of motion[b]	Forces in static work	0-5	1-11	assessed score/maximum score*100
	Forces in dynamic work	0-5		
	Forces in repetitive work	0-5		
	Frequency of motion	0-5		

[a]Assessment scale: 0=Does not apply; 1=Very minor; 2=Minor; 3=Average; 4=High; 5=Very High
[b]Assessment scale: 0=Does not apply (or is very infrequent); 1=Less than 10% (50 min) of shift time; 2= Less than 30% (160 min) of shift time; 3= Between 30%(160 min) and 60% (320 min) of shift time; 4= More than 60% (320 min) of shift time; 5= Almost continuously during whole shift
[c]work posture items in sum variable were weighted based on the energy expenditure of postures (Landau, 1978; Rohmert & Landau, 1983)

Paper II: The Growth Mixture Modeling (GMM) was used to study the developmental pathways (trajectories) of mobility limitations (MLs) between the study waves (1985, 1992, 1997 and 2009) during follow-up (Muthén, 2003). Latent classes which tend to have analogous development over time within the data are identified by GMM. In order to select the best-fitted model we modelled two to five classes using GMM. The best fitted model was selected according to substantive interpretability of classes, lowest value of sample size adjusted Bayesian Information Criterion (BIC), lowest value (close to 0) of Akaike Information Criterion (AIC), relevance, higher entropy and significant Leo-Mendell-Rubin(LMR) value (Muthén, 2003; Nylund, Asparouhov, & Muthén, 2007). The best-fitted model was a four-class model in our study which represented Low persistent MLs, Low-increasing MLs, High-decreasing MLs and High persistent MLs respectively. The baseline characteristics and exposure variable were presented according to four latent class trajectories of MLs stratified by type of pension. The odds ratios (OR) and their 95% confidence intervals (CI) for membership of trajectory of MLs according to the categories of LTPA and shift work were derived through multinomial logistic regression. Two models were fitted; age adjusted (model I) and model II was further adjusted for occupational groups, gender, alcohol intake, smoking status, BMI and chronic diseases. Adjusted interaction estimates of the exposures were calculated as predictive margins. Mplus version 7.11(Muthen & Muthen, 3463 Stoner Ave., Los Angeles, CA) was used to conduct GMM. All the other analyses were done in STATA 14.0 (StataCorp LP, College Station, Texas 77845, USA).

Paper III: The binary regression with log link was used to calculate the risk ratios (RR) and their 95% confidence intervals (CI). Predictive margins of job strain and biomechanical exposures, stratified by gender were calculated for both outcomes as post-estimation in order to check the predictive power of the exposures. Cross-tabulation was done in IBM SPSS statistics version 21.0 (IBM corporation, Armonk, New York, USA) and all other analyses and plotting were done in STATA 13.0 (StataCorp LP, College Station, Texas 77845, USA).

Paper IV: Outcome variable disability was over-dispersed. Therefore, mixed negative binomial regression with robust variances was modelled in order to calculate the regression estimates with the assumption of avoiding the error related to overestimations **(Figure 5).** Population parameters were used in the model. The resulting estimates were presented as prevalence proportion ratios (PR) and their 95% confidence intervals (CI). The estimates for job strain were presented as Bonferroni adjusted pairwise comparisons. Three models were fitted namely; age adjusted (model I), model II was further adjusted for occupational groups and model III was further adjusted for alcohol intake, smoking status, BMI, physical activity and chronic diseases. We used duration of employment (tenure period) in all three models as an exposure item to adjust for duration of exposures. Proportion/percentage calculations were performed in SPSS version 23.0 (IBM corporation, Armonk, New York, USA) and all the other analyses were conducted in STATA 14.0 (StataCorp LP, College Station, Texas 77845, USA).

4.5.2 Relative excessive risk due to interaction

The potential interaction between biomechanical exposure and job strain was quantified using the departure from additivity and was estimated by computing the relative excessive risk due to interaction (RERI) and their 95% CI in *Papers III and IV*. The following formula was adapted to calculate RERI (Rothman, Lash, & Greenland, 2008; VanderWeele & Knol, 2014):

$$RERI = RR_{1,1} - RR_{1,0} - RR_{0,1} + 1$$

Where, $RR_{1,1}$ = Presence of high biomechanical and high job strain (joint exposure), $RR_{1,0}$ = Presence of high biomechanical and absence of high job strain and $RR_{0,1}$ = Absence of high biomechanical and presence of high job strain. The advanced prefix (icp) from Stata was used to calculate estimates of log relative risk to use interaction contrast from the regression settings. The biological interaction is present if RERI >0 and if $RR_{1,1}$ is significantly different from 1 statistical interaction is present. Two models were fitted, the first model was a univariate model and the second model was adjusted for BMI, age, occupational group, smoking status, alcohol intake and physical activity and the confounders were selected on the basis of existing knowledge of the factors that could mask the association between the exposure and outcome of these natures (Woolf

& Pfleger, 2003). The joint prediction of biomechanical exposure and job strain was quantified by calculating the interaction estimates and the model used in *Paper III* was adapted to calculate the joint prediction estimates in *Paper IV*. RERI and 95% CI were calculated using STATA 14.0 (StataCorp LP, College Station, Texas 77845, USA).

4.5.3 Sensitivity analysis

Predictive margins of job profiles to predict disability were calculated with their 95% CIs separately for women and men to report the predictive power of the individual job profiles (*Paper I*). In order to account for potential bias due to dropout, GMM was conducted for overall respondents (as a sensitivity analysis), from 1985-2009 (N=5536) which gave us similar trajectory shapes, so the results for selected respondents were presented (*Paper II*). Since, there were some missing values (<10%) in the items of work-related exposures, the missing values (5.5% for biomechanical exposure, 5% for job control and 7.4% for job demands) were imputed using the calculated median of nearby points, calculated from other items on the scale. In order to prevent reverse causation, those diagnosed with MSDs at baseline were excluded from the analysis (n=2,273 for degenerative MSDs and n=1,991 for back MSDs) (*Paper III*).

Regression imputation was conducted as a sensitivity analysis in order to account for potential bias due to dropouts. In order to do so, the disability related information was imputed for those who were alive and failed to respond using their recent responses to the items related to mobility limitation, age, work ability and occupational class (in the follow-up of 1992 and 1997). No variation in the results produced by the sensitivity analyses was seen compared to the results for original respondents. Furthermore, the analysis was done using ADL and IADL separately as two different outcomes, but the pattern of association was similar as it was in combined ADL and IADL. Likewise, a secondary analysis was done to account for dropout due to mortality where deceased respondents were included in the highest disability group, but the results were still comparable to the original results (*Paper IV*).

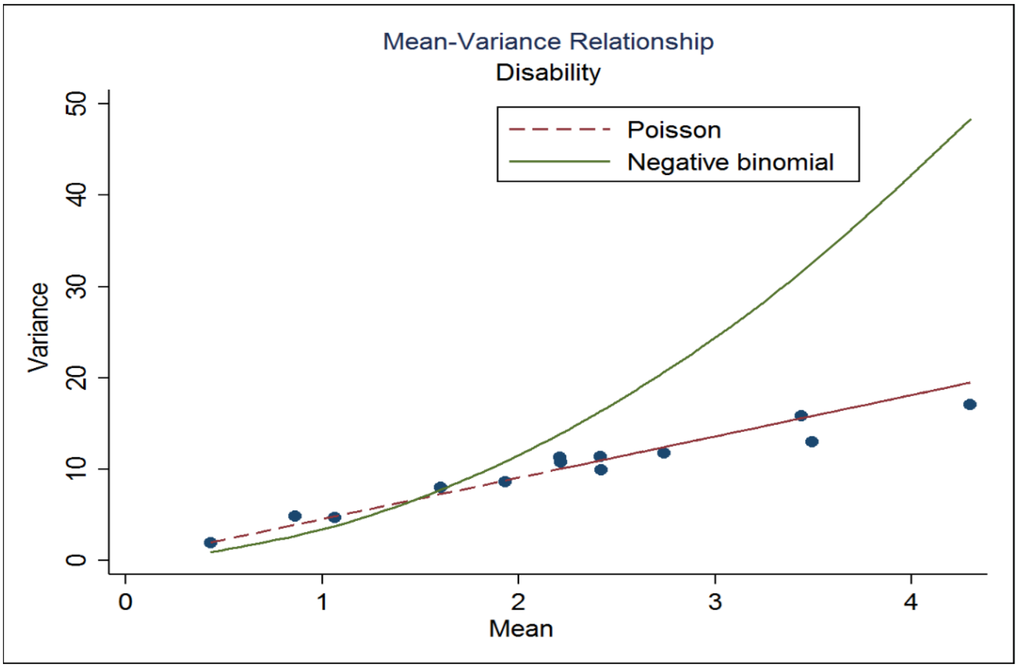

Figure 5: Choosing models Negative Binomial vs. Poisson regression model using the mean variance relationship

5 Results

5.1 Baseline characteristics of the study population

Respondents' ages ranged from 44 to 58 years (mean, SD: 50±3.6) and 55% of the respondents were women. Among women, 63% were white-collar workers compared to 29% of men. Almost 30% of the men were current smokers and 20% of them were heavy drinkers, which was higher than among women (11% and 3%). Men had slightly higher body mass index (BMI) than women (26.2±3.1 vs. 25.2±3.5). Almost 40% of women had high education level, which was higher than men (20%). Likewise, 13% of women had low education level, which was slightly lower than men (21%). The household income was elicited in Finnish Marks/ per month (1 Euro= 6 Finnish Marks in the 2002). There were equal numbers of subjects of both genders with high level of income (17%). Among women, 66% were married/co-habiting compared to 94% of men.

The distribution of chronic illnesses was similar in both genders, only accident or injury, musculoskeletal disorder and digestive disorder showed gender wise significant difference. There were 50% subject with moderate work ability among both genders, followed by excellent work ability (32% among women and 28% among men). Similarly, 49% women were highly active in leisure time physical activity compared to 45% men. There was similarity in duration of employment (years) from baseline until retirement among women and men (9.3±3.6 vs. 9.5±3.8).

5.2 Type of pension stratified by gender

The trend in yearly retirement (two-year intervals) from baseline until all the respondents were retired stratified by gender and type of pensions is presented in **Table 5**. Among women, there were more respondents on old age pension than on disability pension. However, disability pension was more common than old age pension among men. A higher proportion of men were on disability pension during the early to late 80's, but the trend in disability pension retirement was proportionately distributed among women from the early 80's to mid-90. The year 1989/90 was the peak year of retirement among both genders, where most of the men were retired on disability pensions and old age retirement was slightly higher than disability among women.

Table 5: Type of pension stratified by gender

Year of retirement	N (5967)	Women (N=3334)				Men (N=2633)			
		Old age & Others (n=2182)		Disability (n=1152)		Old age & Others (n=1288)		Disability (n=1345)	
		n	%	n	%	n	%	n	%
1981/82	279	58	41	84	59	34	35	103	75
1983/84	576	174	57	133	43	62	23	207	77
1985/86	801	270	68	126	32	158	39	247	61
1987/88	975	381	66	194	34	202	51	198	49
1989/90	1293	382	53	338	47	230	40	343	60
1991/92	855	372	71	153	29	188	57	142	43
1993/94	750	331	78	94	22	245	75	80	25
1995/96	293	156	85	27	15	90	82	20	18
1997/98	124	53	95	3	5	63	93	5	7
1999/2000	21	5	100	0	0	16	100	0	0

5.3 Type of pension stratified by occupational class among women

The trend of retirement among women stratified by occupational class is presented in **Figure 6.** Most of the women retired between 1985/86 and 1992/93. The proportion of old age retirement was comparatively higher among women working in upper blue-collar jobs in midlife. The proportion of disability retirement was likewise higher among blue-collar workers. However, there was not much variation among those in white-collar and upper-blue collar jobs regarding disability retirement.

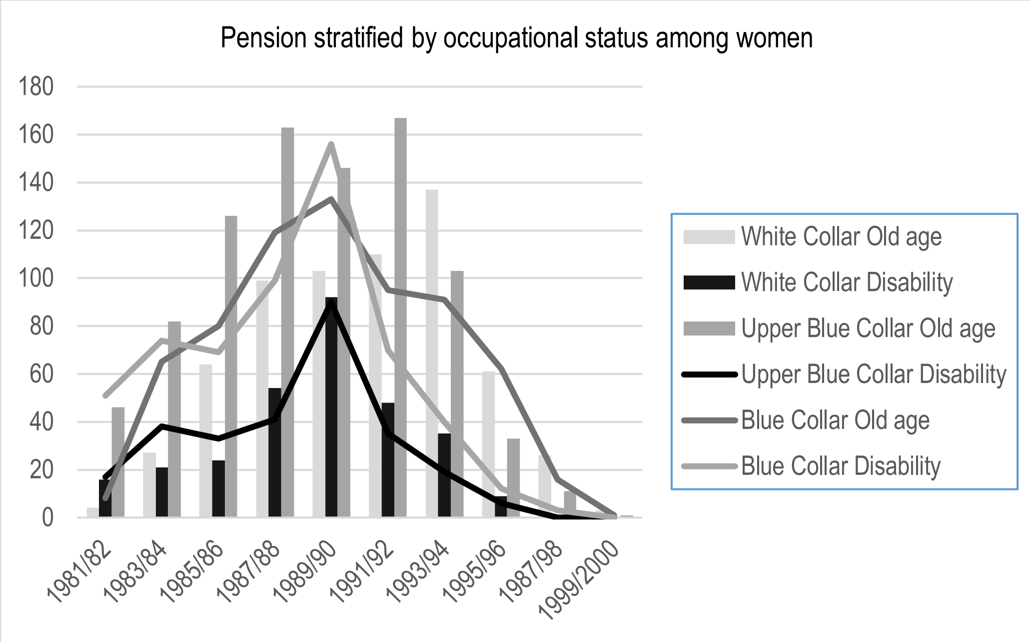

Figure 6: Type of pension stratified by occupational class among women

5.4 Type of pension stratified by occupational class among men

The retirement trend among men stratified by occupational class is presented in **Figure 7.** Among men, the disability retirement trend was substantially higher among those in blue-collar occupations in midlife. However, there was some similarity in the trend for old age pension among all occupational classes.

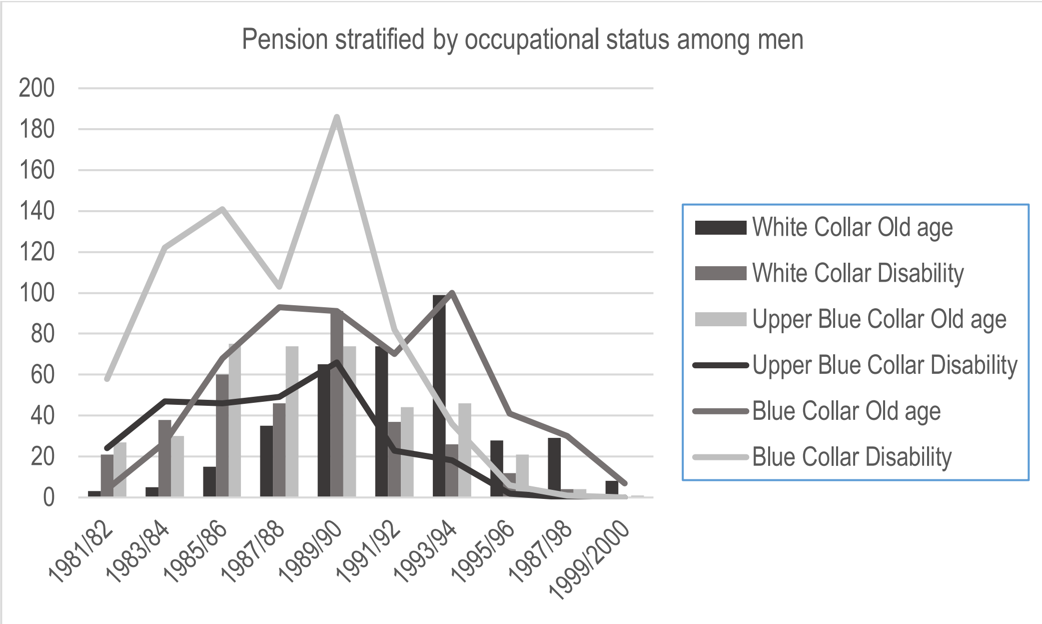

Figure 7: Type of pension stratified by occupational class among men

5.5 Musculoskeletal diseases and risk of disability

The self-reported musculoskeletal diseases in different body sites like neck, finger, toe, hand, leg, thigh, low back, shoulder were collected using the questionnaire in all study waves. In this study it was used in four forms namely neck shoulder, lower limbs, upper limbs and low back (response categorized as "no disease" and "disease present"). There was a high prevalence of low back disease followed by neck-shoulder disease in all study waves The category no disease was used as a reference group to calculate the risk ratio (RR) and 95% CI of later life disability due to MSDs in different body sites. All MSDs (Neck shoulder, lower limb, upper limb and low back) carried a significantly higher risk of disability. Those with low back disease had a higher chance of being disabled followed by those with the disease of lower limbs. (**Figure 8).**

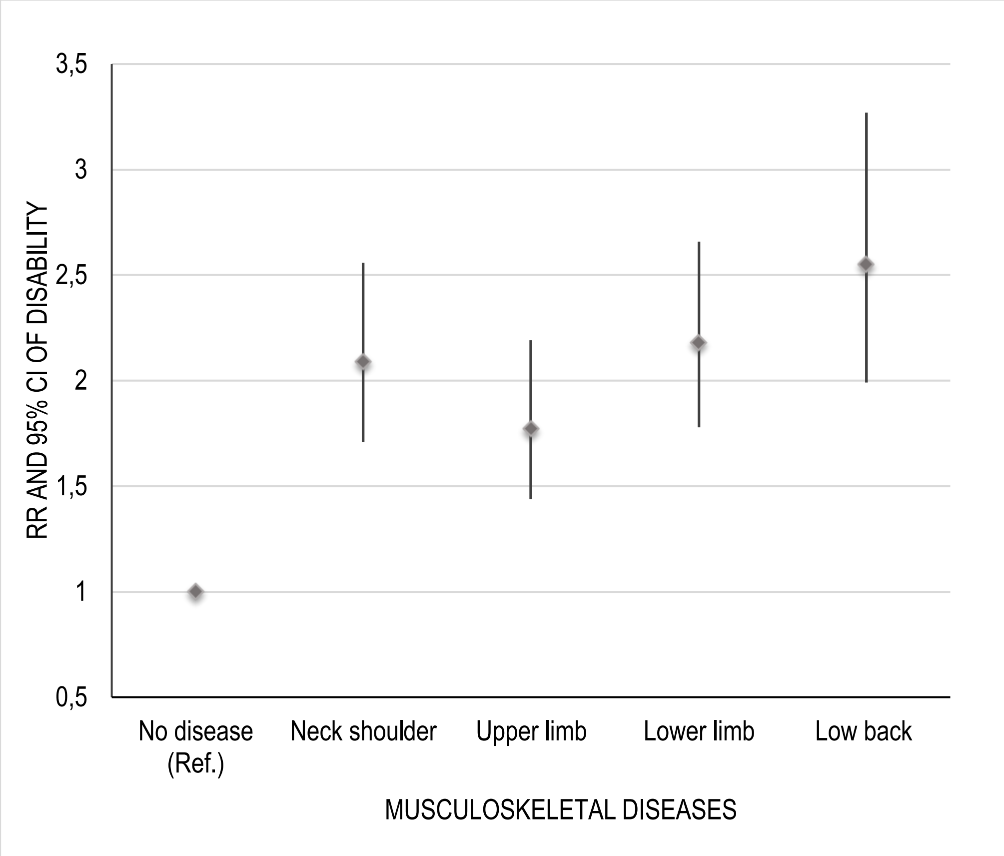

Figure 8: Risk ratio (RR) and 95 % Confidence Interval (CI) for disability in later life according to musculoskeletal diseases in different body sites (diamond denotes RR and line denotes 95% CI)

5.6 Job profiles in midlife and severity of disability in old age

The distribution of employees in different job profile groups varied according to gender, with 73% of the women in auxiliary jobs compared to 27% of the men, while 93 % of the women compared to 4% of the men were in the nursing job profile. The prevalence of disability in later life was 47% (55% women and 45% men). The mean physical load score was highest for the installation job profile (21.9) and lowest for the administrative job profile (7.5). ADL disability was highly prevalent among auxiliary workers, followed by installation and home care workers. The rate ratios (RR) and their 95% CIs were calculated for the association of midlife job profiles and disability in later life. In an age adjusted model most of the job profiles had higher disability rates than did the administrative job profile among women (auxiliary, home care, office, nursing and kitchen supervision job profiles) and men (auxiliary, installation, transportation and technical supervision job profiles). Adjusted for age, lifestyle, socio-economic and chronic diseases, women in the home care (RR 2.1, 95% CI 1.4-3.2), office (1.6, 1.1-2.4), kitchen supervision (2.0, 1.1-3.6) and auxiliary (2.1, 95% CI 1.4-3.2) job profiles had higher rates of disability in later life than did those in administrative job profiles. However, among men the technical supervision (1.7, 1.1-2.7) and auxiliary (1.5, 1.1-2.9) job profiles had higher disability rates. Later life disability was significantly predicted by the physically strenuous job profiles in midlife and, surprisingly, office job profile robustly predicted disability among women. *(Paper I)*.

5.7 Developmental pathways of mobility limitations from midlife to old age

GMM with two to five classes was fitted to identify the best-fitting model for the developmental pathways of MLs from 1981 to 2009. The model with four latent classes emerged as the best-fitting model. Although a five-class model was favoured by fit indices, the four-class model displayed better internal reliability, better substantive interpretability of classes and higher entropy. The four-class model gave us the four developmental pathways of MLs that represented low persistent MLs, low-increasing MLs, high-decreasing MLs and high persistent MLs respectively. The development of MLs among people on statutory pension (SP) and people on disability pension (DP) in low persistent MLs (24% of subjects in SP and 7% of subjects in DP), low increasing (33% and 16%), high decreasing (12% and 12%) and high persistent (33% and 65%) were presented separately. *(Paper II)*.

5.7.1 Shift work in midlife and trajectories of mobility limitations

The estimates of the association of shift work and MLs were presented as odds ratios (OR) and their 95% CIs. The shares of day work, shift work without night shifts and shift work with night shifts was 68%, 15%, and 17% respectively. Among the respondents on SP, in an age-adjusted model those belonging to the low increasing, high decreasing and high persistent MLs trajectories were markedly characterized by shift work with night shifts compared to day work. Further adjusted for gender, smoking status, alcohol intake, BMI, occupational status and chronic diseases, the risk of belonging to the high persistent MLs trajectory was higher among those doing shift work with night shifts (OR 1.49; 95% CI 1.03–2.14). Among the respondents on DP, shift work did not predict any of the MLs trajectories in the age-adjusted model. Likewise, in the fully adjusted model, those doing shift work with night shifts had an increased risk while those doing shift work without night shifts had a lower risk of belonging to all three MLs trajectories than to the low persistent trajectory, but the estimates were not statistically significant. *(Paper II).*

5.7.2 Leisure time physical activity in midlife and trajectories of mobility limitations

Odds ratios and their 95% CIs were estimated to check the association of LTPA with the trajectories of MLs. The shares of subjects with vigorous, moderate and inactive LTPA was 37%, 47% and 16% respectively. Among the respondents on SP, in an age-adjusted model belonging to low increasing, high decreasing and high persistent MLs trajectory was highly characterized by both moderate and inactive LTPA compared to vigorous LTPA. Further adjusted for gender, smoking status, alcohol intake, BMI, occupational status and chronic diseases, moderate and inactive LTPA characterized an increased risk of belonging to the low increasing and high persistent MLs trajectories. Only the inactive LTPA group had an increased risk of belonging to the high decreasing relative to the low persistent MLs trajectory (OR 3.28; 95% CI 1.72–6.23). Furthermore, the risk of belonging to the high persistent MLs trajectory was higher among those who were physically inactive (5.99; 3.39–10.58). Among the respondents on DP, the physically inactive had an increased risk of belonging to the high decreasing and high persistent MLs trajectory, in the age-adjusted model. Likewise, in the fully adjusted model, those with moderate LTPA (OR 2.29; 95% CI: 1.29–4.08) and the physically inactive (6.81; 2.52–18.43) had an increased risk of belonging to the high persistent MLs trajectory relative to the low persistent trajectory. *(Paper II)*.

5.8 Work-related exposures and musculoskeletal diseases

Biomechanical exposure was slightly lower among men (53%) than among women (54%). Of the men, 22% had combined high biomechanical and high strain exposure, which was slightly higher than that among the women (19%). In this prospective study, after 4 years and 11 years of follow up the higher level of job strain and biomechanical exposure were separately and jointly associated with higher risks of degenerative and back MSDs in both genders. However, after 28 years of follow-up the association was diluted and did not persist in both genders. The joint high job strain and high biomechanical exposures in midlife were associated with degenerative MSDs after follow-up of 4 years among women and with both degenerative and back MSDs after 4 years and 11 years of follow up among men. These associations were rather statistical than biological. None of the outcomes was associated with work-related exposures in midlife after 28-year follow-up period.

In a fully adjusted model, adjusted for age, physical activity, occupational group, BMI, alcohol intake and smoking status high biomechanical exposure predicted degenerative (RR 1.30, 95% CI 1.11, 1.52) and back MSDs (1.39, 1.16-1.67) after 4 years of follow up. Likewise, high job strain carried a 30% higher risk of degenerative MSDs than low job strain. After 11 years of follow-up the association of job strain and both outcomes persisted. In a crude joint model, high biomechanical exposure and high job strain jointly predicted both outcomes among women after both 4 and 11 years of follow-up. In a fully adjusted model, the joint association persisted after 4 years for both outcomes, but the association did not persist after 11 years of follow-up. In a fully adjusted model, among men after 11 years of follow-up only high biomechanical exposure predicted degenerative MSDs. Furthermore, high job strain and high biomechanical exposure separately predicted both outcomes after 11 years. High biomechanical exposure carried a 33% and 32% higher risk of back and degenerative MSDs respectively compared to low biomechanical exposure. Likewise, high job strain carried a 32% and a 26% higher risk of back and degenerative MSDs compared to low job strain. None of the outcomes was associated with work-related exposures in midlife after the 28-year follow-up period. The joint high biomechanical exposure and high job strain were associated with higher risk of both outcomes among men after 4 years and 11 years of follow up (crude model). In a fully adjusted model, the risk was attenuated, but retained for both outcomes. The joint exposure (high/high) had higher risk of both degenerative and back MSDs after 4 and 11 years of follow up. RERI was not significant for all the joint estimates for both genders, which clearly indicated the nonexistence of biological interaction. *(Paper III).*

5.9 Work-related exposures and disability

The estimates were presented as prevalence proportion ratios (PR) and 95% CIs for the association of work-related exposures in midlife and disability in later life for all respondents and separately for women and men. In an age-adjusted model, high job strain and high baseline biomechanical exposure predicted increase in the severity of disability in later life compared to low-level exposures. The line of association was similar for gender-stratified results, however, estimates for high biomechanical exposure were higher for women than for men and estimates for high job strain were the opposite. Further adjusted by occupational groups, all the estimates were attenuated among all respondents, women and men. In a fully adjusted model, the estimates were further attenuated, but the line of association remained similar. High vs. low strain had on average a 71% higher likelihood of predicting severity of disability. Likewise high vs. low biomechanical exposure on average 49% (PR 1.49, 95% CI 1.17-1.89) and 37% (1.37, 1.06-1.78) entailed a higher likelihood of increased severity of disability among women and men respectively. In an age adjusted model, active job strain and low biomechanical exposure in combination were protective against disability in later life among all respondents. In a fully adjusted model, high job strain and high biomechanical exposure jointly predicted the increase in severity of disability in later life among all respondents (1.28, 1.19-1.38), women (1.32, 1.21-1.45) and men (1.27, 1.13-1.44). The joint predictions were based on the concept of relative excess risk due to interactions. All the joint predictions were multiplicative and there were no additive interactions in the fully adjusted models.

Prevalence rate ratios (models I, II and III) and 95% CIs for work-related biomechanical exposures and job strain predicting ADL disability and IADL disability are described in **Table 6**. The separate results were in line with the combined ADL and IADL (used as disability in the publication). In a fully adjusted model (model III), the PR of high baseline biomechanical exposure for each unit increase in the severity of activities of daily living (ADL) disability score was 1.54 (95% CI 1.24–1.92) and PR of high job strain was 1.64 (1.12–2.39) compared to lower level of exposures. Likewise, for one unit increase in instrumental ADL (IADL) PR of high biomechanical exposure was 1.22 (1.04-1.44) and PR of high job strain was 1.60 (1.22-2.09). *(Paper IV).*

Table 6: Prevalence proportion ratios (model I, II and III) and 95% CI for work-related biomechanical exposures and job strain predicting ADL disability, IADL disability and disability (combined ADL and IADL)

Work-related exposures	ADL		IADL	
	PR	95 % CI	PR	95 % CI
Model I: Adjusted for age, tenure years (exposure)				
Biomechanical				
High vs. Low	**1.90**	**1.55-2.33**	**1.47**	**1.26-1.71**
Job strain[b]				
Passive vs. Low	1.56	1.08-2.26	1.59	1.22-2.09
Active vs. Low	1.41	0.95-2.12	1.42	1.05-1.92
High vs. Low	**2.25**	**1.56-3.24**	**2.06**	**1.58-2.70**
Active vs. Passive	0.91	0.59-1.39	0.89	0.65-1.22
High vs. Passive	1.44	0.98-2.12	1.30	0.99-1.72
High vs. Active	1.59	1.04-2.42	1.46	1.07-1.99
Model II: Adjusted for age, tenure years (exposure), hazard component and occupational class				
Biomechanical				
High vs. Low	**1.65**	**1.34-2.03**	**1.25**	**1.07-1.46**
Job strain[b]				
Passive vs. Low	1.32	0.91-1.93	1.36	1.03-1.79
Active vs. Low	1.38	0.93-2.07	1.41	1.05-1.90
High vs. Low	**1.92**	**1.33-2.79**	**1.77**	**1.34-2.32**
Active vs. Passive	1.05	0.68-1.60	1.04	0.76-1.42
High vs. Passive	1.46	0.99-2.13	1.30	0.98-1.72
High vs. Active	1.39	0.91-2.12	1.25	0.91-1.71
Model III: Adjusted for age, tenure years (exposure), hazard component, occupational class, sex and other covariates (chronic conditions, physical activity, alcohol intake, BMI and smoking status)				
Biomechanical				
High vs. Low	**1.54**	**1.24-1.92**	**1.22**	**1.04-1.44**
Job strain[b]				
Passive vs. Low	1.29	0.87-1.88	1.36	1.03-1.79
Active vs. Low	1.34	0.89-2.01	1.32	0.98-1.77
High vs. Low	**1.64**	**1.12-2.39**	**1.60**	**1.22-2.09**
Active vs. Passive	1.04	0.68-1.62	0.97	0.71-1.32
High vs. Passive	1.28	0.87-1.99	1.17	0.89-1.54
High vs. Active	1.22	0.80-1.88	1.21	0.88-1.64

BMI, Body Mass Index; CI, Confidence Interval;
PR, Prevalence Proportion Ratios; [b] Bonferroni adjusted pairwise comparisons

6 Discussion

6.1 Summary of the main findings

In this prospective 28-year follow-up study, the numerous work-related exposures in midlife were associated with musculoskeletal diseases, mobility limitations and disability in old age. The association of midlife job profiles and ADL disability in later life was more prominent among women than among men. Job profiles with higher musculoskeletal load were associated with higher disability rates than those with lower musculoskeletal load among both women and men. Among men, technical supervision and auxiliary job profiles in midlife had an increased rate of ADL disability in later life compared to administrative job profile. Among women midlife job profiles like homecare, auxiliary, kitchen supervision along with the office work had higher disability rates compared to administrative job profile.

Four developmental pathways of MLs (trajectories) among the respondents from midlife to later life were identified. The identified trajectories of MLs were low persistent, low increasing, high decreasing and high persistent. There were differences in the development of MLs among the respondents retired on statutory pension (SP) and on disability pension (DP). The higher proportion of respondents retired on DP belonged to high persistent trajectory of MLs than those retired on SP. Likewise, the low persistent trajectory of MLs was more highly belonged by those retired on SP than those retired on DP. However, both retirement groups equally belonged to the high decreasing trajectory of MLs. High persistent MLs was characterized by shift work with night shifts among those who retired in SP. Similarly, physically inactive respondents in both groups were at higher risk of high MLs in later life. Shift work and physical inactivity were potential risk factors for MLs in later life.

Higher level of job strain and biomechanical exposures predicted back and degenerative MSDs among both women and men. The interaction of job strain and biomechanical exposures also predicted MSDs among both women and men mostly around retiring and after retirement, but not in very old age. There was a statistical interaction of these exposures to increase the risk of back and degenerative MSDs, which was mostly multiplicative. Similarly, work related exposures such as high job strain and high biomechanical exposure in midlife highly (separately and jointly) characterized the severity of disability in later life among both women and men.

6.2 Discussion of the main findings

6.2.1 Job profiles and disability in old age among municipal employees

Characterization of severity of disability in old age by most of the manual job profiles among both genders and exceptionally by office job profile among women in this study corroborates the findings from some of earlier studies on the association of midlife occupational class and disability in later life (Kirause et al., 1997; Li, Wu, & Wen, 2000; Huisman et al., 2005; Vermeulen et al., 2011; McCarthy et al., 2013; Hinrichs et al., 2014; Järvholm et al., 2014; Laaksonen & Gould, 2014). Although earlier studies have reported occupational physical activity (comparable to the job profiles used in this study) as risk factors, we believe that the manual occupational classes are those involving the greatest amount of vigorous occupational physical activities. Moreover, the findings of this study contradict the findings by Rydwik et al. (2013) among Swedish cohorts aged 72 years and above. That study reported that occupational physical activity was not associated with disability in later life. The occupational physical activity reported in their study was related to longest held occupation in midlife. Similarly, the severity of disability was examined in terms of ability to perform ADL and IADL task in later life, which is similar to what was used in our study. In addition, the study also reported the protective effect of moderate occupational physical activity against risk of disability among white-collar workers (Rydwik et al., 2013). These differences from our study could be explained by the number of occupational classes used which is 13 job profiles using the detailed job analysis in this study compared to only two occupational classes used (blue collar and white collar) in their study.

In an effort to investigate and link the disability models with the theory of aging, Putnam (2002) reported that later life disability has a potential link with occupations carried out in midlife and occupational class plays a significant role in the process of aging and the progression to physical impairments (Putnam, 2002). The aging theory and disability models are applicable in the results of this study, as most of the study subjects were in their middle age of 44 to 58 years and were transitioning to retirement. Furthermore, in this study a significant number of the subjects exited the labour market on DP before the statutory age. The DP covered the majority of the diseases, disorders and impairments. In addition to physically demanding occupations, a number of other lifestyle and socioeconomic factors in midlife play a significant role in the onset of disability in later life. The effect of those factors may persist throughout the life course (Case et al., 2005; Bowen & Gonzalez, 2010). The trend of disability in old age depends on the personal level or behavioural risk factors that start to accumulate at a young age (The Lancet editorial, 1993). Some of the factors like chronic disease, LTPA, work ability, educational attainment and income were used as explanatory covariates in the present study.

This study suggests that women working in physically undemanding office job profile had a higher chance of severe disability than those in administrative job profile, which concurs with the findings on increased risk of all-cause morbidity and mortality among those doing sedentary work for longer durations in midlife (Mummery et al., 2005; Pulsford et al., 2015). A possible explanation is that at that time office work was not deemed to have higher socioeconomic status. However, this surprising finding in our study needs further confirmation, as there was not much difference in workload among those in the office and administrative job profiles. Nevertheless, the gender difference in our study is consistent with some of the earlier studies (Li, Wu, & Wen, 2000; Alvarado et al., 2007; Miranda et al., 2008; Baruth et al., 2013; Sjölund et al., 2015; Hubertsson et al., 2017). The effect of jobs done in midlife was more pronounced among women than among men. This could be attributed to the fact that poor work postures were less common among men than among women in the manual jobs (Suurnäkki et al., 1991). In addition, the women in our cohort had lower paid jobs and they were not as highly trained and educated as the men during the period of the study, but the situation is now far better. Moreover, among women and men of the same age, women have more difficulties in performing tasks related to activities of daily living (Idland et al., 2013). On the other hand, there was a higher prevalence of disability among women and the mortality rate was higher among men in our study. Furthermore, this study found that men working in technical supervision jobs had a higher chance of disability in later life than those in administrative jobs, which is the other surprising and interesting finding in our study. A possible explanation for this unexpected result is the lifestyle and socio-economic conditions of the field supervisors during the period around 1980 in Finland, which could be assumed as similar to that of other subordinates in manual job profiles whom they used to supervise. Likewise, these explanations could be feasible for the women in kitchen supervision having higher chances of disability than those in administrative jobs. In addition, those with supervision profiles also used to have comparatively longer working careers. The risk of disability and disorders varies by occupational class and depends on the concentration of the exposures during adult life (von Bonsdorff et al., 2011) and on the age of the participants (Baruth et al., 2013; Polvinen et al., 2013). The job history data and information on work-related conditions are valued tools for calculating the level of occupational exposures often used by the experts in the field of occupational health were used in the present study. However most of this information is often self-reported. The findings reported by the studies on the validity and consistency of self-reported tools and techniques mostly depict the similarities in most of the studies (Teschke, et al., 2002) which is also applicable in our study. Although occupational activity and exposures are a crucial part of the daily lives of most adults, studies on occupational exposures as a potential source of ADL and IADL disability later in life are scarce. Future studies should shed light on the association of different level exposures at work in midlife and ADL disability in later life.

6.2.2 Mobility limitations in old age

This study discovered a moderate decline in MLs among people retired on both SP and on DP around the retirement phase, which could be attributed to the fact that the period was a transition to retirement among the study subjects of present stuy, which resulted in temporary respite from work-related exposure (Tuomi et al., 1997). In addition, a higher proportion of men retired on DP than women in this study in overall comparisons, but the stratification according to the retirement year produced slightly different results. The stratified results were consistent with those reported in the study by Falkstedt et al., (2014) among the Swedish population, with higher rates of DP among women than among men (Falkstedt et al., 2014). In the gender-stratified results further stratified for occupational class, retirement on DP was higher among those working in blue-collar jobs among both genders in our study, which concurs with a Norwegian study (Emberland, Nielsen, & Knardahl, 2017) reporting higher rates of DP among those in occupations involving heavy workload. The similarity could be explained by the fact that all three countries, Finland, Norway and Sweden, have very similar occupational structures.

6.2.3 Shift work and mobility limitations in old age

Shift work with night shifts strongly characterized high persistent MLs in the present study, which is in line with earlier findings in different settings (Lipscomb et al., 2002; Overland, Glozier, & Sivertsen, 2008; Takahashi, Iwakiri, & Sotoyama, 2009; Vahtera et al., 2010; Salo et al., 2010; (Delp & Wang, 2013; Yong, Li, & Calvert, 2017). However, comparisons should be made cautiously by attributing the MLs as a progression of MSDs and sleep disturbances to shift work with night shifts. On the other hand, day work with sleep disturbance was also reported to predict low back MSDs (Takahashi, Mastudaira, & Shimazu, 2015), but the results of the present study do not extend to sleep disturbances, which warrants more careful comparisons. Nonetheless, comparison is feasible as one could consider MLs as the post phase of disease in body sites and MSDs (Institute of Medicine, 1997; Putnam, 2002).

The line of association indicated that shift work without night shifts was highly characteristic of increasing and persistent MLs. Shift work without night shifts in the present study is synonymous with evening shifts, which is also a popular term for this kind of work schedule. The aforementioned findings could be attributed to the selection of the subjects in the study. There is a common trend of changing the work schedules from shift work with night shifts to other shifts like day and evening among the people working in the social and health care sector (Härmä et al., 2017). Likewise, there was a lower likelihood of disability retirement due to MSDs among workers able to control their working hours or those with flexible working hours as suggested by the findings from the Finnish Public Sector study (Vahtera et al., 2010). There is a chance of similarity among the respondents in the Finnish Public Sector study and those in the present study as the respondents in this study were public sector employees in various municipalities in Finland. These findings in a way corroborate the findings reported by Vahtera et al., (2010) as those in day work in the present study were at the least risk of highly persistent MLs. The results were almost similar to those in the SP and in DP strata. The findings of this study are parallel to those of Lipscomb et al., (2002) and Trinkoff et al., (2006), which reported a higher rate of deterioration of musculoskeletal health among registered nurses on shift work. Furthermore, these findings are even generalizable to the present study subjects as the largest proportions of study subjects in shift work with night shifts (78%) and shift work without night shifts (18%) were public sector nurses working in municipal hospitals in Finland. There are numerous fluctuations in the findings and methodological inconsistencies in the previous studies on the association between work schedules and health outcomes in later life and the existing evidence requires further validation (Caruso & Waters, 2008; Härmä et al., 2015). Most of the variations reported in such associations were occupation specific. However, Dall'Ora et al., (2016) in their review of the impact of shift work on the wellbeing of the workers reported consistent associations and consistency of epidemiological evidence of loss of wellbeing and output due to shift work across many occupations.

6.2.4 Leisure time physical activity and mobility limitations in old age

The findings regarding the association of LTPA and pathways of MLs in later life were consistent with those of some of the existing research (Leino-Arjas et al., 2004; Gretebeck et al., 2012; Moti, Dlugonski, & Pilutti, 2012; Hinirichs et al., 2014; Nüesch et al., 2015; Artaud et al., 2016; Portegijs et al., 2017). However, the outcome of interest in the present study was the developmental pathways of MLs alongside several other limitations in physical functioning in the aforementioned studies and one could consider the development of MLs as the severity of the decline in physical functioning. Among the people on both SP and DP, lack of physical activity in midlife had a deleterious effect on mobility in later life as most of those who belonged to the high persistent class of MLs were in the inactive LTPA group in our study. The present study findings corroborate the findings by Leino-Arjas et al., (2004) and Portegijs et al., (2017) reporting better walking among those who were physically active in midlife. This study findings also concur with the findings from a sub-study of the cohort by Hinrichs et al., (2014) reporting that being vigorously active in LTPA in midlife avoids MLs in later life. The present findings are also in line with those by Gretebeck et al., (2012) and Moti et al., (2012) reporting the protective effect of moderate to vigorous LTPA against severity of disability in later life. In addition, some of the earlier findings reported that there was less chance of onset and progression of disability among those engaged in social activities (Mendes de Leon & Rajan, 2014) and there was less chance for the physically active to be disabled than for those with sedentary life styles (Pinto et al., 2014). The findings from this study corroborate the findings of both of these studies. However, comparison with the findings reported by Mendes & Rajan (2014) suggests that it is moderately feasible as we were unaware of the kind of social activities in LTPA. Furthermore, the results among those retired on SP were comparable to those of previous studies rather than among those retired on DP. In addition, around one third of the respondents retired on DP represented the high persistent MLs in our study, which could be explained by the fact that after retiring on DP there is a possibility of further deterioration of musculoskeletal health in the process of disablement.

The line of association of interaction of shift work and LTPA and MLs indicated the potentialities of high persistent MLs among the shift workers with night shifts who were physically inactive in midlife. However, the estimates for the characterization of developmental pathways of MLs were not clearly distinguishable among the different combinations of shift work and LTPA. Some of the earlier findings have suggested the similar LTPA levels among shifter workers and day workers (Kivimäki et al., 2001; Huslegge et al., 2017; Loef et al., 2017). On the other hand, various other lifestyle related factors play potential roles in impairing musculoskeletal health in later life (Lin et al., 2011; Murphy et al., 2014) besides LTPA and shift work. The findings in our study were adjusted for the various lifestyle, demographic and health-related factors with masking potentiality, which produced the narrow decline in the estimates. Nevertheless, we believe that this study is the first longitudinal study to investigate the association between shift work and the developmental pathways of MLs.

6.2.5 Midlife work-related exposures and musculoskeletal diseases

In recent years, the association between work-related exposure and MSDs has been abundantly studied using many cross sectional and some longitudinal studies. In this study, degenerative MSDs along with back MSDs were studied in relation to midlife work exposures. This study suggests that back MSDs were predicted by high biomechanical exposures, which corroborates the findings of earlier studies (Kirause et al., 1997; Vingård et al., 2000; Wai et al., 2010; Sterud & Tynes, 2013; Järvholm et al., 2014; Laaksonen & Gould, 2014; Taylor et al., 2014; Widanarko et al., 2015a; Nolet et al., 2016; Sommer, Svendsen, & Frost, 2016; Pietiläinen et al., 2017). Comparison of our findings with most of the existing studies was feasible by considering musculoskeletal symptoms, musculoskeletal pain, musculoskeletal disorders and MSDs as indicators of the musculoskeletal health of certain body sites. Likewise, our study corroborates the findings of several studies (Vingård et al., 2000; Sterud & Tynes, 2013; Janwantanakul, Sihawong, & Sitthipornvorakul, 2015; Widanarko et al., 2015a; Cantley et al., 2016; Nolet et al., 2016; Yoshimoto et al., 2017) regarding prediction of back MSDs by high psychosocial exposures. High psychosocial exposure was presented as high job strain in this study, which made the results comparable to those of most existing studies. Job strain in this study consisted of both job demands and job control, but earlier studies have used either job control or job demand only.

Also consistent with some earlier studies (Latko et al., 1999; Macfarlane, Hunt, & Silman, 2000; Bongers et al., 2006; Jensen, 2008; Miranda et al., 2008; Hooftman et al., 2009; Cantley et al., 2016; Yoshimoto et al., 2017; Hubertsson et al., 2017), the present study found that job strain and biomechanical exposure predict high risk of degenerative MSDs. Interestingly, no literature could be found using the term degenerative MSDs. However, this study used it synonymously to arthritis and other limb related MSDs occurring in some of the earlier studies. Melhorn 1998 and Jensen 2008 in their respective findings indicated the insufficiency in the evidence of a definite dose-response relationship among work-related exposures and MSDs that could later be counterbalanced by additional studies with improved methods and designs in the field. On the other hand, the association of neck-shoulder MSDs and high work-related exposures is well documented (Ohlsson et al., 1995; Hansoon et al., 2000; Pope et al., 2001; Andersen et al., 2002; Buckle & Devereux, 2002; Bongers et al., 2006; Sim, Lacey, & Lewis, 2006; Andersen, Haahr, & Frost, 2007; Tornqvist et al., 2009; Widanarko et al., 2015b; Nordander et al., 2016; Bovenzi, Prodi, & Mauro, 2016). In terms of the broad view one could generalize the present study findings with the aforementioned studies, however our outcome of interest focused mostly on MSDs of the back and lower extremities.

Gender differences

Several studies have reported gender differences in the association between work-related exposures and MSDs (Hansoon et al., 2000; Vingård et al., 2000; Miranda et al., 2008; Hooftman et al., 2009; Ropponen et al., 2013; Plouvier et al., 2015; Nordander et al., 2016; Pietiläinen et al., 2017), which is corroborated by the findings in the present study. The gender difference was reported in terms of dose-response and the level of the effect of the exposure. The effect of psychosocial exposure was more prominent among women and the effect of biomechanical exposure was more prominent among men, which concurs with the findings of earlier studies (Canivet et al., 2013; Hooftman et al., 2009; Pietiläinen et al., 2017). The risk of MSDs in later life was lower among women than among men in in the present study, which corroborates the findings reported by Plouvier et al., (2015). Furthermore, the higher and more prominent effect of physical exposures characterizing the elevated risk of MSDs in this study could be attributed to the higher proportion of men in the jobs with high biomechanical exposure.

Interaction of midlife work exposures in predicting musculoskeletal diseases

In this study biomechanical exposure and job strain jointly predicted MSDs in later life which is consistent with some earlier findings (Vingård et al., 2000; Devereux, Vlachonikolis, & Buckle, 2002; Waters, Dick, & Krieg, 2011; Sabbath et al., 2013; Widanarko et al., 2015a). Both of the work-related exposures predicted higher risk of MSDs (separately) in the present study. This warranted the analysis of a joint effect of the exposures on back and degenerative MSDs and for that purpose, the interaction estimates were used and checked for biological interactions. This study ended up with the results indicating a lack of biological effect. There was a statistical interaction effect, but the aforementioned studies reported that both effects were present and the interaction was biological in predicting overall functional status (Sabbath et al., 2013) and MSDs (Waters, Dick, & Krieg, 2011; Widanarko et al., 2015a). The differences could be attributed to the method of investigation and the nature of the study subjects. The study by Sabbath et al., (2013) used the overall health status of the old aged study subjects compared to back and degenerative MSDs used in the present study. Nevertheless, the estimates calculated and the follow-up time were similar. The study subjects of present study consisted of a cohort in their late working life and the study subjects in a cross-sectional study by Waters et al. (2011) were in active working life. Our findings on interactive prediction with statistical effect contradict some of the earlier findings (Fernandes et al., 2009; Cantley et al., 2016) reporting an absence of interaction of work-related exposures to predict MSDs. These differences were plausible due to the differences in the selection of the respondents. This study comprised various public sector occupations in contrast to the manufacturing cohort in the study by Cantley et al., (2016) and the plastic industry workers in the study by Fernandes et al., (2009). The present study findings were controlled for probable confounders like life style related factors and socio-economic factors, which attenuated the estimates of association. On the other hand, the extent of the midlife exposures, and the concentration of the risk of MSDs differed among people in different occupational classes as reported by some earlier studies (Nordander et al., 2009; Arvidsson et al., 2016). Therefore, the present study findings on prediction of MSDs in late working life and after retiring by separate and joint work-related physical and psychosocial exposures in midlife in a longitudinal study have contributed additional evidence. However, these findings still need confirmation in future studies using more clinical measures of MSDs and other job-exposure matrices.

6.2.6 Midlife work-related exposures and severity of disability in old age

The severity of disability was predicted by the higher level of work-related exposures in the present study. The findings on these associations are consistent with those of some earlier studies with long to short follow-ups (Mäntyniemi et al., 2012 ; Canivet et al.. 2013 ; Sterud & Tynes, 2013; Kulmala et al., 2013; Rijs et al., 2014; Støver et al., 2013; Taylor et al., 2014; Nolet et al., 2016; Emberland et al., 2017). Likewise, the existing evidence suggests an association between lifestyle factors (Backholer et al., 2012; Klijs et al., 2012; Tak et al., 2013; Van Oyen et al., 2014), socioeconomic factors (Picavet & Hoeymans, 2002) and chronic health (Hung et al., 2012; Dembe et al., 2014) and disability in later life. Therefore different socioeconomic, lifestyle and health related factors were used as explanatory factors in our study. These explanatory factors marginally attenuated the association between work-related exposures and disability in the present study, which corroborates the findings reported by Kuh et al., (2014) in their study on maintaining physical capability by the life-course approach of healthy aging.

The same study reported that the onset of disability from midlife to later life is associated with personal factors in adult life (Kuh et al., 2014).

The findings from the present study are consistent with the findings from the GAZEL cohort study (Platts et al., 2013; Warhrendorf et al., 2012; Sabbath et al., 2013). These studies on the GAZEL cohort reported a significant effect of work-related exposures on physical functioning throughout life from active working age to old age after retirement. The present findings are also in line with the results from the English Longitudinal Study of Ageing reporting an association between disabilities related early labour market exit and work-related psychosocial exposures like low job control, and high job demands (Hints et al., 2015). The findings of present study paralleled the findings of the studies among a Dutch cohort reporting job demands and heavy physical load as the risk factors for the deterioration of physical functioning (Geuskens et al., 2011; Rijs et al., 2014). The present study findings are likewise, consistent with the findings among Norwegian employees reporting both job strain and biomechanical exposure at work in midlife as predictors of work disability (Støver et al., 2013). Although present study findings are in line with some of the earlier findings, there are some differences, including the age of the subjects and the outcomes of interest. Most of the present study subjects were old and the ability to perform ADL tasks was used to quantify the severity of disability in old age. On the other hand, these findings slightly oppose the findings by Sommer et al., (2016) reporting a moderate association of job strain and permanent work-related disability, but confirming the findings regarding the high predictive ability of mechanical exposures. The variances could be attributed to differences in the time points of outcome measurements, which was around retirement in the study by Sommer et al., (2016) and in very old age in this study.

Gender specific variation

In addition, future physical functioning in association with midlife work-related exposures varies by gender (von Bonsdorff et al., 2011; Baruth et al., 2013; Karvonen-Gutierrez & Ylitalo, 2013; Sabbath et al., 2013; Falkstedt et al., 2014; Martin & Schoeni, 2014; Plouvier et al., 2015; van der Vorst et al., 2016; Pietiläinen et al., 2017) and those dissimilarities are seen in the present study findings. Disability due to high psychosocial exposure was more prominent among men than women, but the effect of the physical exposure was higher among women than men. In gender stratified studies the self-reported measures of disability should be used carefully and should not be regarded as identical to the objective measurements (Botoseneanu et al., 2016). However, Cuperus et al. (2015) reported undistinguishable differences in the comparison of objective and subjective diagnosis of disability.

Joint prediction of disability in old age by midlife work-related exposures

The other discovery of this study is that work-related biomechanical and job strain jointly predicted severity of disability in later life among both women and men. The study on the interaction of midlife occupational exposures as risk factors for old age functional health outcomes was as crucial as the separate effect of those exposures (Clausen et al., 2014). The present study findings support importance of the interactive effect of those exposures on predicting severity of disability. Some earlier studies have reported evidence of a joint effect of those exposures (Devereux et al., 2002; Sabbath et al., 2013; Widanarko et al., 2015a), which is paralleled by the present findings regardless of the differences in the study design and follow-up period and construction of disability measures. The interaction of high biomechanical exposure and high job strain (age adjusted) was biological in predicting the severity of disability among women. It was completely attenuated in the final model, but those effects were found to be biological in the study by Sabbath et al. (2013). The statistical estimate of interaction was highly predictive of severity of disability among women in our study, which was comparable to the estimates for musculoskeletal disability among women in a study among a Swedish cohort (Vingård et al., 2000) and a study among the GAZEL cohort (Sabbath et al., 2013). There was slight fluctuation in the size of the estimates, which could be the result of the difference in the outcome of interest.

The importance of the type of work and respective working conditions in midlife and their long-term impact on overall musculoskeletal health and better functioning in later life was highlighted in most of our study findings. In addition, our study findings demonstrate beyond doubt the need for mitigating those exposures in midlife not only for better health and for better functioning in midlife, but also for mitigating the risks of MSDs, MLs and disability in later life. There is a limited number of long-term studies on the association of later life disability with midlife occupational exposures and the available evidence lacks consistency. Moreover, there is still a need for intervention studies to study such associations (Kivimäki et al., 2015). More longitudinal studies using other exposure models and disability models are warranted to confirm the joint effects of work-related biomechanical and job strain exposures. The associations of several disease endpoints with work-related factors already observed in existing studies could be replicated by some experimental studies, which would provide and additional confirmation for the evidence already provided by observational studies.

6.3 Methodological considerations

6.3.1 Strengths of the study

Long prospective follow-up of 28 years along with being representative of the main municipal occupations is a major strength of this study. The long-term follow-up of a working cohort from midlife working age, to retirement and after retirement in old age adds a subsequent strength to better understand the effect of exposures. The response rate in this study was very high in all waves. Although there was a substantial response rate throughout the study only 50% of the baseline, respondents participated in the last wave (in 2009) due to the proportional dropouts in each wave and substantial mortality in the elderly samples. Nevertheless, the constantly higher response rate by all surviving subjects in all waves constitutes a momentous strength of our study. Among those, surviving the response rate was significantly higher in all waves and almost half of the respondents from 1981 responded in 2009. The non-respondents were older than the respondents. Most of the employees continued in the same job from the start of the study until retirement; in all more than 70% of the employees had worked in the same occupation for more than 15 years and only 2% changed their occupation (Tuomi et al., 1997). Although self-reported, the response regarding the back and degenerative MSDs was based on diagnosis by a physician. Additional strengths are the use of clustered job profiles based on a detailed job analysis of 216 work related items (Suurnäkki et al., 1991; Nygård et al., 1999). Exploring the risk factors of MSDs, MLs and old age disability a public health indicator among the rapidly growing elderly population is another potential strength of our study. Musculoskeletal health plays a significant role as an indicator of the overall health of the residents of a country. The information on retirement and mortality were taken from the national register, which enhances the reliability of this study. Likewise, in order to construct MLs outcome the ICF classification of physical functioning by WHO was used (WHO, 2001). The ICF classification is a reliable, frequently used and validated method in the contemporary research field (Hinrichs et al., 2014). Moreover, this study is among the few of its kind to endorse a vital concept of the occupational gerontology using the follow-up of almost three decades.

6.3.2 Limitations of the study

Some limitations could be addressed while understanding the findings of this study, most of it could be attributed to the self-reported nature of the data. For instance, the LTPA levels used in this study could lead to over-reporting of the activity levels itself, as they were self-reported with potentiality for recall and information bias (Hinrichs et al., 2014; Donaldson & Grant-Vallone, 2002). In order to replicate the findings of this study, the use of more objectively measured LTPA levels is warranted in future studies. We were likewise unable to include recreational and other kinds of physical activities in this study due to a lack of such information in the data used in this study. Nevertheless, most of the results in this study were adjusted for occupational class, which in a way helps to control for these limitations. Regarding the responses to the diagnosis of the MSDs, the only flaw could be recall bias on the part of the respondents' regarding the exact diagnosis. Furthermore, those responses were self-reported by the participants based on their timely diagnosis by an occupational health physician. In order to construct the psychosocial exposure (job strain) in our study we used the widely accepted job demand control concept from the Karasek model. However, the items included were self-reported and hence open to reporting bias. In addition to job strain, the items used to construct the biomechanical exposure variable were also self-reported. There was the probability of underestimation of the association because we used a single time point of the measurement of the items included to construct the aforementioned exposure variables. Nonetheless, the items available from the other time points were used to check the validity and generalizability of the exposure variables, which produced the very similar results. The exposure items measured during the active working age of the subjects and those measured during their transition to retirement were almost identical regarding sensitivity. Likewise, we believe that the level and concentration of exposure among the respondents did not vary greatly across study waves as most of the participants continued in the same job until retirement (Nygård et al., 1997; Tuomi et al., 1997). There was lack of information regarding the other items related to psychosocial work-related exposures like supportive leadership, social and co-worker support, which could be a further drawback of our study in constructing the work-related psychosocial exposure variable. Moreover, items like supportive leadership and co-worker and social support play a vital role in the onset of disability (Sterud & Tynes, 2013).

There was also a lack of comprehensive information on the fluctuation in working hours as the records on shift work were from the 80's, which may limit generalizability of the results to shift workers of the 21st century. However, there is a consistent change in the working culture and trend in shift work throughout the world (Åkerstedt & Wright, 2009) regardless of technological advances. There could be some exceptions with major alterations in the nature of some jobs due to technological development. This study used the components of ADL and IADL to construct the severity of disability and the components were self-reported. The components of ADL and IADL were also only available in the last study wave in 2009 with some potentiality for bias. However, the main aim of the study was to explore aspects of musculoskeletal health from MSDs to MLs and then disability. ADL disability is also widely used to analyse and determine the overall functional health of elderly people and the components of ADL and IADL are regarded as valid scales of measurement of old age disability even though its self-reported (Schillerstrom, Royall & Palmer, 2008; Gopinath et al., 2012).

6.3.3 Generalizability of the results

Irrespective of the type of study, most of the subjects participating in a certain study are healthier persons. The mortality rates among those who participate voluntarily in any kind of epidemiological studies are lower than among non-volunteers. The phenomena was termed as the "healthy volunteer effect" by Froom et al., (1999). Those who are occupationally active as designated by 'the healthy worker effect' also tend to live longer than general population. The study by Froom et al., (1999) was able to conclude the persistence of a healthy volunteer effect among the occupationally active population and the participants of their study were older than the non-participants. Although the participants of the present study were a cohort of public sector workers working in various occupational capacities and classes, these findings are applicable and generalizable to those working in the private sector. The main reason for the generalizability of these findings to the private sector is the equal treatment and provision in the Finnish labour legislation for all occupations and sectors. In addition, these findings could be applicable to other countries with labor policies equivalent to those implemented by Finland.

7 Conclusions

This study suggests that adverse midlife work exposures play a vital role in predicting musculoskeletal diseases, limitations in mobility and increasing severity of disability in old age among both women and men. These exposures impair overall musculoskeletal health by playing a crucial role from midlife to old age after retirement. The severity of disability in old age was also related to the job profiles derived from detail job analysis in mid-life and the effects were more prominent among women than men. Physically light work like office jobs predicted higher rates of disability among women, which provided an indication of the risk of musculoskeletal hazard carried by prolonged sedentary work. Physical inactivity in midlife was found to be a potential risk factor for limitations in mobility. Being physically active during leisure time in midlife could potentially prevent mobility limitations in later life. These findings endorse the necessity for workplace interventions in both psychosocial and biomechanical risk factors in midlife. Occupational policy and safety measures should be directed at increasing job control and reducing job demands along with reducing biomechanical exposures to prevent probable damage to the musculoskeletal health of the employees during working life as well as after retirement in old age. Occupational health care professionals and ergonomists could concentrate on reducing such exposures already in working life, which could play a significant role in the prevention of musculoskeletal hazards in later life. In addition, the workplace could serve as an arena for prevention of disability in later life by implementing interventions in midlife at work, especially among women and men doing physically heavy jobs like auxiliary work. In general, this could ultimately promote active and healthy aging by helping to avoid deterioration of overall physical and musculoskeletal health in later life in old age. The role of adverse midlife work exposures in the deterioration of musculoskeletal health throughout the life course needs further confirmation with some intervention studies. The findings regarding the role of shift work with night shifts in midlife in limiting mobility in old age are the first of their kind. Therefore, additional studies on mobility limitations among the shift workers are warranted.

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9 References

Ahacic, K., & Kåreholt, I. (2010). Prevalence of musculoskeletal pain in the geneal Swedish population from 1968 to 2002: age, period, and cohort patterns. *Pain*, 151(1), 206–214.

Åkerstedt, J., & Wright, KP. Jr. (2009). Sleep loss and fatigue in shift work and shift work disorder. *Sleep Med Clin*, 4(2), 257–271.

Alvarado, BE., Guerra, RO., & Zunzunegui, MV. (2007). Gender differences in lower extremity function in Latin American elders: seeking explanations from a life-course perspective. *J Aging Health*, 19, 1004-1024.

Andersen, JH., Haahr, JP., & Frost, P. (2007). Risk factors for more severe regional musculoskeletal symptoms: a two-year prospective study of a general working population. *Arthritis Rheum*, 56(4), 1355–1364.

Andersen, JH., Kaergaard, A., Frost, P., Thomsen, J.F., Bonde, JP., Fallentin, N., . . . Mikkelsen, S. (2002). Physical, psychosocial, and individual risk factors for neck/shoulder pain with pressure tenderness in the muscles among workers performing monotonous, repetitive work. *Spine (Phila Pa 1976)*, 27(6), 660–667.

Artaud, F., Sabia, S., Dugravot, A., Kivimäki, M., Singh-Manoux, A., & Elbaz, A. (2016). Trajectories of unhealthy behaviors in midlife and risk of disability at older ages in the Whitehall cohort study. *J Gerontol A Biol Sci Med Sci*, 71(11), 1500–1506.

Arvidsson, I., Gremark, S. J., Dahlqvist, C., Axmon, A., Karlson, B., Björk, J., . . . Nordander, C. (2016). Cross-sectional associations between occupational factors and musculoskeletal pain in women teachers, nurses and sonographers. *BMC Musculoskelet Disord,* 17, 35.

Backholer, K., Pasupathi, K., Wong, E., Hodge, A., Stevenson, C. M., & Peeters, A. (2012). The relationship between body mass index prior to old age and disability in old age. *Int J Obes (Lond),* 36(9), 1180–1186.

Badley, E. M., Webster, G. K., & Rasooly, I. (1995). The impact of musculoskeletal disorders in the population: are they just aches and pains? Findings from the 1990 Ontario health survey. *J Rheumatol*, 22, 733–739.

Balaguier, R., Madeleine, P., Rose-Dulcina, K., & Vuillerme, N. (2017). Trunk kinematics and low back pain during pruning among vineyard workers- A field study at the Chateau Larose-Trintaudon. *PLoS ONE, 12*(4), e0175126.

Baruth, M., Wilcox, S., Schoffman, D. E., & Becofsky, K. (2013). Factors associated with disability in a sample of adults with arthritis. *Disabil Health J*, 6(4), 377–384.

Bongers, PM., de Winter, C. R., Kompier, M. A., & Hildebrandt, V. H. (1993). Psychosocial factors at work and musculoskeletal disease. *Scand J Work Environ Health*, 19(5), 297–312.

Bongers, P. M., Ijmker, S., van den Heuvel, S., & Blatter, B. M. (2006). Epidemiology of work related neck and upper limb problems: psychosocial and personal risk factors (part I) and effective interventions from a bio-behavioural perspective (part II). *J Occup Rehabil*, 16(3), 279–302.

Bonvanie, I. J., Oldehinkel, A. J., Rosmalen, J. G., & Janssens, K. A. (2016). Sleep problems and pain: a longitudinal cohort study in emerging adults. *Pain*, 157(4), 957–963.

Botoseneanu, A., Allore, H. G., Mendes de Leon, C. F., Gahbauer, E. A., & Gill, T. M. (2016). Sex differences in concomitant trajectories of self-reported disability and measured physical capacity in older adults. *J Gerontol A Biol Sci Med Sci*, 71(8), 1056–1062.

Bovenzi, M., Prodi, A., & Mauro, M. (2016). A longitudinal study of neck and upper limb musculoskeletal disorders and alternative measures of vibration exposure. *Int Arch Occup Environ Health*, 89(6), 923–933.

Bowen, M. E., & Gonzalez, H. M. (2010). Childhood socioeconomic position and disability in later life: Results of the Health and Retirement Study. *Am J Public Health,* 100(Suppl. 1), S197–203.

Brown, C. J., & Flood, K. L. (2013). Mobility limitation in older patient: a clinical review. *JAMA*, 310(11), 1168–1177.

Buckle, P. W., & Devereux, J. J. (2002). The nature of work-related neck and upper limb musculoskeletal disorders. *Appl Ergon*, 33(3), 207–217.

Bugajska, J., Żołnierczyk-Zreda, D., Jędryka-Góral, A., Gasik, R., Hildt-Ciupińska K., Malińska, M., & Bedyńska, S. (2013). Psychological factors at work and musculoskeletal disorders: a one-year prospective study. *Rheumatol Int*, 33, 2975–2983.

Case, A., Ferting, A., & Paxson, C. (2005). The lasting impact of childhood health and circumstances. *J Health Econ,* 24, 365-389.

Canivet, C., Choi, B., Karasek, R., Moghaddassi, M., Staland-Nyman, C., &Öostergren, P-O. (2013). Can high psychosocial job demands, low decision latitude, and high job strain predict disability pension? A 12-year follow-up of middle-aged Swedish workers. *Int Arch Occup Environ Health*, 86, 307–319.

Cantley, L. F., Sherman, B. T., Slade, M. D., Galusha, D., & Cullen, M. R. (2016). Expert ratings of job demand and job control as predictors of injury and musculoskeletal disorder risk in a manufacturing cohort. *Occup Environ Med*, 73, 229–236.

Caruso, C. C., & Waters, T. R. (2008). A review of work schedule issues and musculoskeletal disorders with an emphasis on the healthcare sector. *Ind Health*, 46(6), 523–534.
CCOHS. Musculoskeletal disorder (MSDs). https://www.ccohs.ca/topics/hazards/ergonomic/wsmd/, accessed 18 August 2017. Canadian Centre for Occupational Health and Safety, Government of Canada (CCOHS) updated June 2017.
Chaffin, D. B., & Park, K. S. (1973). A longitudinal study of low-back pain as associated with occupational weight lifting factors. *Am Ind Hyg Assoc J*, 34(12), 513–525.
Chan, K. S., Kasper, J. D., Brandt, J., & Pezzin, L. E. (2012). Measurement Equivalence in ADL and IADL difficulty across international surveys of aging: Findings from the HRS, SHARE, and ELSA. *J Gerontol B Psychol Sci Soc Sci*, 67B(1), 121–132.
Clark, P. M., & Ellis, B. M. (2014). A public health approach to musculoskeletal health. *Best Pract Res Clin Rheumatol*, 28(3), 517–532.
Clausen, T., Burr, H., & Borg, V. (2014). Does affective organizational commitment and experience of meaning at work predict risk of disability pensioning? An analysis of register based outcomes using pooled data on 40,554 observations in four occupational group. *Am J Ind Med,* 57(6), 709–717.
Coggon, D., Ntani, G., Palmer, K. T., Felli, V. E., Harari, R., Barrero, L. H., . . . Gray, A. (2013). Disabling musculoskeletal pain in working populations: Is it the job, the person, or the culture? *Pain*, 154, 856–863.
Covinsky, K. E., Lindquist, K., Dunlop, D. D., Gill, T. M., & Yelin, E. (2008). Effect of arthritis in middle age on older-age functioning. *J Am Geriatr Soc*, 56(1), 23–28.
Cuperus, N., Vliet Vlieland, T. P., Mahler, E. A., Kersten, C. C., Hoogeboom, T. J., & van den Ende, C. H. (2015). The clinical burden of generalized osteoarthritis represented by self-reported health-related quality of life and activity limitations: a cross-sectional study. *Rheumatol Int.* 2015, 35(5), 871–877.
da Costa, B. R., & Vieira, E. R. (2010). Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. *Am J Ind Med*, 53(3), 285–323.
Dall'Ora, C., Ball, J., Recio-Saucedo, A., & Griffiths, P. (2016). Characteristics of shift work and their impact on employee performance and wellbeing: A literature review. *Int J Nurs Stud*, 57, 12–27.
Del Campto, M. T., Romo, P. E., de la Hoz, R. E., Villamor, J. M., & Mahíllo-Fernández, I. (2017). Anxiety and depression predict musculoskeletal disorders in health care workers. *Arch Environ Occup Health,* 72(1), 39–44.
Delp, L., & Wang, P. C. (2013). Musculoskeletal disorders among clerical workers in Los Angeles: a labor management approach. *Am J Ind Med*, 56(9), 1072–1081.

Dembe, A. E., Yao, X., Wickizer, T. M., Shoben, A. B., & Dong, X. (2014). Using O*NET to estimate the association between work exposures and chronic diseases. *Am J Ind Med*, 57, 1022-1031.

Devereux, J. J., Vlachonikolis, I. G., & Buckle, P. W. (2002). Epidemiological study to investigate potential interaction between physical and psychosocial factors at work that may increase the risk of symptoms of musculoskeletal disorder of the neck and upper limb. *Occup Environ Med*, 59(4), 269–277.

Díaz-Venegas, C., & Wong, R. (2016). Trajectories of limitations in activities of daily living among older adults in Mexico, 2001-2012. *Disabil Health J*, 9(3), 524–532.

Di Iorio, A., Abate, M., Guralnik, J. M., Bandinelli, S., Cecchi, F., Cherubini, A., . . . Ferucci, L. (2007). From Chronic Low Back Pain to Disability, a multifactorial mediated pathway, The InCHIANTI study. *Spine(Phila pa 1976)*, 32(26), E809–815.

Donaldson, S. I., & Grant-Vallone, E. J. (2002). Understanding self-reported bias in organizational behaviour research. *Journal of Business and Psychology*, 17(2), 245–260.

Emberland, J. S., Nielsen, M. B., & Knardahl, S. (2017). Psychological, social, and mechanical work exposures and disability retirement: a prospective registry study. *BMC Public Health*, 17, 56.

Eriksen, W., Bruusgaard, D., & Knardahl, S. (2004). Work factors as predictors of intense or disabling low back pain; a prospective study of nurses' aides. *Occup Environ Med*, 61(5), 398–404.

Escorpizo, R. (2014). Defining the principles of musculoskeletal disability and rehabilitation. *Best Pract Res Clin Rheumatol*, 28, 367–375.

Falkstedt, D., Backhans, M., Lundin, A., Allebeck, P., & Hemmingsson, T. (2014). Do working conditions explain the increased risks of disability pension among men and women with low education? A follow-up of Swedish cohorts. *Scand J Work Environ Health*, 40(5), 483–492.

Feng, Q., Liu, S., Yang, L., & Zhang, Q. (2016). The prevalence of and risk factors associated with musculoskeletal disorders among sonographers in central China: A cross-sectional study. *PLoS ONE*, 2016, 11(10), e0163903.

Fernandes, Rd, C. P., Carvalho, F. M., Assuncção, A. Á., & Neto, A. M. S. (2009). Interactions between physical and psychosocial demands of work associated to low back pain. *Rev Saúde Pública*, 43(2), 326-334.

Fried, L. P., & Guralnik, J. M. (1997). Disability in older adults: evidence regarding significane, etiology, and risk. *J Am Geriatr Soc*, 45(1), 92–100.

Fried, L. P., Young, Y., Rubin, G., & Bandeen-Roche, K. (2001). WHAS II Collaborative Group. Self-reported preclinical disability identifies older women with early declines in performance and early disease. *J Clin Epidemiol*, 54(9), 889–901.

Froom, P., Melamed, S., Kristal-Boneh, E., Benbassat, J., & Ribak, J. (1999). Healthy volunteer effect in industrial workers. *Journal Clin Epidemiol*, 52(8), 731–735.

Fujino, Y., Iso, H., Tamakoshi, A., Inaba, Y., Koizumi, A., Kubo, T., . . . Japanese Collaborative Cohort Study Group. (2006). A prospective cohort study of shift work and risk of ischaemic heart disease in Japanese male workers. *Am J Epidemiol,* 164(2), 128–135.

Geuskens, G. A., Burdorf, A., Barendregt, P. J., & Hazes, J. M. W. (2011). A high physical workload and high job demands hamper the good prognosis in physical functioning in persons with early inflammatory joint conditions. *Rheumatology*, 50, 789-798.

Gill, T. M., Guralnik, J. M., Pahor, M., Church, T., Fielding, R. A., King, A. C., . . . Miller, M. E., LIFE Study Investigators. (2016). Effect of Structured Physical Activity on Overall Burden and Transitions between States of Major Mobility Disability in Older Persons: Secondary Analysis of a Randomized Trial. *Ann Intern Med*, 165(12), 833–840.

Gommans, F., Jansen, N., Stynen, D., de Grip, A., & Kant, I. (2015). The ageing shift worker: a prospective cohort study on need for recovery, disability, and retirement intentions. *Scand J Work Environ Health*, 41(4), 356–367.

Gopinath, B., Anstey, K. J., Kifley, A., & Mitchell, P. (2012). Olfactory impairment is associated with functional disability and reduced dependence among older adults. *Maturitas*, 72, 50-55.

Gretebeck, R. J., Ferraro, K.F., Black, D. R., Holland, K., & Gretebeck, K. A. (2012). Longitudinal change in physical activity and disability in adults. *Am J Health Behav*, 36(3), 385–394.

Guralnik, J. M., Ferrucci, L., Pieper, C. F., Leveille, S. G., Markides, K. S., Ostir, G. V., . . . Wallace, R. B. (2000). Lower extremity function and subsequent disability: Consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. *J Gerontol A Biol Sci Med Sci*, 55(4), M221–231.

Guralnik, J. M., Ferrucci, L., Simonsick, E. M., Salive, M. E., & Wallace, R. B. (1995). Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. *N Engl J Med*, 332(9), 556–561.

Guralnik, J. M., LaCroix, A. Z., Abbott, R.D., Berkman, L. F., Satterfield, S., Evans, D. A., & Wallace, R. B. (1993). Maintaining mobility in life. I. Demographic characteristics and chronic conditions. *Am J Epidemiol,* 137(8), 845–857.

Häkkänen, M., Viikari-Juntura, E., & Martikainen, R. (2001). Job experience, workload and risk of musculoskeletal disorders. *Occup Environ Med*, 58, 129–135.

Halonen, J. I., Kivimäki, M., Vahtera, J., Pentti, J., Virtanen, M., Ervasti, J., . . . Lallukka, T. (2017) Childhood adversity, adult socioeconomic status and risk of work disability: a prospective cohort study. *Occup Environ Med*, 74, 659–666.

Haldeman, S., Carroll, L., & Cassidy, J. D. (2010). Findings from the bone and joint decade 2000 to 2010 task force on neck pain and its associated disorders. *J Occup Environ Med*, 52(4), 424–427.

Hansen, A. M., Darso, L., Manty, M., Nilsson, C., Christensen, U., Lund, R., . . . Avlund, K. (2014). Psychosocial factors at work and the development of mobility limitations among adults in Denmark. *Scand J Public Health*, 42(5), 417–24.

Hansoon, G. A., Balogh, I., Ohlsson, K., Pålsson, B., Rylander, L., & Skerfving, S. (2000). Impact of physical exposure on neck and upper limb disorders in female workers. *Appl Ergon*, 31(3), 301–310.

Härmä, M., Ropponen, A., Hakola, T., Koskinen, A., Vanttola, P., Puttonen, S., . . . Kivimäki, M. (2015). Developing register-based measures for assessment of working time patterns for epidemiological studies. *Scand J Work Environ Health*, 41(3), 268–279.

Härmä, M., Koskinen, A., Ropponen, A., Puttonen, S., Karhula, K., Vahtea, J., & Kivimäki, M. (2017). Validity of self-reported exposure to shift work. *Occup Environ Med*, 74, 228–230.

Haukka, E., Kaila-Kangas, L., Ojajärvi, A., Saastamoinen, P., Holtermann, A., Jørgensen, M. B., . . . Leino-Arjas, P. (2015). Multisite musculoskeletal pain predicts medically certified disability retirement among Finns. *Eur J Pain*, 19(8), 1119–1128.

Heiden, B., Weigl, M., Angerer, P., & Muller, A. (2013). Association of age and physical job demands with musculoskeletal disorders in nurses. *Appl Ergon*, 44(4), 652–658.

Heiland, E. G., Welmer, A. K., Wang, R., Santoni, G., Angleman, S., Fratiqlioni, L., & Qui, C. (2016). Association of mobility limitations with incident disability among older adults: a population-based study. *Age Ageing,* 45(6), 812–819.

Hinirichs, T., von Bonsdorff, M. B., Törmäkangas, T., von Bonsdorff, M. E., Kulmala, J., Seitsamo, J., . . . Rantanen, T. (2014). Inverse effects of Midlife Occupational and leisure time physical activity on mobility limitation in old age- A 28-Year prospective follow up study. *J Am Geriatr Soc,* 62(5), 812–820.

Hints, T., Kouvonen, A., McCann, M., Jokela, M., Elovainio, M., & Demakakos, P. (2015). Higher effort-reward imbalance and lower job control predict exit from the labour market at the age of 61 years or younger: evidence from the English Longitudinal Study of Ageing. *J Epidemiol Community Health*, 69(6), 543–549.

Hooftman, W. E., van der Beek, A. J., Bongers, P. M., & van Mechelen, W. (2009). Is there a gender difference in the effect of work-related physical and psychosocial risk factors on musculoskeletal symptoms and related sickness absence? *Scand J Work Envrion Health*, 35(2), 85–95.

Hoogendoorn, W. E., van Poppel, M. N., Bongers, P. M., Koes, B. W., & Bouter, L. M. (2000). Systematic review of psychosocial factors at work and private life as risk factors for back pain. *Spine (Phila Pa 1976)*, 25(16), 2114–2125.

Huang, G. D., Feuerstein, M., & Sauter, S. L. (2002). Occupational stress and work-related upper extremity disorders: Concepts and Models. *Am J Ind Med*, 41(5), 298–314.

Hubertsson, J., Turkiewicz, A., Petersson, I. F., & Englund, M. (2017). Understanding occupation, sick leave, and disability pension due to knee and hip osteoarthritis from a sex perspective. *Arthritis Care Res (Hoboken)*, 69(2), 226–233.

Huisman, M., Kunst, A. E., Bopp, M., Borgan, J. K., Borrell, C., Costa, G., . . . Mackenbach, J. P. (2005). Educational inequalities in cause-specific mortality in middle-aged and older men and women in eight western European countries. *Lancet,* 365(9458), 493-500.

Hung, W. W., Ross, J. S., Boockvar, K. S., & Siu, A. L. (2012). Association of chronic diseases and impairments with disability in older adults: a decade of change? *Med Care,* 50(6), 501–507.

Huslegge, G., Gupta, N., Holtermann, A., Jørgensen, M. B., Proper, K. I., & van der Beek, J. (2017). Shift workers have similar leisure-time physical activity levels as day workers but are more sedentary at work. *Scand J Work Environ Health,* 43(2), 127–135.

Idland, G., Pettersen, R., Avlund, K., & Bergland, A. (2013). Physical performance as long-term predictor of onset of activities of daily living(ADL) disability: A 9-year longitudinal study among community-dwelling older women. *Arch Gerontol Geriatr*, 56(3), 501-506.

Ilmarinen, J., Suurnakki, T., Nygård, C-H., & Landau, K. (1991). Classification of municipal occupations. *Scand J Work Environ Health,* 17(suppl 1), 12–29.

Ilmarinen, J. (2006). Towards a longer work life! Ageing and the quality of work life in the European Union. Helsinki, Finland: Finnish Institute of Occupational Health, Ministry of Social Affairs and Health.

Ilmarinen, J., Gould, R., Järvikoski, A., & Järvisalo, J. (2008). Diversity of work ability. In Gould R, Ilmarinen J, Jäarvisalo, Koskinen S (eds.) Dimensions of work ability: results of the health 2000 survey. Helsinki, Finland: Finnish Centre for Pensions (ETK), the social insurance institution (Kela), national public health institute (KTL) and Finnish Institute of Occupational Health (FIOH).

ILO. Shift Work. From ILO night work Convention 1990. http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---

travail/documents/publication/wcms_170713.pdf , accessed 28 November 2017. International Labour Organization (ILO), Geneva, updated May 2004.

Institute of Medicine (US) Committee on assessing rehabilitation science and engineering (1997). Models of Disability and Rehabilitation. In Brandt EN Jr. & Pope AM (eds) Enabling America: assessing the role of rehabilitation science and engineering. Washington (DC), National Academies Press (US).

IOSH. (2017). Musculoskeletal disorders, available in https://www.iosh.co.uk/Books-and-resources/Our-OH-toolkit/Musculoskeletal-disorders.aspx, accessed 17 August 2017. Institute of Occupational Safety and Health, Leicestershire, United Kingdom (IOSH) updated 2017.

Jagger, C., Matthews, R., Matthews, F., Robinson, T., Robine, J. M., & Brayne, C., Medical Research Council Cognitive Function and Ageing Study Investigators. (2007). The burden of disease on disability-free life expectancy in later life. *J Gerontol A Biol Sci Med Sci*, 62(4), 408–414.

Janwantanakul, P., Sihawong, R., Sitthipornvorakul, E., & Paksaichol, A. A. (2015). Screening tool for non-specific low back pain with disability in office workers: a 1-year prospective cohort study. *BMC Musculoskelet Disord*, 16, 298.

Järvholm, B., Stattin, M., Robroek, S. J., Janlert, U., Karlsson, B., & Burdorf, A. (2014). Heavy work and disability pension – a long-term follow-up of Swedish construction workers. *Scand J Work Environ Health*, 40(4), 335–342.

Jensen, L. K. (2008). Knee osteoarthritis: influence of work involving heavy lifting, kneeling, climbing stairs of ladders, or kneeling/squatting combined with heavy lifting. *Occup Environ Med*, 65, 72–89.

Jette, A. M. (2006). Toward a common language for function, disability, and health. *Phys Ther*, 86(5), 726–734.

Joling, C. I., Blatter, B. M., Ybema, J. F., & Bongers, P. M. (2008). Can favorable psychosocial work conditions and high work dedication protect against the occurrence of work-related musculoskeletal disorders? *Scand J Work Environ Health*, 34(5), 345–355.

Jørgensen, J. T., Karlsen, S., Stayner, L., Hansen, J., & Andersen, Z. J. (2017). Shift work and overall and cause-specific mortality in the Danish nurse cohort. *Scand J Work Environ Health,* 43(2), 117–126.

Juvani, A., Oksanen, T., Salo, P., Virtanen, M., Kivimäki, M., Pentti, J., & Vahtera, J. (2014). Effort-reward imbalance as a risk factor for disability pension: the Finnish public sector study. *Scand J Work Environ Health*, 40(3), 266–277.

Karasek, R. A., & Theorell, T. (1990). *Healthy work: stress, productivity and the reconstruction of working life*. New York, NY: Basic Books.

Karasek, R. A. (1979). Job demands, job decision latitude, and mental strain: implications for job redesign. *Admin Sci Q*, 24(2), 285–308.

Kärkkäinen, S., Ropponen, A., Narusyte, J., Mather, L., Åkerstedt, T., Silventoinen, K., . . . Svedberg, P. (2017). Night work as a risk factor of future disability pension due to musculoskeletal diagnoses: a prospective cohort study of Swedish twins. *Eur J Public Health*, 27(4), 659–664.

Karvonen-Gutierrez, C. A., & Ylitalo, K. R. (2013). Prevalence and correlates of disability in a late middle-aged population of women. *J Aging Health*, 25(4), 701–717.

Katz, S. (1983). Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living. *J Am Geriatr Soc*, 31, 721–727.

Kecklund, G., & Axelsson, J. (2016). Health consequences of shift work and insufficient sleep. *BMJ,* 355, i5210.

Kingston, A., Davies, K., Collerton, J., Robinson, L., Duncan, R., Kirkwood, T. B., & Jagger, C. (2015). The enduring effect of education-socioeconomic differences in disability trajectories from age 85 years in the Newcastle 85+ Study. *Arch Gerontol Geriatr,* 60(3), 405–411.

Kirause, N., Lynch, J., Kaplan, G. A., Cohen, R. D., Goldberg, D. E., & Salonen, J. T. (1997). Predictors of disability retirement. *Scand J Work Environ Health*, 23(6), 403–413.

Kivimäki, M., Kuisma, P., Virtanen, M., & Elovainio, M. (2001). Does shift work lead to poorer health habits? A comparison between women who had always done shift work with those who had never done shift work. *Work & Stress*, 15(1), 3–13.

Kivimäki, M., Singh-Manoux, A., Virtanen, M., Ferrie, J. E., Batty, G. D., & Rugulies, R. (2015). IDP-work consortium: pre-defined meta-analyses of individual-participant data strengthen evidence base for a link between psychosocial factors and health. *Scand J Work Environ Health*, 41(3), 312–321.

Kivimäki, M., Virtanen, M., Elovainio, M., Kouvonen, A., Väänänen, A., & Vahtera, J. (2006). Work stress in the etiology of coronary heart disease- a meta-analysis. *Scand J Work Environ Health*, 32(6), 431–442.

Kjellberg, K., Lundin, A., Falkstedt, D., Allebeck, P., & Hemmingsson, T. (2016). Long-term physical workload in middle age and disability pension in men and women: a follow-up study of Swedish cohorts. *Int Arch Occup Environ Health*, 89(8), 1239–1250.

Klijs, B., Mackenbach, J. P., & Kunst, A. E. (2011). Obesity, smoking, alcohol consumption and years lived with disability: a Sullivan life table approach. *BMC Public Health*, 11, 378.

Koller, M. (1996). Occupational health services for shift and night workers. *Appl Ergon*, 27(1), 31–37.

Kuh, D., Karunananthan, S., Bergman, H., & Cooper, R. (2014). A life-course approach to healthy ageing: maintaining physical capability. *Proc Nutr Soc*, 73(2), 237–248.

Kulmala, J., Hinrichs, T., Törmäkangas, T., von Bonsdorff, M. B., von Bonsdorff, M. E., Nygård, C-H., . . . Rantanen, T. (2014). Work-related stress in midlife is associated with higher number of mobility limitation in old age- Results from the FLAME study. *Age(Dordr),* 36(6), 9722.

Kulmala, J., Ngandu, T., Pajala, S., Lehtisalo, J., Levalahti, E., Antikainen, R., . . . Kivipelto, M. (2016). Leisure-Time and Occupational Physical Activity in Early and Late Adulthood in Relation to Later Life Physical Functioning. *J Phys Act Health*, 13(10), 1079–1087.

Kulmala, J., von Bonsdorff, M. B., Stenholm, S., Törmäkangas, T., von Bonsdorff, M. E., Nygård, C-H., . . . Rantanen, T. (2013). Perceived stress symptoms in midlife predict disability in old age: a 28-year prospective cohort study. *J Gerontol A Biol Sci Med Sci*, 68(8), 984-991.

Laaksonen, M., & Gould, R. (2014). The effect of municipality characteristics on disability retirement. *Eur J Public Health*, 24(1), 116–121.

Lafortune, L., Martin, S., Kelly, S., Kuhn, I., Remes, O., Cowan, A., & Brayne, C. (2016). Behavioural Risk Factors in Mid-Life Associated with Successful Ageing, Disability, Dementia and Frailty in Later Life: A Rapid Systematic Review. *PLoS ONE*, 11(2), e0144405.

Landau, K., Luczak, H., & Rohmert, W. (1976). Clusteranalytische Untersuchungen zum Arbeitswissenschaftlichen Erhebungsbogen zur Tätigkeitsanalyse. (*Abstract in English).* AET. *Z Arb Wiss*, 30, 31–39.

Latko, W. A., Armstrong, T. J., Franzblau, A., Ulin, S. S., Werner, R. A., & Albers, J. W. (1999). Cross-sectional study of relationship between repetitive work and the prevalence of upper limb musculoskeletal disorders. *Am J Ind Med*, 36(2), 248–259.

Leino-Arjas, P., Solovieva, S., Riihimaki, H., Kirjonen, J., & Telama, R. (2004). Leisure time physical activity and strenuousness of work as predictors of physical functioning: a 28-year follow up of a cohort of industrial employees. *Occup Environ Med*, 61(12), 1032–1038.

Leveille, S. G. (2004). Musculoskeletal aging. *Curr Opin Rheumatol*, 16(2), 114–118.

Li, C. Y., Wu, S. C., & Wen, S. W. (2000). Longest held occupation in a lifetime and risk of disability in activities of daily living. *Occup Environ Med*, 57(8), 550–554.

Lin, K. C., Chi, L. Y., Twisk, J. W. R., Lee, H. L., & Chen, P. C. (2011). Trajectory stability and factors affecting trajectories over time of the longitudinal age-related change in physical performance among older people. *Exp Aging Res*, 37(3), 358–376.

Lipscomb, J. A., Trinkoff, A. M., Geiger-Brown, J., & Brady, B. (2002). Work-schedule characteristics and reported musculoskeletal disorders of registered nurses. *Scand J Work Environ Health*, 28(6), 394–401.

Loef, B., Huslegge, G., Wendel-Vos, G. C. W., Monique Verschuren, W. M., Vermeulen, R. C. H., Bakker, M. F., . . . Proper, K. I. (2017). Non-occupational physical activity levels of shift workers compared with non-shift workers. *Occup Environ Med*, 74, 328–335.

Macfarlane, G. J., Hunt, I. M., & Silman, A. J. (2000). Role of mechanical and psychosocial factors in the onset of forearm pain: prospective population based study. *BMJ*, 321(7262), 676–679.

Maenner, M. J., Smith, L. E., Hong, J., Makuch, R., Greenberg, J. S., & Mailick, M. R. (2013). Evaluation of an activities of daily living scale for adolescents and adults with developmental disabilities. *Disabil Health J*, 6(1), 8-17.

Manini, T. M., Beavers, D. P., Pahor, M., Guralnik, J. M., Spring, B., Church, T. S., . . . Gill, T. M., LIFE Study Investigators. (2017). Effect of Physical Activity on Self-Reported Disability in Older Adults: Results from the LIFE Study. *J Am Geriatr Soc*, 65(5), 980-988

Mänty, M., Møller, A., Nilsson, C., Lund, R., Christensen, U., & Avlund, K. (2014). Association of physical workload and leisure time physical activity with incident mobility limitations: a follow-up study. *Occup Environ Med*, 71(8), 543–548.

Mäntyniemi, A., Oksanen, T., Salo, P., Virtanen, M., Sjösten, N., Pentti, J., Kivimäki, M., & Vahtera, J. (2012). Job strain and the risk of disability pension due to musculoskeletal disorders, depression or coronary heart diseas: a prospective cohort study of 69,842 employees. *Occup Environ Med*, 69(8), 574–581.

March, L., Smith, E. U. R., Hoy, D. G., Cross, M. J., Sanchez-Riera, L., Blyth, F., . . . Woolf, A. D. (2014). Burden of disability due to musculoskeletal (MSK) disorders. Best *Practice & Research Clinical Rheumatology*, 28, 353–366.

Marras, W. S., Cutlip, R. G., Burt, S. E., & Waters, T. R. (2009). National occupational research agenda (NORA) future directions in occupational musculoskeletal disorder health research. *Appl Ergon*, 40(1), 15–22.

Martin, L. G., & Schoeni, R. F. (2014). Trends in disability and related chronic conditions among the forty-and-over population: 1997-2010. *Disabil Health J*, 7(1 Suppl), S4–14.

Masala, C., & Petretto, D. R. (2008). From disablement to enablement: conceptual models of disability in the 20th century. *Disabil Rehabil*, 30(17), 1233–1244.

Mathiassen, S. E. (2006). Diversity and variation in biomechanical exposure: what is it, and why would we like to know? *Appl Ergon*, 37, 419–427.

Mathiowetz, N. A. (2000). Methodological issues in the measurement of work disability. In Mathiowetz N & Wunderlich GS (eds) Survey measurement of work disability: summary of a workshop.Institute of Medicine (US) and National Research Council (US) Committee to review the social security administration's disability decision process research. Washington (DC), National Academies Press (US).

McCarthy, V. J. C., Perry, I. J., & Greiner, B. A. (2013). Has your work worked you too hard? Physically demanding work and disability in a sample of the older Irish population. *Ir J Med Sci*, 182, 47-55.

Melhorn, J. M. (1998). Cumulative trauma disorders and repetitive strain injuries. The future. *Clin Orthop Relat Res*, 351, 107–126.

Mendes de Leon, C. F., Rajan, K. B. (2014). Psychosocial influences in onset and progression of late life disability. *J Gerontol B Psychol Sci Soc Sci*, 69(2), 287–302.

Miranda, H., Punnett, L., Viikari-Juntura, E., Heliövaara, M., & Knekt, P. (2008). Physical work and chronic shoulder disorder. Results of a prospective population-based study. *Ann Rheum Dis*, 67(2), 218–223.

Missikpode, C., Michael, Y. L., & Wallace, R. B. (2016). Midlife Occupational Physical Activity and Risk of Disability Later in Life: National Health and Aging Trends Study. *J Am Geriatr Soc*, 64(5), 1120–1127.

Mody, G. M., & Brooks, P. M. (2012). Improving musculoskeletal health: global issues. *Best Pract Res Clin Rheumatol,* 26(2), 237–249.

Morie, M., Reid, K. F., Miciek, R., Lajevardi, N., Choong, K., Krasnoff, J. B., . . . Lebrasseur, N. K. (2010). Habitual physical activity levels are associated with performance in measures of physical function and mobility in older men. *J Am Geriatr Soc*, 58, 1727–1733.

Moti, R. W., Dlugonski, D., Pilutti, L., Sandroff, B., & McAuley, E. (2012). Premorbid physical activity predicts disability progression in relapsing-remitting multiple sclerosis. *J Neurol Sci*, 323(1-2), 123–127.

Mummery, W. K., Schofield, G. M., Steele, R., Eakin, E. G., & Brown, W. J. (2005). Occupational sitting time and overweight and obesity in Australian workers. *Am J Prev Med*, 29, 91-97.

Murphy, R. A., Patel, K. V., Kritchevsky, S. B., Houston, D. K., Newman, A. B., Koster, A., . . . Harris, T. B. (2014). Weight change, body compostion, and risk of mobility disability and mortality in older adults: A population-based cohort study. *J Am Geriatr Soc*, 62(8), 1476–1483.

Murray, C. J. L., Vos, T., Lozano, R., Naghavi, M., Flaxman, A. D., Michaud, C., . . . Memish, Z. A., GBD 2010 DALYs and HALE collaborators. (2012). Disability adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*, 380(9859), 2197–2223.

Murray, C. J. L., Barber, R.M., Foreman, K. J., Ozgoren, A. A., Abd-Allah, F., Abera, S. F., . . . Vos, T., GBD 2013 DALYs and HALE collaborators. (2015). Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990-2013: quantifying the epidemiological transition. *Lancet*, 386(10009), 2145–2191.

Mustard, C. A., Chambers, A., Ibrahim, S., Etches, J., & Smith, P. (2015). Time trends in musculoskeletal disorders attributed to work exposures in Ontario using three independent data sources, 2004-2011. *Occup Environ Med*, 72, 252–257.

Muthén, B. (2003). Statistical and substantive checking in growth mixture modeling: comment on Bauer and Curran. *Psychol Methods*, 8(3), 369–377.

Nagi, S. Z. (1965). Some conceptual issues in disablity and rehabilitation. In: Sussman MB (Ed). Sociology and rehabilitation. Washington DC: American Sociological Association, 1965:100–113.

National Research Council (US) and Institute of Medicine (US) (2001). Panel on musculoskeletal disorders and the workplace: low back and upper extremities. Washington (DC): National Academies Press (US); 6, Biomechanics.

Neupane, S., Miranda, H., Virtanen, P., Siukola, A., & Nygård, C-H. (2011). Multi-site pain and work ability among an industrial population. *Occup Med*, 61(8), 563–569.

Neupane, S., Leino-Arjas, P., Nygård, C-H., Oakman, J., & Virtanen, P. (2017). Developmental pathways of multisite musculoskeletal pain: what is the influence of physical and psychosocial working conditions? *Occup Environ Med*, 74, 468–475.

Nolet, P. S., Kristman, V. L., Côte, P., Carroll, L. J., Hincapié, C. A., & Cassidy, J. D. (2016). The association between history of work-related low back injury and future low back pain: a population based cohort study. *Eur Spine J*, 25(4), 1242–1250.

Nordander, C., Hansson, G. A., Ohlsson, K., Arvidsson, I., Balogh, I., Strömberg, U., . . . Skerfving, S. (2016). Exposure-response relationships for work-related neck and shoulder musculoskeletal disorders--Analyses of pooled uniform data sets. *Appl Ergon*, 55, 70–84.

Nordander, C., Ohlsson, K., Akesson, I., Arvidsson, I., Balogh, I., Hansson, G. A., . . . Skerfving, S. (2009). Risk of musculoskeletal disorders among females and males in repetitive/constrained work. *Ergonomics*, 52(10), 1226–1239.

Nüesch, E., Pablo, P., Dale, C. E., Prieto-Merino, D., Kumari, M., Bowling, A., . . . Cassas, J. P. (2015). Incident disability in older adults: prediction models based on two British prospective cohort studies. *Age Ageing*, 44(2), 275–282.

Nusselder, W. J., Looman, C. W., & Mackenbach, J. P. (2005). Nondisease factors affected trajectories of disability in a prospective study. *J Clin Epidemiol*, 58(5), 484–494.

Nygård, C-H., Suurnäkki, T., Landau, K., & Ilmarinen, J. (1987). Musculoskeletal load of municipal employees aged 44-58 years in different occupational groups. *Int Arch Occup Environ Health,* 59(3), 251-261.

Nygård, C-H., Huuhtanen, P., Tuomi, K., & Martikainen, R. (1997). Perceived work changes between 1981 and 1992 among aging workers in Finland. *Scand J Work Environ Health*, 23(suppl 1), 12-19.

Nygård, C-H., Suurnäkki, T., Peltomaa, T., & Ilmarinen, J. (1999). Job demands of ageing employees over a 12-year period. FinnAge- Respect for the aging: Action programme to promote health, work ability and well-being of aging workers in 1990-96. In Ilmarinen J & Louhevaara V (Eds.), People and Work Research Report 26, Finnish Institute of Occupational Health, 251-259.

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study. *STRUCTURAL EQUATION MODELING*, 14(4), 535–569.

Ohlsson, K., Attewell, R. G., Pålsson, B., Karlsson, B., Balogh, I., Johnsson, B., . . . Skerfving, S. (1995). Repetitive industrial work and neck and upper limb disorders in females. *Am J Ind Med*, 27(5), 731–747.

Overland, S., Glozier, N., Sivertsen, B., Stewart, R., Neckelmann, D., Krokstad, S., & Mykletun, A. (2008). A comparison of insomnia and depression as predictors of disability pension: the HUNT study. *Sleep*, 31(6), 875–880.

Pahor, M., Guralnik, J. M., Ambrosius, W. T., Blair, S., Bonds, D. E., Church, T. S., . . . Williamson, J. D., LIFE Study Investigators. (2014). Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. *JAMA*, 311(23), 2387–2396.

Palazzo, C., Ravaud, J-F., Papelard, A., Ravaud, P., & Poiraudeau, S. (2014). The burden of Musculoskeletal Conditions. *PLOS ONE,* 9(3), e90633.

Picavet, H. S., & Hoeymans, N. (2002). Physical disability in The Netherlands: prevalence, risk groups and time trends. *Public Health*, 116(4), 231–237.

Pietiläinen, O., Laaksonen, M., Lahelma, E., Salonsalmi, A., & Rahkonen, O. (2017). Occupational class inequalities in disability retirement after hospitalization. *Scand J Public Health*, 1403494817726618. doi: 10.1177/1403494817726618.

Pinto, R. Z., Ferreira, P. H., Kongsted, A., Ferreira, M. L., Maher, C. G., & Kent, P. (2014). Self-reported moderate-to-vigorous leisure time physical activity predicts less pain and disability over 12 months in chronic and persistent low back pain. *Eur J Pain*, 18(8), 1190–1198.

Platts, L. G., Netuveli, G., Webb, E., Zins, M., Golberg, M., Blane, D., & Wahrendorf, M. (2013). Physical occupational exposures during working life and quality of life after the labour market exit: results from the GAZEL study. *Aging Ment Health*, 17(6), 697–706.

Plouvier, S., Chastang, J. F., Cyr, D., Bonenfant, S., Descatha, A., Goldberg, M., & Leclerc, A. (2015). Occupational biomechanical exposure predicts low back pain in older age among men in the Gazel cohort. *Int Arch Occup Environ Health*, 88(4), 501-510.

Polvinen, A., Gould, R., Lahelma, E., & Martikainen, P. (2013). Socioeconomic differences in disability retirement in Finland: the contribution of ill-health, health behaviours and working conditions. *Scand J Public Health*, 41(5), 470–478.

Pope, D. P., Silman, A. J., Cherry, N. M., Pritchard, C., & Macfarlane, G. J. (2001). Association of occupational physical demands and psychosocial working environment with disabling shoulder pain. *Ann Rheum Dis*, 60(9), 852–858.

Portegijs, E., Keskinen, K. E., Tsai, L-T., Rantanen, T., & Rantakokko, M. (2017). Physical limitations, walkability, perceived environmental facilitators and physical activity of older adults in Finland. *Int J Environ Res Public Health*, 14(3), E333.

Pulsford, R. M., Stamatakis, E., Britton, A. R., Brunner, E. J., & Hillsdon, M. (2015). Associations of sitting behaviours with all-cause mortality over a 16-year follow-up: the Whitehall II study. *Int J Epidemiol*, 44(6), 1909-1916.

Putnam, M. (2002). Linking aging theory and disability models: Increasing the potential to explore aging with physical impairment. *Gerontologist,* 42(6), 799–806.

Rijs, K. J., van der Pas, S., Geuskens, G. A., Cozinjnsen, R., Koppes, L. L. J., van der Beek, A. J., & Deeg, D. J. H. (2014). Development and validation of physical and psychosocial job-exposure matrix in older and retired workers. *Ann Occup Hyg*, 58(2), 152–170.

Roffey, D. M., Wai, E. K., Bishop, P., Kwon, B. K., & Dagenais, S. (2010). Causal assessment of occupational standing or walking and low back pain: results of a systematic review. *The spine journal*, 10(3), 262–272.

Rohmert, W., & Landau, K. (1983). A new technique for job analysis. 1st edition. Taylor and Francis Ltd, London.

Ropponen, A., Samuelsson, Å., Alexanderson, K., & Svedberg, P. (2013). Register- based data of psychosocial working conditions and occupational groups as predictors of disability pension due to musculoskeletal diagnoses: a prospective cohort study of 24543 Swedish twins. *BMC Musculoskelet Disord*, 14, 268.

Roquelaure, Y., Ha, C., Leclerc, A., Touranchet, A., Sauteron, M., Melchior, M., . . . Goldberg, M. (2006). Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population. *Arthritis Rheum*, 55(5), 765–778.

Rothman, K. J., Lash, T. L., & Greenland, S. (2008). Chapter 5: Concepts of Interaction. In: *Modern epidemiology*. 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins, 74–83.

Rydwik, E., Welmer, A-K., Angleman, S., Fratiglioni, L., & Wang H-X. (2013). Is midlife occupational physical activity related to disability in old age? The SNAC-Kungsholmen Study. *PLoS ONE*, 8(7), e70471.

Sabbath, E. L., Glymour, M. M., Descatha, A., Leclerc, A., Zins, M., Goldberg, M., & Berkman, L. F. (2013). Biomechanical and psychosocial occupational exposures: Joint predictors of post-retirement functional health in the French GAZEL cohort. *Adv Life Course Res*, 18(4), 235–243.

Salo, P., Oksanen, T., Sivertsen, B., Hall, M., Pentti, J., Virtanen, M., Vahtera, J., & Kivimäki, M. (2010). Sleep disturbances as a predictor of cause-specific work disability and delayed return to work. *Sleep*, 33(10), 1323–1331.

Santos, K. O. B., de Araújo, T. M., Carvalho, F. M., & Karasek, R. (2017). The job content questionnaire in various occupational contexts: applying a latent class model. *BMJ Open*, 7, e013596.

Sarquis, L. M., Coggon, D., Ntani, G., Walker-Bone, K., Palmer, K. T., Felli, V. E., . . . Salazar Vega, E. J. (2016). Classification of neck/shoulder pain in epidemiological research: a comparison of personal and occupational characteristics, disability, and prognosis among 12,195 workers from 18 countries. *Pain*, 157(5), 1028–1036.

Schillerstrom, J. E., Royall, D. R., & Palmer, R. F. (2008). Depression, Disability and intermediate Pathways: A review of Longitudinal Studies in Elders. *J Geriatr Psychiatry Neurol,* 21, 83.

Schuntermann, M. F. (2005). The implementation of the International Classification of Functioning, Disability and Health in Germany: experiences and problems. *Int J Rehabil Res*, 28(2), 93–102.

Shiftwork, Solutions. (2017). Employee Shift Work Schedules: An Introduction. http://shift-work.com/articlesnewsletters/shiftwork-articles/employee-shift-work-schedules-an-introduction/ , accessed 28 November 2017. Shiftwork Solutions, updated 2017.

Shumway-Cook, A., Ciol, M. A., Yorkston, K. M., Hoffman, J. M., & Chan, L. (2005). Mobility limitations in the Medicare population: prevalence and sociodemographic and clinical correlates. *J Am Geriatr Soc,* 53(7), 1217–1221.

Sim, J., Lacey, R. J., & Lewis, M. (2006). The impact of workplace risk factors on the occurrence of neck and upper limb pain: a general population study. *BMC Public Health*, 6, 234.

Sivertsen, B., Overland, S., Neckelmann, D., Glozier, N., Krokstad, S., Pallesen, S., . . . Mykletun, A. (2006). The long-term effect of insomnia on work disability: the HUNT-2 historical cohort study. *Am J Epidemiol*, 163(11), 1018–1024.

Sjölund, B. M., Wimo, A., Engstrom, M., & von Strauss, E. (2015). Incidence of ADL Disability in Older Persons, Physical Activities as a Protective Factor and the Need for Informal and Formal Care--Results from the SNAC-N Project. *PLoS ONE*, 10(9), e0138901.

Sommer, T. G., Svendsen, S. W., & Frost, P. (2016). Sickness absence and permanent work disability in relation to upper- and lower –body pain and occupational mechanical and psychosocial exposure. *Scand J Work Environ Health*, 142(6), 481–489.

Spector, W. D., & Fleishman, J. A. (1998). Combining activities of daily living with instrumental activities of daily living to measure functional disability. *J Gerontol B Psychol Sci Soc Sci*, 53(1), S46–57.

Stankevitz, K., Schoenfisch, A., de Silva, V., Tharindra, H., Stroo, M., & Ostbye, T. (2016). Prevalence and risk factors of musculoskeletal disorders among SriLankan rubber tappers. *Int J Occup Environ Health*, 22(2), 91–98.

Statistics, Finland. (2017). Findicator. Recipients of disability pension: disability pensioners of the earnings-related pension scheme. http://findikaattori.fi/en/76 , accessed 15 November 2017. Statistics Finland, updated March 30 2017.

Sterud, T., & Tynes, T. (2013). Work-related psychosocial and mechanical risk factors for low back pain: a 3-year follow-up study of the general working population in Norway. *Occup Environ Med*, 70(5), 296–302.

Støver, M., Pape, K., Johnsen, R., Fleten, N., Sund, E. R., Ose, S. O., & Bjørngaard, J. H. (2013). Work environment and disability pension- an 18 year follow-up study in a Norwegian working population. *Scand J Public Health*, 41(6), 587-596.

Suurnäkki, T., Nygård, C-H., & Ilmarinen, J. (1991). Stress and strain of elderly employees in municipal occupations. *Scand J Work Environ Health*, 17(suppl 1), 30-39.

Tak, E., Kuiper, R., Chorus, A., & Hopman-Rock, M. (2013). Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: a meta-analysis. *Aging Res Rev*, 12(1), 329–338.

Takahashi, M., Iwakiri, K., Sotoyama, M., Hirata, M., & Hisanga, N. (2009). Musculoskeletal pain and night shifts naps in nursing home care workers. *Occup Med (Lond),* 59(3), 197–200.

Takahashi, M., Mastudaira, K., & Shimazu, A. (2015). Disabling low back pain associated with night shift duration: sleep problems as a potentiator. *Am J Ind Med*, 58(12), 1300–1310.

Tas, U., Verhagen, A. P., Bierma-Zeinstra, S. M. A., Odding, E., & Koes, B. W. (2007). Prognostic factors of disability in older people: a systematic review. *Br J Gen Pract*, 57(537), 319–323.

Taylor, J. B., Goode, A. P., George, S. Z., & Cook, C. E. (2014). Incidence and risk factors for the first-time incident low back pain: a systematic review and meta-analysis. *The spine journal*, 14(10), 2299–3019.

Teschke, K., Olshan, A. F., Daniels, J. L., De Roos, A. J., Parks, C. G., Schulz, M., & Vaughan, T. L. (2002). Occupational exposure assessment in case-control studies: opportunities for improvement. *Occup Environ Med,* 59(9), 575–583.

The Lancet editorial. (1993). Ageing at work: consequences for industry and individual. *THE LANCET*, 340(8837), 87–88. (no authors listed)

Tornqvist, E. W., Hageberg, M., Hagman, M., Risberg, E. H., & Toomingas, A. (2009). The influence of working conditions and individual factors on the incidence of neck and upper limb symptoms among professional computer users. *Int Arch Occup Environ Health*, 82(6), 689–702.

Trinkoff, A. M., Le, R., Geiger-Brown, J., Lipscomb, J., & Lang, G. (2006). Longitudinal relationship of work hours, mandatory overtime, and on.call to musculoskeletal problems in nurses. *Am J Ind Med*, 49(11), 964–971.

Tsang, A., Von Korff, M., Lee, S., Alonso, J., Karam, E., Angermeyer, M. C., . . . Watanabe, M. (2008). Common chronic pain conditions in developed and developing countries: gender and age differences and comorbidity with depression-anxiety disorders. *J Pain*, 9(10), 883–891.

Tüchsen, F., Christensen, K. B., Lund, T., & Feveile, H. (2008). A 15-year prospective study of shift work and disability pension. *Occup Environ Med*, 65(4), 283–285.

Tuomi, K., Toikkanen, J., Eskelinen, L., Backman, A. L., Ilmarinen, J., Järvinen, E., & Klockars, M. (1991). Mortality, disability and changes in occupation among aging municipal employees. *Scand J Work Environ Health*, 17(suppl 1), 58–66.

Tuomi, K., Huuhtanen, P., Nykyri, E., & Ilmarinen, J. (2001). Promotion of work ability, the quality of work and retirement. *Occupational Medicine*, 51(5), 318–324.

Tuomi, K., Ilmarinen, J., Klockars, M., Nygård, C-H., Seitsamo, J., Huuhtanen, P., . . . Aalto, L. (1997). Finnish research project on aging workers in 1981-1992. *Scand J Work Environ Health*, 23(suppl 1), 7–11.

Vahtera, J., Laine, S., Virtanen, M., Oksanen, T., Koskinen, A., Pentti, J., & Kivimäki, M. (2010). Employee control over working times and risk of cause-specific disability pension: the Finnish Public Sector Study. *Occup Environ Med*, 67, 479–485.

van der Vorst, A., Zijlstra, G. A., Witte, N., Duppen, D., Stuck, A. E., Kempen, G. I. J. M., & Schols, J. M. G. A., (on behalf of the D-SCOPE Consortium). (2016). Limitations in Activities of Daily Living in Community-Dwelling People Aged

75 and Over: A Systematic Literature Review of Risk and Protective Factors. *PLoS ONE*, 11(10), e0165127.

Van Oyen, H., Berger, N., Nusselder, W., Charafeddine, R., Jagger, C., Cambois, E., Robine, J. M., & Demarest, S. (2014). The effect of smoking on the duration of life with and without disability, Belgium 1997-2011. *BMC Public Health*, 14, 723.

Vandergrift, J. L., Gold, J. E., Hanlon, A., & Punnet, L. (2012). Physical and psychosocial ergonomic risk factors for low back pain in automobile manufacturing workers. *Occup Environ Med*, 69(1), 29–34.

VanderWeele, T. J., & Knol, M. J. (2014). A tutorial on Interaction. *Epidemiol Methods*, 3(1), 33–72.

Verbrugge, L.M., & Jette, A. M. (1994). The disablement process. *Soc Sci Med,* 38(1), 1–14.

Vermeulen, J., Neyens, J. C. L., van Rossum, E., Spreeuwenberg, M. D., & de Witte, L. P. (2011). Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. *BMC Geriatrics*, 11, 33.

Vingård, E., Alfredsson, L., Hagberg, M., Kilbom, A., Theorell, T., Waldenström, M., . . . Hogstedt, C. (2000). To what extent do current and past physical and psychosocial occupational factors explain care seeking for low back pain in a working population? Results from the musculoskeletal intervention Norrälje study. *Spine (Phila Pa 1976)*, 25(4), 493–500.

Virkkunen, H., Härmä, M., Kauppinen, T., & Tenkanen, L. (2006). The triad of shift work, occupational noise, and physical workload and risk of coronary heart disease. *Occup Environ Med,* 63(6), 378–386.

von Bonsdorff, M. B., Rantanen, T., Laukkanen, P., Suutama, T., & Heikkinen, E. (2006). Mobility limitations and cognitive deficits as predictors of institutionalization among community-dwelling older people. *Gerontology,* 52(6), 359–365.

von Bonsdorff, M. B., Seitsamo, J., Ilmarinen, J., Nygård, C-H., von Bonsdorff, M. E., & Rantanen, T. (2011). Work ability in midlife as a predictor of mortality and disability in later life: a 28-year prospective follow-up study. *CMAJ*, 183(4), E235-242.

von Bonsdorff, M. B., Seitsamo, J., von Bonsdorff, M. E., Ilmarinen, J., Nygård, C-H., & Rantanen, T. (2012). Job strain among blue-collar and white-collar employees as a determinant of total mortality: a 28-year population based follow-up. *BMJ Open*, 2(2), e000860.

von Bonsdorff, M. E., Rantanen, T., Törmäkangas, T., Kulmala, J., Hinrichs, T., Seitsamo, J., . . . von Bonsdorff, M. B. (2016). Midlife work ability and mobility limitation in old age among non-disability and disability retirees – a prospective study. *BMC Public Health,* 16, 154.

Wai, E. K., Roffey, D. M., Bishop, P., Kwon, B. K., & Dagenais, S. (2010). Causal assessment of occupational lifting and low back pain: results of a systematic review. *Spine J,* 10(6), 554–566.

Wang, X., Dong, X. S., Choi, S. D., & Dement, J. (2017). Work-related musculoskeletal disorders among construction workers in the United States from 1992 to 2014. *Occup Environ Med*, 74(5), 374–380.

Wahrendorf, M., Sembajwe, G., Zins, M., Berkman, L., Goldberg, M., & Siegrist, J. (2012). Long-term effects of psychosocial work stress in midlife on health functioning after labor market exit – results from the GAZEL study. *J Gerontolol B Psychol Sci Soc Sci*, 67(4), 471–480.

Waters, T. R., Dick, R. B., & Krieg, E. F. (2011). Trends in work-related musculoskeletal disorders: A comparison of risk factors for symptoms using quality of work life data from the 2002 and 2006 general social survey. *J Occup Environ Med*, 53(9), 1013–1024.

Westerlund, H., Kivimäki, M., Singh-Manoux, A., Melchior, M., Ferrie, J. E., Pentti, J., . . . Vahtera, J. (2009). Self-rated health before and after retirement in France (GAZEL): a cohort study. *Lancet,* 374(9705), 1889–1896.

Widanarko, B., Legg, S., Devereux, J., & Stevenson, M. (2015a). Interaction between physical and psychosocial work risk factors for low back symptoms and its consequences amongst Indonesian coal mining workers. *Appl Ergon*, 46 Pt A, 158–167.

Widanarko, B., Legg, S., Devereux, J., & Stevenson, M. (2015b). Interaction between physical and psychosocial risk factors on the presence of neck/shoulder symptoms and its consequences. *Ergonomics*, 58(9), 1507–1518.

Wolfe, F., Smythe, H. A., Yunus, M. B., Bennett, R. M., Bombardier, C., Goldenberg, D. L., . . . Sheon, R. P. (1990). The American College of Rheumatology 1990 Criteria for the Classification of Fibromyalgia. Report of the Multicenter Criteria Committee. *Arthritis Rheum*, 33(2), 160–172.

Wong, E., Stevenson, C., Backholer, K., Woodward, M., Shaw, J. E., & Peeters, A. (2015). Predicting the risk of physical disability in old age using modifiable mid-life risk factors. *J Epidemiol Community Health*, 69(1), 70–76.

Woolf, A. D., & Pfleger, B. (2003). Burden of major musculoskeletal conditions. *Bull World Health Organ*, 81(9), 646–656.

World Health organization (WHO). (2003). The burden of musculoskeletal conditions at the start of the new millennium. Report of a WHO scientific group. WHO technical report series: 919. Geneva, *WHO*.

World Health Organization (WHO). (1980). International Classification of impairments, disabilities and handicaps (ICIDH). Geneva, *WHO*.

World Health Organization (WHO). (2001). International Classification of Functioning, Disability and Health (ICF). Geneva, *WHO*.

Yong, L. C., Li, J., & Calvert, G. M. (2017). Sleep-related problems in the US working population: prevalence and association with shiftwork status. *Occup Environ Med*, 74(2), 93–104.

Yoshimoto, T., Oka, H., Katsuhira, J., Fuji, T., Masuda, K., Tanaka, S., & Matsudaira, K. (2017). Prognostic psychosocial factors for disabling low back pain in Japanese hospital worker. *PLoS ONE*, 12(5), e0177908.

Yue, P., Xu, G., Li, L., & Wang, S. (2014). Prevalence of musculoskeletal symptoms in relation to psychosocial factors. *Occup Med (Oxf)*, 64(3), 211–216.

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ORIGINAL ARTICLE

Midlife job profiles and disabilities in later life: a 28-year follow-up of municipal employees in Finland

K. C. Prakash[1,5] · Subas Neupane[1,5] · Päivi Leino-Arjas[1,2] · Mikaela B. von Bonsdorff[3] · Taina Rantanen[3] · Monika E. von Bonsdorff[3] · Jorma Seitsamo[2] · Juhani Ilmarinen[4] · Clas-Håkan Nygård[1,5]

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Abstract

Purpose Occupations during adult life may have long-term effects and subsequently increase the risk of disability in old age. We investigated the associations between job profile groups in midlife and disability in old age for women and men.

Methods This prospective 28-year follow-up study (1981–2009) examined 2998 municipal employees (1892 women and 1106 men) aged 44–58 years at baseline. A detailed analysis of the demands of 88 occupations based on interviews and observations at the work places was made at baseline. Thirteen job profile clusters emerged. Questionnaire information on health, lifestyle and socio-demographic factors was collected at baseline. In 2009, five Activities of Daily Living and seven Instrumental Activities of Daily Living tasks were assessed. A sum score of '0–12' was calculated using 12 dichotomous tasks where '0' indicates no difficulties in any tasks and '1–12' indicates increasing disability. Negative binomial regression was used to calculate rate ratios (RR) and their 95 % confidence intervals (CIs) for disability due to midlife job profiles.

Results After adjusting for age, socioeconomic, lifestyle and health-related characteristics, women in auxiliary (RR 2.1, 95 % CI 1.4–3.2), home care (2.1, 1.4–3.2), kitchen supervision (2.0, 1.1–3.6) and office (1.6, 1.1–2.4) job profiles had a higher risk of disability in later life than those in administrative jobs. Auxiliary (1.5, 1.1–2.9) and technical supervision (1.7, 1.1–2.7) job profiles carried an increased risk among men.

Conclusion Midlife job profiles mainly linked with physically heavy work were strong predictors of disability in later life. In women, office work also increased the risk of disability.

Keywords Middle age · Job profile · ADL/IADL disability · Later life · Longitudinal studies

Introduction

Disability, or difficulty in accomplishing activities in any domain of life due to a health or physical problem (Maenner et al. 2013), occurs as a result of an imbalance between the physical capabilities of an individual and the demands of the physical environment (Brandt and Pope 1997). The ability to perform Activities of Daily Living (ADL; Katz 1983) without difficulties is vital from the perspective of independent living in old age as the functional capacity declines (Maenner et al. 2013). With the aging of the population, knowledge of potentially modifiable determinants of variation in ADL disability in old age is needed to eventually tackle the societal challenges arising from an increasing number of subjects with disabilities.

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✉ K. C. Prakash
Prakash.kc@uta.fi

1 School of Health Sciences, University of Tampere, 33014 Tampere, Pirkanmaa Region, Finland

2 Finnish Institute of Occupational Health, Helsinki, Finland

3 Gerontology Research Center and Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland

4 Juhani Ilmarinen Consulting Ltd, Helsinki, Finland

5 Gerontology Research Center, University of Tampere, 33014 Tampere, Finland

There is evidence on a relationship of ADL disability with low socioeconomic position (Picavet and Hoeymans 2002), low leisure-time physical activity (Tak et al. 2013), relative weight (Backholer et al. 2012; Klijs et al. 2011), smoking (van Oyen et al. 2014), alcohol consumption (Klijs et al. 2011) and impairments of health (Hung et al. 2012). These factors may affect the development of old age ADL disability even from early periods on over the life course (Kuh et al. 2014).

Although occupational activity is an indispensable part of the daily life of most adults, studies on occupation as a possible source of ADL disability later in life are scarce. Li et al. (2000) studied the relationship of the longest held occupation and ADL disability (disability in one or more of six items) in a nested case–control design in two cohorts of a total of 2198 subjects in Taiwan. Information on occupation was obtained by interview of the subjects or their next of kin and categorized to, first, 11 occupational groups and, second, four occupational social classes. Two occupational groups, i.e., agricultural, animal husbandry, forestry, fishing workers, and craft and related trades workers, had an increased risk (odds ratio 1.9) of ADL disability when socio-demographic factors, education, lifestyle and morbidity were controlled for. Unskilled blue-collar workers had also an increased risk compared with high-level white-collar workers. In a study in Ireland, McCarthy et al. (2013) found that physically demanding work history was associated with ADL disability allowing for relative weight among 328 subjects, particularly in the 70–80-year-olds, in a cross-sectional analysis. On the contrary, a study among a random sample of urban Swedes (Rydwik et al. 2013) showed no association of retrospectively assessed occupational physical activity in midlife with personal or instrumental ADL disability in old age in an analysis comprising 1809 subjects and adjusted for demographic and socioeconomic factors.

Thus, in earlier studies, jobs have been described by the occupational title or by surveys among the workers. In particular, when studying aging workers the perception of the work could change with the declining capacity and therefore bias the results. The aim of the present study was to investigate how midlife job characteristics based on a detailed objective job analysis and clustered into job profile groups predict disability in later life among a cohort of Finnish municipal workers who were followed up for 28 years from midlife to old age. Analyses were made separately for women and men.

Methods

Participants and design

A prospective follow-up of the Finnish Longitudinal Study on Municipal Employees (FLAME) was conducted by the Finnish Institute of Occupational Health. A baseline survey was conducted in 1981 with the latest follow-up in 2009. A total of 6257 people (85.2 % response rate) aged 44–58 years and representative of the largest municipal occupational groups in Finland participated in the study in 1981. The analysis of the present study was based on those respondents who were alive and replied to both the baseline and the latest follow-up survey questionnaires in 2009. Only those subjects for whom information was available on ADL and Instrumental ADL (IADL) tasks from 2009 were included in the analysis ($N = 2998$). According to the mortality data (January 1981–July 2009) from the Finnish National Population Register, 2096 (33.5 %) of the baseline respondents had died during the 28-year follow-up period. The ethics committee of the Finnish Institute of Occupational Health approved the study.

Measures of variables

Job profile

The job analysis has been described in detail elsewhere (Ilmarinen et al. 1991). The AET method was used to analyze physical, psychosocial and mental demands in work (Rohmert and Landau 1983). Information on the characteristics of the jobs of the employees was obtained from a separate job analysis consisting of interviews and observations at the work places carried out by researchers trained for the purpose. Based on a detailed analysis of the contents and demands (216 items) of the 88 individual job titles, 13 profile groups emerged in cluster analysis (Ilmarinen et al. 1991) and were generalized for the occupation in the whole sample. The variation in demands and other characteristics within one occupation was less than the variation between occupations. The job analysis was carried out in the jobs of 133 different employees in different parts of Finland in 1981 (Ilmarinen et al. 1991) and repeated in 1993 (Nygård et al. 1999). According to the results, there were no larger changes in work demands among the studied municipal occupations between 1981 and 1993.

The items in the job analysis covered the work system (work objects, equipment and environment), work tasks and work demands (perception, decision making, education and physical load). These items were coded (0–5) according to their duration or frequency. The 13 job profile groups which emerged were auxiliary, installation, home care, transport, dump, office, administrative, kitchen supervision, technical supervision, dentist, physician, teaching and nursing. For example, the auxiliary job profile was a cluster of nine different occupational titles (unskilled assistant, painter, cleaner, hospital aides, kitchen helper, construction worker, street sweeper, park worker and laborer); installation job profile was a

Table 1 Main work-related exposures and conditions according to the AET analysis in the 13 job profile groups (adapted from Ilmarinen et al. 1991)

Job profile groups	Stress factors (exposures and conditions)
Auxiliary	Poor work postures, dynamic muscle work, proprioceptive information input, climatic conditions, dangerous environment
Installation	Coordinated body movements, strength in dynamic and static work, sensory perception
Home care	Dynamic muscle work, use of strength in dynamic and static work, possible conflicts with patients, responsibility for safety
Transport	Visual information, accuracy, coordination of body movements, static muscle work
Dump	Walking, outdoor environment (dirty and wet), climate
Office	Accuracy, visual information, need for knowledge, static muscle work
Nursing	Dynamic muscle work (walking), working postures, accuracy in information input, complex and time-pressured decision making
Technical supervision	Contacts with subordinates, need for special knowledge, decision making, visual perception
Kitchen supervision	Information input and processing (smell, taste), contacts with subordinates, time-pressured decision making
Dentist	Visual reception of information, contacts with subordinates, coordination of body movements, complex decision making, responsibility for patients
Physician	Complex and time-pressured decision making, accuracy in sensory perception, contacts with colleagues, demands for professional training
Teaching	Responsibility for and contacts with pupils, complex decision making, advanced professional training
Administrative	Processing of information, complex and time-pressured decision making, accuracy, social environment

cluster of six different occupational titles (firemen, janitor, mechanics/pipe fitter, car mechanics, carpenter and electrician). Likewise, the administrative job profile was a cluster of four different occupational titles (social worker, head ward nurse, head nurse and office supervisor). The main work-related exposures and conditions according to the AET analysis in the 13 job profile groups are presented in Table 1. The contents of the table are adapted from Ilmarinen et al. 1991, where there is more detailed description of the contents and the demands of the different job profile groups. The mean physical load score for each job profile was calculated separately by using the AET method (Nygård et al. 1987) and generalized for all the respondents in the study.

Disability

ADL and Instrumental Activities of Daily Living (IADL) were assessed using a questionnaire survey distributed among the participants in 2009. These two activities (ADL and IADL) are widely used and accepted as measures of disability among the old (Schillerstrom et al. 2008; Spector and Fleishman 1998; Jagger et al. 2007; Gopinath et al. 2012). At least some difficulties in performing any ADL or IADL task were termed and classified as disability (Verbrugge and Jette 1994). Five ADL tasks (eating, going to bed, dressing, bathing and toileting) and seven IADL tasks (preparing meals, doing laundry, shopping, doing light domestic work, dosing/taking medicine, using the phone and management of personal finances) were assessed on a scale 0–4, (4 = manage without difficulties, 3 = manage with little difficulties, 2 = manage with lots of difficulties, 1 = cannot manage without help from others and 0 = cannot manage with help of others as well). In this analysis, the five ADL tasks and seven IADL tasks were dichotomized (as shown in Table 2) and then summed up to get a continuous score '0-12' (Chan et al. 2012). Score '0' represented those who could perform all the tasks without any difficulty (classified as non-disabled in this study), and those who had at least some difficulty in performing one or more of the 12 tasks scored 1–12 depending on the number of tasks entailing difficulties (classified as disabled in this study). The higher the score, the more severe the disability.

Covariates

Socio-demographic characteristics

The age of the respondents at baseline ranged from 44 to 58 years. It was dichotomized at the median as 44–49 and 50–58. Marital status was elicited as unmarried, married/co-habiting, separated, widowed and categorized as unmarried, married/co-habiting and separated/widowed. Basic education was elicited as '1 = no or elementary school partly, 2 = elementary school or middle school partly, 3 = middle school or high school partly, 4 = high school graduate' and classified as low (1), intermediate (2) and high (3–4). The total household income per month was collected and categorized for this study as low (less than 374

Table 2 Recoding of ADL and IADL scale

Activities	Original scale	Dichotomized ADL and IADL	
ADL tasks (0–4) Eating Going to bed Dressing Bathing Toileting	4: Manage without difficulties	4: Manage without difficulties	Recoded as '0'
IADL tasks (0–4) Preparing meals Doing laundry Doing light domestic work Dosing/taking medicine Shopping Using phone Management of personal finances	3: Manage with little difficulties 2: Manage with lots of difficulties 1: Cannot manage without help from others 0: Cannot manage with help as well	0: Cannot manage with help as well 1: Cannot manage without help from others 2: Manage with lots of difficulties 3: Manage with little difficulties	Recoded as '1'

euros), intermediate (374–986 euros) or high (more than 986 euros).

Lifestyle-related characteristics

Lifestyle-related details were also collected by questionnaire at baseline. The current smoking data were collected as cigarettes/day, and those reporting smoking at least one cigarette per day were classified as smokers. Information on alcohol consumption was based on seven categories (never, not so often, once a month, twice a month, once a week, twice a week or daily) and for this study we classified as never, occasionally (not so often or once a month) and often (twice a month, once a week, twice a week or daily). Physical activity during the previous year was collected on five categories (brisk exercise at least two times a week, brisk exercise at least once a week, some exercise at least once a week, some exercise less than once a week or no exercise), and it was classified in this study as brisk exercise (brisk exercise at least two times a week and brisk exercise at least once a week), some exercise (some exercise at least once a week and some exercise less than once a week) or no exercise. Body mass index (BMI; kg/m^2) was calculated using self-reported height and weight and was dichotomized to <30 and ≥ 30 kg/m^2.

Work ability and health-related characteristics

The first item of the work ability index measured on a scale 0–10 was collected, and in this study three categories were used (von Bonsdorff et al. 2011): poor (0–6), moderate (7–8) and excellent (9–10). Information on diseases was based on self-reported diagnoses by a physician for accident or injury, musculoskeletal disorders, cardiovascular disorders, respiratory disorders, mental disorders, nervous/sensory disorders, urinary tract disorders, skin disorders and digestive tract disorder. Here, we used the dichotomy no disease versus disease present.

Statistical analysis

The descriptive characteristics of the subjects were first presented as frequencies and percentages. Then, the mean musculoskeletal load scores for different job profile group were presented and the disability (gender stratified) by job profile was tested by Pearson Chi-square test. An interaction term between gender and job profile was tested and found statistically significant ($p < 0.001$) with respect to disability, and therefore, the analyses were stratified by gender.

As the distribution of the outcome variable was not normally distributed and the variance was higher than the mean (over-dispersion), negative binomial regression was used to calculate rate ratios (RRs) and their 95 % confidence intervals (CIs). Predictive margins of job profiles were calculated with their 95 % CIs as post-estimation of group means. According to the job analysis, the lowest physical load was in the administrative job profile (Table 5) which therefore was used as the reference group in the regression analysis. Four models were fitted. Model I was age adjusted; model II was further adjusted for age and BMI, smoking pattern, alcohol intake, physical exercise, basic education, marital status and total household income. Model III was adjusted for age and chronic disease/disorders, perceived work ability, and model IV was adjusted for all those factors used in models I, II and III. The analysis was done with SPSS version 21.0 and STATA 13.0.

Results

About two-thirds of the study participants were women. Baseline socioeconomic, lifestyle and health-related

Table 3 Baseline characteristics of 2998 respondents and non-respondents according to their gender

Basic characteristics	$N = 2998$ *n* (%)	Respondents			Non-respondents			
		Women % ($n = 1892$)	Men % ($n = 1106$)	*p* value	$N = 3259$ *n* (%)	Women % ($n = 1568$)	Men % ($n = 1691$)	*p* value
Socioeconomic								
Age (year)				0.677				0.271
44–49	1579 (53)	52	53		1141 (35)	34	36	
50–58	1419 (47)	48	47		2118 (65)	66	64	
Marital status				**<0.001**				**<0.001**
Unmarried	348 (12)	17	2		428 (13)	21	6	
Married/co-habiting	2276 (76)	66	94		2382 (73)	59	86	
Separated and widow	370 (12)	17	4		445 (14)	20	8	
Basic education				**<0.001**				**<0.001**
Low	487 (16)	13	21		836 (26)	19	32	
Intermediate	1530 (51)	47	59		1752 (54)	52	57	
High	960 (32)	40	20		638 (20)	29	11	
Household income				**<0.001**				**0.003**
Low	148 (5)	6	3		264 (9)	10	7	
Intermediate	2286 (78)	77	80		2486 (80)	78	82	
High	494 (17)	17	17		256 (11)	12	11	
Lifestyle-related								
Smoking (smokers)	338 (11)	8	17	**<0.001**	866 (27)	15	38	**<0.001**
Alcohol consumption				**<0.001**				**<0.001**
Never	943 (32)	42	13		918 (28)	47	12	
Occasionally	1508 (50)	50	52		1473 (46)	46	45	
Often	529 (18)	8	35		828 (26)	7	43	
Physical exercise				**0.153**				**0.001**
Brisk exercise	1543 (53)	52	53		1405 (45)	48	42	
Some exercise	1215 (41)	41	42		1396 (44)	42	46	
No exercise	178 (6)	7	5		350 (11)	10	12	
BMI ($\geq$30 kg/m^2)	231 (8)	8	8	0.875	368 (12)	11	12	0.259
Work ability				**0.024**				**<0.001**
Poor (0–6)	540 (19)	18	21		851 (28)	23	32	
Moderate (7–8)	1468 (51)	50	51		1558 (50)	51	50	
Excellent (9–10)	880 (30)	32	28		674 (22)	26	18	
Health-related disorders/disease								
Accident/injury[a]	315 (10)	9	14	**<0.001**	513 (16)	12	19	**<0.001**
Musculoskeletal[a]	1105 (37)	39	33	**0.002**	1311 (40)	42	39	0.129
Cardiovascular[a]	517 (17)	17	18	0.597	856 (26)	25	28	0.057
Respiratory[a]	306 (10)	10	10	0.627	454 (14)	14	14	0.573
Mental[a]	49 (2)	2	1	0.224	71 (2)	2	2	0.604
Digestive[a]	359 (12)	11	13	0.143	465 (14)	14	14	0.668
Nervous/sensory[a]	337 (11)	9	14	**<0.001**	415 (13)	10	16	**<0.001**
Urinary[a]	207 (7)	8	5	**0.010**	198 (6)	8	4	**<0.001**
Skin[a]	259 (9)	9	8	0.155	290 (9)	10	8	**0.043**

Bold indicates statistically significant difference

P (χ^2) = p value derived from Chi-square test

BMI Body Mass Index

[a] Physician diagnosed

characteristics of the respondents and non-respondents stratified according to gender are presented in Table 3. There was no significant difference in the age groups between women and men. Fewer women (18 %) had poor work ability compared to men (21 %). Less than 10 % of both women and men reported taking no exercise. The gender-stratified baseline characteristics of non-respondents were almost similar to those of respondents.

The baseline distribution of job profiles according to gender of respondents and non-respondents is presented in Table 4. The distribution of employees in different job profile groups varied according to gender, with 73 % of the women in auxiliary jobs compared to 27 % of the men, while 93 % of the women compared to 4 % of the men were in the nursing job profile. The distribution of the mean physical load score and those having disabilities (disability score 1–12) in different job profiles is presented in Table 5. Among the study subjects, 53 % had no difficulty in doing any of the ADL and IADL tasks (among the disabled 55 % were women and 45 % were men). There was a significant difference according to gender in the distribution of disability in different job profiles. In the auxiliary job profile, the

Table 4 Distribution of 13 job profiles among respondents and non-respondents stratified by gender

Job profiles	Respondents ($N = 2998$)[±]			Non-respondents[±]		
	n (%)	Women (%)	Men (%)	*n* (%)	Women (%)	Men (%)
Auxiliary work	475 (16)	73	27	813 (25)	54	46
Installation work	315 (11)	0	100	546 (17)	0	100
Home care work	261 (9)	100	0	239 (7)	100	0
Transport work	219 (7)	0	100	353 (11)	0	100
Dump work	13 (<1)	1	12	35 (1)	0	100
Office work	187 (6)	97	3	155 (5)	94	6
Nursing work	616 (21)	93	7	430 (13)	92	8
Kitchen supervision	71 (2)	100	0	75 (2)	100	0
Technical supervision	95 (3)	0	100	108 (3)	0	100
Dentist	56 (2)	89	11	39 (1)	79	21
Physician	58 (2)	29	71	28 (1)	29	71
Teaching work	264 (9)	52	48	226 (7)	40	60
Administrative work	368 (12)	70	30	212 (7)	66	34

[±] *p value* derived from Chi-square test (<0.001) (gender stratified)

Table 5 Distribution of the mean physical load score and disability score among 13 job profile groups

Job profiles	$N = 2998$, *n* (%)	Physical load score[a]	Disability score 1–12 (overall and gender stratified)[±]		
			$N = 1407$, *n* (%)	Women (%)	Men (%)
Auxiliary work	475 (16)	21.5	275 (20)	66	34
Installation work	315 (11)	21.9	185 (13)	0	100
Home care work	261 (9)	18.3	127 (9)	100	0
Transport work	219 (7)	16.2	124 (9)	0	100
Dump work	13 (<1)	9.9	6 (1)	0	100
Office work	187 (6)	10.0	74 (5)	98	2
Nursing work	616 (21)	13.6	227 (16)	90	10
Kitchen supervision	71 (2)	15.5	36 (3)	100	0
Technical supervision	95 (3)	10.7	61 (4)	0	100
Dental work	56 (2)	11.7	19 (1)	79	21
Physician's work	58 (2)	11.7	20 (1)	30	70
Teaching work	264 (9)	8.9	127 (9)	46	54
Administrative work	368 (12)	7.5	126 (9)	60	40

[±] $p < 0.001$

[a] Mean physical load score calculated according to AET method

Table 6 Rate ratios (RR) with their 95 % CI for disability in later life due to midlife job profile among women and men

Gender	Job Profile	RR (95 % CI)				
		n (%)[a]	Model I	Model II	Model III	Model IV
Women	Auxiliary work	182 (23)	2.39 (1.73–3.30)[b]	2.29 (1.54–3.40)[b]	2.26 (1.63–3.15)[b]	2.15 (1.43–3.21)[b]
	Home care work	127 (16)	2.29 (1.62–3.24)[b]	2.03 (1.36–3.03)[b]	2.02 (1.43–2.87)[b]	2.13 (1.40–3.22)[b]
	Office work	73 (9)	1.78 (1.21–2.60)[b]	1.72(1.14–2.58)[b]	1.51 (1.02–2.22)[b]	1.63 (1.08–2.44)[b]
	Nursing work	205 (26)	1.42 (1.05–1.92)[b]	1.31(0.95–1.82)	1.27 (0.93–1.71)	1.34 (0.97–1.87)
	Kitchen supervision	36 (5)	2.22 (1.32–3.72)[b]	2.28 (1.29–4.04)[b]	2.20 (1.31–3.71)[b]	2.01 (1.14–3.57)[b]
	Dental work	15 (2)	0.79 (0.42–1.49)	1.03 (0.54–1.96)	0.94 (0.50–1.79)	0.70 (0.37–1.34)
	Physician's work	6 (1)	1.84 (0.69–4.88)	1.59 (0.59–4.29)	1.59 (0.59–4.26)	1.22 (0.41–3.63)
	Teaching work	58 (8)	1.42 (0.94–2.16)	1.34(0.87–2.06)	1.35 (0.89–2.06)	1.19 (0.78–1.82)
	Administrative work	76 (10)	1	1	1	1
Men	Auxiliary work	93 (15)	2.13 (1.44–3.13)[b]	1.94(1.25–3.03)[b]	2.09 (1.42–3.08)[b]	1.47 (1.09–2.86)[b]
	Installation work	185 (29)	1.44 (1.02–2.01)[b]	1.37 (0.93–2.01)	1.43 (1.02–2.01)[b]	1.24 (0.81–1.90)
	Transport work	124 (20)	1.43 (1.00–2.04)[b]	1.25 (0.83–1.88)	1.33 (0.93–1.89)	1.20 (0.77–1.88)
	Dump work	6 (1)	0.95 (0.38–2.42)	1.12 (0.42–3.00)	1.06 (0.42–2.69)	0.94 (0.35–2.56)
	Office work	1 (<1)	1.55 (0.40–5.99)	1.33 (0.34–5.20)	1.28 (0.33–4.96)	1.48 (0.38–5.79)
	Nursing work	45 (4)	0.81 (0.46–1.42)	0.71 (0.39–1.29)	0.69 (0.40–1.21)	0.63 (0.34–1.17)
	Technical supervision	95 (9)	1.75 (1.15–2.66)[b]	1.69 (1.09–2.60)[b]	1.78 (1.18–2.70)[b]	1.68 (1.06–2.66)[b]
	Dental work	6 (1)	1.45 (0.43–5.01)	1.40 (0.41–4.85)	1.50 (0.44–5.15)	1.55 (0.46–5.21)
	Physician's work	41 (4)	0.75 (0.42–1.35)	0.70 (0.39–1.27)	0.82 (0.46–1.48)	0.75 (0.42–1.35)
	Teaching work	69 (11)	1.20 (0.80–1.78)	1.18 (0.78–1.78)	1.16 (0.78–1.73)	1.05 (0.68–1.63)
	Administrative work	50 (8)	1	1	1	1

Model I: age adjusted

Model II: adjusted for age, socioeconomic (marital status, total household income), lifestyle (alcohol consumption, smoking, BMI, Physical exercise)

Model III: adjusted for age, health-related characteristics (musculoskeletal disorders, accident/injury, CVD, mental disorders, nervous sensory disorders), work ability score

Model IV: adjusted for all the confounders from models I, II and III (final model)

[a] Numbers and percentages of respondents with disability in different job profiles (separately for women and men)

[b] Statistical difference <0.05

prevalence of disability was higher among women (66 %) than men. Likewise, in the nursing job profile 90 % of the respondents having some disability were women. Similarly, in the office job profile almost all the respondents having some disability were women. Similarly, the mean score of physical load was lowest in administrative job profile group (7.5) and was highest in installation group (21.9).

The rate ratios (RR) and their 95 % confidence intervals for disability in 13 job profiles for women and men are shown in Table 6. The rate ratios (RR) for disability among women were significantly higher for most of the job profiles compared to the administrative job profile in the age-adjusted model. The results did not change much after adjusting separately for socio-demographic and lifestyle variables (model II) and health-related characteristics (model III) along with age. Adjusted for socio-demographic, lifestyle and health-related characteristics along with age (model IV), auxiliary (RR 2.15, 95 % CI 1.43–3.21), home care (RR 2.13, 95 % CI 1.40–3.22) and kitchen supervision (RR 2.01, 95 % CI 1.14–3.57) job profiles had a higher risk of disability among women than did the administrative job profile. The office job profile for women also carried a higher risk of disability (RR 1.63, 95 % CI 1.08–2.44) even after controlling for all possible covariates in model IV.

For men, the job profiles auxiliary, installation, transport and technical supervision had significantly higher risk of old age disability than the administrative job profile in the age-adjusted model. In men also, the results did not change much after adjusting separately for socio-demographic and lifestyle variables (model II) and health-related characteristics (model III) along with age. After controlling for several factors in model IV, only the relationships of auxiliary work (RR 1.47, 95 % CI 1.09–2.86) and technical supervision (RR 1.68, 95 % CI 1.06–2.66) with disability remained.

The predictive margins and 95 % CI of job profiles were calculated to ascertain their difference in predicting disability as a post-estimation. Most of the groups had a high prediction rate, and some of the groups had no significant difference due to there being very few cases for comparisons. The predictive margins and their 95 % confidence intervals (CI) for different job profile groups of women and men are presented in Supplementary Figures 1 and 2.

Discussion

We assessed the role of midlife job profiles derived from the detailed job analysis in the prediction of ADL disability in later life in a cohort of municipal employees who were followed up for 28 years. The associations were more prominent among women than men. Compared with administrative work, we found that women who were in the auxiliary, homecare, kitchen supervision and office work job profiles in midlife had an increased risk of disability 28 years later even after controlling for a range of possible confounders, including socioeconomic factors, health-related lifestyle, relative weight, various diseases, injuries and work ability. Among men, the job profiles with an increased risk of ADL disability were auxiliary work and technical supervision.

High disability rates in old age were found among those persons with high over all physical load in midlife (auxiliary and home care work) but also among those with prolonged sedentary work (office). The auxiliary job profile in our study is a construct of mostly physically demanding jobs (those of painters, kitchen helpers and construction workers) (Nygård et al. 1987). In line with this, physically demanding work has been shown to be related to functional limitations and ADL disability in old age (McCarthy et al. 2013). Other studies have shown that lower occupational class employees are at an increased risk of morbidity and disability in old age (Li et al. 2000; Huisman et al. 2005). A high risk of disability was reported among a manual occupational group who worked for a long period in the same job compared to a non-manual occupational group (Li et al. 2000). In addition, occupational class (Groffen et al. 2013) and heavy occupational physical activity (Hinirichs et al. 2014) have been found to be associated with mobility limitation in old age.

An interesting finding is that men with a low physically demanding job profiles, such as technical supervision, were at increased risk of disability. This finding is in line with the findings of the Swedish Twin study, which showed that technology-related occupations were more hazardous for disability than were administrative occupations (Ropponen et al. 2013). One explanation may be that during the 1980s technical supervisors in the municipal sector in Finland had similar educational and socioeconomic background as their subordinates (i.e., installation work) so they started their career in a physically heavier job and reach their position as supervisor later on in their career. These reasons could also be generalized for the women in the kitchen supervision job profile, who were also at a comparatively high risk of disability in later life.

One unexpected result in our study was that the women in the office job profile were at an increased risk of disability in later life. Office work is an occupation with low occupational physical strain and some occupational psychosocial strain, but the risk of later life disability due to this job profile was not attenuated by other confounding factors. This finding in our study supports the prediction of physical functioning difficulties of later life by work-related factors among women in the French GAZEL cohort (Sabbath et al. 2013), but contradicts those of an earlier study reporting that midlife moderate occupational physical activity in white-collar workers was associated with a decreased risk of later life disability (Rydwik et al. 2013). Although occupational hazards may have no adverse effect on a person's physical functioning while that person is occupationally active, they may eventually lead to functional decline and disability years later or after retirement (McCarthy et al. 2013; Kenny et al. 2008; Cassou et al. 1992). The unexpected finding in our study can be explained by the fact that office workers usually work for long periods in a sitting position, which has been shown to increase the risk of all-cause morbidity and mortality (Mummery et al. 2005). But some of the very recently published studies have found that there is no association of any kind of occupational sitting with overall mortality (Pulsford et al. 2015) and other health problems (Picavet et al. 2016) in a long follow-up. The results from earlier studies, however, are not consistent; thus, this finding in our study needs further confirmation in future longitudinal studies.

Women in the homecare job profile in our study had significantly higher risk of later life disability, which confirms the findings of a cross-sectional study on an Irish population (McCarthy et al. 2013). High occupational physical activity has also been reported to be a risk factor for mobility limitations in old age in many earlier studies (Hinirichs et al. 2014; Vermeulen et al. 2011; den Ouden et al. 2011). Although physically demanding works are related to functional ability and disability in old age, there are various other factors which influence the association. We used demographic, socioeconomic, lifestyle and health-related characteristics as explanatory factors in our study. Some earlier life course studies have suggested that adverse socioeconomic conditions in early life may have long-term effects on disability (Bowen and Gonzalez 2010; Case et al. 2005). However, the data on socioeconomic conditions in early life were not available in our study.

Earlier analysis of the present study population in their active working lives showed that midlife work does not prevent the decline in work ability (Ilmarinen et al. 1997). Physical demands were the highest work stressors and the main predictors of work disability (RR 1.8–2.0) in auxiliary, transport and home care work (Tuomi et al. 1991). These three groups also had the highest musculoskeletal load based on a thoroughly objective job analysis in the field (Nygård et al. 1991). In the present study population, the perceived strain of work in midlife increased significantly in an 11-years follow-up (Nygård et al. 1997), parallel to a decrease in functional capacity and work ability (Nygård et al. 1999; Ilmarinen et al. 1997), whereas the independent assessment of the job by the researchers did not show any significant changes during the same period (Nygård et al. 1999). Earlier longitudinal studies of work-related effects on disabilities/abilities have been rather short and cross-sectional.

In our study, women were at a comparatively higher risk of disability than men. One of the main reasons may be that there were more number of women in high risk job profile groups like auxiliary work compared to men and some of the job profiles were gender-specific. For example, there were only women in high risk job profile like home care work which could have increased the risk prevalence among them. Otherwise, this difference was expected, because earlier studies have reported a gender difference in disability in manual occupations (Li et al. 2000; Alvarado et al. 2007; Murray et al. 2011). Furthermore, the effects of a high level of occupational physical activity have been found to differ between men and women (McCarthy et al. 2013; Rossignol et al. 2003; Alvarado et al. 2007; Russo et al. 2006; Zunzunegui et al. 2009), with women engaged in high occupational physical activity having a higher risk of disability than men. Higher disability rates among women compared to men can be explained by the fact that there were more women working in physically heavy occupations in the 1980s (von Bonsdorff et al. 2012; Tuomi et al. 1991). Likewise, among women in physically demanding jobs, poor work postures were more common than among men (Suurnäkki et al. 1991) which has been shown to be associated with lower physical functional capacity among aged women (Nygård et al. 1988). More importantly, among the same-aged women and men, women have greater difficulties than men in performing ADL tasks (Idland et al. 2013) because of their lower physical capacity. To summarize, a few earlier studies on the relationship of paid work with ADL disability rely on survey information on occupation or retrospective work history. So, our study adds to the existing literature by the exploration of long-term effects of different type of job profiles of midlife in ADL disability of later life through a long follow-up of 28 years.

Strengths and limitations

A major strength of our study was the longitudinal study design with a long prospective follow-up of almost three decades. This seems in fact to be the first prospective analysis of the relationship of occupational factors and ADL disability. The large sample was representative of municipal occupations in Finland. Most of the employees continued in the same job from the start of the study until retirement, and no major changes in their work were seen from baseline until retirement (Nygård et al. 1999). In all, more than 70 % of the employees had worked in the same occupation for more than 15 years and only 2 % changed their occupation (Tuomi et al. 1997). An additional strength is the use of a detailed job analysis based on objective assessments. On the other hand, the implication of the method was that information on work characteristics was available on aggregate level. The response rate among those alive remained high in all waves, but due to significant mortality in an elderly sample in addition to other dropouts, about 50 % of the participants in 1981 responded also in 2009. A limitation of the design was the availability of ADL disability data from the last survey (2009) only. Except for the job analysis, all other measures were self-reported, being possibly subject to information and reporting bias. Nonetheless, the ADL is a valid and standard scale and is widely used in predicting and analyzing health and functional status among old people (Schillerstrom et al. 2008; Gopinath et al. 2012). A potential issue limiting the generalizability of the results to today's working life is that the nature of some jobs may have changed during the 28 years of follow-up.

Conclusion

In conclusion, the job profiles derived from the detailed job analysis in midlife strongly predicted disability after about three decades, particularly in women. From the policy perspective, the prevention of disability in later life, especially among those doing manual jobs, should be initiated already in working age. Further studies should shed light on individual exposures at work that are harmful in relation to ADL.

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Compliance with ethical standards

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Informed consent Informed consent was obtained from all individual participants included in the study.

References

Alvarado BE, Guerra RO, Zunzunegui MV (2007) Gender differences in lower extremity function in Latin American elders: seeking explanations from a life-course perspective. J Aging Health 19:1004–1024

Backholer K, Pasupathi K, Wong E, Hodge A, Stevenson C, Peeters A (2012) The relationship between body mass index prior to old age and disability in old age. Int J Obes 36:1180–1186

Bowen ME, Gonzalez HM (2010) Childhood socioeconomic position and disability in later life: results of the Health and Retirement Study. Am J Public Health 100(Suppl. 1):S197–S203

Brandt EN Jr, Pope AM (1997) Models of disability and rehabilitation. Enabling America: assessing the role of rehabilitation science and engineering. National Academies Press, Washington, DC, pp 62–80

Case A, Ferting A, Paxson C (2005) The lasting impact of childhood health and circumstances. J Health Econ 24:365–389

Cassou B, Derriennic F, Iwatsubo Y, Amphoux M (1992) Physical disability after retirement and occupational risk factors during working life: a cross sectional epidemiological study in Paris area. J Epidemiol Community Health 46:506–511

Chan KS, Kasper JD, Brandt J, Pezzin LE (2012) Measurement equivalence in ADL and IADL difficulty across international surveys of aging: findings from the HRS, SHARE, and ELSA. J Gerontol B Psychol Sci Soc Sci 67(1):121–132

den Ouden ME, Schuurmans MJ, Arts IEMA, van der Schouw YT (2011) Physical performance characteristics related to disability in older persons: a systematic review. Maturitas 69:208–219

Gopinath B, Anstey KJ, Kifley A, Mitchell P (2012) Olfactory impairment is associated with functional disability and reduced dependence among older adults. Maturitas 72:50–55

Groffen DA, Koster A, Bosma H et al (2013) Socioeconomic factors from midlife predict mobility limitation and depressed mood three decades later; findings from the AGES-Reykjavik Study. BMC Public Health 13:101–106

Hinirichs T, von Bonsdorff MB, Törmäkangas T et al (2014) Inverse effects of midlife occupational and leisure time physical activity on mobility limitation in old age- A 28-year prospective follow up study. J Am Geriatr Soc 62(5):812–820

Huisman M, Kunst AE, Bopp M et al (2005) Educational inequalities in cause-specific mortality in middle-aged and older men and women in eight western European countries. Lancet 365:493–500

Hung WW, Ross JS, Boockvar KS, Siu AL (2012) Association of chronic diseases and impairments with disability in older adults: a decade of change? Med Care 50(6):501–507

Idland G, Pettersen R, Avlund K, Bergland A (2013) Physical performance as long-term predictor of onset of activities of daily living(ADL) disability: a 9-year longitudinal study among community-dwelling older women. Arch Gerontol Geriatr 56:501–506

Ilmarinen J, Suurnakki T, Nygård C-H, Landau K (1991) Classification of municipal occupations. Scand J Work Environ Health 17(suppl 1):12–29

Ilmarinen J, Tuomi K, Klocars M (1997) Changes in the work ability of active employees as measured by the work ability index over an 11-year period. Scand J Work Environ Health 23(suppl1):49–57

Jagger C, Matthews R, Matthews F et al (2007) The burden of diseases on disability-free life expectancy in later life. J Gerontol Med Sci 62A(4):408–414

Katz S (1983) Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living. J Am Geriatr Soc 31:721–727

Kenny GP, Yardley JE, Martineau L, Jay O (2008) Physical work capacity in older adults: implications for the aging worker. Am J Ind Med 51(8):610–625

Klijs B, Mackenbach JP, Kunst AE (2011) Obesity, smoking, alcohol consumption and years lived with disability: a sullivan life table approach. BMC Public Health 11:378

Kuh D, Karunananthan S, Bergman H, Cooper R (2014) A life-course approach to healthy ageing: maintaining physical capability. Proc Nutr Soc 73(2):237–248

Li CY, Wu SC, Wen SW (2000) Longest held occupation in a lifetime and risk of disability in activities of daily living. Occup Environ Med 57:550–554

Maenner MJ, Smith LE, Hong J, Makuch R, Greenberg JS, Mailick MR (2013) Evaluation of an activities of daily living scale for adolescents and adults with developmental disabilities. Disabil Health J 6(1):8–17

McCarthy VJC, Perry IJ, Greiner BA (2013) Has your work worked you too hard? Physically demanding work and disability in a sample of the older Irish population. Ir J Med Sci 182:47–55

Mummery WK, Schofield GM, Steele R, Eakin EG, Brown WJ (2005) Occupational sitting time and overweight and obesity in Australian workers. Am J Prev Med 29:91–97

Murray ET, Hardy R, Strand BH, Cooper R, Guralnik JM, Kuh D (2011) Gender and life course occupational social class differences in trajectories of functional limitations in midlife: findings from the 1946 British birth cohort. J Gerontol A Biol Sci Med Sci 66(12):1350–1359

Nygård C-H, Suurnäkki T, Landau K, Ilmarinen J (1987) Musculoskeletal load of municipal employees aged 44–58 years in different occupational groups. Int Arch Occup Environ Health 59(3):251–261

Nygård C-H, Luopajärvi T, Suurnäkki T, Ilmarinen J (1988) Muscle strength and muscle endurance of middle aged women and men associated to type, duration and intensity of muscular load at work. Int Arch Occup Environ Health 60(4):291–297

Nygård C-H, Eskelinen L, Suvanto S, Tuomi K, Ilmarinen J (1991) Association between functional capacity and work ability among elderly municipal employees. Scand J Work Environ Health 17:122–127

Nygård C-H, Huuhtanen P, Tuomi K, Martikainen R (1997) Perceived work changes between 1981 and 1992 among aging workers in Finland. Scand J Work Environ Health 23(suppl 1):12–19

Nygård C-H, Suurnäkki T, Peltomaa T, Ilmarinen J (1999) Job demands of ageing employees over a 12-year period. FinnAge-respect for aging: action programme to promote health, work ability and well-being of aging workers in 1990–1996 (people and work). Ilmarinen J, Louhevaara V (eds) People and work research report 26. Finnish Institute of Occupational Health, Helsinki, pp 251–262

Picavet HSJ, Hoeymans N (2002) Physical disability in The Netherlands: prevalence, risk groups and time trends. Public Health 116(4):231–237

Picavet HSJ, Pas LW, van Oostrom SH et al (2016) The relation between occupational sitting and mental, cardiometabolic, and musculoskeletal health over a period of 15 years. The Doetinchem Cohort Study. PLoS One 11(1):e0146639. doi:10.1371/journal.pone.0146639

Pulsford RM, Stamatakis E, Britton AR, Brunner EJ, Hillsdon M (2015) Associations of sitting behaviours with all-cause

mortality over a 16-year follow-up: the Whitehall II Study. Int J Epidemiol 44(6):1909–1916. doi:10.1093/ije/dyv191
Rohmert W, Landau K (1983) A new technique for job analysis, 1st edn. Taylor and Francis Ltd, London
Ropponen A, Samuelsson Å, Alexanderson K, Svedberg P (2013) Register-based data of psychosocial working conditions and occupational groups as predictors of disability pension due to musculoskeletal diagnoses: a prospective cohort study of 24543 Swedish twins. BMC Musculoskelet Disord 14:268
Rossignol M, Leclerc A, Hilliquin P et al (2003) Primary osteoarthritis and occupations: a national cross sectional survey of 10412 symptomatic patients. Occup Environ Med 60(11):882–886
Russo A, Onder G, Cesari M et al (2006) Lifetime occupation and physical function: a prospective cohort study on persons aged 80 years and older living in a community. Occup Environ Med 63(7):438–442
Rydwik E, Welmer A-K, Angleman S, Fratiglioni L, Wang H-X (2013) Is midlife occupational physical activity related to disability in old age? The SNAC-Kungsholmen Study. PLoS ONE 8(7):e70471
Sabbath EL, Glymour MM, Descatha A et al (2013) Biomechanical and psychosocial occupational exposures: joint predictors of post-retirement functional health in the French GAZEL cohort. Adv Life Course Res 18:235–243
Schillerstrom JE, Royall DR, Palmer RF (2008) Depression, disability and intermediate pathways: a review of longitudinal studies in elders. J Geriatr Psychiatry Neurol 21(3):183–197
Spector WD, Fleishman JA (1998) Combining activities of daily living with instrumental activities of daily living to measure functional disability. J Gerontol Soc Sci 53B(1):S46–S57
Suurnäkki T, Nygård C-H, Ilmarinen J (1991) Stress and strain of elderly employees in municipal occupations. Scand J Work Environ Health 17(suppl 1):30–39
Tak E, Kuiper R, Chorus A, Hopman-Rock M (2013) Prevention of onset and progression of basic ADL disability by physical activity in community dwelling older adults: a meta-analysis. Aging Res Rev 12(1):329–338
Tuomi K, Toikkanen J, Eskelinen L et al (1991) Mortality, disability and changes in occupation among aging municipal employees. Scand J Work Environ Health 17(Suppl l):58–66
Tuomi K, Ilmarinen J, Klockars M et al (1997) Finnish research project on aging workers in 198-1992. Scand J Work Environ Health 23(suppl 1):7–11
Van Oyen H, Berger N, Nusselder W et al (2014) The effect of smoking on the duration of life with and without disability, Belgium 1997–2011. BMC Public Health 14:723
Verbrugge LM, Jette AM (1994) The disablement process. Soc Sci Med 38(1):1–14
Vermeulen J, Neyens JCL, van Rossum E, Spreeuwenberg MD, de Witte LP (2011) Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. BMC Geriatr 11:33
von Bonsdorff MB, Seitsamo J, Ilmarinen J, Nygård CH, von Bonsdorff ME, Rantanen T (2011) Work ability in midlife as a predictor of mortality and disability in later life: a 28-year prospective study. CMAJ 183(4):E235–E242
von Bonsdorff MB, Seitsamo J, von Bonsdorff ME, Ilmarinen J, Nygård CH, Rantanen T (2012) Job strain among blue-collar and white-collar employees as a determinant of total mortality: a 28-year population based follow-up. BMJ Open 2(2):e000860
Zunzunegui MV, Alvarado BE, Béland F, Vissandjee B (2009) Explaining health differences between men and women in later life: a cross-city comparison in Latin America and the Caribbean. Soc Sci Med 68(2):235–242

Paper II

Trajectories of mobility limitations over 24 years and their characterization by shift work and leisure time physical activity in midlife

Prakash K.C.*[1, 2], Subas Neupane[1, 2], Päivi Leino-Arjas[3], Mikko Härmä[3], Mikaela B.von Bonsdorff[4,5], Taina Rantanen[4], Monika E.von Bonsdorff[4,5], Timo Hinrichs[6], Jorma Seitsamo[3], Juhani Ilmarinen[7], Clas-Håkan Nygård[1, 2]

[1] Faculty of Social Sciences (Health Sciences), University of Tampere, Tampere, Finland

[2] Gerontology Research Center, University of Tampere, Tampere, Finland

[3]Finnish Institute of Occupational Health, Helsinki, Finland

[4]Gerontology Research Center, Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland

[5]Folkhälsan Research Center, Helsinki, Finland

[6]Division of sports and Exercise Medicine, Department of Sport, Exercise and Health, University of Basel, Basel, Switzerland

[7]Juhani Ilmarinen Consulting Ltd, Helsinki, Finland

Conflict of interest: The authors declare that they have no conflict of interest.

*Corresponding author

Prakash K.C., MSc (Public Health)

Faculty of Social Sciences (Health Sciences), University of Tampere

FI-33014, Tampere, Finland

Email: Prakash.kc@uta.fi; prakashkc10@gmail.com

Phone: +358-443111531, Fax: +358-33641511

ABSTRACT:

OBJECTIVES: We aimed to investigate the trajectories of mobility limitations (MLs) and how shift work and leisure-time physical activity in midlife separately and jointly predicted assignment to MLs trajectories separately for those on statutory pensions (SP) and on disability pensions (DP).

METHODS: Subjects who responded MLs questionnaires in 2009 and in at least one of the data collection waves in 1985, 1992 and in 1997 (N=3048) in Finnish Longitudinal Study on Aging Municipal Employees (FLAME) were included. International Classification of Functioning was used to code MLs. Growth mixture modeling was used to identify the trajectories of MLs. Odds ratio (OR) and their 95% Confidence Interval (CI) were assessed by using multinomial logistic regression. Adjusted predictive margins were used to present interaction estimates.

RESULTS: We identified four trajectories of MLs, namely low persistent, low increasing, high decreasing and high persistent. Among the SP recipients, shift work with night shifts was associated with an increased risk (adjusted OR 1.49; 95% CI 1.03–2.14) of belonging to the high persistent MLs trajectory. The inactive LTPA (SP: 5.99, 3.39-10.58, DP: 6.81, 2.52-18.43) was similarly associated with high persistent MLs trajectory. Inactive LTPA and shift work with night shifts jointly had around 70% chance of belonging to high persistent MLs.

CONCLUSIONS: Nearly two-third of the people retired due to disability belonged to high MLs trajectory. The robust predictor of high MLs was shift work with night shifts and inactive LTPA. Among the shift workers, vigorous LTPA during midlife could prevent high MLs in later life.
KEY WORDS: Longitudinal study**;** Occupational epidemiology; Work Schedule; Physical functioning; Disability process

INTRODUCTION

Bodily functions like walking, moving around, changing and maintaining body position along with carrying, handling and moving objects and using transportation are the key components of mobility. The limitations in carrying out these tasks are termed as mobility limitations (MLs) [1]. Among people in old age MLs are the most common cause of physical disablement [2, 3], which emerges due to the loss in equilibrium between demands of physical surroundings and physical competences of an individual [3–5]. MLs are associated with disruption of quality of life among older adults and predict all-cause mortality [6]. In this era of population aging, MLs are becoming a major public health issue due to their higher impact on elevating dependency ratio and the proportion of health care use [2, 6, 7].

Numerous risk factors of MLs in later life start to accumulate early from midlife. These include behavioral, environmental, lifestyle-related and socio-economic factors [3, 7–9], but little is known about the link between work history, work-related exposures in midlife and their association with MLs in later life. The study of the role of work-related factors in midlife in the progression of MLs in later life is fundamental due to the significant role of the work history in the disablement process [10]. Physically demanding work with vigorous occupational physical activity in midlife increases the risk of MLs in later life [11], whereas, lower work-related stress [12] and better work ability [13] in midlife were found to be protective to MLs in later life.

Furthermore, shift work is gradually being documented as a risk factor for sleep disturbances and several chronic diseases [14-16], as well as all-cause mortality [17]. Shift workers have mostly similar leisure-time physical activity patterns as day workers, but results on physical activity levels at work differ [18-20]. Lack of leisure-time physical activity (LTPA) is a potential risk factor of MLs [11] and later life physical disabilities [21, 22]. Shift work [23-25] and sleep disturbances [26] predict musculoskeletal disorders and pain in different body sites, but we are not aware of earlier longitudinal studies examining the link between shift work and MLs. Here, we investigated the association between shift work and the trajectories of development of MLs in a longitudinal study of Finnish municipal employees separately for those retired in statutory pension (SP) and disability pension (DP). In addition, we aimed to describe the association of LTPA with different trajectories of MLs and the association of interaction of shift work and LTPA with the different classes of trajectories of MLs over the time.

MATERIALS AND METHODS

Participants and design

This is a longitudinal study with prospective follow-up of 28 years based on the Finnish Longitudinal Study on Aging Municipal Employees (FLAME), which was conducted by the Finnish Institute of Occupational Health, Helsinki Finland from 1981 to 2009 [13, 27]. The follow-up process of respondents is described in detail in **Supplement Figure 1**. We studied those who replied to the MLs items in the last study wave in 2009 and in at least one of the previous study waves in 1985, 1992 or 1997 (N=3048). According to the mortality data obtained from the Finnish National Population Register, 33.2% of the baseline respondents had died during the 28-year follow-up period. Those who were deceased during the follow-up were mostly men, blue-collar workers, regular smokers, high alcohol consumers, subjects with high BMI and were diagnosed with chronic diseases compared to the respondents with data on MLs trajectory. The ethics committee of the Finnish Institute of Occupational Health approved the FLAME study and the national Data Protection Ombudsman provided the ethical clearance for the register linkage.

Mobility Limitation

The assessment of Mobility Limitations (MLs) was done by using self-reported questionnaires distributed among the participants in 1985, 1992, 1997 and 2009. The 'mobility' domain (*d4*) on component *d* termed as 'activities and participation' of the International Classification of Functioning, Disability and Health (ICF) were used to code the items included in the outcome variable MLs [1]. The domain *d4* is comprised of four main categories, which are changing and maintaining body position (*d410–d429*), carrying moving, and handling objects (*d430–d449*), walking (*d450*) and moving around (*d455*). We used the nine items of the survey questionnaire to cover these categories of ICF, which are described in detail in **Supplemental Table 1**. All the components except walking 2 km were assessed on four levels of difficulty (manage without difficulties, manage with little difficulties, manage with lots of difficulties and cannot manage) and walking 2 km was assessed on five levels (no difficulty – cannot manage with the help of others as well). For the present analyses, all of the nine items were dichotomized (no difficulty "0" Vs. at least some difficulty "1"). Then the dichotomized items were summed up to get a summary score "0–9" (score '0' represented no limitations in carrying out any of the 9 tasks and those who had at least some limitations in carrying out one or more of the 9 tasks scored '1–9' depending on the number of tasks entailing limitations) [11–13].

Work Schedule (Shift work)

Work schedule was requested using the question "Which time do you carry out your main work?" with the following response alternatives: fixed day work, fixed evening work, fixed night work, 2-shift work (day and evening), 3-shift work (day, evening and night) and other work schedules. The six responses were then categorized into three groups: "*day work*", "*shift work without night shifts*" (those in 2-shift work or in fixed evening work) and "*shift work with night shifts*" (those in 3-shift work or in fixed night works) [20].

Type of Pension

The data on the type of pensions, date of award, and primary diagnosis for disability pension (DP) were obtained from the Finnish Centre for Pensions. The obtained data were cross-linked to the survey using the unique personal identification number. The statutory retirement age of the municipal employees was 63 years and all of our respondents were retired by July 2000. In this study, we categorized retirement in two groups: Statutory pension (SP, i.e., old-age pension, part-time, early voluntary and others) and Disability pension (DP, i.e., retirement due to a medically confirmed illness before the statutory retirement age). [13]

Leisure-time Physical Activity (LTPA)

Information of LTPA during the previous year was assessed using a self-reported questionnaire about the average involvement of respondents in LTPA during the previous year which was based on five responses ("0: brisk exercise at least twice a week", "1: brisk exercise at least once a week", "2: some form of exercise once a week", "3: some form of exercise less than once a week" or "4: not engaging in exercise"). In this study we categorized LTPA in three groups (vigorous: 0–1; moderate: 2–3; and inactive: 4) [11].

Covariates

The information on covariates used in this study was collected at baseline. Age of the respondents ranged from 44 to 58 years at baseline. Two occupational groups namely white-collar and blue-collar were created based on 13 job profiles clustered from 133 different job titles [11, 12]. Those reporting smoking at least one cigarette per day were classified as current smokers. Information on alcohol intake was classified into none, at most two drinks a month and at least one drink a week being based on seven original categories. Information on major chronic diseases was related to the diagnosis of chronic diseases of different body systems like musculoskeletal disease (MSD), cardiovascular disease (CVD), chronic obstructive pulmonary disorder (COPD) and neurological diseases. Body mass index (BMI) was calculated by using the self-reported weight (kg) / height^2 (m2).

Statistical analysis

The descriptive characteristics of the subjects are presented as frequencies and percentages according to four latent class trajectories of MLs stratified by type of pensions. As our aim was to detect the developmental pathways of MLs between the study waves during the follow up, we used Growth Mixture Modeling (GMM) [28]. GMM is a method that identifies within the data, the multiple latent classes that tend to have a similar development over time. We fitted the GMM with two to five classes and selected the best-fitted model according to different fit criteria. The selection of the best fitted model was based on the lowest value (close to 0) of sample size adjusted Bayesian Information Criterion (BIC), lowest value (close to 0) of Akaike Information Criterion (AIC), higher entropy, substantive interpretability of classes and highly significant Leo-Mendell-Rubin(LMR) and relevance [28, 29]. The fit indices are presented in detail in **Supplemental Table 2**. Although a five-class model was favored by fit indices, the four-class model displayed better internal reliability, better substantive interpretability of classes and a higher entropy. The four-class model gave us the latent classes that represent Low-persistent MLs, Low-increasing MLs, High-decreasing MLs and High-persistent MLs respectively.

Multinomial logistic regression was used to calculate the odds ratios (OR) and their 95% confidence intervals (CI) for trajectory group memberships according to the categories of shift work and LTPA. Two models were fitted; model I: adjusted for age and model II: further adjusted for gender, occupational groups, smoking status, alcohol intake, BMI and chronic diseases (CVD, MSD, COPD and neurological disease). The potential interaction between shift work and LTPA was quantified to check the joint prediction of these exposures. Adjusted predictive margins and their 95 % CI were calculated for interactive predictions of these exposures as the post-estimation of the effects, which was adjusted for age, gender, occupational groups, smoking status, alcohol intake, chronic diseases and BMI. In order to account for potential bias due to dropout, we conducted a GMM for overall respondents (as a sensitivity analysis), from 1985-2009 (N=5536) which gave us similar trajectory shapes, so the results for selected respondents are presented (N=3048). GMM was done in Mplus version 7.11(Muthen & Muthen, 3463 Stoner Ave., Los Angeles, CA) and other analyses were done in STATA 14.0 (StataCorp LP, College Station, Texas 77845, USA).

RESULTS

The baseline characteristics stratified by type of retirement and their proportions in each of the four trajectories of MLs are described in detail in **Table 1.** Of the 3048 participants, 1987 (65%) were retired on SP and 1061 (35%) of them on DP. The mean age at baseline was 49.6 years (SD 3.8) and 63% of the respondents were women. The proportion of day work, shift work without night shifts and shift work with night shifts was 68%, 15%, and 17% respectively. Likewise, 37% of the respondents were vigorously involved in LTPA, 47% were moderately involved and 16% were physically inactive. The four trajectories for development of MLs over the follow-up period are shown in **Figure 1** (SP) and **Figure 2** (DP) and for overall respondents in **Supplement Figure 2**. Among the respondents on SP, one third belonged to the high persistent, nearly another third to the low increasing (31%), almost one fourth to the low persistent (24%) and 12% to the high decreasing trajectory of MLs. Among the respondents on DP, largest proportion (65%) of participants belonged to the high persistent followed by the low increasing (16%), high decreasing (12%) and low persistent trajectory (7%) of MLs.

Table 1, Figure 1 and Figure 2 here

The association of shift work and LTPA with MLs trajectory membership separately for SP and DP are presented in **Table 2**. Among the respondents on SP, in a fully adjusted model, adjusted for gender, smoking status, alcohol intake, BMI, occupational status and chronic diseases (model II), moderate and inactive LTPA characterized increased risk of belonging to the low increasing and high persistent MLs trajectory relative to low persistent MLs trajectory. Likewise, inactive LTPA group had an increased risk of belonging to the high decreasing MLs trajectory. Furthermore, the risk of belonging to the high persistent MLs trajectory was higher among those in shift work with night shifts (OR 1.49; 95% CI 1.03–2.14) and those who were physically inactive (5.99; 3.39–10.58).

Among the respondents on DP, in the fully adjusted model (model II), those with moderate LTPA (2.29; 1.29–4.08) and the physically inactive (6.81; 2.52–18.43) had an increased risk of belonging to the high persistent MLs trajectory. In addition, those in shift work with night shifts had an increased risk while those in shift work without night shifts had a decreased risk for belonging to all three MLs trajectories compared to low persistent trajectory, but the estimates were not statistically significant. The association of shift work and LTPA with MLs trajectory for overall respondents are presented in **Supplemental Table 3.** The adjusted predictive margins for the association of interaction of shift work and LTPA with MLs trajectories are presented as post-estimation of the effects in **Figure 3**. In the fully adjusted model, the interaction of shift work without night shifts and vigorous LTPA highly characterized the lack of MLs. Furthermore, the interaction of shift work with night shifts and inactive LTPA robustly predicted high decreasing trajectory of MLs.

Table 2 and Figure 3 here

DISCUSSION

In this prospective study, we found that most of the people on SP belonged to low persistent MLs trajectory. The proportion of high persistent MLs trajectory was higher among those retired on DP. However, we observed an equal proportion of people in both groups (SP and DP) who had a rapidly decreasing MLs trajectory alleviating towards null during their old age. The robust predictors of high persistent MLs were shift work with night shift and being physically inactive in LTPA in both groups. Similarly, physically inactive subjects had an increased risk of belonging to the high decreasing MLs trajectory. The interactive prediction suggests that those in shift works and inactive LTPA had a higher chance of belonging to high persistent MLs trajectory.

The comparison with the existing literature suggests that most of our results and findings are plausible. We found that there was a slight decrease in MLs among those in both DP and SP strata from 1992 to 1997, which could be the temporary effect of the relief from the shift work and increase in LTPA, as it was the phase of transition to retirement [30]. We found that shift work without night shifts was protective (though not significant) as to low-increasing, high decreasing and high persistent MLs relative to low persistent MLs trajectory in both strata. Our findings could be explained by selection, since especially in the health and social care sector, changing from shift work with night shifts to day work and shift work without night shifts is common [31]. Likewise, our aforementioned results corroborate the findings by Vahtera et al. (2009) in which they have reported that high work-time control by employees was a protective factor to the disability retirement due to musculoskeletal disorders [32]. However, we are not aware regarding the flexibility of our subjects to choose their work-shifts.

We found that shift work with night shifts possess a high risk for all classes of MLs including a substantial prediction of high persistent MLs trajectory, which is apparently in line with some of the previous studies that have reported shift work as a predictor of musculoskeletal disorders and pain in different body sites [23-25, 33]. This could be plausible because one could consider MLs as a late phase of musculoskeletal disorders and diseases in different body sites [4, 5]. Furthermore, the items that we included in the construction of MLs cover the functions of different body sites [1]. Likewise, the respondents in Lipscomb et al (2002) were registered nurses and the adverse work schedules resulted in an increased risk of musculoskeletal problems in them [23], which is generalizable to our results as well, because most of our study subjects in shift work schedules were nurses. Shift work without night shifts and shift work with night shifts had the largest proportion of public sector nurses in our study.

Epidemiological evidences on the association of shift work with adverse chronic health outcomes are inconsistent [34, 35] with fluctuating trends in findings and unparalleled methods. Similarly, the association might be conditional due to the lack of sufficient sleep and further investigation on those pathways is suggested [26]. Nonetheless, the consistent effects are reported across most of the occupational sectors [36], which is generalizable to our respondents who were public sector employees actively involved in different occupations during the baseline.

We found that being physically inactive in midlife was highly predictive of high persistent MLs in later life among the subjects in both strata. This finding is in line with an earlier finding from the same cohort by Hinrichs, et al. (2014) that reported protective effects of vigorous LTPA [11] and the findings by Leino-Arjas et al. (2004) that reported being involved in higher LTPA assures better walkability [37]. Furthermore, sustained physical activity from moderate to active level in midlife was significantly associated with decreased disability among a cohort followed for 20 years [21] and another followed up for 2 years [22], which is in line with our findings among the people on SP, but there was a minor dissimilarity in the construction of outcome variable. Findings from our study reveal the same level of risk of high persistent MLs characterized by inactive and moderate LTPA among the people in both pension schemes, but being physically inactive in leisure time was significantly associated with low increasing and high decreasing MLs among people on SP only. These findings support the idea that after retiring in DP, there is a chance of constantly higher MLs rather than increasing and decreasing and we could see that around one third of our subjects in DP fall under high persistent trajectory of MLs.

We found that the interaction of all three work shifts and active LTPA produced more than 20% higher chance of being protective to MLs. Similarly, all three work shifts and physical inactivity during leisure time jointly characterized high persistent MLs, which clearly indicated the role of LTPA rather than work shifts in case of the joint predictions. Likewise, the lack of clear characterization on the difference in interactive prediction by shift work and LTPA could be justified by the fact that there was no significant difference in cross-distribution ($p>0.05$) of these predictors. Furthermore, it is already known that there is no difference in LTPA levels among day workers and shifters [18, 19]. Although LTPA and shift work were associated to MLs, various other factors play the role in limiting the physical functions in old age [38, 39]. We used demographic, socio-economic, lifestyle and health-related characteristics as explanatory factors in our study, which attenuated the associations marginally.

Strengths and limitations

Long prospective follow-up along with being representative of largest municipal occupations illustrates the major strength of our study. According to our awareness of literature, our study is the first to examine the trajectories of MLs and their association with LTPA and shift work separately and jointly. The constantly high response rate in all waves by those who were alive added a significant strength to our study. One can consider some of the limitations of this study while inferring the findings. LTPA and items used in MLs were self-reported and thus possibly subject to information and recall bias, and could have led to over-estimated LTPA levels [11, 40]. Future studies using an objective measure of LTPA are recommended to validate and replicate these findings. In addition, another shortcoming in our study is not to have included non-LTPA or other recreational physical activities. However, adjustment for occupational class possibly covers most of the non-LTPA. Furthermore, in order to construct MLs, we used the ICF classification that has been validated and frequently used [11, 12]. The generalizability of the results to today's shift workers may suffer from the long follow-up time, due to the probable changes in the nature of some jobs with the advancement in technology. Nonetheless, most of our study subjects continued in the same occupations from the baseline until their retirement with no evident major changes [30]. The information on shift work was limited due to the lack of comprehensive information on working hour characteristics and their changes, so the inclusion of those along with the sleep insufficiency in further studies is warranted.

Conclusions

We found four trajectories of MLs in this longitudinal study of municipal employees namely, low persistent, low increasing, high decreasing and high persistent. Assignment to the high persistent MLs trajectory was predicted by moderate LTPA and physical inactivity among those retired on SP and on DP. Shift work with night shift predicted high persistent MLs in SP strata. An interaction of physical inactivity during leisure time with all three types of shift work produced a higher chance of belonging to the high persistent MLs trajectory. Active involvement in LTPA during midlife could prevent later life MLs independent of other factors.

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REFERENCES

1. World Health Organization. International Classification of Functioning, Disability and Health (ICF). *Geneva, WHO* 2001.
2. Heiland EG, Welmer AK, Wang R, et al. Association of mobility limitations with incident disability among older adults: a population-based study. *Age Ageing.* 2016;45(6):812–819.
3. Guralnik JM, LaCroix AZ, Abbott RD, et al. Maintaining mobility in life . I. Demographic characteristics and chronic conditions. *Am J Epidemiol.* 1993;137(8):845–857.

4. Brandt E, Pope A. Models of disability and rehabilitation. Enabling America: Assessing the role of rehabilitation science and engineering, *National Academy press*, *Washington DC* 1997; pp 62–80.
5. Putnam M. Linking aging theory and disability models: Increasing the potential to explore aging with physical impairment. *Gerontologist.* 2002;42(6):799–806.
6. Bergland A, Jørgensen L, Emaus N, Strand BH. Mobility as a predictor of all-cause mortality in older men and women: 11.8-year follow-up in the Tromsø study. *BMC Health Serv Res.* 2017;17(1):22.
7. von Bonsdorff M, Rantanen T, Laukkanen P, Suutama T, Heikkinen E. Mobility limitations and cognitive deficits as predictors of institutionalization among community-dwelling older people. *Gerontology.* 2006;52(6):359–365.
8. Shumway-Cook A, Ciol MA, Yorkston KM, Hoffman JM, Chan L. Mobility limitations in the medicare population: prevalence and sociodemographic and clinical correlates. *J Am Geriatr Soc.* 2005;53(7):1217–1221.
9. Brown CJ, Flood KL. Mobility limitation in the older patient: a clinical review. *JAMA.* 2013;310(11):1168–1177
10. Verbrugge LM, Jette AM. The disablement process. *Soc Sci Med.* 1994;38(1):1–14.
11. Hinrichs T, von Bonsdorff MB, Törmäkangas T, et al. Inverse effects of Midlife Occupational and leisure time physical activity on mobility limitation in old age- A 28-Year prospective follow up study. *J Am Geriatr Soc.* 2014;62(5):812–820.
12. Kulmala J, Hinrichs T, von Bonsdorff MB, et al. Work-related stress in midlife is associated with higher number of mobility limitation in old age- Results from the FLAME study. *Age.* 2014;36(6):9722.
13. von Bonsdorff ME, Rantanen T, Törmäkangas T, et al. Midlife work ability and mobility limitation in old age among non-disability and disability retirees – a prospective study. *BMC Public Health.* 2016;16:154.
14. Kecklund G, Axelsson J. Health consequences of shift work and insufficient sleep. *BMJ.* 2016;355:i5210.
15. Virkkunen H, Härmä M, Kauppinen T, Tenkanen L. The triad of shift work, occupational noise, and physical workload and risk of coronary heart disease. *Occup Environ Med.* 2006;63(6):378–386.
16. Fujino Y, Iso H, Tamakoshi A, et al. A prospective Cohort study of shift work and risk of ischaemic heart disease in Japanese male workers. *Am J Epidemiol.* 2006;164(2):128–135.

17. Jørgensen JT, Karlsen S, Stayner L, Hansen J, Andersen ZJ. Shift work and overall and cause-specific mortality in the Danish nurse cohort. *Scand J Work Environ Health.* 2017;43(2):117–126.
18. Kivimäki M, Kuisma P, Virtanen M, Elovainio M. Does shift work lead to poorer health habits? A comparison between women who had always done shift work with those who had never done shift work. *Work & Stress*. 2001;15(1):3–13.
19. Huslegge G, Gupta N, Holtermann A, Jørgensen MB, Proper KI, van der Beek J. Shift workers have similar leisure-time physical activity levels as day workers but are more sedentary at work. *Scand J Work Environ Health.* 2017;43(2):127–135.
20. Loef B, Huslegge G, Wendel-Vos GCW, et al. Non-occupational physical activity levels of shift workers compared with non-shift workers. *Occup Environ Med*. 2017;74:328–335.
21. Gretebeck RJ, Ferraro KF, Black DR, Holland K, Gretebeck KA. Longitudinal change in physical activity and disability in adults. *Am J Health Behav*. 2012;36(3):385–394.
22. Moti RW, Dlugonski D, Pilutti L, Sandroff B, McAuley E. Premorbid physical activity predicts disability progression in relapsing-remitting multiple sclerosis. *J Neurol Sci*. 2012;323(1-2):123–127.
23. Lipscomb JA, Trinkoff AM, Geiger-Brown J, Brady B. Work-schedule characteristics and reported musculoskeletal disorders of registered nurses. *Scand J Work Environ Health*. 2002;28(6):394–401.
24. Takahashi M, Matsudaira Ko, Shimazu A. Disabling low back pain associated with night shift duration: sleep problems as a potentiator. *Am J Ind Med*. 2015;58:1300–1310.
25. Del Campto MT, Romo PE, de la Hoz Re, Villamor JM, Mahíllo-Fernández I. Anxiety and depression predict musculoskeletal disorders in health care workers. *Arch Environ Occup Health.* 2017;72(1):39–44.
26. Bonvanie IJ, Oldehinkel AJ, Rosmalen JG, Janssens KA. Sleep problems and pain: a longitudinal cohort study in emerging adults. *Pain*. 2016;157(4):957–963.
27. Ilmarinen J, Suurnäkki T, Nygård C-H, Landau K. Classification of municipal occupations. *Scand J Work Environ Health*. 1991;17(suppl 1):12–29.
28. Muthén B. Statiscical and substantive checking in growth mixture modeling: comment on Bauer and Curran. *Psychol Methods*. 2003:8(3):369–377.
29. Nylund KL, Asparouhov T, Muthén BO. Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study. *Structural Equation Modeling: A multidisciplinary Journal*. 2007;14(4):535–569.
30. Tuomi K, Ilmarinen J, Klockars M, et al. Finnish research project on aging workers in 1981-1992. *Scand J Work Environ Health*. 1997;23(suppl 1):7–11.

31. Härmä M, Koskinen A, Ropponen A, et al. Validity of self-reported exposure to shift work. *Occup Environ Med*. 2017;74:228–230.
32. Vahtera J, Laine S, Virtanen M, et al. Employee control over working times and risk of cause-specific disability pension: the Finnish Public Sector Study. *Occup Environ Med*. 2010;67:479–485.
33. Kärkkäinen S, Ropponen A, Narusyte J, et al. Night work as a risk factor of future disability pension due to musculoskeletal diagnoses: a prospective cohort study of Swedish twins. Eur J Public Health. 2017. doi. 10.1093/eurpub/ckx084.
34. Härmä M, Ropponen A, Hakola T, et al. Developing register-based measures for assessment of working time patterns for epidemiological studies. *Scand J Work Environ Health*. 2015;41(3):268–279.
35. Caruso CC, Waters TR. A review of work schedule issues and musculoskeletal disorders with an emphasis on the healthcare sector. *Ind Health*. 2008;46:523–534.
36. Dall'Ora C, Ball J, Recio-Saucedo A, Griffiths P. Characteristics of shift work and their impact on employee performance and wellbeing: A literature review. *Int J Nurs Stud*. 2016;57:12–27.
37. Leino-Arjas P, Solovieva S, Riihimaki H, Kirjonen J, Telama R. Leisure time physical activity and strenuousness of work as predictors of physical functioning: a 28 year follow up of a cohort of industrial employees. Occup Environ Med. 2004;61(12):1032–1038.
38. Murphy RA, Patel KV, Kritchevsky SB, et al. Weight change, body compostion, and risk of mobility disability and mortality in older adults: A population-based cohort study. *J Am Geriatr Soc*. 2014;62(8):1476–1483.
39. Lin KC, Chi LY, Twisk JWR, Lee HL, Chen PC. Trajectory stability and factors affecting trajectories over time of the longitudinal age-related change in physical performance among older people. *Exp Aging Res*. 2011;37(3):358–376.
40. Donaldson SI, Grant-Vallone EJ. Understanding self-reported bias in organizational behaviour research. *Journal of Business and Psychology*. 2002;17(2):245–260.

List of Figures:

Table 1: Distribution of basic characteristics and exposures in four different trajectories of mobility limitations (MLs) stratified according to type of pensions, FLAME, 1985-2009

Basic-characteristics	N (3048)	Membership of trajectory of mobility limitations							
		Statutory Pension (SP) (%), n=1987				Disability Pension (DP) (%), n=1061			
		Low persistent (473)	Low increasing (612)	High decreasing (237)	High persistent (665)	Low persistent (71)	Low increasing (172)	High decreasing (129)	High persistent (689)
Age[a]	49.6±3.8	49.0±3.3	50.2±3.4	48.9±3.0	50.6±3.4	48.7±3.5	49.1±3.3	48.6±2.9	49.3±3.3
BMI[a]	25.3±3.2	24.2±2.6	24.9±2.8	24.9±3.2	26.1±3.3	24.1±3.2	24.9±2.9	25.1±2.8	26.1±3.5
Gender									
Women	1918	47	67	65	77	45	54	41	64
Men	1130	53	33	35	30	55	46	59	36
Occupational class									
White-collar	1747	66	67	59	58	62	64	43	42
Blue-collar	1301	34	33	41	42	38	36	57	58
Smoking- status									
None	1945	62	65	70	69	59	56	66	60
Former smokers	754	31	23	24	19	30	28	29	25
Current smokers	349	7	12	6	12	11	16	5	15
Alcohol intake									
None	2233	69	76	74	79	72	68	62	73
<2 drinks/months	570	22	17	20	15	21	20	26	20

≥1drink/week	227	9	7	6	6	7	12	12	7
Chronic diseases									
MSD	952	13	21	30	40	11	22	35	49
CVD	523	4	14	12	21	15	16	17	28
COPD	313	4	7	8	14	4	10	12	16
Neurological	342	4	9	12	11	14	15	17	16
Major-Exposures									
Shift work									
Day work	2076	66	65	63	58	81	84	81	76
SW without night shifts	461	19	15	15	18	13	7	7	14
SW with night shifts	511	15	20	22	24	6	9	12	10
LTPA									
Vigorous	1134	57	44	42	28	52	42	36	22
Moderate	1446	39	49	46	53	41	46	49	48
Inactive	468	4	7	12	19	7	12	15	30

Note FLAME, Finnish Longitudinal Study on Aging Municipal Employees; BMI, Body Mass Index; MSD, Musculoskeletal Diseases; CVD, Cardiovascular Diseases; COPD, Chronic Obstructive Pulmonary Disease; LTPA, Leisure Time Physical Activities; SW, Shift Work; [a]expressed as mean and SD (Standard Deviation)

Table 2: Odds ratio (OR) and their 95% confidence intervals (CI) for association of shift work and LTPA with mobility limitations (MLs) trajectories among statutory and disability pensioners, FLAME, 1985-2009

MLs Trajectories[a]	Statutory Pension (SP)		Disability Pension (DP)	
	Model I	Model II	Model I	Model II

	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Low increasing Vs. Low persistent								
Shift work								
Day work	1.0	Reference	1.0	Reference	1.0	Reference	1.0	Reference
SW without night shifts	0.88	0.63-1.22	0.80	0.56-1.15	0.54	0.22-1.36	0.49	0.19-1.27
SW with night shifts	1.44	1.03-2.00	1.09	0.76-1.56	1.56	0.49-4.91	1.24	0.38-4.03
LTPA								
Vigorous	1.0	Reference	1.0	Reference	1.0	Reference	1.0	Reference
Moderate	1.64	1.28-2.11	1.39	1.07-1.82	1.36	0.76-2.44	1.39	0.75-2.56
Inactive	2.20	1.24-3.89	1.94	0.99-3.22	1.98	0.69-5.71	1.91	0.65-5.61
High decreasing Vs. Low persistent								
Shift work								
Day work	1.0	Reference	1.0	Reference	1.0	Reference	1.0	Reference
SW without night shifts	0.83	0.54-1.29	0.68	0.43-1.09	0.55	0.21-1.46	0.44	0.15-1.24
SW with night shifts	1.57	1.04-2.34	1.34	0.87-2.08	2.05	0.65-6.48	2.33	0.71-7.70
LTPA								
Vigorous	1.0	Reference	1.0	Reference	1.0	Reference	1.0	Reference
Moderate	1.60	1.15-2.22	1.36	0.96-1.93	1.77	0.95-3.28	1.83	0.95-3.53
Inactive	4.14	2.22-7.73	3.28	1.72-6.23	3.29	1.12-9.63	2.80	0.93-8.48
High persistent Vs. Low persistent								
Shift Work								
Day work	1.0	Reference	1.0	Reference	1.0	Reference	1.0	Reference

SW without night shifts	1.24	0.90-1.70	0.98	0.68-1.42	1.20	0.57-2.51	0.73	0.32-1.66
SW with night shifts	2.03	1.47-2.80	1.49	1.03-2.14	2.09	0.73-5.94	1.46	0.49-4.40
LTPA								
Vigorous	1.0	Reference	1.0	Reference	1.0	Reference	1.0	Reference
Moderate	2.81	2.16-3.65	2.22	1.65-2.98	2.68	1.59-4.53	2.29	1.29-4.08
Inactive	9.34	5.36-15.77	5.99	3.39-10.58	9.80	3.75-25.56	6.81	2.52-18.43

Note LTPA, Leisure Time Physical Activity; SW, Shift Work; OR, Odds Ratio; CI, Confidence Interval; [a]low persistent trajectory group serve as base (outcome); Model I: Age adjusted; Model II: Further adjusted for gender, occupational class, smoking status, alcohol intake, BMI (Body Mass Index) and chronic diseases

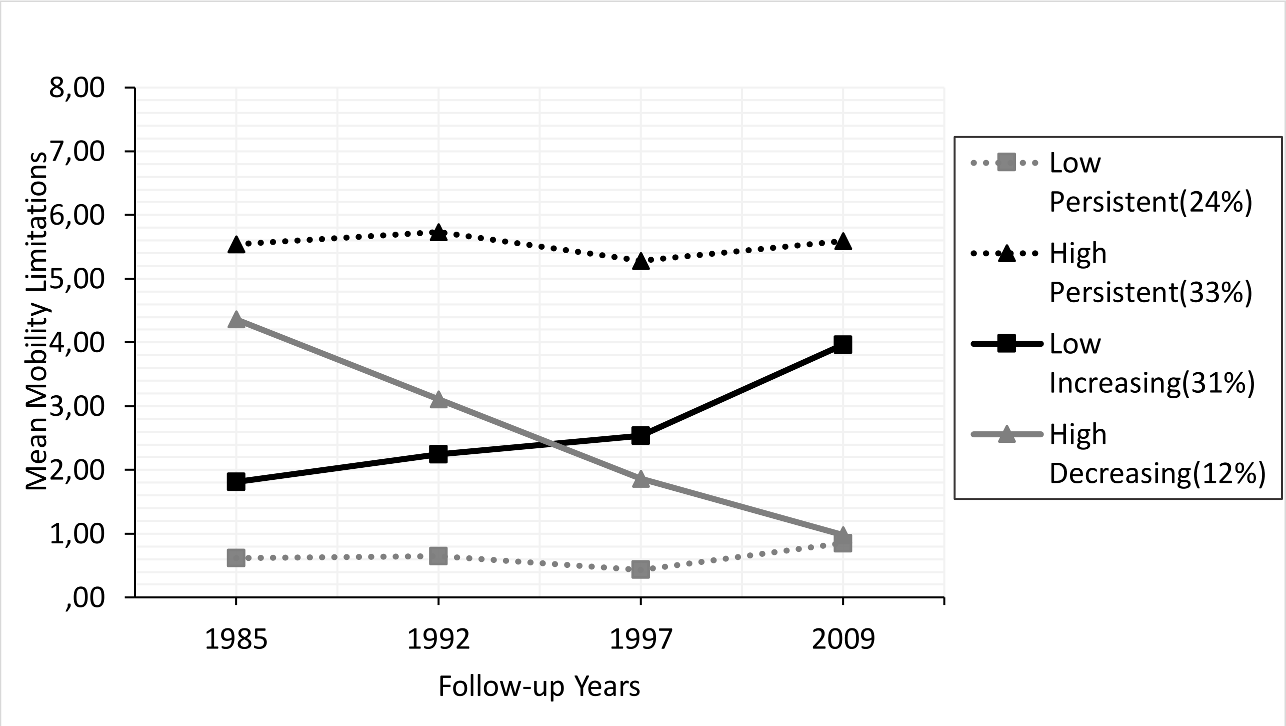


Figure 1: Four different trajectories of mobility limitations (MLs) among statutory pensioners (SP), FLAME, 1985-2009

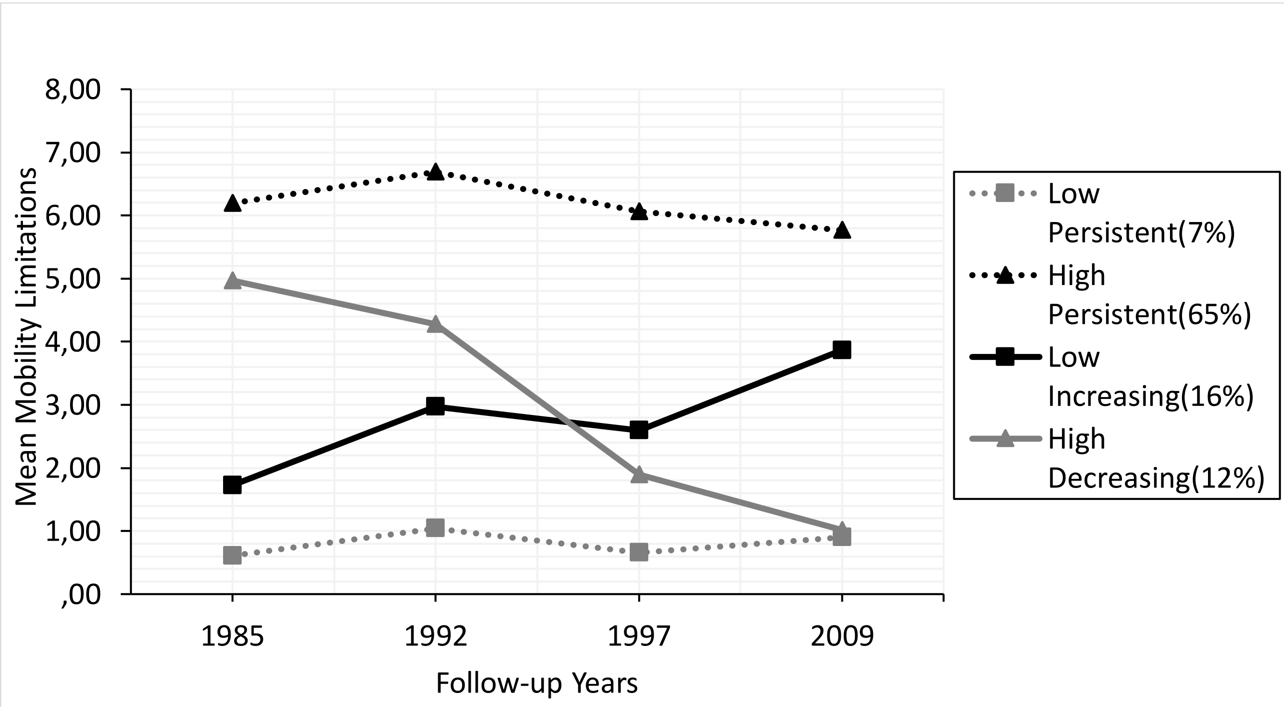


Figure 2: Four different trajectories of mobility limitations (MLs) among disability pensioners (DP), FLAME, 1985-2009

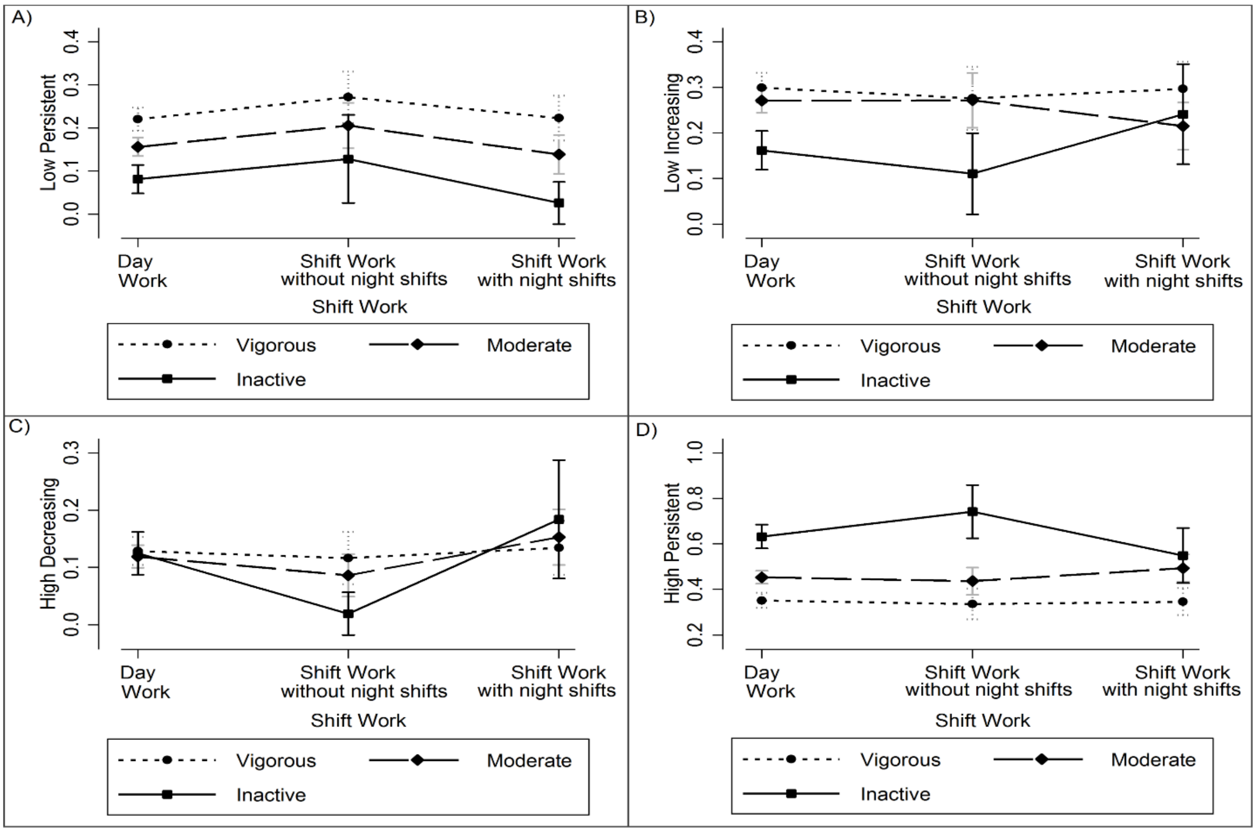
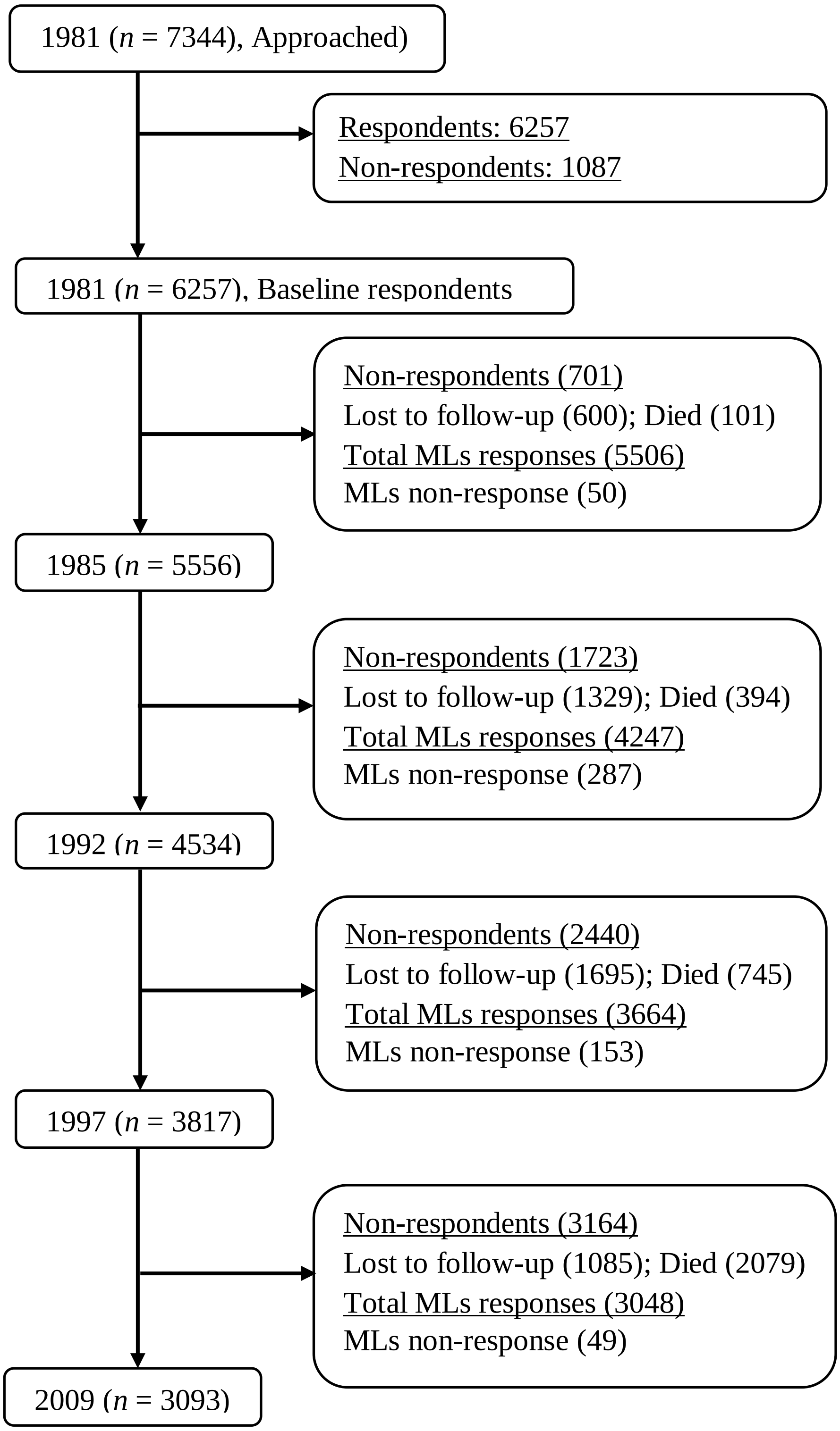


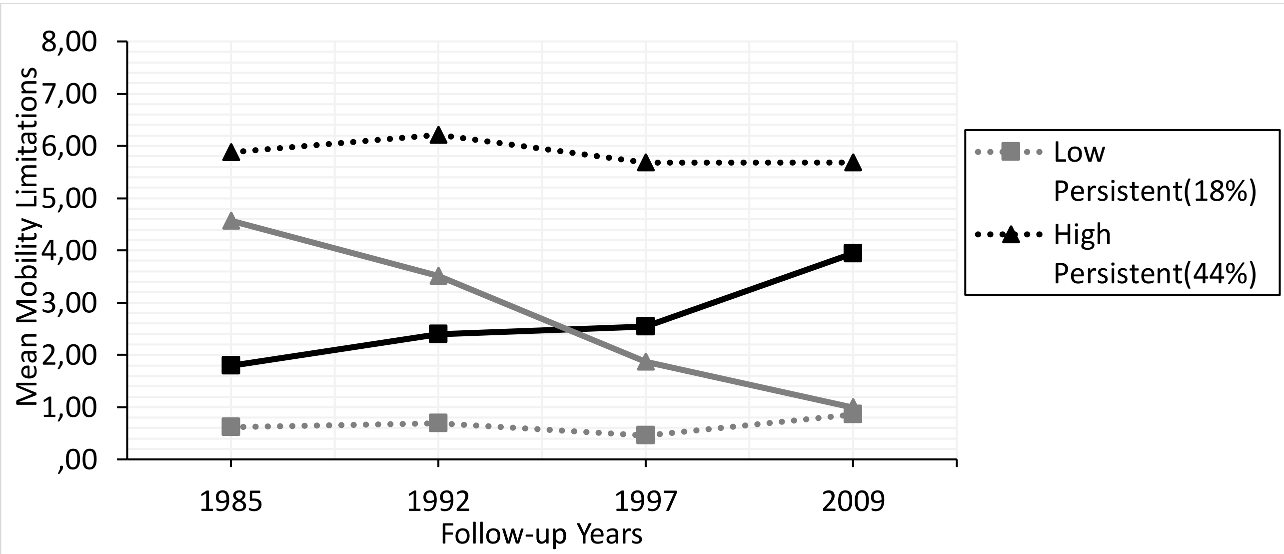
Figure 3: Adjusted predictive margins (adjusted for age, gender, occupational class, smoking status, alcohol intake, BMI and chronic diseases) for interaction of shift work (Day Work/Shift work without night shifts/Shift work with night shifts) and leisure time physical activity (LTPA, Vigorous/Moderate/Inactive) to predict low persistent (A), low increasing (B), high decreasing (C) and high persistent (D) trajectories of mobility limitations (MLs), FLAME, 1985-2009.



Supplement Figure 1: Follow-up of study subjects, Finnish Longitudinal study on Aging Municipal Employees (FLAME) 1981-2009. (Partly adapted: Prakash et al. 2017, American Journal of Epidemiology, doi: https://doi.org/10.1093/aje/kwx189)

Supplemental Table 1: International classification of functioning (ICF), disability and health categories (in **d** Activities and Participation: component **d4** Mobility) used to crease Mobility Limitation (0-9)

d4: Mobility	List of category	Questionnaire: Any difficulties in……
d410-d429: Changing and maintaining body position	d410: Changing basic body position	Squatting and standing up again? Bending down deep?
	d415: Maintaining a body position	Maintaining body position/sitting still for 2 hours?
d430-d449: Carrying moving and handling objects	d430: Lifting and carrying objects	Lifting and carrying more than 10 Kg?
	d440: Fine hand use	Precise movements of hands?
	d445: Hand and arm use	Lifting hands over the head?
d450-d469: Walking and moving	d450: Walking	Walking 2 kilometers?
	d455: Moving around	Running 100 meters? Climbing three floors/stairs?



Supplement Figure 1: Four latent class trajectories for mobility limitations 1985-2009, FLAME (overall respondents)

Supplemental Table 2: Fit-indices for trajectories of mobility limitation

Classes	BIC	Sample size adjusted BIC	AIC	LMR (*p*-value)	Entropy	No. of free parameters
2	49021.40	48992.80	48967.20	7420.55 (<0.001)	0.83	9
3	48055.01	48010.53	47970.70	982.02 (<0.001)	0.75	14
4	47732.69	47672.32	47618.27	353.61 (<0.001)	0.73	19
5	47603.81	47527.56	47459.28	164.88 (<0.001)	0.68	24

BIC, Bayesian Information Criteria; AIC, Akaike Information Criteria; LMR, Lo-Mendell-Rubin

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Original Contribution

Work-Related Biomechanical Exposure and Job Strain as Separate and Joint Predictors of Musculoskeletal Diseases: A 28-Year Prospective Follow-up Study

K. C. Prakash*, Subas Neupane, Päivi Leino-Arjas, Mikaela B. von Bonsdorff, Taina Rantanen, Monika E. von Bonsdorff, Jorma Seitsamo, Juhani Ilmarinen, and Clas-Håkan Nygård

* Correspondence to K. C. Prakash, Faculty of Social Sciences (Health Sciences), University of Tampere, Kalevantie 4, FI-33014 Tampere, Finland (e-mail: Prakash.kc@uta.fi, prakashkc10@gmail.com).

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We investigated how work-related biomechanical exposure and job strain in midlife separately and jointly predicted back and degenerative musculoskeletal diseases (MSDs). A total of 6,257 employees participated in the Finnish Longitudinal Study on Aging Municipal Employees (FLAME) in 1981 and were followed up for 28 years. Risk ratios and the relative excessive risk due to interaction and 95% confidence intervals were modeled for separate and joint prediction estimates, respectively. After adjustment for confounders, job strain predicted degenerative MSDs among women after 4 and 11 years of follow-up. After 11 years, both exposures predicted both types of MSDs among men. Joint exposure predicted both types of MSDs after 4 years among women (for back MSDs, risk ratio (RR) = 1.58, 95% confidence interval (CI): 1.15, 2.18; for degenerative MSDs, RR = 1.59, 95% CI: 1.21, 2.07) and men (for back MSDs, RR = 1.50, 95% CI: 1.05, 2.15; for degenerative MSDs, RR = 1.61, 95% CI: 1.16, 2.22) and both types of MSDs after 11 years (for back MSDs, RR = 1.72, 95% CI: 1.21, 2.43; for degenerative MSDs, RR = 1.68, 95% CI: 1.25, 2.46) among men only, but the relative excessive risk due to interaction was not significant throughout. However, after 28 years, the separate and joint exposures did not predict MSDs. Workplace interventions should be focused on reducing job strain along with biomechanical exposure for possible prevention of MSDs in working life and around the time of retirement, but there may be other pathways of onset of MSDs in old age.

biomechanical exposure; interaction; job strain; musculoskeletal diseases; occupational exposure; psychosocial exposure; work

Abbreviations: CI, confidence interval; GAZEL, Gaz et Électricité; MSD, musculoskeletal disease; RERI, relative excess risk due to interaction; RR, risk ratio.

Musculoskeletal diseases (MSDs) have been and continue to be growing problems in all parts of the world (1) and among both general and working populations (2, 3). In the Global Burden of Disease Study (1990–2013), Murray et al. (1) estimated that MSDs account for 21.3% of total years lived with disability worldwide. Low-back MSDs and osteoarthritis have been reported as the most recurrent forms of MSD (4, 5). The consequences of MSDs are more prominent among aged people than among those in midlife (6, 7).

A wide range of occupational risk factors present during working life are considered to be deleterious to musculoskeletal health, which in turn results in different types of MSD diagnosis (8) and ultimately impairs the physical functioning of workers in their later lives (9). The progression of MSDs is linked to numerous work-related exposures, such as high psychosocial stress exposures (10–12) and high physical and biomechanical exposures (13–15) from midlife to old age. These exposures are known predictors of work-related MSDs of different body parts, like the back (16–18), neck/shoulders (19, 20), and joints (21). There is variation in the types of occupations performed by men and women; therefore, the risk of MSDs due to occupational exposures may vary by sex (22). Findings from the Gaz et Électricité (GAZEL) cohort study suggested that occupational biomechanical exposure during active life has persistent effects up to old age among men (23). The role of these work-related exposures in the onset of MSDs during the late working career, as well as after retiring, has been addressed in earlier studies (24, 25).

In recent years, psychosocial factors like high strain at work have gained increasing attention in observational and experimental studies, as they have been found to be linked to both physical and mental illness (26). The existing evidence suggests an interplay of various biomechanical and psychosocial risk factors associated with work underlying the onset of MSDs (8, 27) and also has served to stress the importance of studying the epidemiologic interactions of work-related biomechanical and psychosocial exposures as risk factors for MSDs (28–30). In some earlier studies, investigators have reported findings on the interactive effects of work-related biomechanical and psychosocial exposures on MSDs (14, 31, 32) and functional health (33). In a cross-sectional study in Brazil, Fernandes et al. (31) found that the 2 kinds of work-related exposures separately predicted MSDs, but there were no interactive predictions. Likewise, in a 2-year follow-up study in a manufacturing cohort, Cantley et al. (14) also noted an absence of an interactive effect of these 2 types of work-related exposures on injury and MSDs. However, Waters et al. (32), in a cross-sectional study, reported the presence of interaction which was additive in the prediction of MSDs of the back and arms. Similarly, in the GAZEL cohort, Sabbath et al. (33) noted an interactive effect of work-related psychosocial and biomechanical exposures on functional health after retirement which was also more than additive.

The joint associations of work-related biomechanical exposures and job strain with future health outcomes have been highlighted in earlier studies; however, there is a lack of clear epidemiologic evidence of associations with musculoskeletal health. Therefore, there is a need for more longitudinal evidence to ascertain the possible joint effects of these co-occurring exposures of working life, which might be beneficial in preventing future MSDs and ultimately promote active and healthy aging. In this study we aimed to investigate the separate and joint effects of work-related biomechanical exposures and job strain at midlife/baseline (1981) on degenerative MSDs and back MSDs after 4 years (in 1985), 11 years (in 1992), and 28 years (in 2009), using 28-year follow-up data on Finnish public sector employees.

METHODS

Participants and design

The Finnish Longitudinal Study on Aging Municipal Employees (FLAME) is a prospective follow-up study initiated by the Finnish Institute of Occupational Health in 1981, with follow-up taking place in different waves in 1985 (after 4 years), 1992 (after 11 years), and 2009 (after 28 years) (34, 35). Out of 7,344 potential subjects, 6,257 persons aged 44–58 years (85.2% response rate) participated in the study in 1981. The present analysis was based on the respondents for whom information on MSDs was available after 4 years of follow-up (n = 3,533 for degenerative MSDs after excluding baseline degenerative MSD cases and n = 3,783 for back MSDs after excluding baseline back MSD cases), 11 years of follow-up (n = 2,878 and n = 3,098, respectively), and 28 years of follow-up (n = 2,001 and n = 2,132, respectively). According to mortality data (January 1981–July 2009) from the Finnish National Population Register, 2,079 (33.2%) of the baseline respondents died during the 28-year follow-up period (35).

The process of following up respondents is described in detail in Figure 1. The ethics committee of the Finnish Institute of Occupational Health (Helsinki, Finland) approved the study, and informed consent was obtained from all participants.

Biomechanical exposure

Work-related biomechanical exposure was assessed with 8 questions related to exposure to vibration, similar repeated movements, standing in one place, bent or twisted postures, continuous walking or movement, carrying objects by hand, and sudden strainful efforts. The questions could be answered on a scale of 0–4 ("0 = not at all," "1 = a little," "2 = somewhat," "3 = often," and "4 = quite often"). The summary scores (Cronbach's α = 0.83), ranging from 0 to 29 (higher scores indicating high biomechanical exposure and lower scores indicating low biomechanical exposure), were dichotomized into high (>13) and low (≤13) categories using the median value of 13. The selection of items and formation of the binary exposure scale were partly adapted from the study by Sabbath et al. (33).

Job strain

Job control. Job control was assessed with 10 questions related to respondents' possibilities for control, guidance, and influence at work: providing guidance in the job, influencing the work environment, participating in the planning of the work, gaining a promotion, chances of further training in professional skills, chances to use one's own abilities and talent to learn new things, gaining recognition and respect, working with coworkers, and seeing the meaning of the work. The questions could

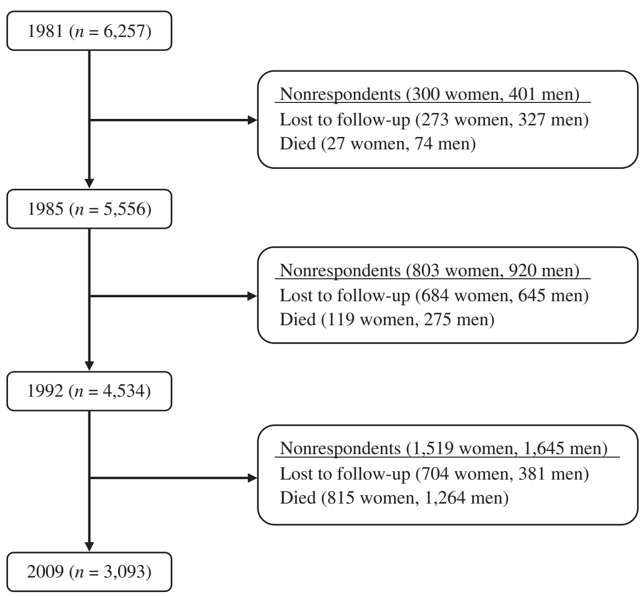

Figure 1. Selection of respondents and loss to follow-up among Finnish municipal employees in a study of work-related exposures and risk of musculoskeletal diseases, Finnish Longitudinal Study on Aging Municipal Employees, 1981–2009.

be answered on a scale of 0–3 (“0 = not at all,” “1 = a little,” “2 = somewhat,” and “3 = a lot”). The summary scores (Cronbach’s $\alpha = 0.86$), ranging from 0 to 30, were dichotomized into high (>16) and low (≤16) categories using the median value of 16 (36).

Job demands. Job demands were assessed with 8 questions on job-related demands and pressure: fast work pace, tight time schedule, responsibilities, conflicting demands regarding work tasks and responsibilities, pressure and interference from the supervisor, pressure of failing or committing errors, seclusion or loneliness, and uninteresting work. The questions could be answered on a scale of 0–3 (“0 = not at all,” “1 = a little,” “2 = somewhat,” and “3 = a lot”). The summary scores (Cronbach’s $\alpha = 0.77$), ranging from 0 to 24, were dichotomized into high (>6) and low (≤6) categories using the median value of 6 (36).

Job strain. The job strain variable was created using the job demand-control concept from the Karasek model (37, 38). Four levels of job strain were constructed using the dichotomized values of job demands and control: low strain (high control and low demands), passive job (low control and low demands), active job (high control and high demands), and high strain (low control and high demands) (36).

Musculoskeletal diseases

Information on MSDs was reported by respondents based on physicians’ diagnoses. In this study, we used 2 outcomes, namely degenerative MSDs (any of the 4 degenerative MSDs: osteoarthritis of the cervical spine, osteoarthritis of the lower back, sciatica, and osteoarthritis of the limbs) and back MSDs (any of the 3 back-related MSDs: osteoarthritis of the cervical spine, osteoarthritis of the lower back, and sciatica). All of the responses were binary and coded as “0” (no disease) or “1” (presence of disease).

Covariates

Information on smoking status was elicited as number of cigarettes smoked per day, and persons who reported smoking at least 1 cigarette per day were classified as smokers. Information on alcohol intake was based on 7 categories, and for this study we classified intake as none, ≤2 drinks per month, or ≥1 drink per week. Information on leisure-time physical activity in the previous year was elicited in 5 categories, and it was classified in this study as very active, moderately active, or inactive. Body mass index (weight (kg)/height (m)^2) was calculated using self-reported height and weight. Two occupational groups, blue-collar (example: auxiliary, transport) and white-collar (example: administrative, physician), were created on the basis of 13 job profiles which represented clusters of 133 different job titles (35).

Statistical analysis

The descriptive characteristics of the subjects were first determined as frequencies and percentages, and we conducted Pearson’s χ^2 tests, which showed strong evidence of a relationship between work-related exposures and MSDs. Then we also checked initial interactions using maximum likelihood. The interaction term for sex and work-related exposures with respect to MSDs was found to be statistically significant ($P < 0.001$); therefore, the analyses were stratified by sex. Since there were very few missing values (<10%) in the items on work-related exposures, the missing values (5.5% for biomechanical exposure, 5% for job control, and 7.4% for job demands) were imputed using the calculated median of nearby points, calculated from other items on the scale. Risk ratios (RRs) and their 95% confidence intervals were modeled using binary regression with a log link function. The lowest levels of both biomechanical exposure and job strain (low strain) were used as reference categories in the analysis. In order to check the predictive power of the exposures, we calculated predictive margins of job strain and biomechanical exposures, by sex, for both outcomes. For joint prediction, the potential interaction between biomechanical exposure and job strain was quantified using departure from additivity, which was estimated by computing the relative excessive risk due to interaction (RERI) and its 95% confidence interval. Calculation of the RERI was based on following formula (39, 40):

$$\mathrm{RERI} = \mathrm{RR}_{1,1} - \mathrm{RR}_{1,0} - \mathrm{RR}_{0,1} + 1,$$

where $\mathrm{RR}_{1,1}$ = the presence of high biomechanical exposure and high job strain (joint exposure), $\mathrm{RR}_{1,0}$ = the presence of high biomechanical exposure and the absence of high job strain, and $\mathrm{RR}_{0,1}$ = the absence of high biomechanical exposure and the presence of high job strain.

In order to prevent reverse causation, we excluded persons diagnosed with MSDs at baseline from the analysis ($n = 2{,}273$ for degenerative MSDs and $n = 1{,}991$ for back MSDs). The advanced prefix “icp” from Stata 14.0 (StataCorp LP, College Station, Texas) was used to calculate estimates of log relative risk from the regression settings that generated the interaction estimates. Additive biological interaction is present if RERI > 0 with statistical significance. Likewise, if $\mathrm{RR}_{1,1}$ is significantly different from 1, interaction is present. Two models were fitted; the first model was a crude model, and the second model adjusted for potential confounders such as age, body mass index, smoking status, occupational group, alcohol intake, and physical activity. Selection of the confounders was based on previous knowledge of the factors that could mask an association between the exposure and outcomes of this nature (41). Frequency-percentage calculation and cross-tabulation were conducted using IBM SPSS, version 21.0 (IBM Corporation, Armonk, New York). All of the other analyses and plotting were conducted in Stata 14.0.

RESULTS

Table 1 presents the distribution of baseline characteristics, biomechanical exposures, and job strain and the joint distribution of exposures stratified by sex. The ages of the respondents ranged from 44 years to 58 years (mean age = 50 (standard deviation, 3.6) years), and 55% of the respondents were women. Table 2 presents the crude risk ratios for MSDs due to work-related exposures in midlife after 4 years, 11 years, and 28 years of follow-up. High biomechanical and job strain exposures significantly predicted back MSDs and degenerative MSDs among both sexes after 4 and 11 years. Likewise, high

Table 1. Distributions of Relevant Baseline Characteristics and Work-Related Exposures Among Finnish Men and Women ($n = 6{,}257$) in a Study of Relationships Between Biomechanical Exposure and Job Strain and Musculoskeletal Diseases, Finnish Longitudinal Study on Aging Municipal Employees, 1981

Baseline Characteristic	Women ($n = 3{,}460$)		Men ($n = 2{,}797$)		*P* Value[a]
	No. of Persons	%	No. of Persons	%	
Occupational group					<0.001
Blue-collar	1,289	37	1,980	71	
White-collar	2,171	63	817	29	
Age, years[b]	50.41(3.62)		50.51(3.61)		0.266[c]
Smoking status					<0.001
No	3,057	88	1,955	70	
Yes	376	11	828	30	
Missing data	27	1	14	<1	
Alcohol intake					<0.001
None	2,990	86	1,285	46	
≤2 drinks per month	340	10	923	33	
≥1 drink per week	100	3	569	20	
Missing data	30	1	20	1	
Physical activity					0.007
Very active	1,683	49	1,265	45	
Moderately active	1,393	40	1,218	44	
Inactive	275	8	253	9	
Missing data	109	3	61	2	
Body mass index[b,d,e]	25.24 (3.53)		26.16 (3.14)		<0.001[c]
Work-related exposure[f]					
Biomechanical exposure					<0.001
Low	1,382	40	1,456	52	
High	2,032	59	1,308	47	
Missing data	46	1	33	1	
Job strain					<0.001
Low-strain	1,017	29	705	25	
Passive job	621	18	575	21	
Active job	900	26	617	22	
High-strain	922	27	900	32	
Joint exposure (biomechanical/job strain)					<0.001
Low/low-strain	626	18	517	18	
Low/passive job	252	7	293	11	
Low/active job	328	10	334	12	
Low/high-strain	222	7	345	12	
High/low-strain	424	12	213	8	
High/passive job	358	10	275	10	
High/active job	564	16	276	10	
High/high-strain	686	20	544	19	

[a] *P* value derived from χ^2 test.
[b] Values are expressed as mean (standard deviation).
[c] Variable tested with analysis of variance.
[d] Weight (kg)/height (m)^2.
[e] Data were missing for 35 women and 36 men.
[f] See Methods section for definitions.

Table 2. Crude Estimates of the Risk of Musculoskeletal Diseases According to Work-Related Exposures (Biomechanical Exposure and Job Strain; Separate Predictions) Among Finnish Women and Men After 4, 11, and 28 Years of Follow-up, Finnish Longitudinal Study on Aging Municipal Employees, 1981–2009

Work-Related Exposure	Back MSDs[a]				Degenerative MSDs[a]			
	Women		Men		Women		Men	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
4 Years of Follow-up (n = 5,556)								
Biomechanical exposure								
Low	1	Referent	1	Referent	1	Referent	1	Referent
High	1.60	1.37,1.86	1.35	1.13, 1.61	1.51	1.32, 1.72	1.35	1.15, 1.58
Job strain								
Low-strain	1	Referent	1	Referent	1	Referent	1	Referent
Passive job	1.43	1.18, 1.75	1.22	0.95, 1.55	1.40	1.18, 1.67	1.20	0.96, 1.50
Active job	1.29	1.03, 1.60	1.27	0.96, 1.69	1.25	1.03, 1.52	1.40	1.10, 1.79
High-strain	1.33	1.09, 1.63	1.30	1.03, 1.66	1.47	1.23, 1.74	1.24	0.99, 1.54
11 Years of Follow-up (n = 4,534)								
Biomechanical exposure								
Low	1	Referent	1	Referent	1	Referent	1	Referent
High	1.25	1.08, 1.43	1.49	1.26, 1.77	1.25	1.10, 1.41	1.43	1.23, 1.65
Job strain								
Low-strain	1	Referent	1	Referent	1	Referent	1	Referent
Passive job	1.20	0.98, 1.44	1.27	0.99, 1.61	1.20	1.02, 1.41	1.22	0.99, 1.49
Active job	1.18	0.97, 1.41	1.26	0.96, 1.67	1.12	0.95, 1.34	1.11	0.87, 1.42
High-strain	1.34	1.11, 1.61	1.47	1.16, 1.84	1.28	1.09, 1.50	1.38	1.13, 1.68
28 Years of Follow-up (n = 3,093)								
Biomechanical exposure								
Low	1	Referent	1	Referent	1	Referent	1	Referent
High	1.18	0.97, 1.43	1.44	1.04, 2.00	1.13	1.00, 1.28	1.07	0.86, 1.32
Job strain								
Low-strain	1	Referent	1	Referent	1	Referent	1	Referent
Passive job	1.21	0.93, 1.57	1.02	0.67, 1.57	1.08	0.91, 1.27	1.17	0.91, 1.53
Active job	1.20	0.91, 1.57	0.75	0.42, 1.32	1.03	0.86, 1.23	1.03	0.74, 1.43
High-strain	1.09	0.83, 1.42	1.17	0.78, 1.74	0.97	0.82, 1.16	1.14	0.87, 1.49

Abbreviations: CI, confidence interval; MSD, musculoskeletal disease; RR, risk ratio.

[a] Numbers of subjects included in the analysis for each follow-up period: with 4 years of follow-up, $n = 3{,}533$ for degenerative MSDs after exclusion of baseline degenerative MSD cases and $n = 3{,}783$ for back MSDs after exclusion of baseline back MSD cases; with 11 years of follow-up, $n = 2{,}878$ and $n = 3{,}098$, respectively; and with 28 years of follow-up, $n = 2{,}001$ and $n = 2{,}132$, respectively.

biomechanical exposure predicted back MSDs among men and degenerative MSDs among women after 28 years.

Figure 2 presents the adjusted risk ratios for MSDs due to higher levels of work-related exposures in midlife among women and men. The estimates presented in the figure were adjusted for age, physical activity, occupational group, body mass index, alcohol intake, and smoking status. Among women, after 4 years biomechanical exposure in midlife predicted both back MSDs (RR = 1.39, 95% confidence interval (CI): 1.16, 1.67) and degenerative MSDs (RR = 1.30, 95% CI: 1.11, 1.52); job strain predicted only degenerative MSDs (RR = 1.30, 95% CI: 1.09, 1.56) (Figure 2A). However, only job strain predicted both outcomes after 11 years (Figure 2B). Among men, biomechanical exposure predicted degenerative MSDs after 4 years (Figure 2D), and both types of exposures predicted back MSDs (for biomechanical exposure, RR = 1.33, 95% CI: 1.08, 1.64; for job strain, RR = 1.32, 95% CI: 1.05, 1.68) and degenerative MSDs (for biomechanical exposure, RR = 1.32, 95% CI: 1.10, 1.57; for job strain, RR = 1.26, 95% CI: 1.03, 1.53) after 11 years (Figure 2E), but the association did not persist to 28 years in either sex (Figure 2, parts C and F).

Tables 3 and 4 present risk ratios for MSDs due to the different combinations of biomechanical exposure and job strain in midlife and RERIs for the joint effect of biomechanical

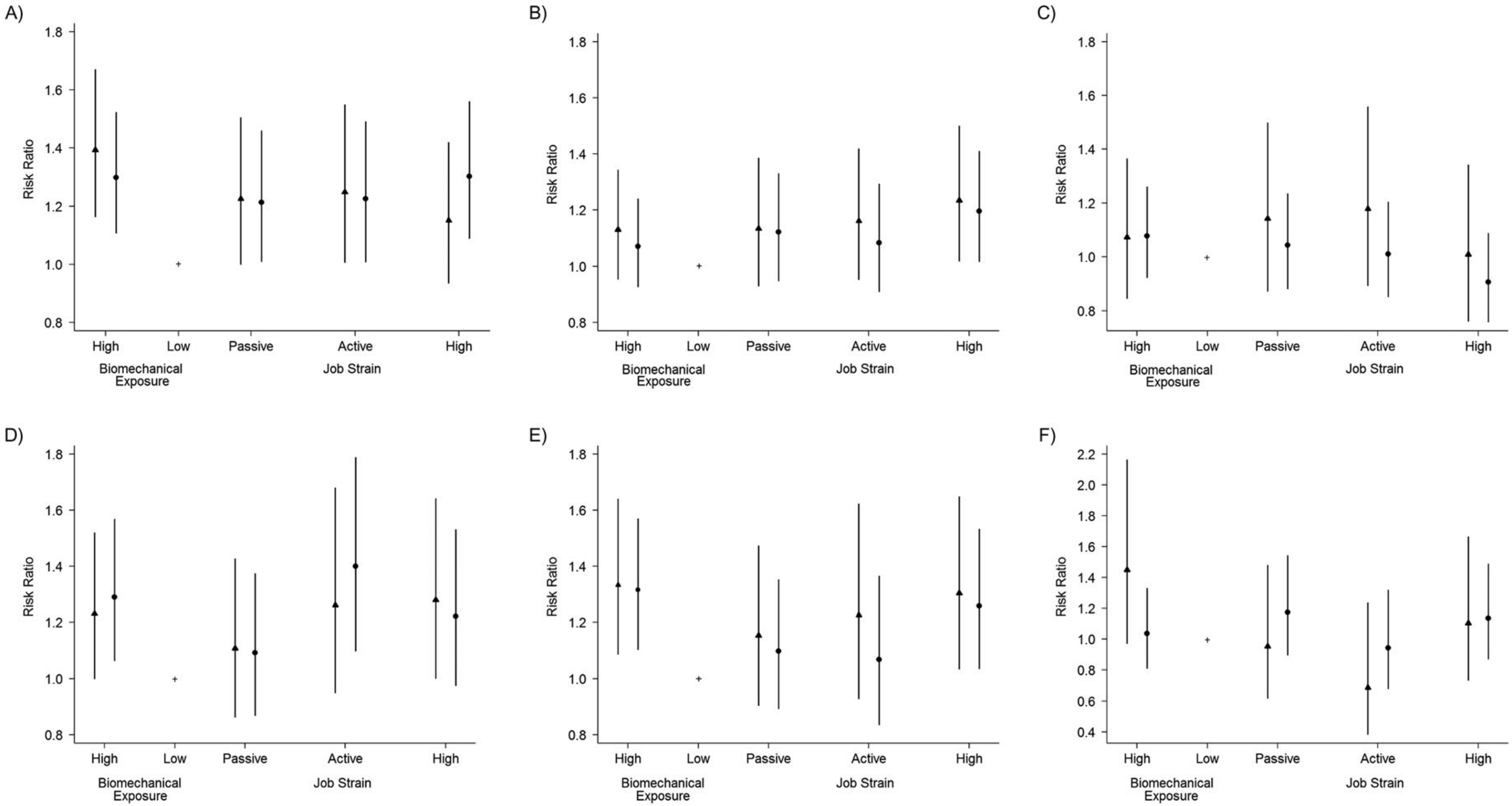

Figure 2. Risk ratios for the associations of work-related exposures (biomechanical exposure and job strain; separate predictions) with musculoskeletal diseases (MSDs) after 4 (parts A and D), 11 (parts B and E), and 28 (parts C and F) years of follow-up among Finnish women (parts A–C) and men (parts D–F), Finnish Longitudinal Study on Aging Municipal Employees, 1981–2009. Results were adjusted for age, smoking status, alcohol intake, body mass index, occupational group, and physical activity. "Low" was the referent category (risk ratio = 1.0) for both biomechanical exposure and job strain. Triangles, back MSDs; circles, degenerative MSDs. Bars, 95% confidence intervals.

Table 3. Risk of Musculoskeletal Diseases Due to Different Combinations of Biomechanical Exposure and Job Strain and RERI for the Interaction Between Biomechanical Exposure and Job Strain (Joint Predictions) Among Finnish Women After 4, 11, and 28 Years of Follow-up, Finnish Longitudinal Study on Aging Municipal Employees, 1981–2009

Work-Related Exposure		Back MSDs[a]				Degenerative MSDs[a]			
		Crude		Adjusted[c]		Crude		Adjusted[c]	
Biomechanical Exposure[b]	Job Strain[b]	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
4 Years of Follow-up (n = 3,160)									
No	No	1	Referent	1	Referent	1	Referent	1	Referent
Yes	No	1.68	1.27, 2.23	1.54	1.13, 2.08	1.59	1.24, 2.04	1.37	1.05, 1.80
No	Yes	1.23	0.85, 1.79	1.20	0.82, 1.76	1.43	1.05, 1.94	1.36	0.99, 1.86
Yes	Yes	1.89	1.45, 2.44	1.58	1.15, 2.18	1.94	1.55, 2.43	1.59	1.21, 2.07
		−0.02[d]	−0.64, 0.60	−0.15[d]	−0.76, 0.45	−0.08[d]	−0.63, 0.48	−0.15[d]	−0.67, 0.37
11 Years of Follow-up (n = 2,657)									
No	No	1	Referent	1	Referent	1	Referent	1	Referent
Yes	No	1.24	0.96, 1.61	1.16	0.87, 1.54	1.32	1.06, 1.64	1.13	0.89, 1.45
No	Yes	1.47	1.11, 1.97	1.71	1.06, 1.91	1.85	1.14, 1.87	1.39	1.08, 1.78
Yes	Yes	1.44	1.14, 1.83	1.29	0.97, 1.72	1.41	1.15, 1.73	1.20	0.94, 1.53
		−0.29[d]	−0.80, 0.25	−0.30[d]	−0.82, 0.22	−0.37[d]	−0.83, 0.0)	−0.32[d]	−0.74, 0.10
28 Years of Follow-up (n = 1,932)									
No	No	1	Referent	1	Referent	1	Referent	1	Referent
Yes	No	1.14	0.80, 1.63	0.99	0.67, 1.46	1.19	0.96, 1.47	1.13	0.90, 1.42
No	Yes	1.20	0.79, 1.84	1.18	0.77, 1.80	0.88	0.64, 1.21	0.86	0.63, 1.18
Yes	Yes	1.13	0.81, 1.59	0.92	0.61, 1.41	1.11	0.90, 1.37	0.96	0.74, 1.25
		−0.21[d]	−0.87, 0.45	−0.24[d]	−0.87, 0.38	0.03[d]	−0.34, 0.42	−0.03[d]	−0.40, 0.34

Abbreviations: CI, confidence interval; MSD, musculoskeletal disease; RERI, relative excess risk due to interaction; RR, risk ratio.

[a] Numbers of subjects included in the analysis for each follow-up period: with 4 years of follow-up, *n* = 1,970 for degenerative MSDs after exclusion of baseline degenerative MSD cases and *n* = 2,124 for back MSDs after exclusion of baseline back MSD cases; with 11 years of follow-up, *n* = 1,656 and *n* = 1,978, respectively; and with 28 years of follow-up, *n* = 1,224 and *n* = 1,314, respectively.

[b] "Yes" indicates a high level of job strain or high biomechanical exposure.

[c] Adjusted for age, physical activity, occupational group, body mass index, alcohol intake, and smoking status.

[d] RERI.

exposure and job strain for all 3 follow-up periods among women and men, respectively. In a crude model, women who had a higher level of both exposures in midlife (+, +) were at greater risk of both MSDs after 4 and 11 years than were women without any exposures in midlife (−, −). After adjustment for confounders, the association persisted for both types of MSDs (for back MSDs, RR = 1.58, 95% CI: 1.15, 2.18; for degenerative MSDs, RR = 1.59, 95% CI: 1.21, 2.07) after 4 years but for none after 11 years. Likewise, among men, in the crude model the joint exposures predicted both types of MSDs after 4 and 11 years; the finding was retained in the adjusted model for both back MSDs and degenerative MSDs after 4 years (for back MSDs, RR = 1.50, 95% CI: 1.05, 2.15; for degenerative MSDs, RR = 1.61, 95% CI: 1.16, 2.22) and 11 years (for back MSDs, RR = 1.72, 95% CI: 1.21, 2.43; for degenerative MSDs, RR = 1.68, 95% CI: 1.25, 2.46). As among women, RERI was not significant for any joint predictions among men, which indicated an absence of biological interaction. The risk continued to diminish to the point where none of the interactions between exposures in midlife predicted MSDs after 28 years of follow-up in either sex.

Figure 3 presents the adjusted predicted margins of MSDs over 4, 11, and 28 years of follow-up according to work-related exposures in midlife among women and men, which were calculated as postestimation. After 4 (Figure 3, parts A and D) and 11 (Figure 3, parts B and E) years of follow-up, persons who had high exposures in midlife had a greater chance of getting MSDs than did those with low exposures. However, after 28 years (Figure 3, parts C and F), there was no difference in the predictability of high- and low-level exposures. Adjusted predicted margins of both MSDs according to job strain and work-related biomechanical exposure at the same time points (1985 (A) and 1992 (B)) are presented in Web Figure 1, available at https://academic.oup.com/aje.

DISCUSSION

In this prospective 28-year follow-up study, we found that a higher level of biomechanical exposure and job strain separately and jointly predicted higher risks of back and degenerative MSDs after 4 and 11 years of follow-up. However, there

Table 4. Risk of Musculoskeletal Diseases Due to Different Combinations of Biomechanical Exposure and Job Strain and RERI for the Interaction Between Biomechanical Exposure and Job Strain (Joint Predictions) Among Finnish Men After 4, 11, and 28 Years of Follow-up, Finnish Longitudinal Study on Aging Municipal Employees, 1981–2009

Work-Related Exposure		Back MSDs[a]				Degenerative MSDs[a]			
		Crude		Adjusted[c]		Crude		Adjusted[c]	
Biomechanical Exposure[b]	Job Strain[b]	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
4 Years of Follow-up (n = 2,396)									
No	No	1	Referent	1	Referent	1	Referent	1	Referent
Yes	No	1.50	1.03, 2.19	1.38	0.90, 2.11	1.62	1.16, 2.27	1.54	1.01, 2.15
No	Yes	1.50	1.07, 2.10	1.53	1.09, 2.14	1.29	0.94, 1.79	1.31	0.93, 1.81
Yes	Yes	1.51	1.11, 2.05	1.50	1.05, 2.15	1.58	1.20, 2.09	1.61	1.16, 2.22
		−0.49[d]	−1.23, 0.25	−0.40[d]	−1.12, 0.32	−0.33[d]	−0.99, 0.33	−0.24[d]	−0.89, 0.42
11 Years of Follow-up (n = 1,877)									
No	No	1	Referent	1	Referent	1	Referent	1	Referent
Yes	No	1.71	1.19, 2.46	1.52	1.01, 2.29	1.83	1.36, 2.47	1.64	1.18, 2.30
No	Yes	1.45	1.04, 2.03	1.35	0.95, 1.90	1.40	1.05, 1.87	1.32	0.98, 1.76
Yes	Yes	1.94	1.44, 2.61	1.72	1.21, 2.43	1.89	1.47, 2.43	1.68	1.25, 2.46
		−0.23[d]	−0.97, 0.52	−0.15[d]	−0.83, 0.54	−0.34[d]	−0.99, 0.29	−0.28[d]	−0.86, 0.30
28 Years of Follow-up (n = 1,142)									
No	No	1	Referent	1	Referent	1	Referent	1	Referent
Yes	No	1.52	0.82, 2.81	1.39	0.70, 2.74	1.33	0.88, 2.01	1.28	0.81, 2.01
No	Yes	1.15	0.65, 2.03	1.07	0.60, 1.91	1.22	0.86, 1.73	1.22	0.86, 1.73
Yes	Yes	1.59	0.95, 2.62	1.44	0.79, 2.61	1.27	0.90, 1.80	1.26	0.84, 1.88
		−0.09[d]	−1.25, 1.07	−0.02[d]	−1.09, 1.05	−0.28[d]	−1.00, 0.44	−0.24[d]	−0.95, 0.46

Abbreviations: CI, confidence interval; MSD, musculoskeletal disease; RERI, relative excess risk due to interaction; RR, risk ratio.

[a] Numbers of subjects included in the analysis for each follow-up period: with 4 years of follow-up, $n = 1{,}563$ for degenerative MSDs after exclusion of baseline degenerative MSD cases and $n = 1{,}659$ for back MSDs after exclusion of baseline back MSD cases; with 11 years of follow-up, $n = 1{,}300$ and $n = 1{,}222$, respectively; and with 28 years of follow-up, $n = 777$ and $n = 818$, respectively.

[b] "Yes" indicates a high level of job strain or high biomechanical exposure.

[c] Adjusted for age, physical activity, occupational group, body mass index, alcohol intake, and smoking status.

[d] RERI.

was no significant association after 28 years of follow-up. Joint exposure in midlife significantly predicted both types of MSDs among both sexes after 4 years and among men only after 11 years, but not after 28 years. None of the estimates of joint exposure were sufficient for significant RERI, which indicated the absence of biological interaction.

Our findings are consistent with those of earlier studies regarding the separate predictions. Of all forms of MSD, back MSD has been most widely studied in relation to work-related exposures in midlife. A higher level of biomechanical exposure and job strain at midlife in our study separately predicted a higher risk of back MSDs in later life until around the time of retirement, which is consistent with the findings of some earlier studies (16–18, 42). Also consistent with previous studies (11, 23), we found a clear sex difference in risk of MSDs due to work-related exposures during midlife. We found that a higher level of both biomechanical exposure and job strain predicted the risk of MSDs among women late in their careers but not among men. The risk of MSDs after 11 years of follow-up, which was around the time of retirement for our subjects, was higher among men than among women, which concurs with the findings in the GAZEL cohort (23). The findings of our study were comparable with those of a Swedish study in which Canivet et al. (43) reported a significantly higher risk of receiving a disability pension among persons with high levels of work-related psychosocial exposures (high job demands, low decision latitude, and high job strain), and the risk was greater in men than in women.

The comparatively higher risk of MSDs due to high biomechanical exposure among men than among women after 11 years of follow-up could be explained in our study by the higher percentage of men working in blue-collar jobs. Job strain was more highly predictive of MSDs than biomechanical exposure among women throughout follow-up, but among men it was the opposite, which perhaps could be described by a sex difference in the nature of the jobs performed. This result could be generalized to the other working populations as well, because more of the jobs with higher psychosocial/job strain exposure are carried out by women than by men and vice versa.

Interestingly, we found no significant association of work-related exposures in midlife with any forms of MSD in old age

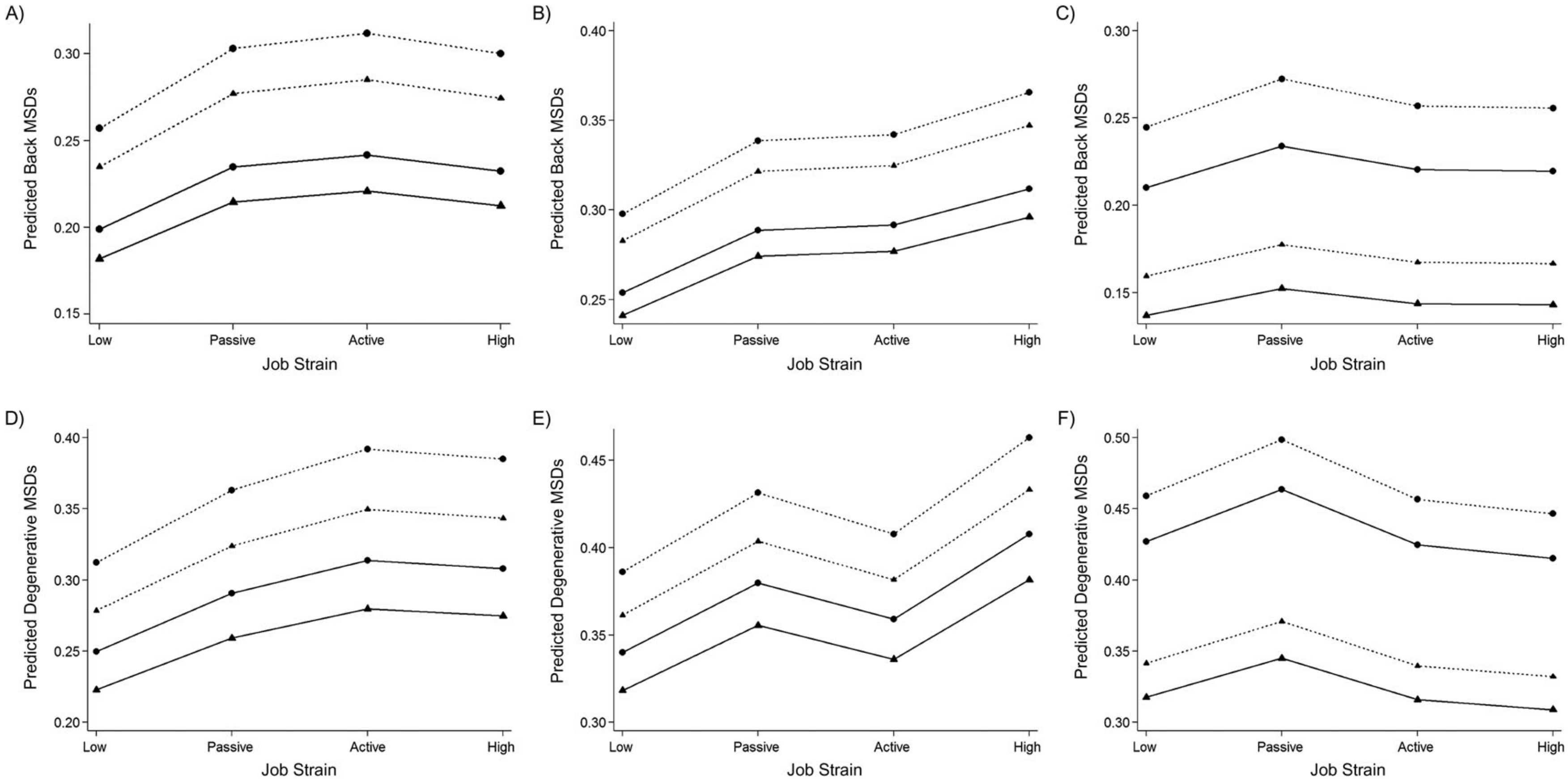

Figure 3. Predicted margins of back musculoskeletal diseases (MSDs) and degenerative MSDs according to baseline work-related biomechanical exposure and job strain after 4 (parts A and D), 11 (parts B and E), and 28 (parts C and F) years of follow-up among Finnish women (circles) and men (triangles), Finnish Longitudinal Study on Aging Municipal Employees, 1981–2009. Results were adjusted for age, smoking status, alcohol intake, body mass index, occupational group, and physical activity. Dashed lines, high biomechanical exposure; solid lines, low biomechanical exposure.

after 28 years of follow-up in either sex. The reason for the nonsignificant association between exposures and MSDs in old age may be the dilution of the effect of the work-related exposures almost more than a decade after retiring. Moreover, there might be several other pathways to onset of MSDs in very old age. We used age, body mass index, physical activity, smoking status, alcohol intake, and occupational group to adjust the model, as these covariates were the most likely confounders. Among these confounders, occupational group markedly confounded the association, as it is already known that respondents in different occupations are at different levels of risk for MSDs depending upon the extent of their exposure in midlife, and the nature of exposure also varies according to type of job (20, 44).

Regarding the joint effect of biomechanical exposure and job strain, we found similarities with the sparse evidence from some other studies (32, 33). The similarity was that MSDs in the late career and around retirement were predicted by joint exposures in midlife. However, our study contradicts the findings from some earlier studies (14, 31), which found an absence of interaction between exposures in the prediction of MSDs. The differences may be due to the fact that in the study by Cantley et al. (14), all of the respondents were members of a manufacturing cohort followed up for 2 years, while our respondents worked in various occupations and we used a long follow-up period. The progression of MSDs is mostly linked with biomechanical exposures among blue-collar workers (20, 44), which could be generalized to manufacturing cohorts. Similarly, in the study by Fernandes et al. (31), the study population consisted of plastics industry workers, and in contrast to our study, that study was cross-sectional.

We also checked departure from additivity using the RERI estimates for biological interaction. We found that none of the interactions were biological. These findings contradict those of Waters et al. (32) and Sabbath et al. (33), as they found the interaction of the exposures to be additive in the prediction of MSDs and overall functional health, respectively. These differences could be attributed to methodological differences, along with the differences in the nature and follow-up periods of the studies. The study by Waters et al. was cross-sectional and focused more on respondents of peak working age (32), while our interest extended to the cohort of respondents in late working life. Sabbath et al. used overall functional health as the outcome (33), while our outcome of interest was MSDs, but there were similarities in the follow-up periods and the estimates used (RERI) to quantify biological interaction. Our finding could provide additional evidence regarding prediction of MSDs in the late career and around retirement by the interaction of work-related biomechanical exposure and high job strain in midlife. This finding still needs confirmation in future studies using more objective measures of MSDs and other, more objective job exposures.

A major strength of our study is the longitudinal design, with a long prospective follow-up period of 28 years. Although exposures were self-reported, the responses of the participants regarding the presence of back MSDs and degenerative MSDs were based on diagnosis by a physician. The only possible flaw in the data could have been respondent recall bias regarding the exact diagnosis. The other strength is that our study involved a large representative sample with a high response rate. Furthermore, it contributes to the existing literature calling for epidemiologic studies of interaction between work-related factors in the prediction of MSDs.

Although we used the widely accepted Karasek model of job strain, this could have been subject to reporting bias, because all of the items on job control and job demands, along with biomechanical exposure, were self-reported. However, in an earlier study, Huuhtanen et al. (45) found high correlation between expert and subjective ratings of work-related exposures. Another possible limitation is the chance of underestimation of the association between the work-related exposures and MSDs because the exposures were assessed at a single time point at baseline. Nevertheless, more than 70% of the respondents continued to work in the same job for more than 15 years from the baseline survey in 1981 until their retirement (46). An additional drawback could be the lack of data on items like social support at work, which could have been a significant item along with job strain at work and has been shown to be associated with musculoskeletal health (47, 48). Nevertheless, the stable work history of most of our participants indicates possible stability for both biomechanical exposure and job strain in our cohort throughout working life (49).

We conclude that work-related biomechanical exposure and job strain in midlife are risk factors for MSDs in the late career and around retirement in both sexes, as these exposures separately and jointly predicted the risk of back MSDs and degenerative MSDs. These findings support the need for workplace interventions regarding psychosocial risk factors like job strain, along with biomechanical risk factors. This could prevent the development of MSDs during working life, in the late career, and around the time of retirement. In old age, there could be other pathways for the onset of MSDs than job-related exposures incurred during working life.

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Author affiliations: Health Sciences, Faculty of Social Sciences, University of Tampere, Tampere, Finland (K. C. Prakash, Subas Neupane, Clas-Håkan Nygård); Finnish Institute of Occupational Health, Helsinki, Finland (Päivi Leino-Arjas, Jorma Seitsamo); Gerontology Research Center and Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland (Mikaela B. von Bonsdorff, Taina Rantanen, Monika E. von Bonsdorff); Juhani Ilmarinen Consulting Ltd., Vantaa, Finland (Juhani Ilmarinen); Gerontology Research Center, University of Tampere, Tampere, Finland (K. C. Prakash, Subas Neupane, Clas-Håkan Nygård); and Folkhälsan Research Center, Helsinki, Finland (Mikaela B. von Bonsdorff, Monika E. von Bonsdorff).

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REFERENCES

1. GBD 2013 DALYs and HALE Collaborators; Murray CJ, Barber RM, et al. Global, regional, and national disability-adjusted life years (DALYs) for 306 diseases and injuries and healthy life expectancy (HALE) for 188 countries, 1990–2013: quantifying the epidemiological transition. *Lancet*. 2015; 386(10009):2145–2191.
2. Tsang A, von Korff M, Lee S, et al. Common chronic pain conditions in developed and developing countries: gender and age differences and comorbidity with depression-anxiety disorders. *J Pain*. 2008;9(10):883–891.
3. Haldeman S, Carroll L, Cassidy JD. Findings from the Bone and Joint Decade 2000 to 2010 Task Force on Neck Pain and Its Associated Disorders. *J Occup Environ Med*. 2010;52(4): 424–427.
4. Storheim K, Zwart JA. Musculoskeletal disorders and the Global Burden of Disease Study [editorial]. *Ann Rheum Dis*. 2014;73(6):949–950.
5. Woolf AD. Global burden of osteoarthritis and musculoskeletal diseases. *BMC Musculoskelet Disord*. 2015; 16(suppl 1):S3.
6. Gardner BT, Dale AM, VanDillen L, et al. Predictors of upper extremity symptoms and functional impairment among workers employed for 6 months in new job. *Am J Ind Med*. 2008;51(12):932–940.
7. Silverstein M. Meeting the challenges of an aging workforce. *Am J Ind Med*. 2008;51(4):269–280.
8. da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. *Am J Ind Med*. 2010;53(3):285–323.
9. Leveille SG. Musculoskeletal aging. *Curr Opin Rheumatol*. 2004;16(2):114–118.
10. Eriksen W, Bruusgaard D, Knardahl S. Work factors as predictors of intense or disabling low back pain; a prospective study of nurses' aides. *Occup Environ Med*. 2004;61(5): 398–404.
11. Ropponen A, Samuelsson Å, Alexanderson K, et al. Register-based data of psychosocial working conditions and occupational groups as predictors of disability pension due to musculoskeletal diagnoses: a prospective cohort study of 24,543 Swedish twins. *BMC Musculoskelet Disord*. 2013;14:268.
12. Warhrendorf M, Sembajwe G, Zins M, et al. Long-term effects of psychosocial work stress in midlife on health functioning after labor market exit—results from the GAZEL study. *J Gerontol B Psychol Sci Soc Sci*. 2012;67(4):471–480.
13. Ahacic K, Kåreholt I. Prevalence of musculoskeletal pain in the general Swedish population from 1968 to 2002: age, period, and cohort patterns. *Pain*. 2010;151(1):206–214.
14. Cantley LF, Tessier-Sherman B, Slade MD, et al. Expert ratings of job demand and job control as predictors of injury and musculoskeletal disorder risk in a manufacturing cohort. *Occup Environ Med*. 2016;73(4):229–236.
15. Feldt T, Hyvönen K, Mäkikangas A, et al. Development trajectories of Finnish managers' work ability over a 10-year follow-up period. *Scand J Work Environ Health*. 2009;35(1):37–47.
16. Nolet PS, Kristman VL, Côte P, et al. The association between a lifetime history of work-related low back injury and future low back pain: a population based cohort study. *Eur Spine J*. 2016;25(4):1242–1250.
17. Rijs KJ, van der Pas S, Geuskens GA, et al. Development and validation of a physical and psychosocial job-exposure matrix in older and retired workers. *Ann Occup Hyg*. 2014;58(2):152–170.
18. Taylor JB, Goode AP, George SZ, et al. Incidence and risk factors for the first-time incident low back pain: a systematic review and meta-analysis. *Spine J*. 2014;14(10): 2299–2319.
19. Kraatz S, Lang J, Kraus T, et al. The incremental effect of psychosocial workplace factors on the development of neck and shoulder disorders: a systematic review of longitudinal studies. *Int Arch Occup Environ Health*. 2013;86(4):375–395.
20. Nordander C, Ohlsson K, Akesson I, et al. Risk of musculoskeletal disorders among females and males in repetitive/constrained work. *Ergonomics*. 2009;52(10): 1226–1239.
21. Lacaille D, Sheps S, Spinelli JJ, et al. Identification of modifiable work-related factors that influence the risk of disability in rheumatoid arthritis. *Arthritis Rheum*. 2004;51(5): 843–852.
22. Messing K, Stock SR, Tissot F. Should studies of risk factors for musculoskeletal disorders be stratified by gender? Lessons from the 1998 Québec Health and Social Survey. *Scand J Work Environ Health*. 2009;35(2):96–112.
23. Plouvier S, Chastang JF, Cyr D, et al. Occupational biomechanical exposure predicts low back pain in older age among men in the Gazel cohort. *Int Arch Occup Environ Health*. 2015;88(4):501–510.
24. Lahelma E, Laaksonen M, Lallukka T, et al. Working conditions as risk factors for disability retirement: a longitudinal register linkage study. *BMC Public Health*. 2012; 12:309.
25. Mäntyniemi A, Oksanen T, Salo P, et al. Job strain and the risk of disability pension due to musculoskeletal disorders, depression or coronary heart disease: a prospective cohort study of 69,842 employees. *Occup Environ Med*. 2012;69(8): 574–581.
26. Kivimäki M, Virtanen M, Elovainio M, et al. Work stress in the etiology of coronary heart disease—a meta-analysis. *Scand J Work Environ Health*. 2006;32(6):431–442.
27. Roffey DM, Wai EK, Bishop P, et al. Causal assessment of occupational standing or walking and low back pain: results of a systematic review. *Spine J*. 2010;10(3):262–272.
28. Huang GD, Feuerstein M, Sauter SL. Occupational stress and work-related upper extremity disorders: concepts and models. *Am J Ind Med*. 2002;41(5):298–314.
29. Marras WS, Cutlip RG, Burt SE, et al. National Occupational Research Agenda (NORA) future directions in occupational musculoskeletal disorder health research. *Appl Ergon*. 2009; 40(1):15–22.
30. Vandergrift JL, Gold JE, Hanlon A, et al. Physical and psychosocial ergonomic risk factors for low back pain in automobile manufacturing workers. *Occup Environ Med*. 2012;69(1):29–34.
31. Fernandes RC, Carvalho FM, Assunção AA, et al. Interactions between physical and psychosocial demands of work associated to low back pain. *Rev Saude Publica*. 2009;43(2):326–334.

32. Waters TR, Dick RB, Krieg EF. Trends in work-related musculoskeletal disorders: a comparison of risk factors for symptoms using quality of work life data from the 2002 and 2006 general social survey. *J Occup Environ Med*. 2011;53(9): 1013–1024.
33. Sabbath EL, Glymour MM, Descatha A, et al. Biomechanical and psychosocial occupational exposures: joint predictors of post-retirement functional health in the French GAZEL cohort. *Adv Life Course Res*. 2013;18(4):235–243.
34. Ilmarinen J, Suurnäkki T, Nygård CH, et al. Classification of municipal occupations. *Scand J Work Environ Health*. 1991; 17(suppl 1):12–29.
35. von Bonsdorff MB, Seitsamo J, Ilmarinen J, et al. Work ability in midlife as a predictor of mortality and disability in later life: a 28-year prospective follow-up study. *CMAJ*. 2011;183(4): E235–E242.
36. von Bonsdorff MB, Seitsamo J, von Bonsdorff ME, et al. Job strain among blue-collar and white-collar employees as a determinant of total mortality: a 28-year population based follow-up. *BMJ Open*. 2012;2(2):e000860.
37. Karasek RA. Job demands, job decision latitude, and mental strain: implications for job redesign. *Adm Sci Q*. 1979;24(2): 285–308.
38. Karasek R, Theorell T. *Healthy Work: Stress, Productivity and the Reconstruction of Working Life*. New York, NY: Basic Books; 1990.
39. Greenland S, Lash TL, Rothman KJ. Concepts of interaction. In: Rothman KJ, Greenland S, Lash TL, eds. *Modern Epidemiology*. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2008:71–84.
40. VanderWeele TJ, Knol MJ. A tutorial on interaction. *Epidemiol Methods*. 2014;3(1):33–72.
41. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. *Bull World Health Organ*. 2003;81(9):646–656.
42. Sterud T, Tynes T. Work-related psychosocial and mechanical risk factors for low back pain: a 3-year follow-up study of the general working population in Norway. *Occup Environ Med*. 2013;70(5):296–302.
43. Canivet C, Choi B, Karasek R, et al. Can high psychological job demands, low decision latitude, and high job strain predict disability pensions? A 12-year follow-up of middle-aged Swedish workers. *Int Arch Occup Environ Health*. 2013;86(3): 307–319.
44. Arvidsson I, Gremark Simonsen J, Dahlqvist C, et al. Cross-sectional associations between occupational factors and musculoskeletal pain in women teachers, nurses and sonographers. *BMC Musculoskelet Disord*. 2016;17:35.
45. Huuhtanen P, Nygård CH, Tuomi K, et al. Changes in stress symptoms and their relationship to changes at work in 1981–1992 among elderly workers in municipal occupations. *Scand J Work Environ Health*. 1997; 23(suppl 1):36–48.
46. Tuomi K, Ilmarinen J, Klockars M, et al. Finnish research project on aging workers in 1981–1992. *Scand J Work Environ Health*. 1997;23(suppl 1):7–11.
47. Woods V. Work-related musculoskeletal health and social support. *Occup Med (Lond)* 2005;55(3):177–189.
48. Bergsten EL, Mathiassen SE, Vingård E. Psychosocial work factors and musculoskeletal pain: a cross-sectional study among Swedish flight baggage handlers. *Biodmed Res Int*. 2015;2015:798042.
49. Nygård CH, Suurnäkki T, Peltomaa T, et al. Job demands of ageing employees over a 12-year period. In: Ilmarinen J, Louhevaara V, eds. *FinnAge—Respect for the Aging: Action Programme to Promote Health, Work Ability and Well-Being of Aging Workers in 1990–96*. (People and Work research report 26). Helsinki, Finland: Finnish Institute of Occupational Health; 1999:251–259.

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Work-related biomechanical exposure and job strain in midlife separately and jointly predict disability after 28 years: a Finnish longitudinal study

by Prakash KC, Neupane S, Leino-Arjas P, von Bonsdorff MB, Rantanen T, von Bonsdorff ME, Seitsamo J, Ilmarinen J, Nygård C-H

Higher level of work-related biomechanical exposure and job strain in midlife separately and jointly carried a higher risk for increase in disability after 28 years. Mitigation of both of these co-occurring exposures at work in midlife could reduce the risk of disability in later life. Thus the workplace should be promoted as an arena for preventive interventions regarding disability in old age.

Affiliation: School of Health Sciences, University of Tampere, FI-33014, Tampere, Finland. Prakash.kc@uta.fi

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Original article

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Work-related biomechanical exposure and job strain in midlife separately and jointly predict disability after 28 years: a Finnish longitudinal study

by Prakash KC, MSc (Public Health),[1, 2] Subas Neupane, PhD,[1, 2] Päivi Leino-Arjas, PhD,[3] Mikaela B von Bonsdorff, PhD,[4, 5] Taina Rantanen, PhD,[4] Monika E von Bonsdorff, PhD,[4, 5] Jorma Seitsamo, PhD,[3] Juhani Ilmarinen, PhD,[6] Clas-Håkan Nygård, PhD[1, 2]

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Objectives We investigated whether the extent of biomechanical exposures and job strain in midlife separately and jointly predict disability in old age.

Methods Participants of the Finnish Longitudinal Study on Aging Municipal Employees (FLAME) in 1981 (aged 44–58 years) responded to disability questionnaires in 2009 (1850 women and 1082 men). Difficulties in performing five activities of daily living (ADL) and seven instrumental ADL (IADL) were used to assess severity of disability (score range: 0–12, 0=no disability). Information on biomechanical exposures and job strain was collected by questionnaire at baseline. Adjusted prevalence proportion ratios (PR) and 95% confidence intervals (95% CI) were modelled using mixed negative binomial regression with robust variance. The joint effect of two exposures was quantified using the concept of relative excessive risk due to interaction (RERI).

Results The overall prevalence of disability (score: 1–12) was 46.7% (women: 41%; men: 57%). Compared to low-level exposures in an adjusted model, the PR of high baseline biomechanical exposures for each one unit increase in the disability score was 1.31 (95% CI 1.10–1.55) and PR of high job strain was 1.71 (95% CI 1.26–2.32). Associations were rather similar in gender-stratified analyses. Furthermore, the joint effect (high strain/high biomechanical) was multiplicative (women: PR 1.32, 95% CI 1.21–1.45; men: PR 1.27, 95% CI 1.13–1.44), but no additive effect was observed when fully adjusted.

Conclusion High biomechanical exposure and job strain in midlife were strongly associated with the severity of disability in later life. The workplace could serve as arena for preventive interventions regarding disability in old age.

Key terms ADL; ageing; Finland; IADL; interaction; occupation; occupational exposure; old age.

Adequate performance of activities of daily living (ADL) is essential for independent living (1) and difficulty in performing ADL and instrumental ADL (IADL) tasks is commonly used in assessing old age disability (1–3). Physical frailties are known predictors of disability among older people (4, 5). The occupational class in midlife also plays a vital role in the onset of later life disability, with unskilled blue-collar workers being the high-risk group compared to white-collar workers (6). However, work-related biomechanical and psychosocial exposures are undeniably related to work disability among all types of occupations (7), exposures such as monotonous work, whole-body vibration, heavy physical work, prolonged standing, and low level of support being the substantially associated ones.

High occupational physical loading activity in midlife could likewise result in limitations in physical functioning in later life (5, 8–11) which could, eventu-

1 School of Health Sciences, University of Tampere, Tampere, Finland.
2 Gerontology Research Center, University of Tampere, Tampere, Finland.
3 Finnish Institute of Occupational Health, Helsinki, Finland.
4 Gerontology Research Center and Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland.
5 Folkhälsan Research Center, Helsinki, Finland.
6 Juhani Ilmarinen Consulting Ltd, Helsinki, Finland.

Correspondence to: Prakash KC, School of Health Sciences, University of Tampere, FI-33014, Tampere, Finland. [E-mail: Prakash.kc@uta.fi or prakashkc10@gmail.com]

ally progress to disability. The work-related psychosocial exposure during midlife has persistent effects into old age and substantially predicts disability pension in later life (12). There is variation in the type of occupations of women and men, so the extent and nature of work-related exposures and effects may vary by gender (13). The joint effect of these exposures is equally crucial to detect the probable health impact as they are co-occurring exposures of midlife. A study of the GAZEL cohort found an additive effect of the joint biomechanical and psychosocial occupational exposures on post-retirement disability (14) through the interaction effect of the exposures. The same study reported gender-specific variations of the joint effects of the exposures.

The longitudinal evidence on individual associations of biomechanical and psychosocial occupational hazards with disabilities in later life, along with the evidence on the prediction of disability by joint biomechanical and psychosocial exposures is scarce. For the additional examination of the rare joint effect along with the separate effect, we aimed to investigate whether work-related biomechanical exposure and job strain (psychosocial exposure) in midlife separately and jointly predict disability in later life in a cohort of Finnish public sector employees followed up for 28 years.

Methods

Participants and design

This study is based on the Finnish Longitudinal Study on Aging Municipal Employees (FLAME), a prospective follow-up study which was conducted by the Finnish Institute of Occupational Health. A baseline survey was conducted in 1981 with the latest follow-up in 2009. The baseline cohort consisted of 6257 of 7344 (85.2% response rate) public sector employees aged 44–58 years and was representative of the largest municipal occupational groups in Finland (15–17). The study population of the present study comprised individuals who replied at baseline and in 2009 on information about disability, gathered by postal questionnaires (N=2932 complete data on ADL and IADL tasks). According to the mortality data (January 1981 to July 2009) obtained from the Finnish National Population Register, 33.2% of the baseline respondents died during the 28-year follow-up period. The ethics committee of the Finnish Institute of Occupational Health, Helsinki, Finland approved the study.

Disability

The assessment of ADL and IADL tasks was done by questionnaires distributed among the participants in 2009. Difficulty in performing ADL and IADL is widely used as a measure of disability among the older people (2, 18–20). Five ADL tasks (eating, going to bed, dressing, bathing, and toileting) and seven IADL tasks (preparing meals, doing laundry, shopping, doing light domestic work, dosing/taking medicine, using the phone, and management of personal finances) partly adapted from Katz ADL (21) were used. The listed tasks were assessed on a scale 0–4, (4=manage without difficulties, 3=manage with little difficulties, 2=manage with lots of difficulties, 1=cannot manage without help from others, and 0=cannot manage even with help of others). In this analysis, responses were dichotomized (supplementary table A, www.sjweh.fi/index.php?page=data-repository). Then the dichotomized responses were summed up to get a continuous score 0–12. Score 0 represented those who could perform all the tasks without any difficulty (classified as non-disabled in this study) and those who had at least some difficulty in performing one or more of the 12 tasks scored 1–12 depending on the number of tasks entailing difficulties (classified as disabled in this study). The higher the score the more severe the disability (3).

Biomechanical exposure

The assessment of work-related biomechanical exposure was done using the self-reported responses to seven questions related to exposures to biomechanical hazards. The seven self-reported items were (i) continuous walking or movement, (ii) standing in one place, (iii) bent or twisted postures, (iv) similar repeated movements, (v) carrying objects by hand, (vi) sudden strenuous efforts and (vii) other poor postures. All the items were answered on a scale 0=not at all, 1=a little, 2=somewhat, 3=often, and 4=quite often, except item (vii) other poor posture which was answered on 0=not at all, 1= a little, 2=somewhat or 3=often. The summary score (Cronbach's α=0.84) ranging from 0–26 was dichotomized into low (summary score=0–12) and high (summary score=13–26) biomechanical exposure using the median value 12 (22).

Job strain

Job control. Self-reported responses to ten questions related to respondents' possibilities for control, guidance, and influence on the job were used to assess job control: including (i) receiving guidance on the job, (ii) participating in planning the work, (iii) gaining promotion, (iv) having chances for further training in professional skills, (v) gaining recognition and respect, (vi) influencing the work environment, (vii) having chances to use own abilities and talents, (viii) having the aptitude to learn new things, (ix) communicating and working with co-workers, and (x) seeing the meaning of the work were answered on a scale from 0=not at all, 1=a little, 2=somewhat, or 3=a lot. The summary score (Cronbach's α=0.86) ranging from 0–30 was dichotomized into low (summary score=0–16) and high (summary score=17–30) job control using the median value 16 (17, 22).

Job demands. The assessment of job demands was based on the responses of the respondents to eight questions about pressure and demands related to the job. The eight self-reported items were namely: (i) tight time schedule, (ii) hectic pace of work, (iii) taking responsibility, (iv) pressure and interference from supervisor, (v) conflicting demands regarding work tasks and responsibility, (vi) pressure of failure or making mistakes, (vii) isolation or loneliness, and (viii) monotonous work, which were answered on a scale from 0=not at all, 1= a little, 2=somewhat, or 3=a lot. The summary score (Cronbach's α= 0.77) ranging from 0–24 was dichotomized into low (summary score=0–6) and high (summary score=7–24) job demands using the median value 6 (17, 22).

Job strain. Job demand–control concept from the Karasek model was used to create job strain levels (23). The dichotomized values of job demands and control were used to construct the four levels of job strain: namely low strain (high control and low demands), passive job (low control and low demands), active job (high control and high demands), and high strain (low control and high demands).

Covariates

The covariates used in this study were occupational class, age, gender, alcohol intake, smoking status, body mass index (BMI; kg/m^2), physical activity, major chronic diseases and tenure period were assessed in baseline. Two occupational groups namely white- and blue-collar workers were created being based on 13 job profiles, which were a cluster of 133 different job titles (17). The tenure period used in this study was occupationally active years between the baseline of this study and retirement. Those reporting smoking at least one cigarette per day were classified as current smokers. Information on alcohol intake was classified into 0, ≤2 drinks a month, and ≥1 drink a week being based on seven original categories. Physical activity during leisure time in the previous year was classified in this study as active, moderately active, and inactive. Information on major chronic diseases was related to the diagnosis of chronic diseases of different body systems.

Statistical analysis

The descriptive characteristics of the subjects were first cross tabulated as frequencies and percentages according to biomechanical exposure and job strain, with significance level of P<0.05. An interaction term between gender and exposures was tested and found statistically significant (P<0.001) with respect to disability and therefore the analyses were stratified by gender. Disability was over-dispersed so mixed negative binomial regression with robust variances was used to calculate prevalence proportion ratios (PR) and 95% confidence intervals (95% CI). Negative binomial regression was used in order to avoid errors related to overestimations. The estimates for job strain are presented as pairwise comparisons (Bonferroni adjusted). Tenure period from the baseline survey until retirement was also used in the model as an exposure item. Three models were fitted namely; model I was adjusted for age and tenure period, model II was further adjusted for occupational groups, and model III was further adjusted for smoking status, alcohol intake, physical activity, BMI, and chronic diseases.

The potential interaction between biomechanical exposure and job strain was quantified to check the joint prediction of the exposures. PR and 95% CI of multiplicative interaction and relative excessive PR and 95% CI for additive interactions were estimated using the advanced prefix known as "icp" from Stata, which calculates the estimates of log relative risk to use interaction contrast from the regression settings. The setting uses the concepts of relative excessive risk due to interaction ($RERI = RR_{1,1} - RR_{1,0} - RR_{0,1} + 1$) to calculate the estimates (24). In the given formula, $RR_{1,1}$ signifies the presence of high biomechanical and high job strain (joint exposure), $RR_{1,0}$ signifies presence of high biomechanical and absence of high job strain and $RR_{0,1}$ signifies absence of high biomechanical and presence of high job strain. Additive interaction is meant to be present if RERI >0 with statistical significance. Two models were fitted, the first model was adjusted for age and tenure period and the second model was further adjusted for occupational groups, BMI, smoking status, chronic diseases, alcohol intake and physical activity. The overall test of the hypothesis and fit of the models are presented in supplement table D (for pairwise comparisons of job strain) and supplement table E (RERI), www.sjweh.fi/index.php?page=data-repository.

In order to account for potential bias of the study due to dropout, we did a sensitivity analysis for which we conducted a regression imputation. Information on disability was imputed for those who were alive and who failed to respond to the disability-related questionnaires (N=1100) and for that we used the most recent responses (follow-up of 1992 or 1997) from these respondents on chronic conditions, sum score of mobility limitation [squatting, bending, maintaining body position for 2 hours, lifting objects >10 kg, precise hand use, running 100 meters, walking 2 km and climbing three floors based on the International Classification of Functioning (ICF)], workability, occupational class and age. We were able to impute the information on disability for 521 out of 1100 missing responses. The analysis for separate and combined ADL and IADL disability were almost identical, therefore only combined results are presented. Likewise, there was no difference in the pattern of associations in the results produced by the sensitivity analyses with imputed data and those derived using the original data. Therefore, the results are presented for the original respondents only. In order to examine the effect of mortality on the results, we made a secondary analysis where we included the deceased respondents in the highest disability group. The results were comparable to the original results (supplementary table F, www.sjweh.fi/index.php?page=data-repository). Proportion/percentage calculation and cross-tabulation were conducted in SPSS version 23.0 (IBM corporation, Armonk, New York, USA) and all the other analyses and plotting were done in STATA 14.0 (StataCorp LP, College Station, Texas 77845, USA).

Results

Tables 1 and 2 present the distribution of baseline characteristics according to biomechanical exposure and job strain among 1850 women and 1082 men, respectively. The overall prevalence of disability was 46.7% (severity score: 1–12), which was 41% and 57% among women and men, respectively. The baseline characteristics according to biomechanical exposure and job strain among non-respondent women (N=1542) and men (N=1630) are presented in supplement tables B and C, www.sjweh.fi/index.php?page=data-repository. PR and 95% CI for biomechanical exposure and job strain (pairwise comparisons) predicting disability are presented separately for all, men and women in table 3 in three different models. In the age-adjusted model, high baseline biomechanical exposure and high job strain was significantly associated (model I) with a unit increase in the severity of disability in later life compared to low-level exposures. The estimates were attenuated when

Table 1a. Baseline characteristics of women according to job strain and work-related biomechanical exposures, Finnish Longitudinal study on Aging Municipal Employees (FLAME), 1981–2009.

Baseline characteristics	N=1850		Biomechanical exposure				Job strain							
			Low (N=849)		High (N=1001)		Low (N=615)		Passive (N=443)		Active (N=349)		High (N=443)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	49.6	3.4	49.7	3.4	49.5	3.3	49.7	3.5	50.0	3.4	49.4	3.2	49.5	3.4
Body mass index	25.0	3.4	24.6	3.4	25.3	3.3	24.7	3.4	25.1	3.5	25.0	3.4	25.4	3.2
Tenure period	9.3	3.6	9.8	3.6	9.0	3.6	9.3	3.8	9.2	3.6	9.5	3.2	9.3	3.7

Table 1b. Baseline characteristics of women (continued).

Baseline characteristics	N=1850		Biomechanical exposure		Job strain			
			Low (N=849)	High (N=1001)	Low (N=615)	Passive (N=443)	Active (N=349)	High (N=443)
	N	%	%	%	%	%	%	%
Occupational class								
White collar	1256	68	87	52	84	53	77	53
Blue collar	594	32	13	48	16	47	23	47
Chronic diseases								
No	637	35	43	27	46	31	29	26
Yes	1212	65	57	73	54	69	71	74
Physical activity								
Active	943	52	53	52	56	47	57	48
Moderately active	750	41	40	42	37	47	37	45
Inactive	117	7	7	6	7	6	6	7
Smoking status								
Never	1473	80	76	83	79	80	79	80
Former	229	12	15	10	13	12	13	11
Current	148	8	9	7	8	8	8	9
Alcohol intake								
0	1596	87	85	87	90	90	82	83
≤2 drinks/month	190	10	11	10	8	8	14	13
≥1drink/week	55	3	4	3	2	2	4	4

further adjusted for occupational groups (model II). When adjusted further for BMI, alcohol intake, chronic diseases, smoking status, and physical activity during previous years (model III), the estimates were mitigated, but the direction of association remained unchanged. High versus low biomechanical exposure had on average 49% and 37% higher likelihood, respectively for women and men for a unit increase in severity of disability. Likewise, high versus low strain carried significantly higher likelihood for a unit increase in severity of disability among women (PR 1.47, 95% CI 1.08–2.01) and men (PR 2.15, 95% CI 1.42–3.26), respectively.

The joint prediction of disability in old age by job strain and biomechanical exposure in midlife are presented in figure 1 (all respondents) and figure 2 (gender stratified) respectively in two different models. In the model adjusted for age, the passive/high, active/high, high/low, low/ high and high/high combinations of the categories of jobs strain and biomechanical exposures were on average highly associated with a unit increase in severity of disability in old age compared to low/low combination (model I) among all subjects and among men. Among women only passive/high, active/high, low/high, and high/high were highly associated (model I). Further adjustment for chronic diseases, occupational class, and other covariates in model II attenuated the estimates, but did not change the direction of associations among all subjects, women and men. The estimates for joint (high/high) job strain and biomechanical exposures described higher multiplicative interactions among all (PR 1.28, 95% CI 1.19–1.38), women (1.32, 1.21–1.45), and men (1.27, 1.13–1.44) in the final model compared to the low/low combination.

RERI estimates for the additive interaction of job strain and biomechanical exposure are shown in table 4 in two models. The joint prediction of high strain and high biomechanical exposure was additive among women in model I (RERI 0.27, 95% CI 0.04–0.49) but was attenuated and the direction was changed after further adjustment in model II.

Table 2a. Baseline characteristics of men according to job strain and work-related biomechanical exposures, Finnish Longitudinal study on Aging Municipal Employees (FLAME), 1981–2009.

Baseline characteristics	N=1082		Biomechanical exposure				Job strain							
			Low (N=743)		High (N=348)		Low (N=355)		Passive (N=275)		Active (N=156)		High (N=296)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	49.6	3.4	49.6	3.3	49.7	3.4	49.7	3.5	50.1	3.4	49.3	3.3	49.3	3.1
Body mass index	25.9	2.8	25.9	2.8	25.8	2.9	25.7	2.8	25.7	2.9	26.0	2.9	26.2	2.7
Tenure period	9.5	3.8	9.8	3.8	8.9	3.7	10.2	3.9	9.1	3.6	9.7	3.9	8.8	3.6

Table 2b. Baseline characteristics of men (continued).

Baseline characteristics	N=1082		Biomechanical exposure		Job strain			
			Low (N=743)	High (N=348)	Low (N=355)	Passive (N=275)	Active (N=156)	High (N=296)
	N	%	%	%	%	%	%	%
Occupational class								
White collar	422	39	53	10	56	21	58	25
Blue collar	660	61	47	90	44	79	42	75
Chronic diseases								
No	391	36	42	24	46	33	36	28
Yes	691	64	58	76	54	67	64	72
Physical activity								
Active	570	53	56	48	58	48	53	52
Moderately active	442	42	40	44	36	45	45	42
Inactive	53	5	4	8	5	6	2	6
Smoking status								
Never	412	38	39	35	38	38	38	39
Former	489	45	45	46	47	47	35	46
Current	181	17	16	19	15	15	27	15
Alcohol intake								
0	554	52	52	50	52	57	45	50
≤2 drinks/month	356	33	32	35	31	30	36	36
≥1drink/week	164	15	16	15	17	13	19	14

Table 3. Prevalence proportion ratios (PR) and 95% confidence intervals (95% CI) for the association between work-related exposures (biomechanical and job strain) and later life disability, Finnish Longitudinal study on Aging Municipal Employees (FLAME), 1981–2009.

Work-related exposures	All		Women		Men	
	PR	95 % CI	PR	95 % CI	PR	95 % CI
Biomechanical [a]						
High vs low	1.62	1.38–1.91	1.98	1.59–2.47	1.75	1.36–2.24
Job strain [a, b]						
Passive vs low	1.72	1.27–2.32	1.40	0.95–2.06	2.16	1.40–3.35
Active vs low	1.50	1.09–2.07	1.25	0.82–1.92	2.12	1.31–3.43
High vs low	2.31	1.70–3.14	2.15	1.40–3.32	2.55	1.67–3.90
Active vs passive	0.87	0.63–1.21	0.90	0.58–1.38	0.98	0.61–1.58
High vs passive	1.34	0.99–1.82	1.54	1.02–2.34	1.18	0.77–1.80
High vs active	1.54	1.10–2.16	1.72	1.08–2.75	1.21	0.75–1.93
Biomechanical [c]						
High vs low	1.35	1.14–1.60	1.69	1.33–2.14	1.47	1.13–1.92
Job strain [b, c]						
Passive vs low	1.44	1.07–1.95	1.22	0.82–1.80	1.88	1.20–2.94
Active vs low	1.49	1.08–2.05	1.22	0.80–1.86	2.15	1.34–3.45
High vs low	1.94	1.42–2.65	1.86	1.20–2.87	2.24	1.44–3.48
Active vs passive	1.03	0.74–1.43	0.99	0.65–1.54	1.14	0.69–1.88
High vs passive	1.35	0.99–1.83	1.52	1.00–2.30	1.19	0.78–1.82
High vs active	1.30	0.93–1.83	1.53	0.95–2.44	1.04	0.63–1.71
Biomechanical [d]						
High vs low	1.31 [e]	1.10–1.55	1.49	1.17–1.89	1.37	1.06–1.78
Job strain [b, d]						
Passive vs low	1.43 [e]	1.06–1.93	1.13	0.76–1.69	1.99	1.26–3.13
Active vs low	1.37 [e]	0.99–1.90	1.08	0.70–1.67	2.08	1.30–3.34
High vs low	1.71 [e]	1.26–2.32	1.48	0.97–2.24	2.15	1.39–3.34
Active vs passive	0.96 [e]	0.68–1.35	0.95	0.61–1.49	1.05	0.62–1.76
High vs passive	1.19 [e]	0.89–1.61	1.30	0.87–1.96	1.08	0.71–1.64
High vs active	1.24 [e]	0.88–1.75	1.37	0.86–2.17	1.03	0.62–1.71

[a] Model I: adjusted for age, tenure period.
[b] Bonferroni adjusted pairwise comparisons.
[c] Model II: adjusted for age, tenure period and occupational group.
[d] Model III: adjusted for age, tenure period, occupational group, and other covariates (chronic diseases, physical activity, alcohol intake, body mass index and smoking status).
[e] Adjusted for items in model III including gender.

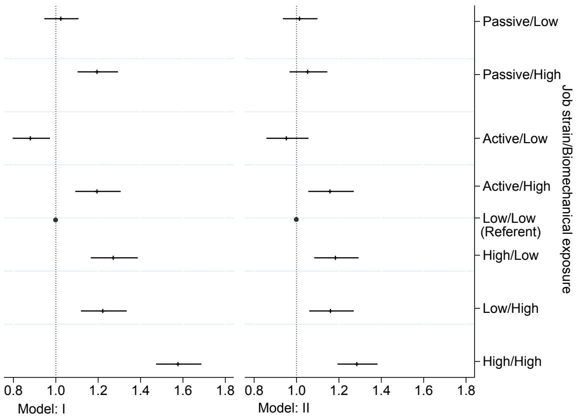

Figure 1. Prevalence proportion ratios (PR) and 95% confidence intervals (95% CI) for the association of later life disability and different combinations of joint work-related exposures (job strain and biomechanical exposure) of midlife among all subjects; model I: adjusted for age and tenure period; model II: further adjusted for gender, occupational group, chronic diseases, body mass index, alcohol intake, smoking status and physical activity; low/low category of exposures serve as referent (ref); Finnish Longitudinal study on Aging Municipal Employees (FLAME), 1981–2009.

Discussion

The findings of this longitudinal study of a cohort of Finnish public sector employees provides a strong evidence that high job strain and biomechanical exposure in working life separately and jointly predict the severity of disability in later life. The higher level of both exposures was decidedly deleterious in both genders. The interactions of the high/high level of exposures compared to low-level in midlife was highly associated with a unit increase in severity of disability in later life among both women and men.

Although occupational activity and exposures is a crucial part of the daily lives of most adults, studies on occupational exposures as a potential source of ADL and IADL disability later in life are scarce. Only a limited number of earlier studies have acknowledged work-related exposures as the long-term risk factors of old age disability and impaired functioning (6, 14, 20, 25, 26). Heavy physical load and high job demands were reported to be a risk factor for a decline in physical functioning (27) and functional limitations (28) among the Dutch cohorts. Biomechanical exposure and job strain in working life significantly predicted post-retirement disability among the GAZEL cohort (14) and work disability among Norwegian employees (6, 29). Likewise, higher level of work-related exposures was found to be long-term risk factors for musculoskeletal disability (30), disability pensioning (12, 31–33), and other chronic conditions (34). The findings of the present study corroborate these earlier findings, however, the respondents of our study were older and the outcome of interest was disability related to ADL.

Even though studies on the association between work-related exposures in working life and disability are limited, there is a lack of consistency in the findings. The results of our study contradict the findings of a Swedish study, which reported that occupational physical activity had no significant association with ADL disability (35). In our study, biomechanical exposure, which includes frequent occupational physical activities, was associated with high likelihood of higher disability. The risk of disability and disorders depends on the extent of exposures and varies by occupational class (6, 16, 36). Physically demanding work in midlife was found to be associated with ADL disability among women in a study in Ireland (26). Similarly, longest held manual occupations carried high risk of ADL disability among a Taiwanese cohort (6) and the risk of disability pensioning in Swedish construction workers (37). Consequently, our findings

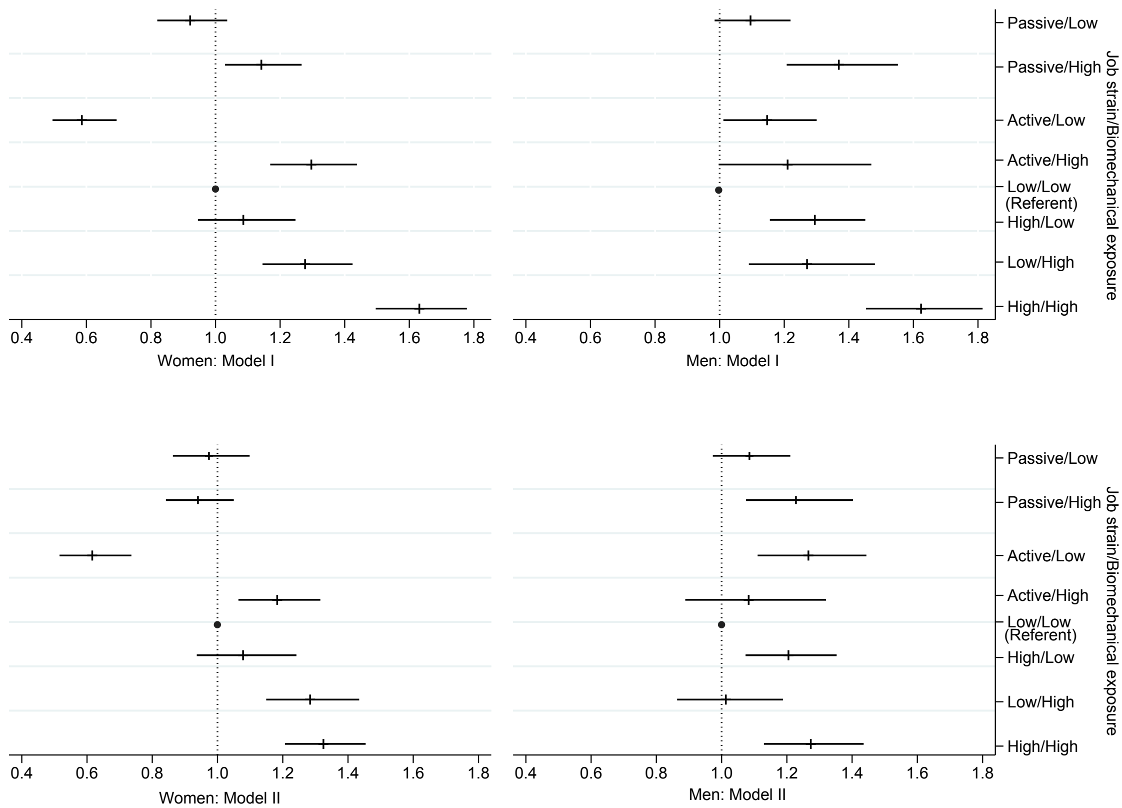

Figure 2. Prevalence proportion ratios (PR) and 95% confidence intervals (95% CI) for the association of later life disability and different combinations of joint work-related exposures (job strain and biomechanical exposure) of midlife among women and men; model I: adjusted for age and tenure period; model II: further adjusted for occupational group, chronic diseases, body mass index, alcohol intake, smoking status and physical activity; low/low category of exposures serve as referent (ref); Finnish Longitudinal study on Aging Municipal Employees (FLAME), 1981–2009.

are parallel with these earlier studies because the high risk of disability was attenuated but persisted after we adjusted our results for occupational class (white- versus blue-collar) in model II. Work-related exposures as risk factors for future health outcomes may vary by gender (14, 16, 25, 38). The gender specific variation was clearly seen in our findings. The independent likelihood of higher disability due to high biomechanical exposure was higher among women and due to high strain was higher among men, which are parallel to the findings of (38).

An interaction effect is equally important along with the independent effects of work-related exposure on health functioning outcomes (33). Biomechanical exposure and job strain in working life jointly predicted post-retirement disability in the GAZEL cohort (14). Likewise, elevated risk of musculoskeletal disability was associated with combined high physical and psychosocial work exposures in a working population in Sweden (38) and in the UK (39). Our findings are in line with these earlier studies, although there were some differences in the follow-up period, methodological considerations, the age of the respondents, and type of disability. The joint effect was biological with a significant RERI of 0.32 in the GAZEL cohort (14), and we found a RERI of 0.27 among women for the high/high combination of exposures in the age-adjusted model, but it was not significant in the fully adjusted model. Similarly, the statistical estimate of joint exposure (risk ratio) was 3.6 for musculoskeletal disability among women in a Swedish cohort (38) and 1.91 in a mixed population in the GAZEL cohort (14) and the same estimate was 1.28 (PR) in our study. These variations could be explained by the differences in methods and outcome of interest. The exposure of interest used in (14, 38) was cumulative, but we used the exposures from baseline only. Furthermore, the outcome in those studies were more related to musculoskeletal-pain-related disabilities compared to ADL in our study. Our study has added some epidemiological evidence to the current body of literature regarding the risk of disability in old age associated with the joint work-related exposures in midlife. Prevention of high work-related exposures in midlife could be significant not only for better physical

Table 4. Estimates of excessive prevalence of higher disability due to interaction between job strain and biomechanical exposure expressed as relative excessive risk due to interaction (RERI) and 95% confidence interval (95% CI) for the association between joint work-related exposures (biomechanical and job strain) and later life disability, Finnish Longitudinal study on Aging Municipal Employees (FLAME), 1981–2009.

Interactions	All		Women		Men	
Job strain / biomechanical exposure	RERI	95 % CI	RERI	95 % CI	RERI	95 % CI
Passive /High						
Model I [a]	0.05	-0.09–0.19	0.07	-0.12–0.26	0.07	-0.19–0.33
Model II [b]	0.05 [c]	-0.19–0.09	-0.21	-0.41– -0.01	0.16	-0.07–0.39
Active / High						
Model I [a]	0.22	0.06–0.38	0.57	0.38–0.77	-0.10	-0.42–0.21
Model II [b]	0.11 [c]	-0.05–0.28	0.38	0.18–0.58	-0.14	-0.44–0.16
High / High						
Model I [a]	0.09	-0.09–0.25	0.27	0.04–0.49	0.06	-0.22–0.34
Model II [b]	-0.06 [c]	-0.22–0.10	-0.04	-0.26–0.19	0.05	-0.18–0.29

[a] Adjusted for age and tenure period.
[b] Adjusted for age, tenure period, occupational group, smoking status, alcohol intake, body mass index, physical activity and chronic diseases.
[c] Adjusted for items in model II including gender.

functioning and good health in midlife, but also and equally for better health outcomes in later life as well (25). Thus midlife is the best phase of life to start prevention of health problems of old age (5). Most of our findings highlight the significance of working conditions and low work-related exposures in midlife not only for proper physical functioning and good health in midlife but also for better physical functioning and reduction of the risk of disability in later life as well. Future studies should shed more light on the interactive predictability of these work-related exposures using different exposure models.

Strengths and limitations

One of the strengths of this study is a long prospective follow-up of almost three decades. Another strength is that our study involved a large representative sample of diverse occupations. Exploring the predictors of old age disability, a public health indicator among the rapidly growing elderly population is another potential strength. The information on retirement and mortality were taken from the national register rather than other sources, which increases the reliability of the study. This study contributes to the existing literature demanding interaction studies of longitudinal design investigating the interactions of work-related exposures in midlife to predict functional limitations and disability in old age. Among those who were alive, the response rate was significantly higher in all waves and almost half of the respondents from 1981 also responded in 2009 and the non-respondents were older than the respondents.

A potential limitation of the design was the availability of disability data from the last survey (2009) only and its self-reported nature, which could have possibly been a subject of information and reporting bias. Nonetheless, the assessment of ADL task and using the severity of difficulty in performing the task are taken as a valid and widely used measurement of old age health and functional status (18). Although both exposure variables were self-reported and were subject to reporting bias, we used the widely accepted Karasek model to create job strain. On the other hand, previous findings indicate at correlation between subjective and expert ratings on work-related exposures (40). The measurement of the exposure variable at a single time point at baseline could be the subject of an underestimation of the association, but we believe that the exposure level did not change much during the follow-up because almost 3/4 of the respondents did not change their jobs for >15 years (41). Furthermore, no major changes in their work were seen from the baseline survey until their retirement (41). The other drawback could be the lack of data on items like social support and supportive leadership at work, which has been shown to be associated with disability (8). The respondents in our study worked in the public sector, but the findings are relevant to private sector employees as well because in Finland the labor legislation applies equally to all sectors and occupations. The results could be generalized to countries with labor policies similar to those in Finland.

Concluding remarks

Job strain and biomechanical exposure in working life separately and jointly predicted disability in later life. The higher the level of work-related biomechanical exposures and job strain in midlife the higher was the chance of increase in the severity of disability in later life. These findings imply the need for mitigating both of these exposures at work through proper workplace interventions that could help in beginning to prevent old age disability already in working age.

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References

1. Tas U, Verhagen AP, Bierma-Zeinstra S MA, Odding E, Koes BW. Prognostic factors of disability in older people: a systematic review. Br J Gen Pract. 2007;57(537):319–23.
2. Chan KS, Kasper JD, Brandt J, Pezzin LE. Measurement Equivalence in ADL and IADL difficulty across international surveys of aging: Findings from the HRS, SHARE, and ELSA. J Gerontol B Psychol Sci Soc Sci. 2012;67B(1):121–32. https://doi.org/10.1093/geronb/gbr133.
3. Prakash KC, Neupane S, Leion-Arjas P, von Bonsdorff MB, Rantanen T, von Bonsdorff ME, et al. Midlife job profiles and disabilities in later life: a 28-year follow-up of municipal employees in Finland. Int Arch Occup Environ Health. 2016;89(6):997–1007. https://doi.org/10.1007/s00420-016-1133-7.
4. den Ouden ME, Schuurmans MJ, Arts IE, van der Schouw YT. Physical performance characteristics related to disability in older persons: A systematic review. Maturitas. 2011;69(3):208–19. https://doi.org/10.1016/j.maturitas.2011.04.008.
5. Vermeulen J, Neyens J CL, van Rossum E, Spreeuwenberg MD, de Witte LP. Predicting ADL disability in community-dwelling elderly people using physical frailty indicators: a systematic review. BMC Geriatrics. 2011;11:33. https://doi.org/10.1186/1471-2318-11-33.
6. Li C, Wu SC, Wen SW. Longest held occupation in a lifetime and risk of disability in activities of daily living. Occup Environ Med. 2000;57(8):550–4. https://doi.org/10.1136/oem.57.8.550.
7. Sterud T. Work-related psychosocial and mechanical risk factors for work disability: a 3-year follow-up study of the general working population in Norway. Scand J Work Environ Health. 2013;39(5):468–76. https://doi.org/10.5271/sjweh.3359.
8. Guilley E and Lalive d'Epinay CJ. Social status and mortality with activity of daily living disability in later life. J Gerontolol B Psychol Sci Soc Sci. 2008; 63(3):S192–6. https://doi.org/10.1093/geronb/63.3.S192.
9. Groffen D AI, Koster A, Bosma H, van den Akker M, Aspelund T, Siggeirsdóttir K, et al. Socioeconomic factors from midlife predict mobility limitation and depressed mood three decades later; Findings from the AGES-Reykjavik Study. BMC Public Health. 2013;13:101–6. https://doi.org/10.1186/1471-2458-13-101.
10. Idland G, Pettersen R, Avlund K, Bergland A. Physical performance as long-term predictor of onset of activtities of daily living (ADL) disability: A 9 year longitudinal study among community-dwelling older women. Archives of Gerontology and Geriatrics. 2013;56(3):501–6. https://doi.org/10.1016/j.archger.2012.12.005.
11. Hinirichs T, von Bonsdorff MB, Törmäkangas T, von Bonsdorff ME, Kulmala J, Seitsamo J, et al. Inverse effects of Midlife Occupational and leisure time physical activity on mobility limitation in old age- A 28-Year prospective follow up study. J Am Geriatr Soc. 2014;62(5):812–20. https://doi.org/10.1111/jgs.12793.
12. Ropponen A, Samuelsson Å, Alexanderson K, Svedberg P. Register- based data of psychosocial working conditions and occupational groups as predictors of disability pension due to musculoskeletal diagnoses: a prospective cohort study of 24543 Swedish twins. BMC Musculoskelet Disord. 2013;14:268. https://doi.org/10.1186/1471-2474-14-268.
13. Messing K, Stock SR, Tissot F. Should studies of risk factors for musculoskeletal disorders be stratified by gender? Lessons from the 1998 Québec health and social survey. Scand J Work Environ Health. 2009; 35(2):96–112. https://doi.org/10.5271/sjweh.1310.
14. Sabbath EL, Glymour MM, Descatha A, Leclerc A, Zins M, Goldberg M, et al. Biomechanical and psychosocial occupational exposures: Joint predictors of post-retirement functional health in the French GAZEL cohort. Advances in Life Course Research. 2013;18:235–43. https://doi.org/10.1016/j.alcr.2013.07.002.
15. Ilmarinen J, Suurnakki T, Nygård C-H, Landau K. Classification of municipal occupations. Scand J Work Environ Health. 1991;17(suppl 1):12–29.
16. von Bonsdorff MB, Seitsamo J, Ilmarinen J, Nygård CH, von Bonsdorff ME, Rantanen T. Work ability in midlife as a predictor of mortality and disability in later life: a 28-year prospective follow-up study. CMAJ. 2011;183(4):E235–42. https://doi.org/10.1503/cmaj.100713.
17. von Bonsdorff MB, Seitsamo J, von Bonsdorff ME, Ilmarinen J, Nygård CH, Rantanen T. Job strain among blue-collar and white-collar employees as a determinant of total mortality: a 28-year population based follow-up. BMJ Open. 2012;2(2):e000860. https://doi.org/10.1136/bmjopen-2012-000860.
18. Spector WD, Fleishman JA. Combining activities of daily living with instrumental activities of daily living to measure functional disability. J Gerontolol B Psychol Sci Soc Sci. 1998;53B(1):S46–57. https://doi.org/10.1093/geronb/53B.1.S46.
19. Jagger C, Matthews R, Matthews F, Robinson T, Robine J-M, Brayne C. The burden of disease on disability-free life expectancy in later life. J Gerontol A Biol Sci Med Sci. 2007;62(4):408–14. https://doi.org/10.1093/gerona/62.4.408.
20. Kulmala J, von Bonsdorff MB, Stenholm S, Törmäkangas T, von Bonsdorff ME, Nygård C-H, et al. Perceived stress symptoms in midlife predict disability in old age: a 28-year prospective cohort study. J Gerontol A Biol Sci Med Sci. 2013;68(8):984–91. https://doi.org/10.1093/gerona/gls339.
21. Katz S. Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily

living. J Am Geriatr Soc. 1983:31:721–7. https://doi.org/10.1111/j.1532-5415.1983.tb03391.x.

22. KC P, Neupane S, Leion-Arjas P, von Bonsdorff MB, Rantanen T, von Bonsdorff ME, et al. Work-related biomechanical exposure and job strain as separate and joint predictors of musculoskeletal diseases: A 28-year prospective follow-up study. Am J Epidemiol kwx189. https://doi.org/10.1093/aje/kwx189.

23. Karasek RA. Job demands, job decision latitude, and mental strain: implications for job redesign. Admin Sci Q. 1979;24(2):285–308. https://doi.org/10.2307/2392498.

24. van der Weele TJ, Knol MJ. A tutorial on Interaction. Epidemiol. Methods. 2014;3(1):33–72.

25. Warhrendorf M, Sembajwe G, Zins M, Berkman L, Goldberg M, Siegrist J. Long-term effects of psychosocial work stress in midlife on health functioning after labor market exit – results from the GAZEL study. J Gerontolol B Psychol Sci Soc Sci. 2012;67(4): 471–80. https://doi.org/10.1093/geronb/gbs045.

26. McCarthy VJC, Perry IJ, Greiner BA. Has your work worked you too hard? Physically demanding work and disability in a sample of the older Irish population. Ir J Med Sci. 2013;182:47–55. https://doi.org/10.1007/s11845-012-0824-7.

27. Geuskens GA, Burdorf A, Barendregt PJ, Hazes JMW. A high physical workload and high job demands hamper the good prognosis in physical functioning in persons with early inflammatory joint conditions. Rheumatology. 2011;50:789–98. https://doi.org/10.1093/rheumatology/keq359.

28. Rijs KJ, van der pas S, Geuskens GA, Cozijnsen R, Koppes LLJ, van der Beek AJ, et al. Development and validation of physical and psychosocial job-exposure matrix in older and retired workers. Ann Occup Hyg. 2013;58(2):152–70.

29. Støver M, Pape K, Johnsen R, Fleten N, Sund ER, Ose So, et al. Work environment and disability pension- an 18 year follow-up study in a Norwegian working population. Scand J Public Health. 2013;41(6):587–96. https://doi.org/10.1177/1403494813486965.

30. Grooten WJA, Mulder M, Josephson M, Alfredsson L, Wiktorin C. The influence of work-related exposures on the prognosis of neck/shoulder pain. Eur Spine J. 2007;16(2):2083–91. https://doi.org/10.1007/s00586-007-0481-0.

31. Canivet C, Choi B, Karasek R, Moghaddassi M, Staland-Nyman C, Östergren P. Can high psycholodgical job demands, low decision latitude, and high job strain predict disability pensions? A 12-year follow-up of middle-aged Swedish workers. Int Arch Occup Environ Health. 2013;86(3):307–19. https://doi.org/10.1007/s00420-012-0766-4.

32. Benavides FG, Duran X, Gimeno D, Vanroelen, Martinez JM. Labour market trajectories and early retirement due to permanent disability: a study based on 14972 new cases in Spain. European Journal of Public Health. 2015;25(4):673–7. https://doi.org/10.1093/eurpub/cku204.

33. Clausen T, Burr H, Borg V. Does affective organizational commitment and experience of meaning at work predict risk of disability pensioning? An analysis of register based outcomes using pooled data on 40,554 observations in four occupational group. Am J Ind Med. 2014;57(6):709–17. https://doi.org/10.1002/ajim.22313.

34. Dembe AE, Yao X, Wickizer TM, Shoben AB, Dong X. Using O*NET to estimate the association between work exposures and chronic diseases. Am J Ind Med. 2014;57(9):1022–31. https://doi.org/10.1002/ajim.22342.

35. Rydwik E, Welmer A-K, Angleman S, Fratiglioni L, Wang H-X. Is Midlife Occupational Physical Activity Related to Disability in Old Age? The SNAC-Kungsholmen Study. PLoS ONE. 2013;8(7):e70471. https://doi.org/10.1371/journal.pone.0070471.

36. Arvidsson I, Gremark SJ, Dahlqvist, Axmon A, Karlson Björn, Björk J, et al. Cross-sectional associations between occupational factors and musculoskeletal pain in women teachers, nurses and sonographers. BMC Musculoskelet Disord. 2016;17:35. https://doi.org/10.1186/s12891-016-0883-4.

37. Järvholm B, Stattin M, Robroek SJ, Janlert U, Karlsson B, Burdorf A. Heavy work and disability pension – a long term follow-up of Swedish construction workers. Scand J Work Environ Health. 2014;40(4):335–42. https://doi.org/10.5271/sjweh.3413.

38. Vingård E, Alfredsson L, Hagberg M, Kilbom A, Theorell T, Waldenström M, et al. To what extent do current and past physical and psychosocial occupational factors explain care-seeking for low back pain in a working population? Results from the musculoskeletal intervention Norrälje study. Spine (Phila Pa 1976). 2000;25(4):493-500. https://doi.org/10.1097/00007632-200002150-00017.

39. Devereux JJ, Vlachonikolis IG, Buckle PW. Epidemiological study to investigate potential interaction between physical and psychosocial factors at work that may increase the risk of symptoms of musculoskeletal disorder of the neck and upper limb. Occup Environ Med. 2002;59(4):269–77. https://doi.org/10.1136/oem.59.4.269.

40. Huuhtanen P, Nygård C-H, Tuomi K, Martikainen R. Changes in stress symptoms and their relationship to changes at work in 1981-1992 among elderly workers in municipal occupations. Scand J Work Environ Health. 1997;23(Suppl 1):36–48.

41. Nygård C-H, Huuhtanen P, Tuomi K, Martikainen R. Perceived work changes between 1981 and 1992 among aging workers in Finland. Scand J Work Environ Health. 1997;23(suppl 1):12–19.

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