FACULTY OF HEALTH AND MEDICAL SCIENCES
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PhD thesis

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Work and physical function.

Associations between physical exposures in working life and signs of early musculoskeletal aging in midlife.

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Preface

The work presented in this PhD thesis was carried out from 2010 to 2013 at the Department of Occupational Medicine at the University Hospital in Køge and at the Research Unit for General Practice in Copenhagen, in collaboration with the Danish National Research Centre for the Working Environment (NRCWE). The study has been funded by the Ministry of Labour and The Danish Working Environment Research Fund. The CAMB study has been funded by the Velux Foundation.

Outline of the thesis

This thesis is based on four papers, three of which have been published in peer-reviewed journals and the fourth was submitted in June 2013. The first paper presents the results from a study about validity of exposure assessments, and the second paper is a published study protocol. Papers III and IV present analyses of associations between exposures in working life and physical function. The timeline of the project and the scientific work is visualized in Figure 1 at page 11, and the papers are briefly presented in “This thesis at a glance” at page 12.

In the introduction of the thesis, the history and background of this project is described, including considerations and results from another peer-reviewed article about work and health not included in the PhD. In 2010 I was invited to contribute to a theme-issue in the Danish medical anthropological journal “Tidsskrift for forskning i sygdom og samfund” (The Journal of Research in Sickness and Society) and this resulted in an article about the conceptualization of this project, and it is therefore added as an appendix to this thesis (Appendix 1).The introduction is followed by methodological considerations and presentation of results from Paper I, before methods and results regarding Paper III and IV are presented briefly. In the final chapter, methods and results regarding all papers are discussed. Finally, conclusion and perspectives of the results and suggestions and plans for future research are presented.

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I am grateful to the participants in the CAMB study who answered the questionnaire and attended the examination at NRCWE and, thus, made this study possible. Also thanks to the participants in the cognitive interviews recruited among employees at Køge Hospital and elsewhere.

Last but not least, warm thanks to members of my family; in particular my father for his English lessons by mail, my mother and Hardy’s participation and support, my parents-in-law’s enthusiasm and interest, and of course to Signe, Marie and Søren.

Papers in the thesis

Paper 1
Appendix 5

Møller A, Reventlow S, Andersen JH, Avlund K, Mortensen OS. Validity of Workers' Self-Reports. Evaluation of a Question Assessing Lifetime Exposure to Occupational Physical Activity. British Journal of Medicine & Medical Research 2012;2(4): 536-552. http://www.sciencedomain.org/abstract.php?iid=137&id=12&aid=614#.UYdiC6IqzFA

Paper 2
Appendix 6

Møller A, Mortensen OS, Reventlow S, Skov PG, Andersen JH, Rubak TS, Hansen ÅM, Andersen LL, Lund R, Osler M, Christensen U, Avlund K. Lifetime Occupational Physical Activity and Musculoskeletal Aging in Middle-Aged Men and Women in Denmark: Retrospective Cohort Study Protocol and Methods. JMIR Research Protocols. 2012;1(2)e7. PMID 23611836 http://www.researchprotocols.org/2012/2/e7/

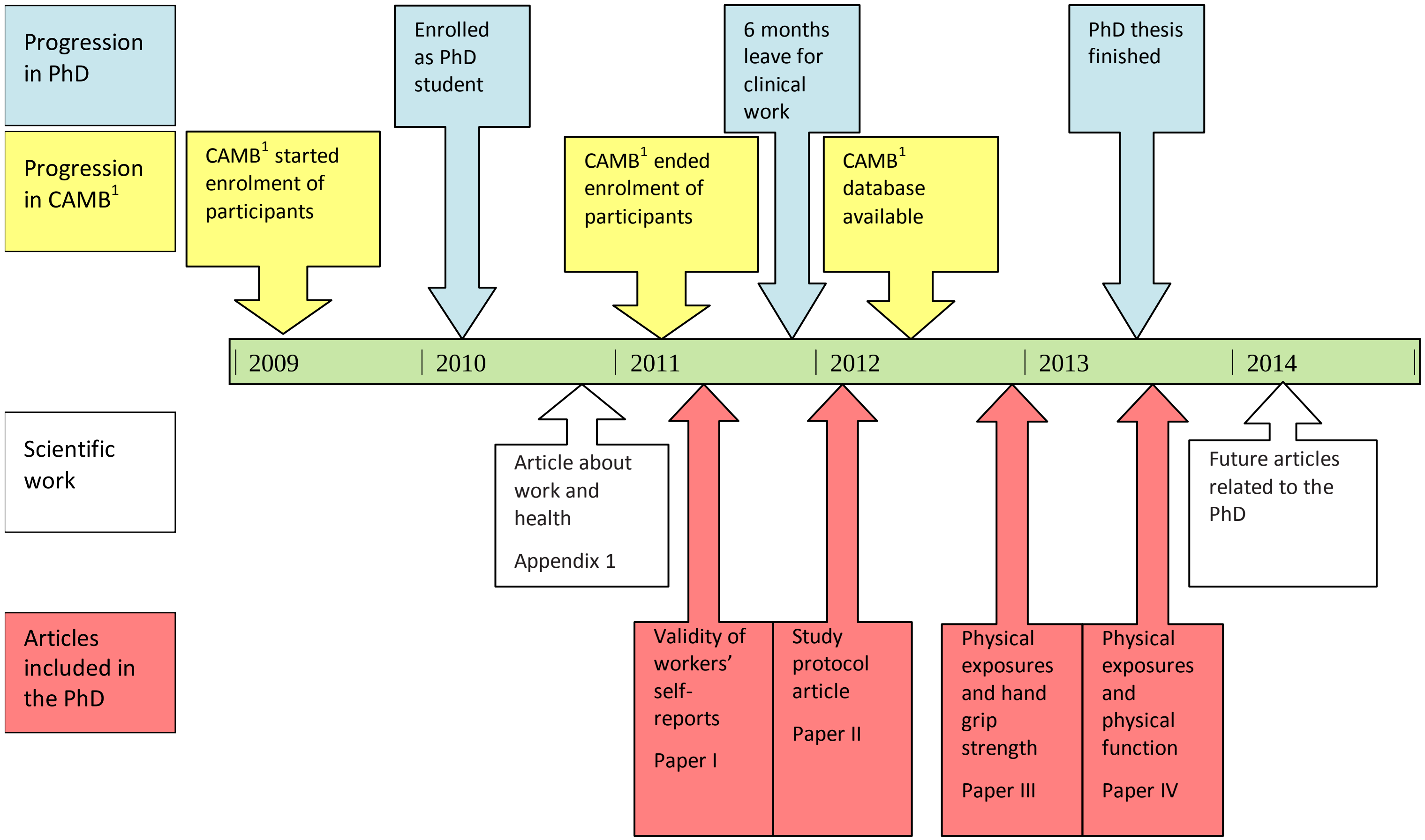
Paper 3
Appendix 7

Møller A, Reventlow S, Hansen ÅM, Andersen LL, Siersma V, Lund R, Avlund K, Andersen JH, Mortensen OS. Does a history of physical exposures at work affect hand-grip strength in midlife? A retrospective cohort study in Denmark. Scandinavian Journal of Work Environment and Health. 2013; epub ahead of print. PMID 23665642 http://www.sjweh.fi/show_abstract.php?abstract_id=3368

Paper 4
Appendix 8

Møller A, Reventlow S, Hansen ÅM, Andersen LL, Siersma V, Lund R, Avlund K, Andersen JH, Mortensen OS. Do Physical Exposures Throughout Working Life Influence Physical Function in Midlife? A Retrospective Cohort Study in Denmark. Submitted to Scandinavian Journal of Work Environment and Health June 2013

Figure 1. Time line. PhD, CAMB and scientific work



1) Copenhagen Aging and Midlife Biobank

This thesis at a glance

Paper	Questions	Methods	Answers
I	How are questions about exposures in working life understood? What is the validity of self-reports of exposure to physical work throughout working life?	Cognitive interviews. Semi-structured interviews. Analyses of agreement between questionnaire data and expert judgements of exposure.	A question about lifetime exposure to occupational physical activity was hard to answer. The validity of workers' self-reports about amount of moderate and hard physical work throughout working life was questionable.
II	Why is this study made? How is the study planned?	Theoretical considerations and review of background literature. Description of the included cohorts.	Description of the background of the project and the conceptual model. Discussion of some of the aspects of exposure assessment and outcome measures used in the study.
III	Does a history of physical exposures affect hand grip strength in midlife?	Cumulative assessment of physical exposures and associations with upper limb muscle strength measured as hand grip strength.	No association between exposures and hand grip strength except from exposure to kneeling among men, which was associated with slightly higher hand grip strength.
IV	Does a history of physical exposures affect physical function in midlife?	Cumulative assessment of physical exposures and associations with dynamic measures of physical function, chair rise and balance performance.	Poorer chair rise performance among exposed men. Poorer balance performance among exposed women. In general, work had little influence on physical function in midlife.

Abbreviations in the thesis and papers

AKF: Anvendt Kommunal Forskning (“Danish Institute of Governmental Research”)

AMTI: Advanced Mechanical Technology, Inc.

CAMB: Copenhagen Aging and Midlife Biobank

CD: Chronic diseases

D-ISCO / DISCO: the Danish version of ISCO (DISCO-88: The DISCO version from 1988)

DALWUH: The Danish Longitudinal Study on Work, Unemployment and Health

HEG: homogeneous exposure groups

HGS: Hand grip strength

ISCO: International Standard Classification of Occupations

JEM: job exposure matrix

LTPA: Leisure-time physical activity

MP: The Metropolit Cohort (Metro)

NRCWE: The National Research Centre for the Working Environment

OPA: occupational physical activity

R^2: The proportion of the variation explained by a regression model in %

SD: standard deviation

English summary

In Denmark, work is often mentioned as one of the primary causes of unspecific musculoskeletal symptoms in middle-aged workers, even though musculoskeletal disorders are multi-factorial in aetiology and common in the population in general. “Nedslidning” is a Danish term that describes the process of physical deterioration caused by exposures throughout working life and resulting in decreased physical function. No matching term is known in other countries, and the term is not accepted as a diagnosis.

In this thesis, physical deterioration is seen as signs of the underlying musculoskeletal aging process, the onset and rate of which vary among people. The aim of this PhD thesis is to assess the extent to which a history of physical work influences the musculoskeletal aging process and thereby physical function. Access to the Copenhagen Aging and Midlife Biobank (CAMB) was a unique possibility of studying the relationship between work and physical deterioration and information about job histories and physical measurements concerning 5000 middle-aged Danes was obtained.

A question about lifetime occupational physical activity included in the CAMB-questionnaire was planned to be the primary exposure measure in the study. However, as part of this PhD, a study of the validity of workers’ self-reports of physical exposures in working life was conducted. The study concluded that the question was hard to answer for participants with a history of manual work and that the validity of self-reports concerning lifetime exposure to physical work was low. Therefore, exposures were assigned from a Danish database including information on daily exposure to lifting, standing/walking, and kneeling in Danish jobs. Each participant’s total physical exposures throughout working life were calculated, and physical function were measured in three tests: Hand grip strength, chair rise (the number of times a person can rise from a chair in 30 seconds) and balance performance.

The data did not indicate any association between lifting and standing/walking throughout working life on one side and hand grip strength in midlife on the other side, but exposure to kneeling was associated with slightly higher hand grip strength among the male participants. Male participants exposed to physical work had poorer chair rise performance compared to non-exposed male participants, whereas there was no association between physical exposures and balance performance

among male participants. Among the female participants, a history of physical exposures was associated with poorer balance performance, but there was no statistically significant association with hand grip strength and chair rise performance.

In general, physical exposures in working life explained only a minor part of the variation in physical function among middle-aged people, and the associations were non-linear.

In conclusion, the variation in physical function among middle-aged Danes in this cohort was only to a small extent explained by physical exposures throughout working life. This finding emphasizes the importance of a multi-factorial model of musculoskeletal health. Based on results regarding chair rise performance there were signs of a faster and/or an earlier musculoskeletal aging process among male participants with a history of physically demanding work. Furthermore, this thesis shows that questions concerning lifetime exposures should be thoroughly pre-tested in the target-group before used in a questionnaire.

Dansk resume (Danish summary)

Som læge i almen praksis og i arbejdsmedicinen har jeg ofte oplevet, at et fysisk krævende arbejdsliv nævnes som den primære årsag til symptomer som smerte, ømhed og træthed i muskelskeletsystemet. Symptomer i muskelskeletsystemet er imidlertid meget almindelige og har mange forskellige årsager, heriblandt påvirkninger i arbejdsmiljøet. "Nedslidning" er en dansk betegnelse, der beskriver fysisk slid på kroppen, der skyldes påvirkninger i arbejdslivet, og som har betydning for den fysiske funktionsevne. ”Nedslidning” kendes ikke i andre lande, og accepteres ikke som en diagnose i Danmark.

I denne Ph.d.-afhandling betragtes nedslidning som tegn på aldersforandringer i muskelskeletsystemet. Hastigheden og timingen af aldringsprocessen varierer meget mellem folk og påvirkes både af indre faktorer som arv og konstitution og af ydre faktorer som arbejdsmiljø, livsstil og social status. Formålet med denne Ph.d.-afhandling var at undersøge, i hvilken grad et fysisk krævende arbejdsliv påvirker aldringsprocessen. Adgang til data om arbejdslivshistorie og fysiske målinger på 5000 midaldrende danskere i Copenhagen Aging og Midlife Biobank (CAMB) var en unik mulighed for at undersøge arbejdets betydning for aldringsprocessen. Et fysisk krævende arbejdslivs indflydelse på den fysiske funktionsevne blev undersøgt ved hjælp af tre test af muskelstyrke og funktion.

Det var oprindeligt tanken, at svarene på et spørgsmål om fysisk krævende arbejde i CAMB-spørgeskemaet skulle have udgjort et mål for hvor fysisk krævende arbejdslivet havde været. Det viste sig imidlertid, at nogle af deltagerne i CAMB havde svært ved at svare på det pågældende spørgsmål, og som en del af dette Ph.d.-projekt blev spørgsmålet derfor valideret. Kognitive interviews viste, at spørgsmålet var svært at besvare, især for deltagere med et fysisk krævende arbejdsliv. Desuden var validiteten af oplysningerne lav sammenlignet med ekspertvurderinger af påvirkninger i arbejdslivet. Derfor blev der i stedet, som mål for påvirkninger i arbejdslivet, anvendt oplysninger fra en dansk database, som indeholder information om den daglige varighed af stående/gående og knæliggende arbejde samt mængden af tunge løft. For hver deltager blev de fysiske påvirkninger gennem arbejdslivet summeret og analyseret i forhold til præstation i tre fysiske tests: Håndtrykskraft, ”rejse-sætte-sig-test” (det antal gange personen kan rejse sig fra og sætte sig på en stol i løbet af 30 sekunder) og evnen til at balancere på ét ben.

Studiets analyser viste, at der ikke var en sammenhæng mellem mængden af tunge løft eller stående/gående arbejde gennem arbejdslivet på den ene side og håndgrebsstyrke på den anden side, men knæliggende arbejde var forbundet med lidt højere håndgrebsstyrke hos mænd. Mænd med et fysisk krævende arbejdsliv klarede ”rejse-sætte-sig-testen” dårligere end mænd uden fysisk krævende arbejde, mens der ikke var nogen sammenhæng mellem et fysisk krævende arbejde og balance-evne. Blandt kvinder var et fysisk krævende arbejdsliv forbundet med dårligere balanceevne, men der var ingen statistisk signifikant sammenhæng mellem arbejdspåvirkninger på den ene side og håndgrebsstyrke eller præstationerne i ”rejse-sætte-sig-testen” på den anden side.

Sammenfattende viser denne afhandling, at fysiske påvirkninger i arbejdslivet kun kan forklare en mindre del af variationen i den fysiske funktionsevne, hvilket understreger vigtigheden af en multi-faktoriel sygdomsmodel i studier af muskelskeletsystemets lidelser. Præstationerne i ”rejse-sætte-sig-testen” viste tegn på en hurtigere og/eller tidligere aldringsproces i muskelskeletsystemet blandt mænd med et fysisk krævende arbejdsliv. Desuden viste dette studium, at spørgsmål om et fysisk krævende arbejdsliv bør afprøves omhyggeligt i målgruppen, før de anvendes i et spørgeskema.

Introduction

Clinical considerations about work and health

In my work as a medical doctor I have often met patients with unspecific, musculoskeletal symptoms describing their problems as caused by exposures at work. From my point of view, as a general practitioner or an occupational physician, other determinants of musculoskeletal symptoms should also be considered regarding a multi-factorial or bio-psycho-social model of disease. Patients characterise symptoms as “nedslidning”, Danish term used to describe general physical deterioration or “wearing down” caused by exposures in working life and leading to decreased physical function. The term is seldom used by occupational physicians but often used by politicians when conditions on the Danish labour market are discussed, most recently in the debate about a revision of the law of early retirement in Denmark in 2011(1). It is well-known that hard physical work is a risk factor of musculoskeletal disorders and, thus, of sickness absence and early retirement (2–6), but musculoskeletal disorders are multi-factorial and common in the general population which complicates studies of causality (7).

My clinical experiences in general practice and occupational medicine, and the discrepancy between the perception of the importance of work on health among laymen and occupational physicians, encouraged me to study the relationship between work and health more closely and, more specifically, the relationship between histories of manual work and musculoskeletal health.

“Nedslidning”/physical deterioration

The term “Nedslidning” has been used in Denmark since the 80’s to describe the relationship between work and health, but no matching term is known or used in other countries (1) (Appendix 1). Implicit in the Danish term is a causal pathway between exposures in working life and the symptoms (1), which is not reflected in “physical deterioration”. Many definitions of “nedslidning” exist, including a variety of symptoms, but musculoskeletal symptoms are always included, and I have argued that unspecific musculoskeletal symptoms or physical deterioration could be seen as signs of musculoskeletal aging. Physical activity and training can alter the rate of the aging- (8,9) and the deterioration process (10,11) and thereby increase physical function. It is not reversible processes, but the slope of the decrease in physical function can be altered (9).

The relationship between work and physical function

In cross-sectional studies, a history of high work load has been associated with impaired musculoskeletal health or lower physical performance in elderly people (12–14). A common physiological explanation for a negative association between exposures throughout working life and musculoskeletal health is “wear and tear” explained by underlying biological processes, where acute changes in the musculoskeletal system turn chronic because of insufficient time for recovery (15,16). Few studies have been made among middle-aged workers, and results are ambiguous. Some cross-sectional studies have shown a strengthening effect of manual work on muscles in the upper limb (17–20), whereas a few longitudinal studies have had contradictory results, finding no association (21) or a negative association between work strain at baseline and hand grip strength at follow-up (22). Regarding physical function in midlife, a negative association was seen among those reporting physical strenuousness at baseline (23) in one follow-up study, and Torgen et al. found that long-lasting physical demands were associated with lower dynamic muscle function (19). Though studies are of varying methodological quality, occupational physical activity appears to have different impact in different regions of the body at different times throughout life.

Copenhagen Aging and Midlife Biobank

The establishment of Copenhagen Aging and Midlife Biobank was a unique opportunity to study the influence of a history of manual work on musculoskeletal health and physical function in middle-aged Danes. The aim of CAMB was to study social determinants of early signs of aging in the general population, but, from the beginning, there was only limited focus on determinants in working life. Based on arguments from our research group, questions about working life were added to the CAMB questionnaire, introducing the possibility of studying the influence of work on early signs of aging.

The primary reason for adding questions about working life to the CAMB study was a hypothesis about manual work being detrimental to health in middle-aged people – and the aim of the following research project was to assess to which extent cumulated exposures in working life affect midlife musculoskeletal health and physical function.

Cumulated exposures

In occupational epidemiologic studies of the role of work in development of chronic diseases, the cumulative dose of exposure is assessed as the summation of level or intensity of exposure over a specific time period (24). The importance of cumulated exposures is also emphasized in models used in life course epidemiology. Life course epidemiology is the study of long-term processes linking health in adulthood with exposures throughout the entire life, and life course models have been used in studies of chronic diseases (25). The life course perspective has also been used to understand aging processes including musculoskeletal aging (25), and therefore life course perspective is useful in the conceptual model of this thesis.

Measuring cumulated exposures in working life

When the connection to the CAMB study was established, validated questions about exposures in work were added to the CAMB questionnaire. The question assessing lifetime occupational physical activity included four categories of occupational physical activity: a) sedentary work, b) standing and walking at work, c) moderate, and d) hard physical work (Appendix 2, question in Danish and English). The change in time-frame from: “In current work” to: “During your entire working life” and an assessment of years of exposure in each category were added. However, the question was not pre-tested or validated in this context before use, due to lack of time.

The background of the study of validity and reliability

I was asked to join the project rather late in the process and did not participate in the preparation of the CAMB questionnaire. When the first participants attended the CAMB study, it was noticed that the question about lifetime exposure to occupational physical activity was hard to understand to some of the participants, and I decided to add a study of the response process and the validity of the question about lifetime occupational physical activity to the PhD study. First, cognitive interviews were conducted to understand the response process as described in Paper I. Secondly, the validity and reliability of the answers were studied, comparing questionnaire data with an expert’s judgement of the amount of physical activity in working life, based on semi-structured interviews with participants in CAMB (Paper I). This study of reliability and validity concluded that workers’ self-reports about sedentary work were valid, but information about standing/walking and moderate (and hard) physical work in working life was not valid. Since the aim was to study the influence of a history physical exposures, this question about lifetime occupational physical activity could not be used as the primary exposure measure.

The Knee-Hip Matrix

An interesting alternative to the questionnaire data was found in Aarhus at the Dep. of Occupational Medicine. A PhD student, Tine Steen Rubak, had constructed a database including information about physical exposures in Danish jobs in order to study exposures in work related to the risk of osteoarthritis in the lower limb (26). This database, a job exposure matrix called the Knee-Hip Matrix, included information about amount of heavy lifting, whole body vibration, sitting, and duration of standing and walking and kneeling at work. Since our aim was to study occupational physical activity in general, we included information about amount of lifting and kneeling. However, some jobs normally considered to be physically demanding do not include lifting or kneeling (like cleaning), and therefore exposure to standing and walking was included, too.

Job exposure matrices

Job exposure matrices (JEMs) are databases using coded job titles to assign exposures in epidemiologic studies (27) and are based on expert judgments, registers or measurements. Several research groups have used expert ratings and established JEMs for assessment of physical exposures (28–30), but the imprecise definition of occupational physical activity and lack of accurate measurements of OPA have implications for the validity of information from job exposure matrices, too.

Outcome measures

In the background article about physical deterioration, I argued that unspecific musculoskeletal symptoms in middle-aged people can be seen as early signs of musculoskeletal aging occurring earlier and/or faster in some people compared to others (1). Musculoskeletal aging includes aging processes in muscle, bone and cartilage, resulting in pain and later disability, but early signs of the aging process do not present themselves initially as a disease or a pathological condition. Therefore, I searched for objective measures of musculoskeletal health and physical function, which could be seen as early signs of musculoskeletal aging. Many researchers were involved in the planning of CAMB, including dentists, psychologists, immunologists, etc., and therefore many different measures of early aging were available. However, the number of available and relevant tests for my specific purpose and study was limited. Inspired by the aging model by Verbrugge and Jette, I decided to study signs of the musculoskeletal aging process at three stages: underlying biological processes (measured as chronic inflammation), functional limitations (measured in three tests of static and dynamic physical function), and disability in an occupational context (measured as work ability) (31). Due to the timeframe of the PhD and the delay in the establishment of the CAMB database, focus in this thesis is on the functional limitations.

Functional limitations and physical function

Simple performance tests like chair rise test and balance test have been used world-wide to assess functional limitations in different age-groups and settings, since they are independent of factors in the environment (32,33). Three simple and well-known objective measures of functional limitations were chosen as proxy measures of physical function: hand grip strength (HGS), chair rise and balance performance. Physical function is a predictor of morbidity and mortality. Hand grip strength, as a proxy measure of muscle strength, is a predictor of morbidity and disability in elderly people (33,34), and of mortality in both younger (32) and older age-groups (35–37). Dynamic measures of physical function as chair rise and balance are important predictors of morbidity (33) and mortality in older age-groups (32).

The three chosen outcome measures are not normally used in occupational epidemiology, but, in my opinion, they are useful to assess muscle strength, coordination and physical function in general.

Covariates

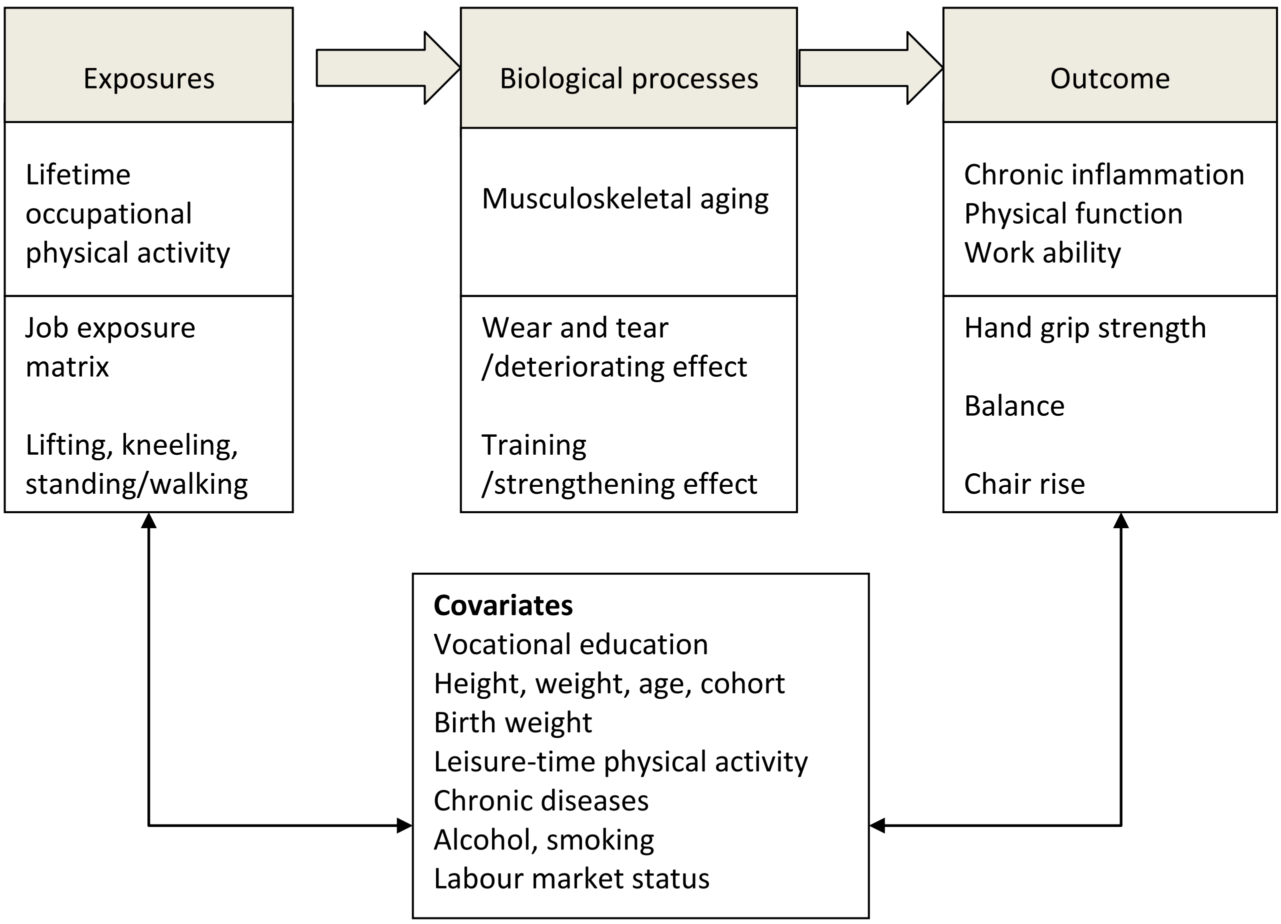
Musculoskeletal health is influenced by both internal and external factors (38). Many risk factors have been identified in the musculoskeletal aging process, and the life course perspective on the aging process includes factors from early start of life through childhood and adulthood (25). As described in Paper II, the CAMB database provided data about various covariates and social, health and life style factors were chosen as covariates in the conceptual model.

Conceptual model

The conceptual model is based on the occupational paradigm about the relationship between exposures and response presented in the first row in Figure 2. From occupational and life course epidemiology, models of accumulation of exposure are applied to the conceptual model in row 2, with a life course perspective on musculoskeletal aging, including three stages in the aging process.

Life time occupational physical activity is characterized by three specific physical exposures during working life, row 3, hypothesising either deteriorating or strengthening effects on muscle strength and function measured in three tests of physical function. All covariates of interest are included in the model, and discussion about their role and inclusion in analyses is presented in the Methods section.

Figure 2. Conceptual model



Aim and hypotheses

The aim of this thesis was to study associations between physical exposures throughout working life and signs of musculoskeletal aging, and thus to qualify the scientific debate about "nedslidning"/ physical deterioration.

The working hypothesis is that a high amount of occupational physical activity throughout working life will affect the onset and/or the rate of the musculoskeletal aging process. More specifically, based on former research in this field, it is hypothesized that there is no association between exposures in working life and hand grip strength since a training or maintaining effect in this age group is possible. Regarding dynamic measures of physical function it is hypothesized that manual workers with a history of hard physical work have poorer performance in balance and chair rise tests compared to non-manual workers.

The following research questions will be answered:

Is a history of physical exposures in working life associated with physical function in midlife, measured as hand grip strength, chair rise and balance performance?

To be able to answer the above question, a study of validity of questionnaire data was performed assessing:

How valid are workers' self-reports of lifetime occupational physical activity?

The results of the study of validity will be presented in the following chapter about exposure assessment, and the results will be discussed in the final chapter of the thesis.

Exposure assessment

Questionnaires for exposure assessment

Exposure assessment in this thesis was planned to be based on a question about lifetime occupational physical activity added to the CAMB questionnaire as described in the introduction. In epidemiological studies, including participants with many different job-titles, exposure assessment based on questionnaires is the most cost-effective method (39), however, the reliability and validity of questions about current work load are questionable (39). Assessment of summated lifetime workload, as was the case in this study, is an additional challenge to participants in surveys. After reports from the CAMB crew noticing that many participants had trouble answering the question about life time occupational physical activity, a study of validity was planned. Few studies have explored which formulation of questions about work demands that allows workers to estimate exposure more accurately (39), and the study was inspired by suggestions by Stock et al. about the use of qualitative studies of questions about work demands.

Validity of workers' self-reports (Paper I)

The aim of the study was to answer the question: *How valid are workers' self-reports of lifetime occupational physical activity?* by validating the question used in the CAMB-questionnaire (See the question in Appendix 2). The validation was a three-stepped process including cognitive interviews, semi-structured interviews and tests of reliability (Table 1 gives an overview of the three steps).

Table 1. A three-step validation process. Methods, materials and analyses.

Step	Content	Method	Material	Analyses
1	Response process, comprehension and interpretation	Cognitive interviews	7 middle-aged workers, primarily working in a hospital	Question Appraisal System, QAS-checklist
2	Validity of self-reports	Semi-structured interviews CAMB questionnaire	64 participants from CAMB[1]	Agreement: Kappa Bland-Altman plots
3	Intra-rater reliability	Re-test of interview-data from step 2 after 3 months	Primary rater's first judgment in step 2 compared with blinded re-test	Agreement: Kappa Bland-Altman plots
	Inter-rater reliability	Expert judgments based on interview-data from step 2	3 experts' judgments compared to primary rater's judgments	Agreement: Bland-Altman plots

Cognitive interviewing

Firstly, cognitive aspects of the response process were studied by cognitive interviews, and, thereby, respondents' interpretation and comprehension of questions (40). A strategic sampling was made based on the following criteria: participants 1) were not included in the CAMB cohort, 2)were a minimum of 50 years old, 3) had had at least 20 years of non-sedentary work in working life. Seven middle-aged persons were included and presented to the questions in the CAMB questionnaire about school and vocational education, job history and exposures in working life. We found that the question about lifetime occupational physical activity had a complicated instruction, and that the respondents found it hard to remember, categorize, and summate occupational exposures throughout working life.

Semi-structured interviews

Secondly, 64 responders to the CAMB questionnaire participated in semi-structured interviews about their working life. The overall aim was to establish a retrospective job history, including information about all exposures in working life. Based on the interviews, individual expert judgments of exposure to OPA were compared with questionnaire-data. Exposure was defined as 20 years of work in one of four categories of OPA equivalent to the question from the CAMB questionnaire: sedentary, standing and walking, moderate or high OPA. Kappa values were calculated for agreement and interpreted according to Landis and Koch's criteria, and agreement was furthermore visualized in Bland-Altman plots. Kappa value for exposure to sedentary work was 'substantial' (0.71) but 'fair' for the other categories of OPA (0.23- 0.37) (Table 2). Agreement between questionnaire and interview was higher in sedentary jobs (Figure 3), since the dots at the left part of the x-axis (sedentary job histories) are closer to "0" at the y-axis compared to dots at the right part of the x-axis (job histories with physical demands).

Exposure	Kappa	95% CI
a)/ sedentary	0.71	0.50-0.93
b)/ standing and walking	0.23	-0.02-0.45
c)/ moderate OPA[a]	0.37	0.17-0.57
d)/ high OPA[a]	0.27	0.04-0.49

Table 2. Validity of self-reports. Agreement between questionnaire and interview

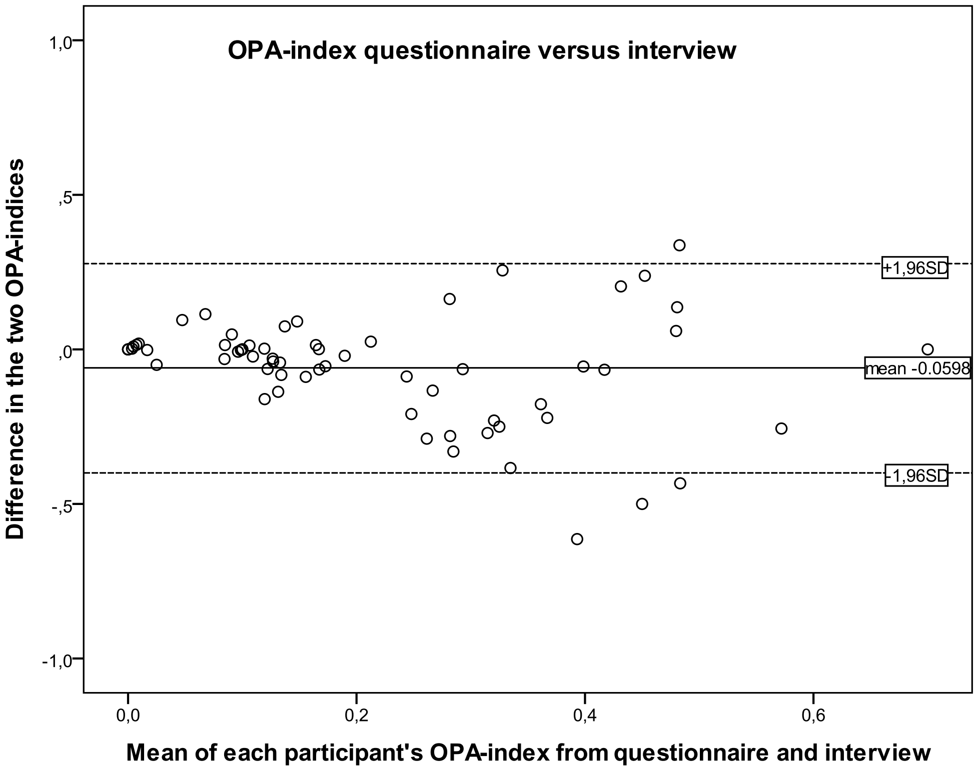


Figure 3. A question about lifetime exposure to occupational physical activity (OPA) was validated, comparing questionnaire and interview data. An index of OPA was calculated (OPA-index) in each participant based on information from the questionnaire and the interviews. The difference between the two OPA-indices is visualized.

Tests of intra- and inter-rater reliability

Thirdly, intra- and inter-rater reliability of expert judgments was tested. Intra-rater reliability of expert judgments was ‘substantial’ or ‘moderate’ (0.60-0.71). Inter-rater reliability was high in sedentary jobs but lower in jobs with physical activity (Figures presented in Appendix 3 and found in paper I).

Conclusion (Paper I)

Our research question was: How valid are workers’ self-reports of lifetime occupational physical activity?

Self-reports of lifetime exposure to sedentary work were valid in the CAMB cohort, whereas the validity of self-reports of exposure to moderate or high levels of OPA was questionable. Therefore, alternatives to exposure assessment were sought, and, as described in the introduction, connection to a Danish job exposure matrix was established.

Methods

Study design and population

This retrospective population-based study included a cross-sectional physical examination as part of the CAMB-study (41). Establishment of CAMB is described thoroughly in Paper II and summarized in Papers III and IV. This study included data from two of the three cohorts in CAMB: ”The Metropolit Cohort” (MP) and “The Danish Longitudinal Study on Work, Unemployment and Health” (DALWUH) from which 12,656 middle-aged men and women were invited. The selection and attrition in the study is illustrated in Figure 4.

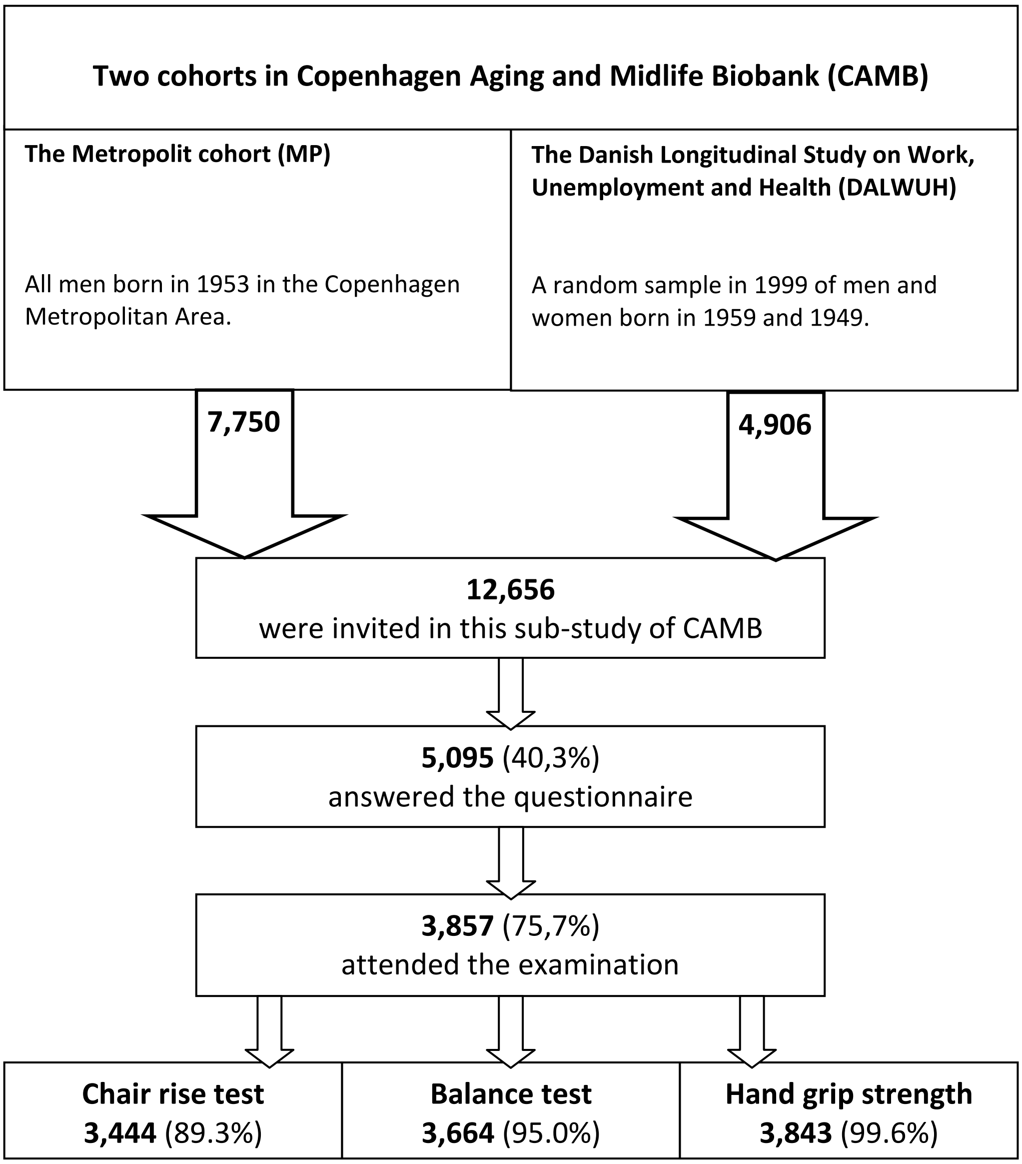


Figure 4. Copenhagen Aging and Midlife Biobank. Two cohorts and participation in questionnaire and tests

Exposure

Physical exposures from the Knee-Hip Matrix

The assessment of physical exposures at work was based on information about job history from the questionnaire, combined with data from a job exposure matrix as described in Papers II, III and IV. Exposure was calculated as the years of employment in each of the jobs retrieved from the questionnaire, multiplied by the corresponding daily amount of lifting, standing/walking and kneeling assigned from the Knee-Hip Matrix (26), and then summarized for the participants' entire working life. Finally, exposures were standardized as ton-years (lifting 1000 kg each day in one year), stand-years (standing/walking at work for six hours each day in one year) and kneel-years (kneeling at work for one hour each day in one year).

Self-reports of physical exposures

The CAMB questionnaire provided information about years of exposure to lifting/moving heavy things or persons. Participants answered the question whether they often/many times a week had been exposed to these tasks, and if they answered yes, number of years of exposure was registered. This question was not a part of the validation process described in Paper I, but self-reports of lifting were used in additional analyses to test the reliability of the job exposure matrix. Self-reports of lifting/moving heavy things were grouped in three: No exposure, 1-20 years of exposure, >20 years of exposure. Analyses of associations between self-reports of physical exposures and physical function have not been published before.

Outcome

Three measures of physical function were used and are described in detail in Papers II, III and IV.

Hand grip strength

HGS was measured with a Jamar dynamometer. Each participant sat upright in a chair with the elbow flexed at 90 degrees and was instructed to squeeze the dynamometer as fast and as forcefully as possible (42). The maximum force value (kg) of five possible attempts was defined as the hand grip strength.

Balance performance

Balance was tested on a force platform, and the stance was performed with eyes open. The subjects stood on the dominant foot, and balance was defined as the postural sway area (95% confidence ellipse measured in mm^2), i.e., a lower sway area equals better balance (43). Three 30-second attempts were made by each participant, and the lowest sway area from the 3 attempts was used. Due to the non-normal distribution of the sway area, the variable was analyzed in logarithms (log_{10}).

Chair rise

Functional lower limb capacity was measured as the number of chair rises performed during a 30 second test (44). Participants were instructed to perform as many chair rises as they could in a 30 second period. The test was performed using a chair (height 45 cm) with a mechanical contact in the seat, enabling automatic recording of the number of posture transitions and the number of cycles completed, e.g. 21.2 cycles in 30 seconds (41,43). Because the test was somewhat tiring each participant made only a single attempt.

Covariates

Men were included from two cohorts (MP and DALWUH). From the CAMB questionnaire, information about weight and height was obtained. Information about vocational education was categorized into five groups: Unskilled, skilled manual worker, and short cycle, medium cycle, or long cycle further education. The questionnaire provided information about the number of chronic diseases among participants, and these were grouped in three: 0, 1, and ≥2 or more chronic diseases. The diseases considered relevant for length of exposures in working life and physical function were asthma, diabetes, hypertension, angina pectoris, stroke, myocardial infarction, bronchitis, emphysema, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression/other psychiatric diseases, and back pain. Leisure-time physical activity (LTPA) was categorized as medium/hard: >4 hours a week, light: <4 hours a week, and sedentary: reading/watching television in leisure time. Historical data about birth weight were available from the “Metropolit Cohort” and included in additional analyses.

Statistical analysis

The associations between exposures (summation of exposure-years) and outcomes (HGS, balance, and chair rise) were assessed in linear regression models. As the effects of physical exposures were supposed to be gender-specific, all analyses were performed separately for each sex.

First, univariate associations between specific exposures and the three outcomes were analysed. Then, covariates seen as confounders were included in multivariate analyses. Increasing epidemiological knowledge led the attention to the differences between confounders and mediators, and the role of covariates in the multivariate analyses was therefore changed from Paper II to Papers III and IV.

Confounders

Since the two cohorts differed regarding scope and social background (Paper II), "cohort" was included as a confounder. In analyses of HGS; age, height, weight, and education were included in Model 1. Height is hypothesized to affect both the exposure and outcome (by being a proxy of physical strength and thereby affecting both choice of job and physical function in midlife). Weight, or BMI, has been used as a confounder in other studies of HGS and therefore included in the analyses. However, since weight often changes throughout life, weight was not included in Model 1 in Papers III and IV. Chronic diseases and leisure-time physical activity could be both confounders and mediators in associations between exposures and outcomes with life course perspective, and therefore those two covariates were added separately to Model 1 in all analyses.

Analytic models

General linear models were applied to the data set as described above. However, since the effect of physical exposure on physical performance has been suggested to be both strengthening and deteriorating, a linear term may be too limited to characterize these associations (45). Therefore, the shape of the associations was studied by modelling them as restricted cubic spline functions (spline regression). The resulting spline functions were then plotted to show the expected difference in outcome attributed to each category of exposure, avoiding a linearity assumption (45,46).

Power calculation

The power calculation was based on Kuh's results from studies of middle-aged Britons (47) which included measurements of HGS and chair rise similar to our measurements. Regarding balance, their performance test was not comparable to our assessment of balance at the AMTI platform. The power calculations are presented in detail in Paper II.

Results

The characteristics of the study population are presented in Tables 3a and 3b (Appendix 4). Mean age was 59 (53-64 years) and men constituted 79.2% of the study population, since the MP cohort included only male participants. Women were exposed to fewer exposure-years compared to men (Table 3b, Appendix 4), especially according to kneel-years, but mean seniority in work based on the five longest-held employments was almost similar, 31.46(SD=8.12) years in men and 29.69(SD=8.94) years in women. Mean HGS was 1.6 times higher in men compared to women, but women had better balance than men (mean area 25% less than mean area among men, but women were also shorter than men), see Table 3a and 3b, Appendix 4. Regarding chair rise performance, women achieved on average one chair rise less than men in 30 seconds (20.38 vs. 21.58).

Exposure and HGS

Men

A negative association between ton-years and HGS was found in the unadjusted analysis (Table 4, Appendix 4). However, when adjusting for age, height, weight, cohort and vocational education the association between ton-years and HGS disappeared (Model 1). Exposure to kneel-years was positively associated with higher HGS in Model 1, increasing HGS by 0.030 kg per exposure-year (p=0.007). In spline regression analyses associations between each of the three physical exposures and HGS were evaluated visually (Figure 5, Appendix 4). Exposure to ton-years and stand-years was slightly positively associated with HGS, and the findings from the linear regression according to kneel-years in men was confirmed.

Women

In women no significant associations were seen in either of the models (Table 4, Appendix 4). The associations were non-linear and primarily negative, but statistically insignificant (Figure 5, Appendix 4).

Exposure and chair rise

Men

There was a negative association between exposure-years and chair rise in men. Exposure to ton-, stand-, and kneel-years was associated with poorer chair rise performance in unadjusted analyses. Adjustment for age, height, cohort and vocational education (Model 1) attenuated the effect of ton-,

and stand-years though it was still statistically significant, whereas the association between exposure to kneel-years and chair rise disappeared (Table 4, Appendix 4).
Spline regression analyses confirmed the findings from the linear analyses, and an increasing negative effect of exposure to ton-years was observed in men (Figure 6, Appendix 4). The effect reached a maximum decrease of almost 2 chair rises among men exposed to 20-30 ton-years, but the association was non-linear, and further exposure to ton-years did not decrease chair rise performance.

Women

Exposure was associated with lower chair rise performance in unadjusted analyses according to ton- , and stand-years, but the associations were attenuated in adjusted models (Table 4, Appendix 4). In spline regression analyses associations between exposure-years and chair rise were non-linear and with broad confidence intervals due to few female participants with higher exposures (Figure 6, Appendix 4). Similar to men, a negative association was seen between exposure to 1-25 ton-years and chair rise performance, with a maximum decrease of almost three chair rises in women exposed to 20 ton-years. However, the association was non-linear and further exposure-years increased chair rise performance.

Exposure and balance

Men

In the unadjusted analysis, exposure to ton-years was associated with a 0.1% increase in balance area per ton-year in men (p=0.03). However, when adjusting for age, height, cohort and vocational education (Model 1), the association disappeared (Table 4, Appendix 4). Stand- and kneel-years were not associated with balance performance in men in any of the models. In spline regression analyses (Model 1), the lack of associations between exposures and outcome was confirmed (see Figure 7, Appendix 4).

Women

In linear models, significant associations were seen between stand- and kneel-years and balance among women. Balance area was increased by 0.4% per stand-year ($10^{0.00172}$) and 1.9% per kneel-year ($10^{0.00831}$) (p=0.02 and p=0.003 respectively) in Model 1. Spline regressions confirmed the findings but indicated a non-linear association between these two exposures and balance in women (Figure 7, Appendix 4).

Additional analyses

Exposure to ton-years from the JEM categorized in three groups was compared to self-reports of exposure to lifting in three groups. The associations between self-reports of lifting and HGS and chair rise were almost similar to the associations between ton-years and the outcomes (Table 5). Self-reports of exposure showed a positive association with HGS in both men and women (though not statistically significant), and a negative association with chair rise in both men and women in this case. Regarding associations between lifting and balance, a negative association was seen in men in the lowest exposure group, but no association was found in women.

Attrition analyses

Responders to the questionnaire and participants attending the physical examination had significantly higher education and were more likely to be employed compared to non-responders/non-participants (Results from the total CAMB sample and based on data from Danish registers (41)). This trend continued in this study: participants attending the physical tests were exposed to fewer exposure-years compared to responders only answering the questionnaire, reflecting participants' higher educational level.

Table 5. Multivariate linear regression models. Exposure to lifting assessed in the JEM (the Knee-Hip Matrix) and from answers in the CAMB questionnaire in three groups. Adjusted for height, age, cohort, and vocational education (p-values: * **p<0.0001, ** p<0.001, * p<0.05 , ns: not statistically significant).

Outcome	**Exposure** **JEM**	**Women** **β**	**Men** **β**	**Exposure** **Self-reports**	**Women** **β**	**Men** **β**
Hand grip strength, kg	0 ton-years	ref	ref	0 years	ref	ref
	1-20 ton-years	0.52 ns	0.29 ns	1-20 years	0.36 ns	0.35 ns
	>20 ton-years	0.26 ns	0.69 ns	>20 years	0.63 ns	0.63 ns
Chair rise, n/30 sec	0 ton-years	ref	ref	0 years	ref	ref
	1-20 ton-years	-0.49 ns	-0.75**	1-20 years	-0.63 ns	-0.64*
	>20 ton-years	-0.98 ns	-1.57***	>20 years	-1.41*	-0.58*
Balance, Log_{10} area	0 ton-years	ref	ref	0 years	ref	ref
	1-20 ton-years	-0.01 ns	-0.01 ns	1-20 years	-0.03 ns	0.03*
	>20 ton-years	0.04 ns	0.01 ns	>20 years	-0.01 ns	0.01 ns

Discussion

Theoretical background and conceptual model

The entrance into this thesis was a clinical and academic interest in the phenomenon of "nedslidning" (physical deterioration). Unspecific musculoskeletal symptoms are the primary symptoms of physical deterioration, and considered part of the musculoskeletal aging process in this thesis. All human beings will experience symptoms of musculoskeletal ageing as pain, decline in physical function, and disability, but the onset of symptoms will vary as well as the rate of the aging process. This theoretical view on the relationship between work and physical function is similar to the theory about "risk advancement periods" which describes causation in chronic diseases. *"Causation not only comprises the occurrence of a disease (that without exposure would not have occurred at all) but also the accelerated occurrence of a disease (that without exposure would have occurred later in life)"* (48). In this case the "disease" is the age-related functional decline. As mentioned, everyone will experience functional decline, but the question is to what extent exposures in working life affect the onset and rate of the decline.

The association between work and health on functional decline was studied by using a combination of theoretical perspectives. Based on a multi-factorial model of health, basic principles about exposure and response from occupational epidemiology were combined with life course perspectives on chronic diseases and aging. One strength of the conceptual model was that accumulation of exposure was in focus in both occupational and life course epidemiology. However, in occupational epidemiology focus is on work-related exposures, whereas exposures in working life play only a minor role in life course epidemiology. The interrelationship and interdependency among determinants of musculoskeletal health (38) have been a larger challenge than expected. Risk factors for chronic disease often cluster together because many are related to socioeconomic position (25), which is a problem in this study, too. Analytic models were simplified during the work with the thesis, and inclusion of covariates could also be discussed further, since changes in covariates over the life course have not been evaluated in this study.

In the following, exposure assessment and choice of outcome measures will be discussed, as well as the results of the study. Strengths and limitations, including different types of bias will be evaluated, before the conclusion and perspectives of this thesis are presented.

Exposure assessment

Paper I: The validity of workers' self-reports

Problems in categorization of physical demands at work appeared in the cognitive interviews; however, sedentary jobs were easily categorized as such. It may be argued that seven interviews were too few, but most respondents faced the same problems in the response process, and therefore inclusion of participants was stopped. The aim of the cognitive interviews was to explore the response process as suggested by Stock et al. (39), and also to be able to design an interview guide for the second step of validation. In the second step, both Kappa values and Bland-Altman plots showed that the lower the level of occupational physical activity in working life, the higher the agreement between self-reports and interviews. This is in line with results by Torgen et al. (49), who found highest validity for sitting and repetitive work when comparing questionnaire information about workloads with objective measures. The lower agreement in higher levels of occupational physical acitivity (OPA) is presumably caused by the problems of categorising OPA levels, as seen in the cognitive interviews. Other researchers in this field have also experienced problems in self-reported information about strain and specific working postures (50–52).

An interesting review about validity and repeatability of questionnaires assessing occupational physical activity was published after finishing the study of validity. Kwak et al. concluded that none of the reviewed questionnaires showed good validity compared to objective measurements (53). The low validity could be partly explained by lack of standardized methods for assessment of occupational physical activity and, thereby, lack of a 'gold standard' as reference method. For lack of a 'gold standard', we have studied the inter-method agreement (54). Our hypothesis was that the information retrieved by interviews was more valid than self-reports, but this hypothesis has not been tested. However, White et al. state that interviews are superior to questionnaires, if questions are complex and if precise information, e.g. about past exposures, is needed (24). From the cognitive interviews it was known that categorization of OPA was difficult. Highly educated workers may have little or no exposure to OPA, and, thus, their jobs are easier to categorize (39). On the other hand, categorization of jobs with moderate or high levels of OPA may bother respondents with low education. Gender, age, socio-demographics, and musculoskeletal complaints have been hypothesized to influence self-reports of exposure assessment (39,50,52,55,56), as well as the physical capacity of the individual, which affects the perceived workload (57). In conclusion, the reported data support the hypothesis that validity depends on study-specific factors often not examined (58).

Validity of the exposure assessment

In this study, the change in exposure assessment, from the use of questionnaire data to assignment of exposures from a job exposure matrix, was hypothesized to increase the validity; however this hypothesis was not tested, either. Self-reports about years of exposure to lifting or moving heavy objects in working life were included in additional analyses in this thesis, and though not completely comparable to exposures from the job exposure matrix, results were in general similar. Evaluating multiple representations of dose, including peak exposure or exposures above a certain level, could be another way to study the validity of exposure assessments. Statistically tests assessing the best fit of the different models could be used to study different measures of dose, too (24). Assessing exposures through personal interviews with workers in the most common physical jobs would have been too time-consuming (59), since this study included participants from the general population and thereby many different job types. In the future, when devices are accessible (60), objective measures of duration and intensity of strain in different job-types could be used to validate job exposure matrices as the Knee-Hip Matrix.

Validity of job exposure matrices

Job exposure matrices have potential biases, including the risk of misclassification of exposure (61). Job-titles were grouped in homologous exposure groups (HEGs) regarding physical exposures. However, the between-worker and within-worker variation in exposure increases the risk of misclassification of exposure in HEGs. As regards physical work, between-worker variation in exposure is based both on differences in anthropometrics and physical capacity and on variation in task-specific exposures due to the use or non-use of safety equipment and to how tools fit the individual. Also economic considerations influence between-worker variation, for instance physical exposure will vary among painters with fixed salary, as opposed to painters on piecework. Day-to-day variations in the individual's exposure regarding tasks, seasonal changes etc. are some of the sources of within-worker variation. To find a difference among exposure groups in studies like this, it is necessary that differences in exposure between groups are substantially larger than differences among workers within the groups (62). Gender differences in exposures in jobs with similar job-titles could cause between-worker variation (63), and the establishment of a gender-specific job exposure matrix addresses this problem (30). As noticed in Papers III and IV, it is assumed that the gender differences are irrelevant in this age-homogeneous cohort.

Standardization of exposure

Another possible bias in this study is the standardization of exposure. Twenty ton-years can be "earned" in only 10 years of heavy work or 40 years of less heavy work. The physiological effect could vary according to intensity (64), but is treated equally in our analyses. Though the use of a continuous measure has its advantages, the inclusion of both intensity and duration in one variable could lead to wrong conclusions about dose-response patterns (65). The lack of a linear dose-response relationship in our study could be explained by the use of a continuous exposure measure.

Timing of exposure

In life course epidemiology, models of sensitive periods are used to describe how the effect of exposures varies during life (25). There is no information in the literature about specific periods in life when physical exposures in working life are more deteriorating than others, but in future analyses it would be interesting to study the influence of the first 20 years of exposure on later physical function. Since 1990 improvements in working environment, ergonomic interventions etc. have been implemented in the western world, and physical exposures at work have declined in the last 40 years (66). Change in exposure over time is not taken into account in the Knee-Hip matrix and could be another bias in this study. However, I expect the effect of this potential bias to be small in this age-homogeneous cohort as discussed in Papers III and IV.

Choice of outcome

Since the aim of the study was to study early signs of musculoskeletal aging, objective measures were needed. When objective measures are used, bias regarding disease progression is avoided (24). If specific disorders, or surgery related to physical wear and tear (like hip replacement because of osteoarthritis), had been used as outcome measures, a selection bias would be introduced due to variation in the induction period (the time from exposure to when the disease evolves). However, as discussed in papers III and IV, this study contains a risk of reverse causation due to the "latent period", i.e. the time before the diagnosis of a specific disorder. Bias due to variation in the latent period of a disease is normally avoided when objective measures of physical function are used. However, since signs of early musculoskeletal aging are present for many years while participants are still working, exposures during this period could be influenced by the musculoskeletal aging process. Thereby 'reverse causality' is introduced, since the outcome might cause a change in exposure and thereby a change in cumulated exposure (24). Therefore, it has been suggested, when computing cumulative doses, to exclude exposure episodes which occur during the period of time when they could be influenced by pre-clinical disease or, in this case, “early signs of musculoskeletal aging”. Using only the first 20 years of exposure in the analyses could be a way to avoid this bias. Apparently, this potential “reverse causality” is a part of the healthy worker effect discussed below.

Study population

Muscle strength, physical function and thereby work ability decrease with age (15), but the question is, if the study population is too young to study the objective of this thesis. The outcome measures have been used among middle-aged Britons where differences among manual and non-manual workers were observed (47). I supposed that the cohorts were comparable, though the CAMB cohort was slightly older. However, large differences were observed between Britons and Danes, for instance regarding leisure-time physical activity. Among Britons, 48.1% men and 50.8% women reported no physical activity in leisure time in the last month, whereas only 11.7 and 7.6 % were inactive throughout the week in the CAMB cohort.

Discussion of results

The aim of this PhD thesis was to study the association between lifetime occupational physical activity and early signs of musculoskeletal aging. I have analyzed how a history of physical exposures in working life was associated with three objective measures of muscle strength and physical function. Associations between exposures and outcomes were not uniform (Table 6), and, in general, physical exposures in working life explained only a minor part of the variations in muscle strength and physical function in this age-group.

Table 6. Summary of results based on results in Table 4, Appendix 4. All exposures and outcomes.

	Men			**Women**		
Exposure	HGS	Chair rise	Balance	HGS	Chair rise	Balance
Ton-years	0	-	0	0	0	0
Stand-years	0	-	0	0	0	-
Kneel-years	+	0	0	0	0	-

0: no statistical significant association
-: a negative association between exposure and outcome
+: a positive association between exposure and outcome

Hand grip strength

There was no association between physical exposures throughout working life and HGS in midlife among women or men, except from exposure to kneeling, which was associated with slightly higher HGS in men. In Paper III, I have argued that the use of hand held tools among manual workers kneeling at work could explain the strengthening effect, since a task-specific strengthening in the upper limb has been shown earlier among power line technicians and waste collectors (17,18). Also Torgen et al. found higher HGS among manual workers using a retrospective exposure assessment comparable to our exposure assessment (19). Stenholm et al. found lower hand grip strength after 22 years of follow-up among people reporting physical work at baseline, but no history or cumulative amount of physical work was assessed in that study (22). In conclusion, we have seen no signs of a deteriorating effect of manual work on midlife HGS in this cohort, no training effect, either, but a possible task specific strengthening in men.

Chair rise

There was no consistency in the results concerning the two dynamic measures of physical function (Table 6). Chair rise, as a proxy measure of functional lower limb capacity, relies on muscle power in the lower limbs which is known to decrease due to musculoskeletal aging (8). A negative association between exposure and chair rise performance was found, and the association was statistically significant in men. The results are in line with a follow-up study by Leino-Arjas et al. finding increased risk of poor physical function in participants reporting high strain at baseline (23). Torgen et al. also found increased risk of poor physical function among middle-aged manual workers, however, their findings were strongest among women (19). The association between exposure and chair rise was not statistically significant in women in this study, but there was a sign of a similar association as that in men, and when self-reports of years of lifting were used as exposure, the association was statistically significant in women, too (Table 5). In conclusion, the results indicate a small but increased risk of earlier/faster musculoskeletal aging in exposed workers.

Balance performance

In this study there was no association between exposures and balance performance in men, but only in women. Very few studies have evaluated balance performance in middle-aged workers, but Punakallio suggested a training effect in workers with high demands of balance at work (67), which could also be explained by the “healthy worker effect” or selection into the job. However, a possible training effect might explain the gender differences seen in this study, though it is obvious from Table 4 that exposures at work explain almost none of the variation in balance in this cohort. In additional analyses, balance performance was grouped and analysed in logistic regression models (results not shown), but that did not change the direction or the strength of the associations. Balancing on one leg requires muscle strength, as does chair rise, but is, in addition, dependent on neurological and motor coordination, and therefore the central nervous system is important to balance performance (68). As mentioned above, it might be too early to detect differences in balance performance among men in this age group. Our hypothesis about a deteriorating effect of work on balance performance, and the power calculations in general, were based on results from the British birth cohort. Difference in balance performance among manual and non-manual workers in the British cohorts could be explained by their low participation in LTPA, compared to the participants in the CAMB cohort, since LTPA is positively associated with balance performance (47).

In conclusion, work explained very little of the variation in balance, but exposed women had poorer balance performance than un-exposed women. Similar associations were not seen in men, perhaps due to a training or maintaining effect in male jobs (67).

Inconsistency of results

Exposures

Using lifting as proxy measure of OPA was obvious, since lifting is the primary exposure in the definition of hard physical work (69). If lifting had been the single proxy measure of occupational physical activity, only an association between OPA and chair rise was seen and only in men. Kneeling and standing/walking were added to cover occupational physical activity at the best, but the direct connection between kneeling and upper limb strength is hypothetical, and perhaps only lifting should have been used as exposure measure in analyses of HGS. On the other hand, no information was available about exposures to the upper limb, since the JEM was established to study disorders in the lower limb. Repetitive work has been associated with degeneration, pain, and disorders in the upper limb (3,70), though additional analyses of self-reports of repetitive work showed no association with HGS in this cohort (analyses not shown). Access to information about exposures to the upper limb in Danish jobs from a job exposure matrix would allow us to study that association more thoroughly.

Outcomes

In this cohort, a history of physical exposures in working life had different effects on muscle strength in upper and lower limb (HGS vs. chair rise). HGS has been used as a proxy measure of general muscle strength, but, as Bohannon argues, HGS is only a valid proxy measure of upper limb muscle strength (71). That statement was confirmed in this study. Since most participants were still attached to the labour market, the possible strengthening effect of work on HGS might disappear, if the cohort was re-tested after retirement. Dynamic measures of physical function, like lower extremity muscle power, have been hypothesized as a more discriminant variable for understanding the relationships between functional limitations and resultant disability with aging (8), and the results regarding chair rise performance will be prominent in the conclusion of the thesis and in future studies in this cohort.

Gender differences

The effect of physical exposures varied among genders. One of the explanations mentioned in Papers III, and IV, is the gender segregation on the Danish Labour market. Men and women with high exposure levels have had different jobs, and jobs specifically assigned to women may have specific exposures (63). In this cohort, women with life time physical exposure had been working as cleaning and nursing assistants, whereas men had had a variety of skilled and unskilled jobs. This gender segregation in skilled jobs has changed since 1970, when participants in this study entered the labour market. In this cohort, 1.5% of the painters were women, whereas 33% of painters in a recent Danish cohort are women (personal communication, Thomas Heilskov Hansen, Dep. of Occupational Medicine Bispebjerg Hospital). Furthermore, women are often exposed to different musculoskeletal constraints than men, even when they have the same job titles (63). Another explanation, to the gender differences in the effect of physical work on physical function, is physiological differences between men and women. Due to their lower muscle strength, women reach their maximum capacity at lower physical demands than men do, and exert more physical effort doing the same tasks (72,73).

Explained variation in physical function by work

In the tables, R^2 (the proportion of the variation explained by the regression model in %) is reported, and the variation in physical performance explained by Model 1 varies from 2.2% to 13.1% in men and from 6.3 to 23.2% in women. Considering a multi-factorial model of health, including a complicated network of determinants of musculoskeletal health, this is not surprising (38). The unexplained variation in midlife physical function has led researchers to study the influence of early factors using the life course perspective. In life course studies exposures like childhood deprivation, socioeconomic status in childhood, youth and adult life and parents' education have been associated with physical function in middle age (74–76), but the effects of early exposures were attenuated in a recent review (77). Birth weight has been shown to be a predictor of HGS, probably because birth weight is a proxy of number of muscle fibres established by birth (78). Genetic predisposition also plays a role in the achievement of muscle strength and function, and, regarding grip strength, heritability is approximately 50% (79) – an "un-preventable" risk factor.

Strengths and limitations

Strengths

The collaboration with CAMB was a unique opportunity to study physical deterioration in a representative Danish cohort, and thereby to contribute to the scientific debate about the influence of work on physical function in middle-aged people. Concerning the few studies available in this area, studies like this are needed to increase knowledge in this field. The large sample size and recruitment from the general population were strengths of this study, and the mean HGS measured in this population corresponded well with recent findings in a Danish population-based study using a Jamar dynamometer (80). The thorough work of validating the question about physical exposures in working life is a strength of the study, too, and the results are in line with the results in the thorough review by Kwak et al. published recently (53), and has consequences to researchers in occupational epidemiology. The coding of almost 7500 job histories in the CAMB database as part of this study is another strength, and the codes are available for other researchers interested in job histories.

Limitations

The cross-sectional study design, and thereby the lack of baseline physical measurements, prevents us from establishing causal relations; however, the retrospective exposure assessment increases the strength of the study design.

Psychosocial factors at work and outside work are determinants of musculoskeletal health (3,38), since poor social support from colleagues, supervisors and management are risk factors for developing or reporting musculoskeletal problems and could influence the coping of musculoskeletal disorders (38). In this study, psychosocial factors have not been included, since information about psychosocial work environment had not been validated. However, I will argue that psychosocial factors are correlated to physical factors, and that the physical factors have the highest impact on variation in physical function.

Differential drop-out

Another limitation in this study was differential drop-out, since attrition analyses have shown lower educational level and higher cumulative amount of exposures among non-participants. If participants were different from non-participants concerning the association between exposure and outcome, selection bias arises (65). If, on the other hand, the association between exposure and outcome is similar among non-responders and non-participants, a higher increase in HGS would be expected and a lower chair rise performance if non-responders/non-participants were included, since attrition analyses showed that non-participants and non-responders had poorer educational level and, therefore, more exposure-years. From the CAMB questionnaire I have had access to self-reports of mobility (running 100 m and climbing stairs), and thereby the possibility of including non-participants in analyses of physical function. In logistic regression analyses an increasing risk of impairment is found in higher exposure groups especially regarding climbing stairs among men (results not shown). Furthermore, non-participating men performed poorer than participating men, indicating a differential attrition to the study among men.

The "healthy worker effect"

Another bias to be considered is the "healthy worker effect", a selection bias indicating that workers who are able to work are different from workers no longer attached to the labour market. Exposure was assigned to all responders to the questionnaire, also people currently outside the labour market, a way to decrease the "healthy worker effect". But, the healthy worker effect is still a possible bias in this study, since the healthy workers are among those most heavily exposed (have been able to "earn" many exposure-years). If focus had been on exposure to 1-30 ton-years, an almost linear dose-response curve was seen among men according to chair rise performance, Figure 6. Including exposures above 30 years changed the curve, maybe because the healthy workers were less “deteriorated”. It is not possible to assess the magnitude of the “healthy worker effect” except from stating that this study gives a broader picture of the association between work and physical function, since we included participants from the background population. Another way to interpret the results is to conclude that some male workers are able to cope with physical exposures for many years without being physically deteriorated.

Selection into the job

Selection into the job is another possible bias, since physical status and capacity in youth could affect the choice of education and future job (81). Including height as a confounder in the analyses is the only possible way to account for that in this study, since we have no other information about physical capacity in youth. Birth weight has been shown to be a predictor of HGS (78), but in additional analyses, inclusion of birth weight as a confounder did not change the associations (Paper III).

Statistical analyses

General linear models were applied to the dataset, since both exposure and outcome were measured in continuous variables. The assumptions of the linear regression models were tested and accepted, however, analyses categorizing exposure in 10 years intervals of exposure suggested a non-linear association between exposures and outcomes (results not shown). Based on this observation, and since the effect of physical exposures could be both strengthening and deteriorating, cubic spline regressions were suggested introduced in the statistical analyses after the study protocol was published. The figures of the associations question the supposed linear association between exposure and outcome, and a simple dose-response pattern was not found. One explanation to this could be the “healthy worker effect”, or the continuous exposure measurement as discussed above as part of non-differential misclassification bias.

Generalizability

This cohort is unique in its age-homogeneousness, and so generalizability is lower, since the labour market has changed during the last 20 years; for example, the prevalence of kneeling at work decreased in Denmark from 1990 to 2000 (82).

Conclusion

This study has shown that a history of hard physical work influences physical function though the influence is not consistent regarding different exposures and outcomes. Furthermore this study has suggested a change in view on physical deterioration as part of the musculoskeletal aging process and furthermore shown some of the limits in this research field regarding exposure assessment and attrition.

The introduction of a qualitative method like cognitive interviewing was beneficial to the study, and pre-tests of questionnaires in sub-groups are important and should be prioritized in future surveys. Both participants and experts were able to assess amount of “sitting at work”/sedentary work validly; however, assessment of physical exposures in working life were not valid in this cohort, probably due to a complicated question about lifetime occupational physical exposure.

The hypothesis about no association between physical exposures and HGS was confirmed for both women and men, except for one of three physical exposures: Men with exposure to kneeling had higher HGS compared to un-exposed men, indicating a training or maintaining effect. The hypothesis regarding lower physical function among exposed participants was confirmed for men, according to lower chair rise performance among exposed men. However, there was no association between physical exposures and balance performance in men, but a poorer balance performance among exposed women.

In general, exposures at work explained only a minor part of the variation in muscle strength and physical function in this cohort, and the associations appeared to be non-linear. Preventing decrease in lower limb muscle power among manual workers should be a priority in the future, and results from intervention studies as FINALE, aiming at reducing physical deterioration by physical training, will be interesting to follow (11).

Perspectives and future research

The combination of different theoretical perspectives on the association between work and health has been a challenge but has also been useful, and, in the following, the results will be evaluated from three different perspectives.

Occupational epidemiology and medicine

"Nedslidning"

The view of "nedslidning" as part of the aging process has been met with resistance among other occupational professionals. However, it is important to emphasize that the aim of the study has not been to discredit patients with musculoskeletal symptoms. On the contrary, the aim is to focus on the importance of an individual assessment of resources and demands regarding current work ability. But, of course, the aim has also been to focus on the influence of work, as one of the bricks in the large puzzle of musculoskeletal health. This thesis is an obvious inspiration to a qualitative study of physical deterioration in Denmark and to the perception of "nedslidning" among different health professionals and patients. In the background article (Appendix 1), I have described how the term "nedslidning" is unknown in other countries. While studying the review by Buckle and Wood (38), I realised that "nedslidning" could also be seen as inequality in musculoskeletal health, since it is primarily blue collar workers or workers with low or no education who show symptoms related to physical deterioration. The problems regarding inequality in health have been debated in Denmark recently, and this perspective on musculoskeletal health will be pursued in the future.

Physical exposures in Danish jobs

It is apparent from this study that few Danes have physical exposures, and, especially among women, only few percent were exposed to hard physical work. The labour market has changed through the last 40 years, and preventive efforts have succeeded in lowering the exposures. However, musculoskeletal diseases are still common as the cause of workers' compensation claims in Denmark (37% of all claims in 2011), and around 20% of claims are accepted, though many "ton-years" are needed to have a claim accepted. The conclusions of this study about occupational exposures and physical function emphasize the use of a multi-factorial model of health in occupational medicine.

General practice

Though there are relatively high prevalence rates for some work-related diseases in general practice, work has often little attention in consultations (83). My experience, from work in general practice, is that general practitioners often lack knowledge about the relationship between work and musculoskeletal disorders. Patients' view of the causal relationship between work and symptoms is often taken for granted. Based on the large variation in physical function in this cohort, it is obvious that many middle-aged patients with musculoskeletal symptoms and disorders need advice about their future work ability. General practitioners have to assess whether patients should be sick-listed or return to work regarding their symptoms and capacity. Many general practitioners use the "health balance", the balance between demands and resources (84), in that assessment. Regarding work ability, doctors could recommend adjustments in the job (in order to change the demands), or give advice about physical therapy or training (to increase the resources or capacity in the patient). However, knowledge in this field is needed in general practice. This study contributes with a description of the large variety in physical function among middle-aged Danes, and the low contribution of work as an explanation of this variation. In future studies in this cohort, the predictive value of simple physical tests will be evaluated, which could be useful to general practitioners, too. General practitioners' coping with patients with work-related musculoskeletal symptoms and their perception of the relationship between work and health would be interesting to study in qualitative studies.

Social and life course epidemiology

In life course epidemiology, occupational history has not had much focus, and occupation is often reduced to socioeconomic status or dichotomized in manual/non-manual workers. Studies of social gradients in musculoskeletal function have shown statistically significant associations between low social status and lower physical performance in the CAMB cohort (43) and in the British birth cohorts (47). The current social status is a proxy measure of many determinants and, therefore, perhaps a much stronger risk factor compared to exposures in working life, as this study has shown. However, it is obvious that though exposures in working life influence the aging process to a relatively small extent, it is important to consider different determinants of musculoskeletal health and aging in future studies – including exposures in working life. Discussions with social epidemiologists have been very useful in the conceptualization of this study, and classical occupational epidemiology can learn from new ways of describing relationships between risk factors and determinants of health. The introduction to the theories of causal diagrams in social epidemiology (85) has been challenging but inspiring regarding the understanding of the complicated relationship between determinants of musculoskeletal health and furthermore relevant to future studies.

Future articles in relation to the thesis

Through the work with this thesis the following research questions have been raised:

Regarding limitations in study design

Is there an association between a history of physical work and change in physical function over time?

Future follow-up studies in this cohort regarding measures of physical function are needed to answer this question.

Regarding differential participation bias

Is there an association between histories of physical work and self-reports of mobility? Are the results in line with results using objective measures as outcomes?

Regarding other measures of the aging process

What is the association between a history of physical work and a marker of inflammation?

Is a history of physical work associated with sickness absence in the last part of the working life? The answer to this question will include a future follow-up study in Danish registers.

Regarding the discrepancy between LTPA and OPA

Physical activity in leisure-time is important to physical function and should be considered in studies of physical performance. However, the relationship between OPA and LTPA is ambiguous. In future follow-up studies in this cohort the influence of LTPA and of changes in LTPA can be included in studies of physical function.

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Appendix 1

Article about work and health, in Danish

Arbejde – sundhed og sygdom

Tidsskrift for Forskning i Sygdom og Samfund

Nr. 16, 2012

Tidsskrift for Forskning i Sygdom og Samfund

Nr. 16: *Arbejde - sundhed og sygdom*

Peer review: Foretages af et tværvidenskabeligt panel bestående af bl.a. læger, antropologer, filosoffer, historikere, psykologer, politologer og sociologer.

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Aims and scopes

The Journal for Research in Sickness and Society is an interdisciplinary journal which has a theoretical background in medical anthropology. The aim and purpose of the journal is to promote and develop research in the borderland between the health sciences and the humanities/the social sciences. The goal of the journal is to function as a forum in which these disciplines may meet and inspire each other – epistemologically, methodologically and theoretically. The journal conveys the debate and theoretical development which takes place in the growing collaboration and research initiatives emerging from this borderland. The journal addresses all with an interest in research in sickness and society and especially health professionals working with education and/or research in interdisciplinary institutions.

Indhold

Originalartikel

Muskuloskeletal aldring, arbejdsevne og ”sundhedsbrøken”

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Artiklen udspringer af et forskningsprojekt om det fysisk krævende arbejdes indflydelse på aldringsprocessen. Fysisk aktivitet i fritiden giver mange helbredsfordele, mens fysisk aktivitet i arbejdet i højere grad sammenkædes med skadelige helbredseffekter, hvilket afspejles i debatten om nedslidning på arbejdsmarkedet. I artiklen gives en oversigt over den eksisterende viden om sammenhængen mellem fysisk krævende arbejde og fysisk funktionsevne. Dernæst beskrives, hvordan brugen af begrebet nedslidning er blevet brugt tidligere og hvordan det bruges aktuelt af både fagprofessionelle og lægfolk. Der argumenteres efterfølgende for, at nedslidning kan ses som et udtryk for tidlig muskuloskeletal aldring. Herefter præsenteres læseren for et ‘life course’ perspektiv på den muskuloskeletale aldringsproces, som tager hensyn til påvirkninger med betydning for aldringsprocessen gennem hele livet. Der rundes af med anbefalinger til både fremtidige studier og til fagprofessionelle, som arbejder med sammenhængen mellem fysisk krævende arbejde og fysisk funktionsevne.

Viden om den gavnlige effekt af fysisk aktivitet er stor og robust og har siden 1990'erne udløst anbefalinger til befolkningen om daglig fysisk aktivitet i fritiden (Centers for Disease Control and Prevention (CDC), 2011; Haskell, Lee, Pate, Powell, Blair, Franklin et al. 2007; Nusselder, Looman, Franco, Peeters, Slingerland & Mackenbach, 2008; Pate, Pratt, Blair, Haskell, Macera, Bouchard et al. 1995; Sundhedsstyrelsen, 2011b). Fysisk aktivitet kan bevare eller øge den fysiske funktionsevne eller endda genetablere den efter en længere sygdomsperiode (Angevaren, Aufdemkampe, Verhaar, Aleman & Vanhees, 2008; Mangani, Cesari, Russo, Onder, Maraldi, Zamboni et al. 2008; Rantanen, Guralnik, Sakari-Rantala, Leveille, Simonsick, Ling et al. 1999). Fysisk aktivitet dækker over alle former for bevægelse og i nyere studier anbefales det at inkludere de arbejdsrelaterede bidrag til fysisk aktivitet (Centers for Disease Control and Prevention (CDC), 2011), hvilket også er tilfældet i den aktuelle danske anbefaling (Sundhedsstyrelsen, 2011a). De sundhedsmæssige effekter af fysisk aktivitet på arbejdet er imidlertid ikke fuldstændigt belyst. Et nyere dansk studium har vist, at fysisk aktivitet i fritiden beskytter mod langtidssygefravær, mens fysisk aktivitet på arbejdet øger risikoen for sygefravær (Holtermann, Hansen, Burr, Sogaard & Sjogaard, 2011). Det er også vist, blandt andet i danske studier, at specifikke ergonomiske påvirkninger i arbejdet, som tunge løft og skub og træk, som er en del af den fysiske aktivitet, øger risikoen for muskel- og skeletbesvær og sygefravær (Hansson & Jensen, 2004; Lund, Labriola, Christensen, Bultmann & Villadsen, 2006). En af årsagerne til at fysisk aktivitet i arbejdet både kan have gavnlige og skadelige effekter er formodentlig at 'fysisk aktivitet i arbejdet' er et meget bredt begreb, som kan dække over store forskelle i aktivitet; fra arbejde som foregår stående eller gående uden yderligere fysiske krav, til hårdt fysisk arbejde med tunge løft. Nygård anfører, at det hårde fysiske arbejde tidligere blev antaget at øge muskelstyrken (Nygard, Luopajarvi, Cedercreutz & Ilmarinen, 1987), men siden 1980'erne har undersøgelser vist tegn på, at arbejdere med mange fysiske krav *ikke* har bedre kondition eller større muskelstyrke end dem med stillesiddende arbejde (Nygard et al., 1987; Nygard, Luopajarvi, Suurnakki & Ilmarinen, 1988). Der kan dog være specifikke muskelgrupper, hvor der kan opnås en træningseffekt (Schibye, Hansen, Sogaard & Christensen, 2001), men generelt indeholder det fysisk krævende arbejde ikke den variation og intensitet, som kræves for at opnå en træningseffekt (Nygard et al., 1988).

For at vurdere fysiske påvirkningers betydning for helbredet fokuserer arbejdsmedicinen på påvirkningens intensitet eller styrke og varigheden af påvirkningen (van der Beek & Frings-Dresen, 1998). Flere studier har vist at varigheden af de fysiske påvirkninger har betydning for udvikling af kroniske bevægeapparatsproblemer og nedsat funktionsevne (Leino-Arjas, Solovieva, Riihimaki, Kirjonen & Telama, 2004; Savinainen, Nygard & Ilmarinen, 2004). De Zwart et al anfører, at årsagen til, at fysiske påvirkninger i arbejdet kan få længerevarende indvirkning på den fysiske funktionsevne, er en proces hvor akutte forandringer kan udvikle sig til kroniske forandringer, hvis der ikke er den nødvendige tid til restitution (de Zwart, Frings-Dresen & van Dijk, 1995). Disse resultater henleder endvidere opmærksomheden på det vigtige i at have et tidsperspektiv på studiet af det fysisk krævende arbejdes betydning for helbredet. Denne opfattelse af et slid på kroppen efter vedvarende påvirkninger er fysiologisk forklaret, men det har ikke gennem forskning været muligt at finde grænseværdier for påvirkningernes intensitet/styrke eller varighed før de har negativ indvirkning på helbredet (Sigsgaard, Bonde & Rasmussen, 2010). Vurdering af årsagssammenhænge vanskeliggøres desuden af, at muskel- og skeletbesvær har høj forekomst i baggrundsbefolkningen, hvor 58 % har oplevet gener i løbet af en 14-dages periode (Kjøller, Juul & Kamper-Jørgensen, 2007). Samtidig er stillesiddende arbejde ved computer også relateret til forekomst af muskel- og skeletbesvær (Andersen, Fallentin, Thomsen & Mikkelsen, 2011) dog uden at den årsagsmæssige sammenhæng er fuldt belyst. Mange studier viser også at andre forhold i arbejdet, som for eksempel det psykosociale arbejdsmiljø, har betydning for forekomsten af muskel- og skeletbesvær (Wahlstrom, 2005).

På trods af forebyggelsestiltag på arbejdsmarkedet, og selv om færre rapporterer fysiske krav i arbejdet i den danske overvågning af arbejdsmiljøet (NAK, Den Nationale Arbejdsmiljø Kohorte, (Det Nationale Forskningscenter for Arbejdsmiljø, 2011)), er der fortsat jobs og brancher med fysiske belastninger i Danmark, hvor hyppigheden af langtidssygemeldinger og udstødning fra arbejdsmarkedet er høj (Vilhelmsen & Baadsgaard, 2011) (avisen.dk, 2011a). Diskussionen om arbejdets betydning for helbredet og for nedslidning på arbejdsmarkedet er derfor fortsat relevant, og hensigten med aktuelle artikel er at give en oversigt over brugen af nedslidningsbegrebet i relation til det fysiske arbejdes betydning for helbredet. Først undersøges brugen af begrebet nedslidning historisk, hvilket fører over i en beskrivelse af den nutidige anvendelse af begrebet blandt professionelle og i den offentlige debat, f.eks. i forbindelse med lancering af efterlønsreformen i 2011. Herefter følger en introduktion til 'life course' perspektivet på aldringsprocessen og forfatternes bud på alternative modeller til studiet af arbejdets betydning for den fysiske funktionsevne. Artiklen tager udgangspunkt i den baggrundsviden om det fysisk krævende arbejdes betydning for helbredet, som er indsamlet i forbindelse med Ph.d.-projektet 'Arbejdets betydning for aldringsprocessen. Giver fysisk krævende arbejde tegn på tidlig aldring hos midaldrende danskere?'. Litteratursøgninger om relationen mellem fysisk aktivitet i arbejdet og midaldrendes fysiske funktionsevne er foretaget i internationale artikeldatabaser i 2010 og 2011. Til den aktuelle artikel er søgningen suppleret med dansksprogede søgninger på litteratur om nedslidningsbegrebet, og der er fundet lægefaglig og samfundsfaglig litteratur samt forskellige publikationer, hvor begrebet bruges og diskuteres. Det har imidlertid ikke været muligt at finde videnskabelig litteratur, hvor begrebet og brugen af det behandles mere grundigt, hvorfor artiklens referencer om nedslidning er ret sparsomme. I stedet har adgang til Infomedias søgebase suppleret med aktuelle indlæg i den offentlige debat. For at kunne belyse udviklingen i opfattelsen af betydningen af det fysisk krævende arbejde og brugen af nedslidningsbegrebet strækker litteratursøgningen sig tilbage til 1980'erne, både for international og dansk litteraturs vedkommende. Forfatterne er forankret i almen medicin, og første forfatter har desuden erfaring fra arbejde i arbejdsmedicin, mens anden forfatter også er antropolog. I denne artikel tages hovedsagelig en almenmedicinsk og arbejdsmedicinsk position.

Begrebet nedslidning

Nedslidning er et begreb som først forekommer i nyere dansk sprogbrug (http://ordnet.dk/ods, 0108 2011; vs. http://ordnet.dk/ddo/forside, 0108 2011). Fra slutningen af 1980'erne var der fra arbejdsmedicinsk side fokus på patienter med stor hyppighed af muskel- og skeletbesvær f.eks. blandt syersker med ensidigt gentaget arbejde, hvor man så en klinisk sammenhæng mellem belastning og efterfølgende gener (Andersen & Gaardboe, 1993). Den lokaliserede muskuloskeletale nedslidning blev beskrevet, og der dannedes et billede af en tilstand, hvor symptomerne genkendtes hos flere i samme erhverv og i andre erhverv med lignede ensformigt fysisk krævende arbejde som slagteriarbejdere og filet-skærere på fiskefabrikker (Jensen, Schibye, Sogaard, Simonsen & Sjogaard, 1993). Begrebet nedslidning dækkede i arbejdsmedicinsk kontekst således både over processen og den efterfølgende tilstand. De symptomer eller kroniske skader, som opstår efter ensidigt gentaget arbejde i en årrække, bliver nu anerkendt som arbejdsbetingede og har fået mere eller mindre specifikke diagnoser tilknyttet som f.eks. nakkeskulder-lidelser, ryglidelser og overbelastningstilstande i arme eller hænder (Sigsgaard et al., 2010). Nedslidning findes ikke i det danske klassifikationssystem over medicinske diagnoser (Sundhedsstyrelsen, 2010), og derfor kan læger ikke anvende betegnelsen nedslidning, hvor der er brug for en medicinsk diagnose. Betegnelsen nedslidning bruges trods dette i mange sammenhænge og af mange forskellige aktører, hvilket vi vil belyse i de følgende afsnit. Et tidligt eksempel på at nedslidning er brugt som en betegnelse for både en tilstand og en proces, ses hos Petterson og Nielsen:

> "Vi mener, at det kroniske belastningssyndrom og nedslidning er udtryk for den samme problematik og dækker over en række næsten identiske sygdomsprocesser, hvor det kroniske belastningssyndrom er den varige ikke reversible effekt af nedslidningsprocessen." (Petersson & Nielsen, 1982).

Brugen af begrebet nedslidning, som en beskrivelse af en række symptomer eller en diagnose, ses både i kommunikation mellem professionelle og med lægfolk. Et tidligt eksempel på dette er Haakon Lærum, der i et notat fra Sundhedskomiteen i 1999 skelner mellem almen- og muskelnedslidning og tilstandene kategoriseres sammen med en række andre sygdomme 'i sygdomspanoramaets bløde ende':

> "Diagnoserne er i flæng: almen nedslidning, muskelnedslidning, fibromyalgi, kronisk belastningssyndrom, kronisk træthedssyndrom, diverse somatiserings- og smertetilstande." (Lærum, 1999)

Et nyere eksempel på en bred definition af nedslidningsbegrebet stammer fra Det Nationale Råd for Folkesundheds beretning fra 2005:

> "Begrebet nedslidning omfatter en række symptomer som påvirker det daglige funktionsniveau. F.eks. søvnproblemer, træthed, uoverkommelighedsfølelse, nedsat selvværd, smerter i bevægeapparatet, hoste og åndenød" (Det Nationale Råd for Folkesundhed, 2007).

En nylig rapport fra Århus Kommune beskæftiger sig grundigt med den arbejdsrelaterede nedslidning i Danmark i relation til et projekt om den intelligente arbejdsbeklædning (Schmidt, Salimi & Karlsen, 2010a; Schmidt, Salimi & Karlsen, 2010b). I et appendiks diskuteres den manglende definition på nedslidningsbegrebet meget relevant, og rapportens forfattere vælger at bruge en meget bred definition på nedslidning:

> "en proces hvor én eller flere længerevarende udefrakommende påvirkninger medfører én eller flere bestemte former for lidelser" (Schmidt et al., 2010a).

Her bruges nedslidning således om processen, der fører til en række muskuloskeletale symptomer, og i rapporten betegnes de skelet- og muskelsygdomme, som opstår pga. længerevarende udefrakommende påvirkninger som 'nedslidningssygdomme'.

Nedslidning som begreb ses også brugt, når arbejdsmedicinske læger kommunikerer til lægfolk i avisartikler (avisen.dk, 2011a) om relationen mellem varige arbejdspåvirkninger og helbred. Det samme er tilfældet i et uddrag af erhvervssygdomslisten i Den Store Danske Encyklopædi, som er skrevet af en arbejdsmedicinsk speciallæge. Her bruges nedslidning om processen, der fører til arbejdsbetingede bevægeapparatssymptomer (Den Store Danske Encyklopædi, 2011). I den egentlige erhvervssygdomsfortegnelse, som beskriver hvilke sygdomme, der anses som arbejdsbetingede, bruges begrebet nedslidning ikke (Retsinformation, 2011). I stedet beskrives de specifikke belastninger/ergonomiske påvirkninger, som giver anledning til bevægeapparatssygdomme og i kommentarer til listen bruges vendingen 'slidt ned' om den proces, der har ført til slidgigtssygdomme (Arbejdsskadestyrelsen, 2006).

Begrebet nedslidning bliver således fortsat brugt af mange fagprofessionelle i relation til forskellige lidelser, påvirkninger og situationer. Nedslidningsbegrebet bruges ofte i den offentlige debat. Et eksempel på dette var f.eks. i forbindelse med lancering af en efterlønsreform i Danmark i det tidlige forår 2011 (Læsernes Stemme, 2011; Larsen, 2011; Reiermann, 2011), hvor argumentet for at beholde efterlønnen i sin nuværende form netop var hensynet til 'de nedslidte'. I den debat er det både politikere og borgere, som bruger begrebet i flæng, både om processen og om den efterfølgende tilstand.

Det er imidlertid interessant, at man i lande som vi normalt sammenligner os med, ikke kender til et tilsvarende begreb. I stedet ser man på bevægeapparatsymptomer og fald i arbejds- og funktionsevne, som konsekvens af disse symptomer (Alavinia, de Boer, van Duivenbooden, Frings-Dresen & Burdorf, 2009; Holmstrom & Engholm, 2003; Ilmarinen, Tuomi & Klockars, 1997). I engelsksproget videnskabelig litteratur oversætter danske forskere nedslidning til 'physical deterioration' (Holtermann, Jorgensen, Gram, Christensen, Faber, Overgaard et al. 2010). Både 'deterioration' og nedslidning kan anskues som metaforer for den fysiologiske proces. Begrebet nedslidning er sammensat af 'ned', en retningsmetafor, og 'slid' for en proces hvor noget slides, og tilsammen indikerer nedslidning en irreversibel proces i en nedadgående/negativ retning. På sammen måde betegner ´deterioration´ en forringelse eller forværring af en tilstand som både kan være relateret til helbredet eller f.eks. til forholdet mellem to nationer (Hornby, 2010).

Begrebet nedslidning kan sammenlignet med det engelske begreb fremstå værdiladet og mindre neutralt, idet der hos de fleste en tæt association til dårlige fysiske arbejdsforhold som årsag til sliddet, hvilket ikke er tilfældet for den engelske betegnelse som bruges i forskellige sammenhænge. Vi har ikke i relation til ph.d.-studiet lavet egentlige sproglige analyser af begrebet, men har mødt denne værdiladede opfattelse af nedslidningsbegrebet gennem interviews med midaldrende danskere om deres arbejdsliv. Disse samtaler har ført til en undren over brugen af begrebet og dets metaforiske status. Artiklen kan således også ses som et oplæg til en undersøgelse af forståelsen og anvendelsen af nedslidningsbegrebet i Danmark. Det vil være relevant da nedslidningsbegrebet fortsat bruges i mange forskellige sammenhænge, hvilket rapporten fra Århus Kommune i 2010 er et eksempel på. I delrapport to bruges ord som 'nedslidningstruede', 'nedslidningskilder', 'nedslidningsrisici', og der beskrives 'manglende nedslidningsopmærksomhed blandt nogle af de ansatte'(Schmidt et al., 2010b). Arbejderbevægelsens erhvervsråd taler om 'nedslidningsbrancher'(Vilhelmsen & Baadsgaard, 2011), og i opslag til forskning inden for arbejdsmiljø gennem Arbejdsmiljøforskningsfonden bruges begrebet nedslidning også hyppigt (Arbejdstilsynet, 2011).

Der er således ikke enighed om en definition eller en afgrænsning af nedslidningsbegrebet, men begrebet bruges fortsat til at beskrive en proces og en tilstand med en række symptomer af almen karakter og fra bevægeapparatet og derfor også som form for diagnose.

Nedslidning som diagnose

Diagnoser kan betragtes som sociale konstruktioner og "knytter an til herskende forståelser af, hvad sundhed og sygdom er i en bestemt periode" (Mik-Meyer & Johansen, 2009). Mik-Meyer anfører, at diagnoser er magtfulde, fordi de giver patienten mulighed for at beskrive lidelsen til omgivelserne og adgang til modtagelse af f.eks. økonomisk kompensation. Da nedslidning ikke eksisterer i den medicinske klassifikation af sygdomme er brugen af nedslidning som en diagnose problematisk, da begrebet er diffust defineret, og begrebet nedslidning knyttes til mange forskellige processer, tilstande og situationer. Fra lægeligt perspektiv passer nedslidning ikke ind i den bio-medicinske sygdomsmodel, idet nedslidning ikke kan klassificeres som en 'disease', altså en sygdom i biologisk forstand, hvor der kræves biologisk information for at kunne stille en diagnose (Gannik & Guassora, 2011). Nedslidning er i højere grad en subjektiv beskrivelse af en tilstand, og passer dermed i højere grad ind i 'illness'-begrebet (Kleinman, Eisenberg & Good, 1978).

En anden årsag til at nedslidning fortsat bruges af både lægfolk og fagprofessionelle i beskrivelsen af forskellige bevægeapparatssymptomer er formodentlig et ønske om at finde en årsag til generne. Dette kan måske ses i relation til en generel tendens i samfundet til 'medikalisering', dvs. at "større og større dele af det normale menneskelivs reaktioner og livsfaser defineres ud fra en medicinsk forståelsesramme" (Hollnagel & Malterud, 2002). Der er et stigende krav fra befolkningen om at finde årsager til gener og sygdomme, og når begrebet nedslidning bruges om almene symptomer og symptomer fra bevægeapparatet kan nedslidning også forstås indenfor rammen af det situationelle sygdomsbegreb. Her betragtes en sygdom som en tilstand, der er resultatet af forholdet 'person-situation', og hvor også sociale processer har en indflydelse på hvordan tilstanden håndteres (Gannik & Guassora, 2011).

I stedet for at arbejde videre med et meget diffust begreb som nedslidning, som det både er meget vanskeligt at kategorisere eller klassificere mere præcist og som ofte alene knyttes til arbejdet, advokerer vi i det følgende for at nedslidning i stedet anskues som en del af den muskuloskeletale aldringsproces.

Nedslidning set som en del af aldringsprocessen

Ifølge Verbrugge og Jette er aldringsprocessen individuel og har forskellig hastighed, og derfor oplever nogen en accelereret aldring, eller en tidligere aldring end andre (Verbrugge & Jette, 1994). Aldringsprocessen er en dynamisk proces, således at man ved mulighed for restitution eller træning kan øge den fysiske kapacitet (Kenny, Yardley, Martineau & Jay, 2008). I den gerontologiske forskning studerer man 'tegn på tidlig aldring', som f.eks. kan være træthed, kronisk inflammation eller nedsat fysisk funktionsevne (Avlund, 2009; Nilsson, Engberg, Nilsson, Karlsmose & Lauritzen, 2003), og som er prædiktorer for morbiditet og mortalitet. Hvis nedslidning ses som en forringelse af fysiske ressourcer i forhold til det, der ses hos jævnaldrende, kan 'tidlig muskuloskeletal aldring' betragtes som synonym for nedslidning, altså en accelereret aldringsproces, der giver anledning til en generel nedsat fysisk funktionsevne sammenlignet med jævnaldrende. Med udgangspunkt i teorier om aldringsprocessen kommer modellen for tidlig muskuloskeletal aldring til at inkludere mange forskellige påvirkninger og tidsmæssige aspekter. Der har i gerontologisk forskning i de senere år været fokus på, at påvirkninger gennem hele livsforløbet er af betydning for aldringsprocessen og dette forskningsperspektiv har fået betegnelsen 'life course' perspektivet.

'Life course' perspektivet

Det var i studiet af hjertekarsygdomme, at man først blev opmærksom på, at det ikke kun var risikofaktorer i voksenlivet som f.eks. blodtryksforhøjelse og forhøjet kolesterolniveau i blodet, der havde betydning for udvikling af hjertekarsygdom i voksenlivet. Forskning gennem 1970'erne viste, at det ikke kun var overflod, som var årsag til livsstilssygdomme, men at deprivation tidligere i livet også havde en betydning. Den norske almenmediciner Anders Forsdahl, blev opmærksom på at forskelle i livsstil ikke udelukkende kunne forklare den store forskel i dødelighed pga. hjertekarsygdomme, han så i Finmarken (Forsdahl, 1977). I stedet fandt han en sammenhæng med høj børnedødelighed i samme befolkningsgruppe og argumenterede for, at de børn, der overlevede en barndom præget af underernæring havde en livslang sårbarhed over for livsstilssygdomme (Forsdahl, 1978) Hans teori var baseret på en tankegang om akkumulering af påvirkninger gennem livet, mens andre inden for samme forskningsfelt har fokuseret på påvirkninger i kritiske perioder, blandt andre David Barker, der har givet navn til 'Barker hypotesen', som beskriver hvordan underernæring i fosterlivet ændrer kroppens metabolisme, som fører til øget risiko for hjertekarsygdomme i voksenlivet (Barker, 1997). Forskning indenfor andre kroniske sygdomme har siden ligeledes påvist en sammenhæng mellem fysiske forhold i fosterliv og barndom og senere helbredsproblemer og kroniske sygdomme (Kuh & Ben-Shlomo, 2004).

En af de underliggende biologiske teorier, der beskriver hvordan akkumulering af påvirkninger gennem livsforløbet får betydning, er teorien om 'allostatic load', som beskriver en kumulativ biologisk byrde, som øges når kroppen forsøger at tilpasse sig livets påvirkninger. Allostatiske systemer er en vigtig del af kroppens naturlige reaktion på forskellige stimuli, f.eks. pulsens øgning, når vi udfører et fysisk krævende arbejde eller hjernens reaktion på en angstprovokerende oplevelse medieret af forskellige hormoner (McEwen, 2000). Hvis der er ubalance i systemerne og manglende mulighed for restitution, kan der ifølge teorien opstå et 'slid' og dette 'slid', betegnes 'allostatic load'. Allostatic load måles vha. forskellige biologiske parametre, og et højt allostatisk load har i mange studier vist at være en prædiktor for tidlig død og fald i fysisk funktionsevne (Karlamangla, Singer, McEwen, Rowe & Seeman, 2002; Seeman, McEwen, Rowe & Singer, 2001). Denne teori er i overensstemmelse med den arbejdsmedicinsk baserede teori om manglende tid til restitution som årsag til kroniske gener af det fysisk krævende arbejde, som vi præsenterede i begyndelsen af artiklen(de Zwart et al., 1995), hvilket viser at man inden for mange forskellige forskningsretninger anskuer aldringsprocessen på samme overordnede måde.

Der er kommet fokus på socioøkonomiske forholds betydning for sygdom og sundhed gennem de seneste 40 år (Iversen, Kristensen, Holstein & Due, 2003; Seeman & Crimmins, 2001). Denne brede tilgang til sygdomsbegrebet er velkendt i Danmark, hvor den bio-psyko-sociale sygdomsmodel er en af de fremherskende sygdomsmodeller (Gannik & Guassora, 2011). Den bio-psyko-sociale sygdomsmodel ser sygdom som "et produkt at de dynamiske vekselvirkninger mellem et menneskes biologiske, psykologiske og sociale omstændigheder" (Holstein, Iversen & Kristensen, 1997). Selve modellen for aldringsprocessen er set med et 'life course' perspektiv parallel med den bio-psyko-sociale sygdomsmodel, hvor tidsperspektivet tilføjer en ny dimension.

Mange forskellige forskningsområder bruger nu 'life course' perspektivet, og ifølge Kuh et al. arbejdes der på at finde en model, som beskriver, hvordan den aldrende menneskelige organisme er resultatet af indre og ydre påvirkninger gennem livet (Kuh, Ben-Shlomo, Lynch, Hallqvist & Power, 2003). Forfatterne lægger desuden vægt på at aldringsprocessen er afhængig af det individuelle respons på påvirkningerne.

Set fra et arbejds- og almenmedicinsk synspunkt er dette perspektiv på aldringsprocessen derfor meget interessant både i forhold til det kliniske arbejde og for forskningen inden for området.

'Life course' perspektiv med fokus på arbejdet

Når man studerer tidlig muskuloskeletal aldring og deraf følgende nedsat fysisk funktionsevne hos midaldrende, og ønsker at vurdere årsagssammenhænge, er det i forlængelse af ovenstående nødvendigt at have et bredere tidsperspektiv på relevante faktorers betydning for aldringsprocessen. Studier af midaldrendes funktionsevne i britiske kohorter viser for eksempel, at både forhold i fostertilstanden, tidlig barndom, ungdom og voksenliv har betydning for den fysiske funktionsevne hos midaldrende (Kuh, Bassey, Hardy, Aihie, Wadsworth & Cooper, 2002; Kuh, Hardy, Butterworth, Okell, Richards, Wadsworth et al. 2006).

I gerontologiske 'life course' studier af den fysiske aldringsproces er arbejdet ofte reduceret til en dikotom parameter: 'manual/non-manual' eller 'blue/white collar' baseret på beskæftigelsen som voksen, som også er en indikator for social status (Kuh, Hardy, Butterworth, Okell, Wadsworth, Cooper et al. 2006). Set med et arbejdsmedicinsk perspektiv er denne opdeling meget generel og giver anledning til bias, da den ikke tager hensyn til individuelle forskelle i arbejdsmæssige påvirkninger set over et livsforløb. Da de fleste midaldrende danskere (50-60-årige), har været på arbejdsmarkedet i 30-45 år, og da det er kendt at fysiske krav i arbejdet har betydning for aldringsprocessen, bør individuelle påvirkninger i arbejdslivet have en større plads i 'life course' studierne.

Arbejdsmedicinsk tankegang kan derfor supplere disse studier, og samtidig kan 'life course' perspektivet bidrage med et bredere syn på sammenhænge mellem arbejde og helbred i arbejdsmedicinsk forskning (Granville & Evandrou, 2010).

Derfor introduceres i det aktuelle ph.d.-studium et 'life course' perspektiv på aldringsprocessen med fokus på arbejdets betydning. Vi benytter i den epidemiologiske del af dette Ph.d.-studium en vurdering af påvirkningers intensitet/styrke og varighed (en eksponeringsvurdering), hvor alle ansættelser og dermed påvirkninger gennem arbejdslivet anses som betydningsfulde for aldringsprocessen, og hvor eksponeringen i de forskellige ansættelser akkumuleres og giver større risiko for senere påvirkning af aldringsprocessen. Dette er parallelt til tankegangen bag den arbejdsanamnese, som man indhenter i den kliniske arbejdsmedicin til vurdering af årsagssammenhænge og efterfølgende rådgivning af patienter (Sigsgaard et al., 2010).

Denne tankegang med akkumulering af påvirkninger over tid har været brugt i nogle nyere studier, hvor det er vist at en stor kumuleret fysisk arbejdsbelastning gennem arbejdslivet mindsker funktionsevnen i alderdommen (Cassou, Derriennic, Iwatsubo & Amphoux, 1992; Li, Wu & Wen, 2000). I et italiensk kohorte studie havde ældre personer med et fysisk krævende arbejdsliv svagere håndgrebsstyrke end jævnaldrende uden tidligere fysisk krævende arbejde (Russo, Onder, Cesari, Zamboni, Barillaro, Capoluongo et al. 2006) uden at dette kunne forklares af andre faktorer. I disse studier har man summeret de fysiske påvirkninger i arbejdet gennem hele arbejdslivet vha. oplysninger fra interviews, men studierne er retrospektive og deltagerne er ældre mennesker, hvorfor der kan være usikkerhed i eksponeringsvurderingen. Samtidig er der måske andre faktorer som kan forklare forskelle i funktionsevne hos ældre, hvis man bruger 'life course' perspektivet på aldringsprocessen. Det er imidlertid sjældent muligt at tage hensyn til forhold helt tilbage fra fostertilstanden, som der lægges op til i epidemiologiske studier med 'life course' perspektiv, da det kræver at befolkningsgrupper følges over længere tid. Sådanne studier er gode til at følge den langsomme aldringsproces, men de er meget tidskrævende og omkostningstunge (Kuh & Ben-Shlomo, 2004).

Derfor er man i hvert enkelt studium med 'life course' perspektiv nødt til at vurdere hvilke faktorer, man vil lægge vægt på i analysen af påvirkningers betydning for sygdomsudvikling og hvad der praktisk kan lade sig gøre. Nogle af de andre faktorer som har stor betydning for den midaldrendes funktionsevne, er livsstilsfaktorer og sociale faktorer, som tidligere beskrevet. Hvis vi kortvarigt vender tilbage til nedslidningsbegrebet og den danske kontekst er der fra myndighedernes side også opmærksomhed på at andre faktorer end arbejdet har betydning for nedslidningsprocessen:

> ”Disse symptomer (som er indeholdt i nedslidningsbegrebet, AM) tilskrives arbejdsmiljøet, men symptomerne kan også forklares ved en generel, uhensigtsmæssig livsstil. (….) De personer, der kommer først på arbejdsmarkedet, er samtidig personer med kort eller slet ingen uddannelse. Det er sandsynligt, at det, vi kalder nedslidning på arbejdspladsen, i højere grad skyldes disse personers livsstil - selvvalgt eller ej.” (Det Nationale Råd for Folkesundhed, 2007)

En undersøgelse fra Det Nationale Forskningscenter for Arbejdsmiljø viste i 2009, at rengøringsassistenters helbred var præget af dårlig livsstil og risikofaktorer for kroniske sygdomme (Jorgensen, Rasmussen, Carneiro, Flyvholm, Olesen, Ekner et al. 2011). Det betyder, at de også pga. deres livsstil kan få problemer med at klare de fysiske krav i arbejdet og altså ikke blot pga. kravene i sig selv. På de danske arbejdspladser er der en øget opmærksomhed på livsstilens betydning for arbejdsevnen (avisen.dk, 2011b), og det vil i de kommende år formodentlig komme endnu mere i fokus qua den demografiske udvikling, hvor der bliver behov for at fastholde så mange som muligt på arbejdsmarkedet (Ilmarinen, 2001).

Konsekvenser af brugen af ’life course’ perspektivet på tidlig muskuloskeletal aldring i forhold til fremtidig forskning og klinisk arbejde

Som arbejdsmedicinsk epidemiologisk forsker med forankring i almenmedicin er det interessant at studere andre fagområders brug af ’life course’ perspektivet på aldringsprocessen. Samtidig ses også en mulighed for at den arbejdsmedicinske metode med indsamling af en individuel arbejdsanamnese kan supplere andre faggruppers studier af aldringsprocessen. Fordelen ved en kombination af teoretiske tilgange til studier af arbejdets betydning for aldringsprocessen, er et bredere perspektiv på sygdom og sygdomsårsager. I artiklen er forskellige teorier om andre livsforholds betydning for sygdomsudvikling og aldringsproces præsenteret, og på den baggrund virker en ensidig fokusering på arbejdet som primær årsag til nedsat fysisk funktionsevne hos midaldrende som reduktionistisk.

Brugen af begrebet nedslidning er efter vores mening for unuanceret både når det bruges på samfundsplan og på individuelt plan og bør afløses af et fokus på sammenhængen mellem alder og arbejdsevne/arbejdskapacitet. Den fysiske funktionsevne falder med alderen (Ilmarinen, 2001; Kenny et al., 2008), og der er fortsat jobs på det danske arbejdsmarked, som indeholder større krav til fysikken, end de fleste midaldrende kan honorere. Arbejdsevnen falder også jævnt med alderen, bl.a. pga. den faldende funktionsevne (Costa & Sartori, 2007; Tuomi, Ilmarinen, Klockars, Nygard, Seitsamo, Huuhtanen et al. 1997), og ældre på arbejdsmarkedet har mange forskellige problemer, der skal tages hånd om (Granville & Evandrou, 2010; Payne & Doyal, 2010). Fleksible ordninger for midaldrende kan sikre fastholdelsen på arbejdsmarkedet (Chan, Tan & Koh, 2000). Det gælder især ansatte i håndværksmæssige fag, blandt rengøringsarbejdere og andre brancher med høje fysiske krav (Vilhelmsen & Baadsgaard, 2011). Balancen mellem ressourcer og belastninger, som er kendt som 'sundhedsbrøken' inden for almen medicin (Hollnagel & Malterud, 2002), bør tænkes ind i den sundhedsprofessionelles møde med den midaldrende patient og muligheder for at øge ressourcer og individuel tilpasning af f.eks. fysiske krav i arbejdet bør vurderes i hvert enkelt tilfælde. Befolkningens sociale forhold og livsstil er imidlertid også vigtig for den enkeltes evne til at udfylde en plads på arbejdsmarkedet. Det betyder, at vi opnår et meget langsigtet perspektiv på muligheden for forebyggelse af arbejdsbetinget tidlig muskuloskeletal aldring – tidligere kendt som nedslidning.

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Abstracts in English

Musculoskeletal aging, work ability, and 'health resource/risk balance'

Anne Møller & Susanne Rewentlow

Physical activity in leisure-time is recommended by authorities as healthy while physical activity at work is often considered to be harmful to your health. In Denmark the term 'nedslidning' is used to describe the gradual physical deterioration due to exposures in the work environment. This article presents a review of the literature about physical work and health, and the historical and present use of the term 'nedslidning' is described. Instead of using the not vey specific term 'nedslidning', the article suggests that the process of deterioration is seen as part of the musculoskeletal ageing process. The reader is presented to a 'life course perspective' on the aging process and to a 'life course perspective' on the relationship between the physical activity in work life and the following physical function in midlife. The paper concludes with a recommendation of the use of these perspectives in future occupational research and in daily life, where professionals are working with the relationship between work environment and health.

Appendix 2

Question 32 in Danish from the CAMB questionnaire and an English translation

32. Når du ser tilbage på hele dit arbejdsliv:

(Du må gerne svare i mere end én kategori)

a) Hvor mange år af dit arbejdsliv har du haft mest stillesiddende arbejde, som ikke kræver fysisk anstrengelse?

b) Hvor mange år af dit arbejdsliv har du haft mest stående eller gående arbejde, som ikke kræver fysisk anstrengelse?

c) Hvor mange år af dit arbejdsliv har du haft mest stående eller gående arbejde med en del løfte- eller bærearbejde?

d) Hvor mange år af dit arbejdsliv har du haft mest tungt eller hurtigt arbejde, som er fysisk anstrengende?

32. Looking back on your entire working life:

(You may answer in more than one category)

a) For how many years of your working life have you had mostly sedentary work without physical strain?

b) For how many years of your working life have you had mostly standing or walking work without major physical activity?

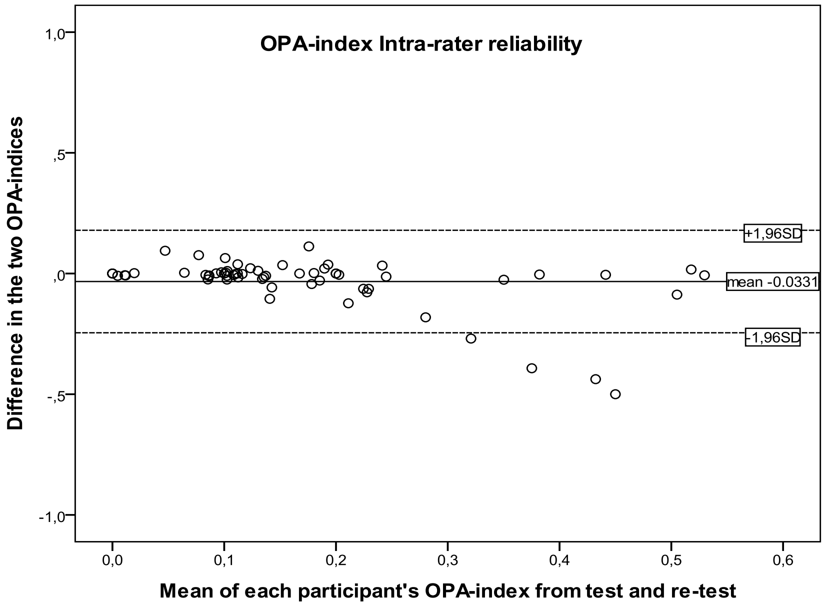
c) For how many years of your working life have you worked mostly standing or walking with some lifting and carrying?

d) For how many years of your working life have you had to work mostly at a high speed, with heavy and physically demanding work?

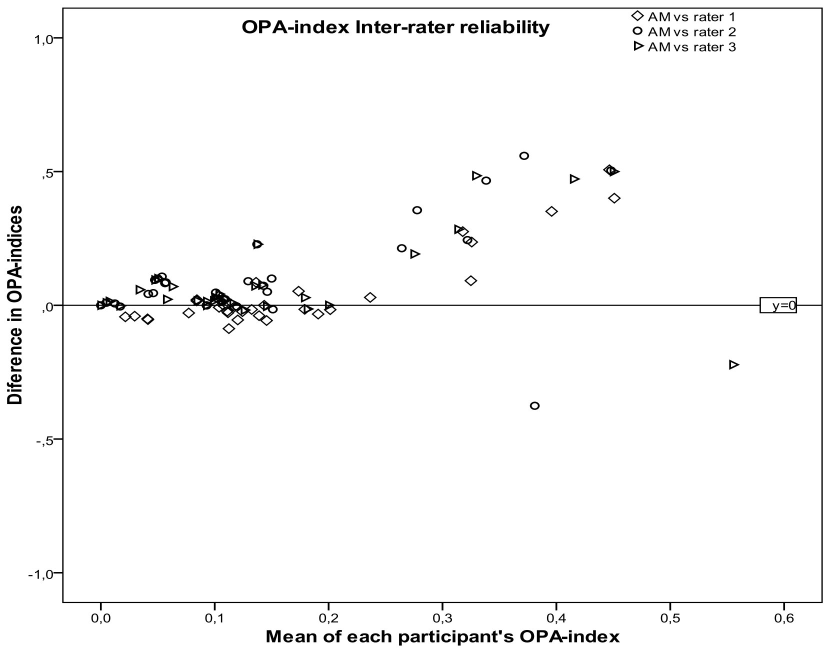
Appendix 3

Intra- and inter-rater reliability

Intra-rater reliability was evaluated by a blinded re-judgment of exposure to occupational physical activity (OPA) three months after the initial judgment. The difference between the two OPA-indices was visualized against the mean of the indices in a Bland-Altman plot.



Inter-rater reliability: Three skilled occupational physicians judged the exposure to occupational physical activity (OPA) in 34 participants, based on data from interviews. The difference in the individual OPA-index between the primary rater and each of the three skilled physicians is visualized.



Appendix 4

Additional tables and figures

Table 3a. Characteristics of the study population (MP=Metropolit Cohort; DALWUH=Danish Longitudinal Study on Work, Unemployment and Health; SD=standard deviation).

	Men				**Women**			
	N	**%**	**Mean**	**SD**	**N**	**%**	**Mean**	**SD**
Age	4035		58.99	2.32	1060		58.58	5.00
Height, cm	3968		179.66	6.76	1045		166.58	6.15
Weight, kg	3941		85.86	14.33	1029		69.79	13.26
Smoking, pack-years	3842		20.68	26.72	999		10.52	14.76
Alcohol consumption, units/week	3973		14.82	14.02	1033		8.05	12.06
Pain index[a]	3990		19.90	10.87	1053		23.64	13.14
Chronic diseases[b]	3993				1052			
No disease	1225	30.7			320	30.4		
1 disease	1326	33.2			311	29.6		
2 or more diseases	1442	36.1			421	40.0		
Vocational education	3964				1039			
Long cycle	738	18.6			131	12.6		
Medium cycle	857	21.6			313	30.1		
Short cycle	336	8.5			107	10.3		
Skilled and semi-skilled	1689	42.6			387	37.2		
Un-skilled	344	8.7			101	9.7		
Leisure-time physical activity[c]	3957				1040			
Medium/hard	1253	31.7			255	24.5		
Light	2240	56.6			706	67.9		
Sedentary	464	11.7			79	7.6		
Labor market status	3953				1033			
Employed	3479	88.0			802	77.6		
Unemployed[d]	474	12.0			231	22.4		
Cohort[e]	4035				1060			
MP	3153	78.14			.	.		
DALWUH	882	21.86			1060	100.0		

[a] Summation of pain in nine regions of the body. Minimum score=9 (no pain in any of the regions). Maximum score= 81 (worst possible pain in all nine regions).
[b] Asthma, diabetes, hypertension, angina, stroke, bronchitis, chronic obstructive pulmonary disease, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression, psychiatric diseases, and back disease.
[c] Intensity of leisure-time physical activity: Medium/ hard : > 4 hours a week, light: <4 hours a week, sedentary: reading/watching television in leisure-time.
[d] Unemployed=currently unemployed and early retirement, disability pensioners etc.
[e] Male participants were from two cohorts.

Table 3b. Characteristics of the study population: exposures and outcomes (SD=standard deviation).

	Men				Women			
Exposure	**N**	**Mean**	**SD**	**Median**	**N**	**Mean**	**SD**	**Median**
Ton-years[a]	3880	12.90	23.15	2.32	1016	6.04	12.38	0
Stand-years[b]	3880	11.26	13.80	3.86	1016	7.43	11.44	0
Kneel-years[c]	3880	7.29	14.99	0	1016	1.14	2.99	0
Outcome								
Hand grip strength, kg	3059	49.19	8.42	49.1	784	30.61	5.49	30.6
Balance area, mm^2	2902	1206.70	1637.78	901.0	762	902.62	869.96	734.5
Balance area, log_{10} area	2902	2.98	0.23	2.95	762	2.89	0.21	2.87
Chair-rise, number in 30 sec	2700	21.58	5.69	21.4	744	20.38	5.34	20.1

[a] Amount of lifting during working life. One ton year is lifting 1000 kg each day in one year.
[b] Total exposure to standing/walking at work. One stand-year is standing/walking for six hours each day in one year.
[c] Total exposure to kneeling at work. One kneel-year is kneeling at work for one hour each day in one year.

Table 4. Multivariate linear regression models. Associations between exposure-years and three measures of physical function. HGS: Hand grip strength (kg), chair rise (number in 30 seconds) and balance area (Log_{10} mm^2). β is regression coefficient. (p-values: * **p<0.0001, ** p<0.001, * p<0.05 ,^{ns}: not statistically significant).

Model	HGS Men		Women		Chair rise Men		Women		Balance Men		Women	
	β	R^{2a}	β	R^{2a}	β	R^{2a}	β	R^{2a}	β	R^{2a}	β	R^{2a}
Ton-years[b], unadjusted	**-0.014***	0.13	-0.016^{ns}	0.13	**-0.037*****	2.1	**-0.035***	0.6	**0.00043***	0.2	0.00061^{ns}	0.1
Model 1[c]	-0.003^{ns}	12.6	-0.004^{ns}	23.2	**-0.020****	10.3	-0.027^{ns}	14.9	0.00023^{ns}	3.2	0.00091^{ns}	7.5
Model 1 and CD[d]	-0.001^{ns}	13.0	-0.005^{ns}	23.7	**-0.017****	13.1	-0.027^{ns}	17.5	0.00017^{ns}	3.2	0.00093^{ns}	6.7
Model 1 and LTPA[e]	-0.003^{ns}	13.4	-0.001^{ns}	24.9	**-0.022*****	14.1	-0.022^{ns}	19.4	0.00029^{ns}	2.2	0.00093^{ns}	5.9
Stand-years[f], unadjusted	-0.014^{ns}	0.05	-0.008^{ns}	0.02	**-0.056*****	1.8	**-0.045***	0.8	0.00014^{ns}	0.007	0.00134^{ns}	0.4
Model 1[c]	0.022^{ns}	12.6	0.001^{ns}	23.1	**-0.024****	10.0	-0.031^{ns}	15.0	-0.00041^{ns}	2.2	**0.00172***	6.3
Model 1 and CD[d]	0.024^{ns}	13.1	0.001^{ns}	23.7	**-0.020***	12.9	-0.026^{ns}	17.4	-0.00052^{ns}	3.2	**0.00162***	7.9
Model 1 and LTPA[e]	0.020^{ns}	13.4	0.002^{ns}	24.9	**-0.026****	13.8	-0.030^{ns}	19.5	-0.00035^{ns}	3.2	**0.00179***	7.2
Kneel-years[g], unadjusted	0.007^{ns}	0.01	-0.053^{ns}	0.07	**-0.035*****	0.8	-0.103^{ns}	0.3	0.00012^{ns}	0.005	**0.00619***	0.7
Model 1[c]	**0.030***	12.8	-0.025^{ns}	23.2	-0.009^{ns}	9.8	-0.074^{ns}	14.8	-0.00020^{ns}	2.2	**0.00831***	6.8
Model 1 and CD[d]	**0.031***	13.3	-0.030^{ns}	23.8	-0.008^{ns}	12.8	-0.068^{ns}	17.3	-0.00025^{ns}	3.2	**0.00818***	8.4
Model 1 and LTPA[e]	**0.026***	13.5	-0.017^{ns}	24.9	-0.014^{ns}	13.6	-0.061^{ns}	19.3	-0.00016^{ns}	3.2	**0.00849***	7.7

[a] The proportion of the variation explained by the regression model in %.

[b] Amount of lifting in working life. One ton-year is lifting 1000 kg each day in one year.

[c] Adjusted for age, height, cohort, and vocational education (and weight in analyses with hand grip strength as outcome).

[d] CD: Chronic diseases in three groups: 0,1 or ≥2 of the following diseases: asthma, diabetes, hypertension, angina, stroke, bronchitis, chronic obstructive pulmonary disease, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression, psychiatric diseases, and back disease. Grouped in None, One, Two or more chronic diseases.

[e] LTPA: Leisure-time physical activity in three groups: Medium/ hard : > 4 hours a week, Light: <4 hours a week, Sedentary: reading/watching television in leisure-time.

[f] Total exposure to standing/walking at work. One stand-year is standing/walking for six hours each day in one year.

[g] Total exposure to kneeling at work. One kneel-year is kneeling at work one hour each day in one year.

Figure 5. Multivariate spline regression analyses and 95% confidence intervals. Associations between exposure-years and hand grip strength adjusted for height, weigth, age, cohort, and vocational education. Expsoure to ton-, stand- and kneel-years at the x-axis, and differences in hand grip strength (kg) in the y-axis. In men (upper row) and women (lower row). Participants are visualized in the bottom of each graph.

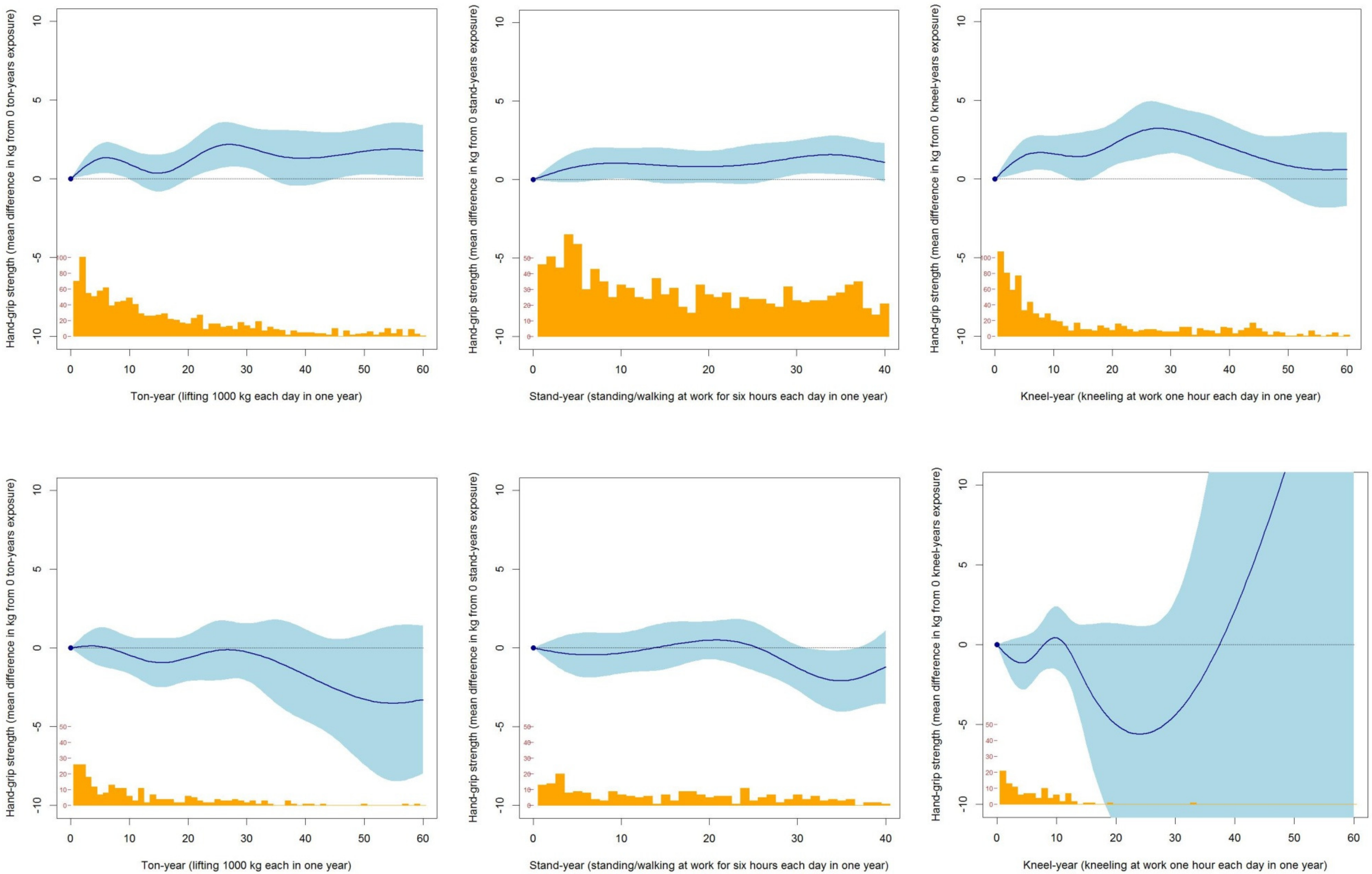


Figure 6. Multivariate spline regressions including 95% confidence intervals. Associations between exposure-years and number of chair-rises/30 seconds adjusted for age, height, cohort, and vocational education. Exposure to ton-, stand-, and kneel-years at the x-axis, and differences in number of chair rises at the y-axis. In men (upper row) and women (lower row). Participants are visualized in the bottom of each graph.

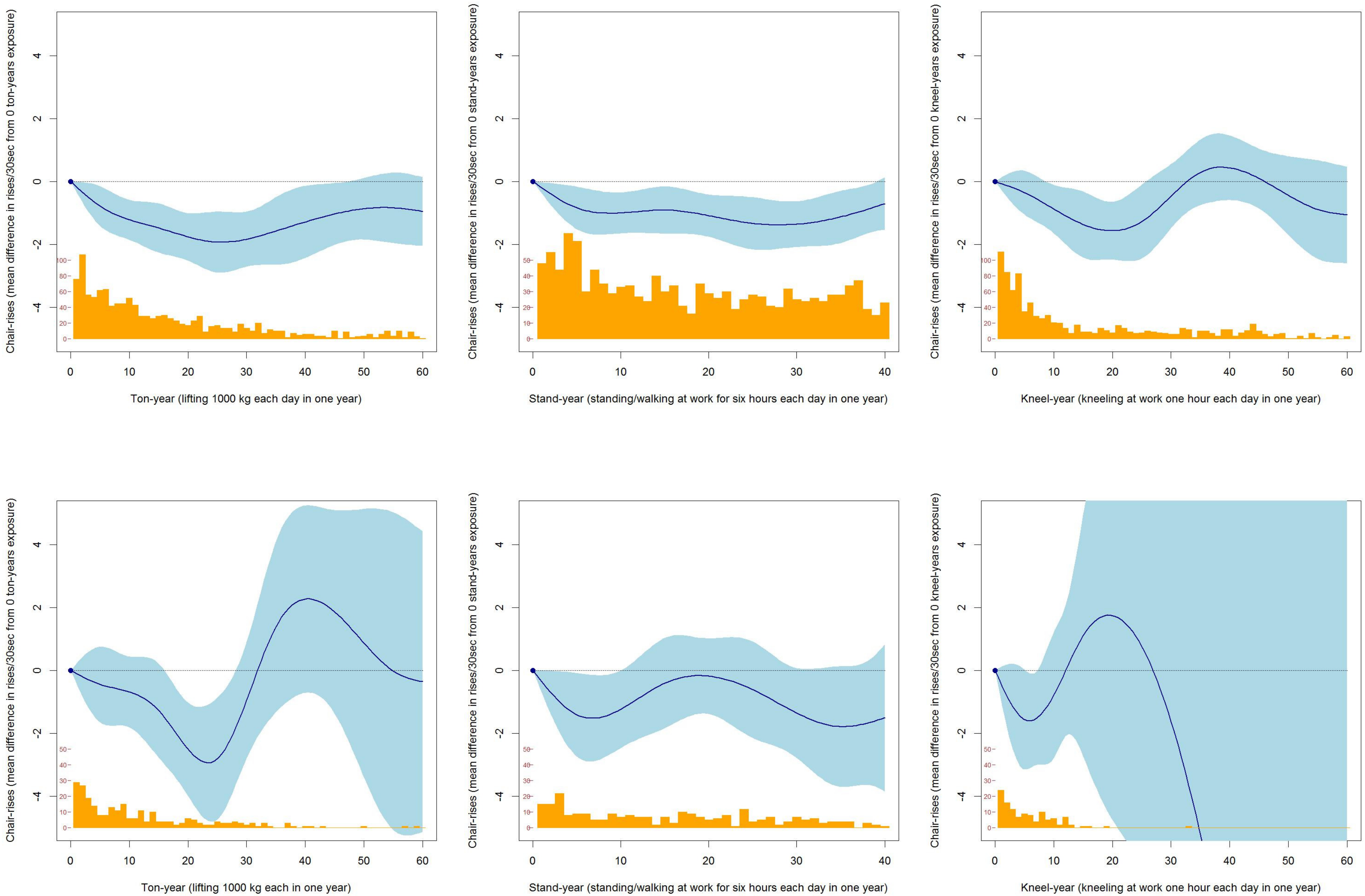
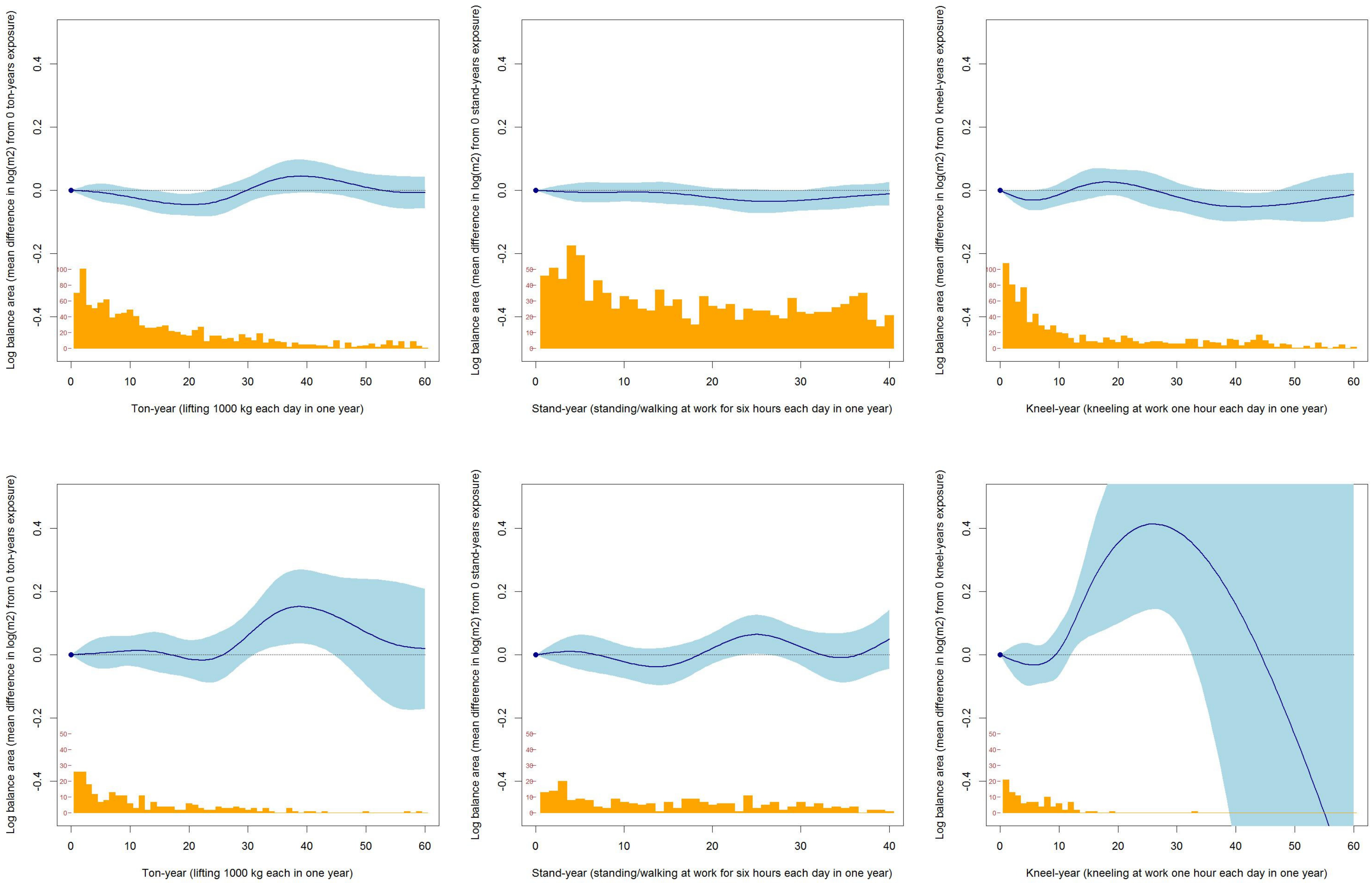


Figure 7. Multivariate spline regressions and 95% confidence intervals. Associations between exposure-years and balance adjusted for age, height, cohort, and vocational education. Exposure to ton-, stand-, and kneel-years at the x-axis, and differences in balance (log_{10} area) at the y-axis. In men (upper row) and women (lower row). Participants are visualized in the bottom of each graph.



Appendix 5

Paper I

Møller A, Reventlow S, Andersen JH, Avlund K, Mortensen OS. Validity of Workers' Self-Reports. Evaluation of a Question Assessing Lifetime Exposure to Occupational Physical Activity. British Journal of Medicine & Medical Research 2012;2(4): 536-552. http://www.sciencedomain.org/abstract.php?iid=137&id=12&aid=614#.UYdiC6IqzFA

British Journal of Medicine & Medical Research
2(4): 536-552, 2012

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Validity of Workers' Self-Reports. Evaluation of a Question Assessing Lifetime Exposure to Occupational Physical Activity

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Authors' contributions

This work was carried out in collaboration between all authors. AM, JHA, OSM and SR planned the study together with KA. KA was responsible for the CAMB data collection. AM interviewed the participants and made the first draft of the article. JHA, OSM, SR and KA made substantial contributions to the analysis and interpretation of data. They drafted the article critically for important intellectual content and all authors have read and approved the final manuscript.

Research Article

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ABSTRACT

Aims: In epidemiological studies exposure assessment based on questionnaires is the most cost-effective method. A question about lifetime exposure to occupational physical

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activity (OPA) was used in a population-based survey (part of the Copenhagen Aging and Midlife Biobank, CAMB). The aim of the study was to validate this question through a three-step process.
Methodology: Firstly, the response process was studied by cognitive interviewing of 7 persons. Secondly, 64 persons participated in semi-structured interviews about their work-life, and expert judgments of exposure to OPA were compared with questionnaire-data. Exposure was 20 years of work in one of four categories of OPA: sedentary, standing and walking, moderate or high OPA. Kappa values were calculated for agreement and interpreted according to Landis and Koch's criteria. Agreement was visualized in Bland-Altman plots. Thirdly, intra- and inter-rater reliability of expert judgments was tested.
Results: Response process: The question had a complicated instruction, and the respondents found it hard to remember, categorize, and summate exposures. Semi-structured interviews: Kappa value for exposure to sedentary work was 'substantial' (0.71) but 'fair' for the other categories of OPA (0.27-0.29). Agreement between questionnaire and interview was higher in sedentary jobs and jobs with high OPA. Intra-rater reliability of expert judgments was 'substantial' or 'moderate' (0.60-0.71). Inter-rater reliability was high in sedentary jobs but lower in the more active jobs.
Conclusion: Self-reports of lifetime exposure to sedentary work are valid in the CAMB cohort, whereas the validity of self-reports of exposure to high levels of occupational physical activity (OPA) are questionable. Thorough pre-testing of questions about lifetime OPA is recommended.

Keywords: Validity; self-reports; occupational physical activity; inter-rater reliability; intra-rater reliability; cognitive interviewing; Bland-Altman plots; qualitative methods.

ABBREVIATIONS

OPA: Occupational Physical Activity; CAMB: Copenhagen Aging and Midlife Biobank; QAS: The Question Appraisal System

1. INTRODUCTION

Reliable and valid assessments of occupational physical activity are needed in the study of work and health (Stock et al., 2005; Kwak et al., 2011). In epidemiological studies, which include participants with many different job-titles, exposure assessment based on questionnaires is the most cost-effective method. Many questionnaires and scales assessing occupational physical activity (OPA) have been used, and a recent review found good repeatability in four of 22 questionnaires. However, none of the reviewed questionnaires showed good validity compared to objective measurements (Kwak et al., 2011). This could be partly explained by lack of standardized methods for assessment of OPA and, thereby, lack of a 'gold standard' as reference method. Another explanation is the lack of studies of workers' capability to describe and judge the level of exposure and Stock et al. (2005) suggest that qualitative interdisciplinary methods like 'cognitive interviewing' are used to pre-test questionnaires concerning physical workload.

The questionnaires reviewed by Kwak et al. (2011) and Stock et al. (2005) assessed current OPA by asking questions about usual activity at work, a 'typical workday', or usual activity in the past week or year. Assessment of lifetime exposure to occupational physical activity is an additional challenge and personal interviews have been used to establish a retrospective job-history, which has been reviewed afterwards by experts, assessing lifetime occupational physical activity (Cassou et al., 1992). However, this is a time-consuming method in large epidemiologic studies and expert judgments have to be validated too.

In the planning of a Danish cohort study (the Copenhagen Aging and Midlife Biobank (CAMB)) (Avlund et al., 2009) we contributed with questions about work-life. CAMB is based on three existing Danish cohorts and aimed at determining the importance of prenatal and perinatal factors, factors in childhood, and factors in early adulthood for early signs of ageing in late midlife. Our study group's main interest is the influence of work on the ageing process and in forthcoming analyses we will study lifetime exposure to occupational physical activity and associations to midlife physical function (Møller et al., 2012).

The questionnaire used in CAMB included 100 different questions about health, social and life-style factors; consequently, the space for questions concerning work-life was limited. Based on more than 20 years of experience and several validity studies on assessment of exposures in work-life at The National Research Centre for the Working Environment (Burr et al., 2003), we included a question about OPA in current work in the CAMB questionnaire. The time-frame of the question was changed to cover the entire work-life, to serve as a cumulative exposure assessment in our study of lifetime OPA and ageing. Pilot studies of the CAMB questionnaire resulted in a slightly changed wording of the question. When inclusion into CAMB started, the research assistants reviewing the questionnaires with the participants found that some participants had difficulty in answering this specific question (Question 32, see Appendix 1).

Therefore, we conducted a supplementary small pilot study by introducing the question to a few people. Respondents with sedentary work-life filled out the question about lifetime exposure to OPA satisfactorily, but respondents with exposure to some OPA in work-life had difficulties answering the question. At that time, we were not able to change the question in the CAMB survey. Therefore, we decided to study to which extent we could rely on data from the questionnaire. We planned a three-step process of validation, aiming at answering the following three research questions:

1) How is a question about life-time OPA interpreted and understood by people with a job history of primarily manual work?
2) How is the agreement between exposures to OPA reported in the CAMB questionnaire and information obtained from interviews?
3) How reliable are expert ratings of lifetime occupational physical activity?

The aim of the first step in the process of validation (see Table 1 for overview) was to study the comprehension and interpretation of the question about lifetime OPA because, despite the recommendations made by Stock et al. (2005), we have not seen qualitative methods used in the pre-test of questionnaires about OPA. Furthermore, the aim of the first step was to gain knowledge to be used in the next step of validation. In the second step, the validity of self-reports of lifetime OPA was evaluated, comparing data from questionnaires and from semi-structured interviews. Finally, intra- and inter-rater reliability of expert judgments of OPA used in the semi-structured interviews was evaluated.

Table 1. A three-step validation process. Methods, materials and analyses

Step	Content	Method	Material	Analyses
1	Response process, comprehension and interpretation	Cognitive interviews	7 middle-aged workers primarily working in a hospital	Question Appraisal System, QAS-checklist
2	Validity of self-reports	Semi-structured interviews CAMB questionnaire	64 participants from CAMB[1]	Kappa Bland-Altman plots
3	Intra-rater reliability	Re-test of interview-data from step 2 after 3 months	Primary rater's first judgment in step 2 compared with blinded re-test	Kappa Bland-Altman plots
	Inter-rater reliability	Expert judgments based on interview-data from step 2	3 expert's judgments compared to initial rater's judgments	Bland-Altman plots

[1]CAMB: Copenhagen Aging and Midlife Biobank

2. MATERIALS AND METHODS

2.1 Study Design

Participants in CAMB filled in the questionnaire before attending a physical examination. Information about work-life from the questionnaire included a list of the five longest held occupations, current job type and physical, ergonomic, chemical, and psychosocial exposures at work. In the question about lifetime OPA, participants were asked to fill in information about number of years of work in four categories of physical activity: a) sedentary work, b) standing and walking at work, c) moderate OPA and d) high OPA (See Appendix 1).

2.2 Comprehension and Interpretation

Cognitive interviewing has been used since the 80's to improve the quality of survey questions (Willis, 2005; Collins, 2003) and in medical research it has been used in the development of new questionnaires (Watt et al., 2008), revision of existing questionnaires after translation (Andersen et al., 2010), or, before use, in a different cultural setting than the primary one (Napoles-Springer et al., 2006; Cortes et al., 2007). Cognitive interviews study the cognitive aspects of the response process and, thereby, respondents' interpretation and comprehension of questions (Tourangeau et al., 2000).

The respondents received a printed copy of the questions about work-life and were encouraged to 'think aloud' while filling in the questionnaire, as described by Willis (Willis, 2005). However, the 'think aloud' technique is a challenge to some respondents, and we therefore also used 'verbal probing', meaning that the interviewer asks questions (probes) during the interview ('concurrent probing') (Willis, 2005). Probes can either be prepared or spontaneous and are used to explore the comprehension of terms and to catch silent misunderstandings of questions. 'Retrospective probing' was used at the end of the interview to make a concluding evaluation of the questions concerning work-life (Willis, 2005). Interviews were digitally recorded, and notes and comments were taken during the interview. The interviews were transcribed verbatim.

2.2.1 Population and data collection

From our small pilot study we knew that respondents with sedentary work filled out the question about lifetime exposure to OPA satisfactorily. However, respondents with exposure to some OPA in work-life had difficulties answering the question. Based on this pilot study, a strategic sampling of participants not included in the CAMB study was made. Selection was based on age (minimum 50 years old) and working experience (at least 20 years of non-sedentary work) (Crabtree and Miller, 1999). Participants were primarily recruited among employees at the hospital, and inclusion continued until no further problems in the question of interest were revealed in the interviews, as in 'sampling to redundancy' (Streiner and Norman, 2008). Four men and three women, average age 59 years, were interviewed. Three hospital workers, one secretary with former employment as an assistant nurse, a laboratory assistant and two men with working experience from outside the hospital. Interviews took place in January and February 2010.

2.2.2 Analysis

The analysis was based on recordings and notes from the interviewer, according to Willis' "The Question Appraisal System" (QAS) (Willis, 2005), using a check-list of seven categories covering the answering process, Table 2. No quantitative measurement of responses was made because the aim of the interviews was primarily to gain an insight into the response process (Watt et al., 2008).

Table 2. The Question Appraisal System

Category	Description
1. Instructions	Look for problems with introductions, instructions, or explanations from the *respondent's* point of view.
2. Clarity	Identify problems related to communicating the *intent* or *meaning* of the question .
3. Assumptions	Determine if there are problems with assumptions made or the underlying logic.
4. Knowledge/ Memory	Check whether respondents are likely to *not* know or have trouble remembering information.
5. Sensitivity/Bias	Assess questions for sensitive nature or wording, and for bias.
6. Response categories	Assess the adequacy of the range of responses to be recorded.
7. Other Problems	Look for problems not identified in steps 1- 6.

2.3 Validity of Self-Reports

The overall aim of the semi-structured interviews was to establish a retrospective job-history, including information about exposures in work-life. The semi-structured interview was based on an interview-guide, but other questions were allowed to be brought up during the interview (Kvale, 1997). The interview guide was designed for this study based on the knowledge from the cognitive interviews (Step 1).

2.3.1 Population and data collection

75 participants from the CAMB-study were invited to participate in the semi-structured interviews. They were selected strategically, based on their answers about lifetime OPA (Question 32). In order to study possible variations in agreement between exposure groups, 15 participants with at least 20 years of exposure in each of the four categories (a-d) were selected and, in addition, another 15 participants with mixed job-histories. In all other aspects, the selection was random, and the first 15 to fit into the five defined groups of exposure were included. They received a mailed invitation to participate in a telephone interview about their work-life, and the researcher (AM) called them within the next two weeks to set an appointment for the telephone interview. The participants were anonymous in the data material, but coded with a unique registration number from the CAMB-study. At the time of the interview, the interviewer was blinded to the participants' information about exposure status in the questionnaire. The participants were interviewed in May and June 2010, and interviews were digitally recorded.

The interview-guide was based on results from the cognitive interviews and the first question in the retrospective part of the interview was: "Now we are going to talk about your employment since you left school, i.e. all the different jobs you have had during your work-life. When did you finish school, and what did you do afterwards?" The interviewer took notes and was thus able to piece together a story about the entire work-life in cooperation with the respondent. Once the interviewer had an overview of the job-history, she asked more thorough questions about exposures in the work environment. Having finished the interview, the interviewer filled in data about employment and exposures in a database, and went through the recordings of the interviews at least once more. Finally, judgment of level and duration of lifetime OPA was made (answer to question 32), and the judgment was not discussed with the participant.

2.3.2 Analysis

Validity was calculated as kappa coefficients of agreement in exposure using the dichotomized outcome: 20 years of exposure in the specific category or not ("exposed" or "non-exposed"). There is no general consensus about interpretation of kappa values, but we used the slightly adapted guidelines from Landis and Koch's (Altman, 1999) (Strength of agreement: 1.00: Perfect agreement, 0.81-1.00: Very good, 0.61-0.8: Good, 0.41-0.60: Moderate, 0.21-0.40: Fair, <0.2: Poor). However, the kappa coefficient is a dimensionless ratio, and the true agreement or clinical implication of the kappa coefficient is not obvious from the size of the coefficient. Therefore, Bland-Altman plots were used to visualize agreement (Bland and Altman, 1999). For that reason, we calculated an index of OPA taking years of exposure into account (Appendix 2). The OPA-index is based on questionnaire information about years of exposure to OPA in 4 groups, and ranges from 0 and 0.7. An OPA-index of "0" means "no OPA during work-life" and one of "0,7" means "having had OPA throughout the entire work-life". Differences in the OPA-index in the interview and the questionnaire were plotted against their mean, and the lines for the mean-value and the 95% limits of agreement were drawn. If the mean is 0 there is perfect agreement, and the narrower the 95% limits, the better agreement (Bland and Altman, 1999).

2.4 Intra- and Inter-Rater Reliability

2.4.1 Population and data collection

2.4.1.1 Intra-rater reliability

Intra-rater reliability of the expert judgment was evaluated by a test-retest of the OPA-index in all participants. The primary rater, AM, performed a blinded re-judgment of the exposure to OPA three months after the initial judgments, based on the data from the interview about job-history and exposures in work-life.

2.4.1.2 Inter-rater reliability

Three skilled, occupational physicians received information about 34 randomly selected participants from the interview-database, and were asked to judge the level and duration of exposure to OPA (years of exposure in group a-d) in each participant.

2.4.2 Analysis

2.4.2.1 Intra-rater reliability

Kappa values for agreement to exposure in test and re-test were calculated. OPA-index for each participant was calculated, and the difference between the primary OPA-index and the re-tested OPA-index was plotted against the mean of the two indices in a Bland-Altman plot.

2.4.2.2 Inter-rater reliability

The difference between the OPA-index judged by the primary rater and each of the three skilled physicians was visualized in one Bland-Altman plot with only one reference-line in y=0, in order to keep the figure simple, and to visualize the agreement which was the primary aim.

3. RESULTS AND DISCUSSION

3.1 Comprehension and Interpretation

3.1.1 Results

Instruction was complicated, aiming at assessing duration (years of exposure in each category), frequency ('mostly') and intensity (level of physical activity in category a) to d)) (Table 3). According to 'Clarity', some respondents were confused about category d) describing 'high speed' and 'heavy and physically demanding work', while they had been working at a 'high speed' but not with heavy work, and 'speed' was not mentioned in the other categories. Questions about employment and exposures back in time caused 'recall problems' in most respondents, and different approaches were used in the search of information, but most participants used first job or graduation as their starting point. 'Computation problems' were obvious in the search for duration of jobs and summation of exposures throughout work-life. Response categories b), c) and d) were overlapping due to vague definitions of levels of physical activity. Category a) was interpreted as office work/work in front of a computer by everyone, and caused no problems. The distinction between category c) or d) was hard, and some respondents asked for examples of job-titles in the categories. Since the instruction included an option of 'answering in more than one category', some filled in e.g. 40 years of work in both category c) and d) to indicate their difficulties in categorization of exposure. One participant found that her job did not fit into any of the categories and wrote 0 years in all four boxes. Only one of seven respondents understood and answered the question about lifetime occupational physical activity the way it was intended by the researchers.

Table 3. The Question Appraisal System used in the analysis of the question about lifetime occupational physical activity. Some categories and citations are shown in this table

Category	Citations and notes from interviews
Instructions	Most respondents sighed when they read the question and explained that it was hard to understand and impossible to answer correctly
Clarity	The use of "speed" only in category d) was confusing. 'I have always worked fast, but my work has not been hard, but "speed" is not mentioned in category a), b), or c)'. '…..Standing and walking' the respondent "tasted" the word and got confused about the meaning of the expression
Assumptions	In the question constant exposure during a work-day is assumed, but respondents were confused by this assumption: 'I was sitting at the office before lunch, and having heavy work while packaging in the afternoon.'
Knowledge/ Memory	Exposures up to forty years back in time are hard to recall, and the question requires difficult mental calculation.
Response categories	Vague response categories result in wrong answers, since they overlap: 'my job is a mixture… I sit, I walk, I stand, I lift and I laugh…it is hard to choose which category'

3.1.2 Discussion

As we presumed after our pilot study, the cognitive interviews revealed some problems, due to the response process. We found problems in the categorization of physical demands at work and assumptions of constant behavior during a workday and during work-life in the question. Furthermore, it was hard to remember occupational physical activity back in time, and it is known that the higher demands on memory in a question, the less accurate the response will be (Tourangeau et al., 2000). Everyday experiences are liable to imply reconstruction or inference more often than special events. The longer distance in time between an experience in the past and the present, the more difficult it is to remember, not only because of the period of time, but because you may have experienced similar things in the meantime (Tourangeau et al., 2000). However, sedentary jobs were easily categorized as such in the interviews.

The participants were selected strategically and the results from the interviews have low external validity. However, the participants were selected among workers who were assumed to have had some exposures to OPA. In the pilot study of the entire CAMB questionnaire, problems in question 32 were not seen, and though participants in that pilot study were selected strategically to mirror the CAMB population, there may have been an underrepresentation of manual workers or persons with low educational background.

It may be argued that seven interviews were too few to reach redundancy, but we found that most respondents faced the same problems in the response process. The aim of the cognitive interviews was to explore the response process to be able to design an interview guide for the second step of validation and we gained a useful insight into the problems linked to recall of exposures and reconstruction of lifetime job history.

3.2 Validity of Self-Reports

3.2.1 Results

64 of 75 (85%) participants accepted the invitation, 47% were women, mean age 56,4 years, and mean length of work-life was 39 years (range 22-48). The kappa value for agreement between questionnaire data and interview data for exposure to sedentary work was 'substantial' (0.71) (Table 4). For standing and walking and moderate OPA agreement was 'fair' (kappa 0.23 and 0.37 respectively). Exposure to 20 years of either moderate or high OPA (category c) and d) together) showed 'moderate' agreement (kappa 0.53).

Table 4. Validity of self-reports. Questionnaire versus interview

	Kappa	95% CI
Exposure to a)/ sedentary	0.71	0.50-0.93
Exposure to b)/ standing and walking	0.23	-0.02-0.45
Exposure to c)/ moderate OPA[a]	0.37	0.17-0.57
Exposure to d)/ high OPA[a]	0.27	0.04-0.49
Exposure to c) or d)	0.53	0.35-0.71

[a]*OPA: Occupational physical activity*

Fig. 1 shows the Bland-Altman plot of agreement in OPA-index between interviews and questionnaires. There is satisfactory agreement in low OPA-indices, which means that a sedentary job is categorized equally by the respondent and the rater. The agreement decreases as the OPA-index increases, but for the few high index jobs agreement seems to increase again.

3.2.2 Discussion

Both kappa values and Bland-Altman plots showed that the lower the level of OPA in the job history, the higher the agreement between self-reports and interviews. This is in line with results presented by Torgen et al. (1999) about 6 year recall of workloads, based on questionnaire information and validated by observation. The lower agreement in reports of higher levels of OPA is presumably a result of the problems of the categorization of OPA levels found in the cognitive interviews. Other researchers in this field have experienced problems in self-reported information about exertion and specific working postures (Wiktorin et al., 1993; Mortimer et al., 1999; Viikari-Juntura et al., 1996).

For lack of a 'gold standard' of OPA assessment we have studied the inter-method agreement (Gardner et al., 2010). To validate information from the questionnaire we could have used measurements, logbooks, or observations (Torgen et al., 1999). But as the aim of the exposure assessment was a lifetime assessment of OPA, this was not possible. Our hypothesis was that the information retrieved by interviews was more valid than self-reports, but this hypothesis has not been tested. However, White et al. (2008) state that interviews are superior to questionnaires if questions are complex and that precise information, e.g. about past exposures, is needed.

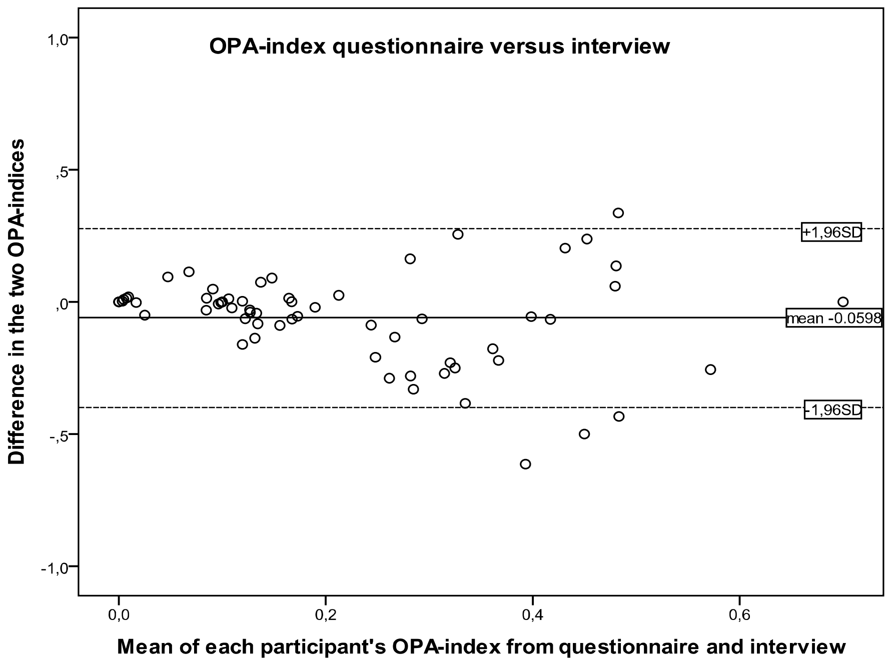

Fig. 1. A question about lifetime exposure to occupational physical activity (OPA) was validated, comparing questionnaire and interview data. An index of OPA was calculated (OPA-index) in each participant based on information from the questionnaire and the interviews. The difference between the two OPA-indices is visualized

In the planning of the study, we chose not to examine the reliability of the question about lifetime OPA because Stock et al. (2005) concluded that the reliability of workers' self-reports about general body postures (e.g. sitting and standing) is 'good to excellent'. We chose to focus on reliability of expert judgments, but, in the light of the results of our study, it would have been interesting also to study the reliability of workers' self-reports.

From the cognitive interviews we knew that categorization of OPA in question 32 was difficult. Highly educated workers may have little or no exposure to OPA (Stock et al., 2005), and thus their jobs are easier to categorize. On the other hand, categorization of jobs with moderate or high levels of OPA may bother respondents with low education. Gender, age, socio-demographics, and musculoskeletal complaints have been hypothesized to influence self-reports of exposure assessment (Sembajwe et al., 2010; Quinn et al., 2007; Viikari-Juntura et al., 1996; Wiktorin et al., 1993; Stock et al., 2005). In forthcoming analyses, it would be interesting to study the effect of these factors in workers' self-reports.

3.3 Intra- and Inter-Rater Reliability

3.3.1 Results

3.3.1.1 Intra-rater reliability

Kappa was 'substantial' for exposure to sedentary work, standing/walking and high OPA (kappa 0.71, 0.62, and 0.64 respectively, Table 5). For exposure to moderate OPA, agreement was 'moderate' (kappa= 0.60). In Fig. 2, intra-rater reliability is shown in a Bland-Altman plot of the agreement in the OPA-index. Intra-rater agreement between initial ratings and blinded ratings three months later was high, but full agreement between the judgments was not obtained.

Table 5. Intra-rater reliability. Test-retest

	Kappa	95% CI
Exposure to a)/ sedentary	0.71	0.48-0.95
Exposure to b)/ standing and walking	0.62	0.42-0.82
Exposure to c)/ moderate OPA[a]	0.60	0.40-0.80
Exposure to d)/ high OPA[a]	0.64	0.31-0.96

a) OPA: Occupational physical activity

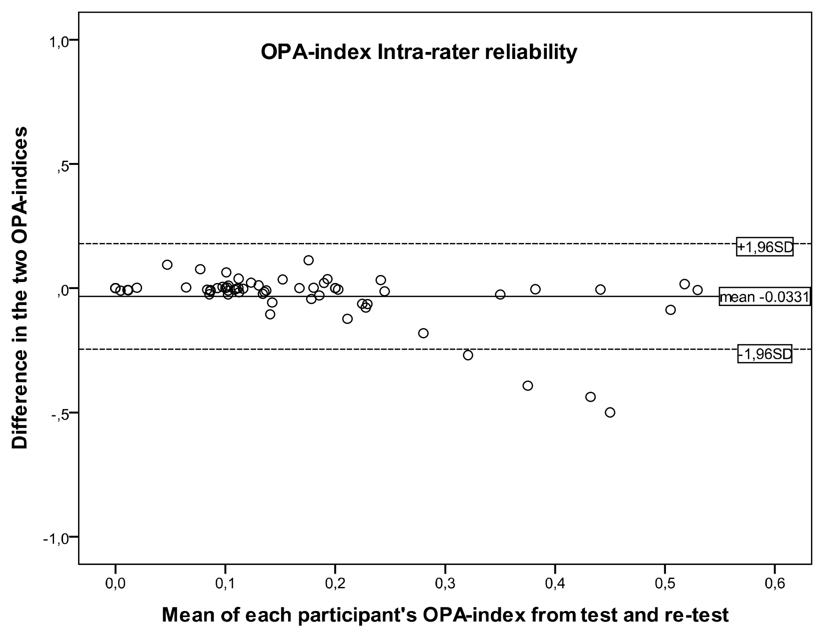

Fig. 2. Intra-rater reliability was evaluated by a blinded re-judgment of exposure to occupational physical activity (OPA) three months after the initial judgment. The difference between the two OPA-indices was visualized against the mean of the indices in a Bland-Altman plot

3.3.1.2 Inter-rater reliability

In Fig. 3, inter-rater reliability is shown, plotting the primary rater against each of the three experts. Inter-rater reliability is high in low OPA-indices but increases with higher OPA-indices. In general, the primary rater tends to score the OPA-index higher than the other experts.

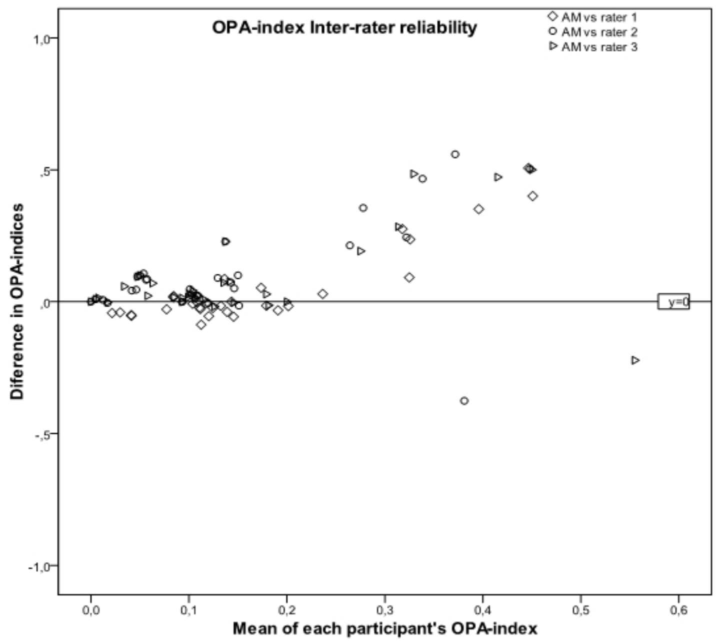

Fig. 3. Three skilled occupational physicians judged the exposure to occupational physical activity (OPA) in 34 participants, based on data from interviews. The difference in the individual OPA-index between the primary rater and each of the three skilled physicians is visualized

3.3.2 Discussion

The reliability of expert judgments of level of OPA in work-life varies according to exposure levels. As seen in the semi-structured interviews, agreement is higher in jobs with lower levels of OPA. Categorization of exposure in group c) or d) was difficult among participants in the cognitive interviews, and, in this third step, it was shown that experts have difficulty in reproducing the categorization of moderate or high level of OPA. The categories are not sufficiently specific for reliable judgment, and we assume that the same results would be found, if reliability of self-reports was tested in the CAMB participants.

According to the reliability of expert judgments, we found good agreement in sedentary jobs but lower agreement in the rating of more physically strenuous jobs. D'Souza et al. found that inter-rater agreement for physical exposure in job-categories was low, except for "sitting position", but their rating procedure was complicated due to heterogeneous exposure-groups (D'Souza et al., 2007). Expert judgments are often seen as a "gold standard" in occupational epidemiology, but risk of misclassification of exposure is still possible. Expert judgments are group-based and individual differences in exposures due to variation in job tasks, ergonomics and capacity among people with same job-title are not taken into account (Benke et al., 1997).

4. CONCLUSION

In a three-step process, we have studied the validity of workers' self-reports and found that self-reports of lifetime exposure to sedentary work are valid in the CAMB cohort, whereas the validity of self-reports of exposure to moderate and high levels of occupational physical activity is questionable.

Our findings are in line with others concluding that self-administered questionnaires may help to classify groups with heterogeneous occupational tasks but are not suitable for studying quantitative exposure-effect relationships (Stock et al., 2005; Viikari-Juntura et al., 1996).

Introducing a qualitative method like cognitive interviewing in the occupational research field was beneficial to our study. Knowledge about comprehension is essential to the validity and, thus, cognitive interviewing or other methods of pre-testing questions are recommended for use in future planning and pre-testing of questions about work-life. Furthermore, we have shown that it is important to pre-test questionnaires in sub-groups, because many factors may influence the way people answer questions about exposures in their work-life.

ETHICAL APPROVAL

The study was presented to the Ethics committee, but the general approval of the CAMB project covered this project (The CAMB project was approved by the Regional Committee on Biomedical Research Ethics, Capital Region, Registration Number H-A-2008-126). "The Danish Data Protection Agency" refused registration of this project, because the questions in both cognitive and semi-structured interviews were only work-related. All authors hereby declare that all human studies have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix 1

Question 32 in Danish from the questionnaire and an English translation. Groups of OPA below.

32. Når du ser tilbage på hele dit arbejdsliv:
(Du må gerne svare i mere end én kategori)

a) Hvor mange år af dit arbejdsliv har du haft mest stillesiddende arbejde, som ikke kræver fysisk anstrengelse?
b) Hvor mange år af dit arbejdsliv har du haft mest stående eller gående arbejde, som ikke kræver fysisk anstrengelse?
c) Hvor mange år af dit arbejdsliv har du haft mest stående eller gående arbejde med en del løfte- eller bærearbejde?
d) Hvor mange år af dit arbejdsliv har du haft mest tungt eller hurtigt arbejde, som er fysisk anstrengende?

32. Looking back on your entire working life:
(You may answer in more than one category)

a) For how many years of your working life have you had mostly sedentary work without physical strain?
b) For how many years of your working life have you had mostly standing or walking work without major physical activity?
c) For how many years of your working life have you worked mostly standing or walking with some lifting and carrying?
d) For how many years of your working life have you had to work mostly at a high speed, with heavy and physically demanding work?

Categories of occupational physical activity (OPA) used in the study according to question 32:

a) : Sedentary work
b) : Standing and walking
c) : Moderate OPA
d) : High OPA

Appendix 2

The OPA- index

We created an arbitrary index of occupational physical activity (OPA), based on answers about lifetime OPA in the questionnaire. It was necessary to construct an index eliminating overlap, while many respondents had written 40 years of employment in more than one category. Filling out both category c) and d) was interpreted as the job having included elements of both moderate and high physical activity.

In the index, it is assumed that category d) has OPA 70% of the time and c) has 20% OPA. Having a job that primarily includes standing and walking/b) has OPA 10% of the time, and a job mostly sedentary has 0% of OPA. The index is a summation of OPA in years divided with the total duration of employment.

An example:

a) A bricklayer working for 40 years in the same job categorized as d):
   OPA-index: (0.7*40)/40= 0.7.
b) A nurse working in a clinical department for 20 years categorized as c), and in an administrative job for 10 years categorized as a).
   OPA-index: (0.2*20+0*10)/(10+20)=0.13.
c) A confectioner working for 30 years wrote "30 years" in b), c) and d) in the questionnaire. Therefore, total years of exposure are 90 years.
   OPA-index: (0.7*30+0.2*30+0.1*30)/(30+30+30)=0.33.

Appendix 6

Paper II

Møller A, Mortensen OS, Reventlow S, Skov PG, Andersen JH, Rubak TS, Hansen ÅM, Andersen LL, Lund R, Osler M, Christensen U, Avlund K. Lifetime Occupational Physical Activity and Musculoskeletal Aging in Middle-Aged Men and Women in Denmark: Retrospective Cohort Study Protocol and Methods. JMIR Research Protocols. 2012;1(2)e7. PMID 23611836 http://www.researchprotocols.org/2012/2/e7/

Protocol

Lifetime Occupational Physical Activity and Musculoskeletal Aging in Middle-Aged Men and Women in Denmark: Retrospective Cohort Study Protocol and Methods

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Abstract

Background: Physical function is essential for performing most aspects of daily life and musculoskeletal aging leads to a decline in physical function. The onset and rate of this process vary and are influenced by environmental, genetic, and hormonal factors. Although everyone eventually experiences musculoskeletal aging, it is beneficial to study the factors that influence the aging process in order to prevent disability. The role of occupational physical activity in the musculoskeletal aging process is unclear. In the past, hard physical work was thought to strengthen the worker, but current studies in this field fail to find a training effect in jobs with a high level of occupational physical activity.

Objective: The aim of this study is to examine the influence of lifetime occupational physical activity on physical function in midlife. The study follows the "occupational life-course perspective," emphasizing the importance of occupational exposures accumulated throughout life on the musculoskeletal aging process taking socioeconomic and lifestyle factors into consideration.

Methods: This study is a retrospective cohort study including a cross-sectional measurement of physical function in 5000 middle-aged Danes. Data was obtained from the Copenhagen Aging and Midlife Biobank (CAMB) which is based on three existing Danish cohorts. Using questionnaire information about the five longest-held occupations, the job history was coded from the Danish version of the International Standard Classification of Occupations (D-ISCO 88) and a job exposure matrix containing information about occupational physical activity in Danish jobs was applied to the dataset. The primary outcomes are three tests of physical function: handgrip strength, balance, and chair rise. In the analyses, we will compare physical function in midlife according to accumulated exposure to high levels of occupational physical activity.

Conclusions: We have a unique opportunity to study the influence of work on early musculoskeletal aging taking other factors into account. In this study, the "healthy worker effect" is reduced due to inclusion of people from the working population and people who are already retired or have been excluded from the labor market. However, low participation in the physical tests can lead to selection bias.

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KEYWORDS

Occupational exposure; work load; physical fitness; musculoskeletal system; aging

Introduction

Physical function is essential for performing most aspects of daily life and it is a predictor of morbidity and mortality [1,2]. Musculoskeletal aging leads to a decline in physical function [3], the onset and rate of which vary and are influenced by environmental, genetic, and hormonal factors [4]. Leisure-time physical activity is important for maintaining physical function and is recommended by authorities in many countries [5], but the role of occupational physical activity (OPA) is more controversial [6]. Until the 1980s, manual workers were considered stronger than non-manual workers because of OPA. Since then, muscle strength and endurance have been shown to be lower in manual workers than in non-manual workers [7-10]. The absence of an observed training effect of OPA on physical function has been explained by a lack of an optimal combination of intensity, frequency, and duration of job tasks [7,11].

Since the 1980s, few studies have focused on prolonged exposure to strenuous physical work as a predictor of loss of muscle strength and impaired physical function. One study found no association between lifetime OPA and handgrip strength [11], but other studies have shown a training effect of OPA on shoulder muscle strength [12] and physical capacity in the upper extremities [13]. Three studies in older people with a history of manual labor showed that overall lifetime OPA may be associated with significantly higher rates of disability, lower physical function, and reduced muscular strength [14-16]. Two factors influence the associations found in these studies of accumulated physical activity and later physical function: exposure assessment and confounding factors.

The exposure assessment is essential. Most of the studies previously cited rely on self-reports of workload because self-reports provide the simplest and most cost-effective method of measuring physical exposure in large epidemiological studies [17]. Although the validity of self-reports vary [18], they are useful for detecting relative differences in physical workload among occupational groups. To supplement self-reports of physical exposure, expert judgments and job exposure matrices (JEMs) have been used in occupational epidemiology [19,20]. JEMs are databases based on expert judgments, registers, or measurements and use coded job titles to assign exposures in epidemiologic studies [21]. They are useful for retrospective exposure assessment in population-based studies in which many types of jobs are represented. Several research groups have used expert ratings and established JEMs for assessment of physical exposure [22,23], but the imprecise definition of OPA and the lack of accurate measurements can affect the validity. The use of a panel of experts for assessment of exposure improves the validity of the judgments [24], but misclassification is still possible because a JEM is a group-based assessment and individual differences in exposures because of variation in job tasks among people with the same job title and differences in ergonomics and capacity are not taken into account [25]. A recent study found high validity of reported job histories comparing information from questionnaires and interviews, whereas self-reports of work-life OPA levels showed varying validity (Møller et al, unpublished data, 2012). Therefore, this study uses a JEM on occupational physical activity based on expert ratings to supplement the exposure assessment.

In the previously mentioned studies, differences in physical function among older people could be attributed to confounding factors throughout life. Using a life-course perspective on aging and functional decline, factors such as socioeconomics, lifestyle, and genetics are relevant to take into consideration [4]. However, it is not always possible to follow trajectories of confounding factors in life-course analyses although they can influence outcomes such as physical function in midlife [26-28].

There has been little focus on occupational exposures in life-course studies of physical function [29]. Thus, it is not known how occupational exposures during the course of life influence the musculoskeletal aging process and the decline in physical function. Our hypothesis is that a high level of OPA affects the timing and/or the rate of the musculoskeletal aging process. In this study, the term “occupational life-course perspective” is used and the aim is to examine the influence of lifetime occupational physical activity on physical function in midlife.

Methods

Study Design

This study is a retrospective cohort study including a cross-sectional measurement of physical function in midlife. Data will be obtained from the Copenhagen Aging and Midlife Biobank (CAMB) [30], which is based on three existing Danish cohorts aimed at determining the importance of prenatal and perinatal factors, factors in childhood, and factors in early adulthood for early signs of aging in late midlife. Physical examinations of the cohort are planned for the future, but not yet funded.

Study Population

This study utilizes data from two of the three CAMB cohorts: The Metropolit Cohort and the Danish Longitudinal Study on Work, Unemployment and Health. From these cohorts, 12,656 middle-aged men and women living in Denmark were invited to participate. Data collection took place between April 2009 and March 2011. Of the initial 12,656 invitations, 39.97% (5059/12,656) answered the postal questionnaire and 30.48% (3858/12,656) attended the examination. Presently, the CAMB database is being prepared for analysis. The analyses will begin in the spring of 2012 when the database will be available for further research and the job exposure matrix has been established.

Description of the Cohorts

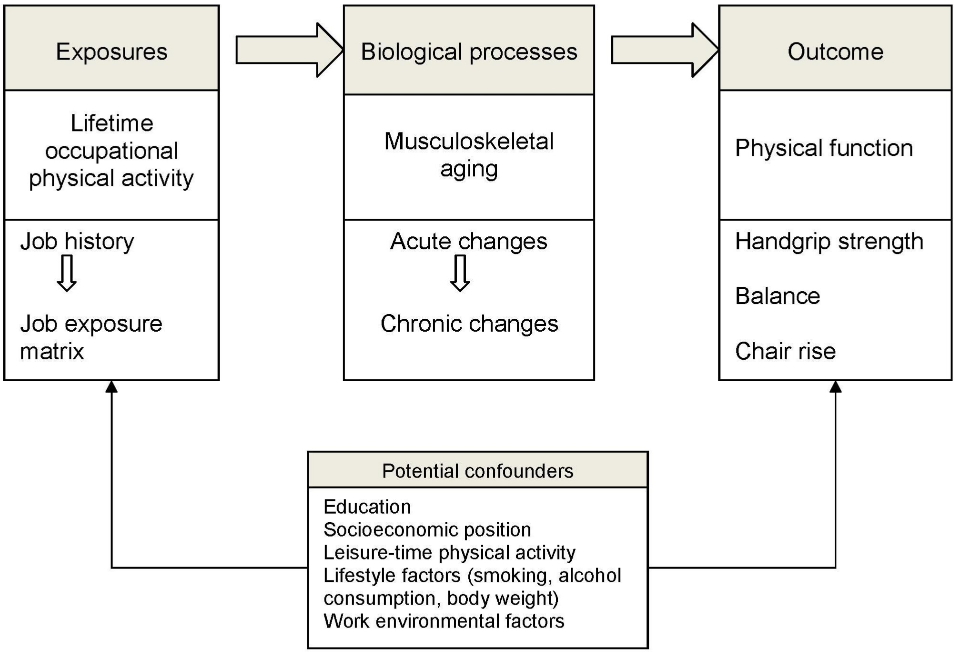
The Metropolit Cohort is defined as the 11,532 men born in 1953 in the Copenhagen Metropolitan area and living in Denmark in 1968. The cohort has been described in detail elsewhere [31]. Data from birth certificates, including information on dimensions at birth and the father's occupational status at the time of birth, were manually collected for all members of the original study population in 1965. That same year, 7987 (69.26%) of these males participated in a school-based survey that included a questionnaire administered by their class teachers. The questionnaire included tests of cognition and questions regarding leisure-time activities and social aspirations. In addition, data from conscription board examinations between 1971-1976, including measurements of height, weight, and cognitive function, were collected from archives in 2004. In 2004, 6292 members of the cohort responded to a health questionnaire. The Metropolit Cohort provides a unique opportunity to study early biological and social influences on the development of a number of social and health outcomes [32-34].

The Danish Longitudinal Study on Work, Unemployment and Health is a prospective population study that began with a baseline postal survey in the spring of 2000 in a stratified random sample (n = 15,227) consisting of two population groups: (1) individuals between 40 and 50 years by October 1, 1999 (7588/11,082, response rate 68.47%), and (2) individuals between 36 and 54 years who were unemployed at least 70% of the time between October 1, 1996 and October 1, 1999 (2350/4200, response rate 55.95%). Both samples were drawn initially from the "Anvendt Kommunal Forskning" (AKF) Longitudinal Register maintained by the Danish Institute of Governmental Research. The AKF Longitudinal Register comprises 100% of the Danish population aged 15 years and older. Data on non-participation was derived from the register. Non-participants included a significantly higher proportion of men, non-native-born Danes, individuals living on transfer income, and individuals with lower education levels (untrained or semi-skilled). In 2006, a follow-up questionnaire was sent to the surviving respondents, now aged 44-62 years (n = 8916) and a completed questionnaire was returned by 6151 respondents (response rate 68.99%). Data included a number of demographic, socioeconomic, psychosocial, and behavioral measures because socioeconomics and the consequences of unemployment were two of the main fields of investigation [35-37].

Conceptual and Analytical Model

Figure 1 illustrates the conceptual model used in this study. The research hypothesis is that prolonged exposure to high levels of OPA is associated with lower levels of physical function in midlife. The physiological link between exposure and outcome is the underlying biological processes, where acute changes in the musculoskeletal system turn chronic because of insufficient time for recovery [38,39] and a cumulative effect of physical wear and tear over the years influences the onset and rate of the musculoskeletal aging process [13]. At the same time, other factors throughout the course of life are associated with the exposure to occupational physical activity and physical function in midlife, which are potential confounders in our conceptual model.

Figure 1. Conceptual model of study.



Exposure Assessment

Occupational physical activity is the main exposure in this study. We define occupational physical activity as "work including mostly standing and walking at work combined with daily lifting of heavy burdens."

Self-reported Measures

The questionnaire provides data on the five longest occupations held plus the current occupation. The job titles were coded using the 1988 revision of the Danish version of the International Standard Classification of Occupations (D-ISCO 88) registration system by a coder with a broad knowledge of the Danish labor market. The International Standard Classification of Occupations (ISCO) was developed by the International Labour Office in 1958 and is a standardized classification and rating system of job types according to skills and education requirements [40].The D-ISCO contains classifications for more than 2000 Danish job titles as four-digit codes and it is used primarily for statistical analysis and research.

The questionnaire provides information about exposure during working life to dust, noise, chemicals, heavy lifting, working with the back bent, about the psychosocial work environment, and OPA. The OPA is categorized into four groups: sedentary work (eg, office work); mainly standing and walking at work (eg, teachers or machine operators); moderate physical exertion (eg, car mechanics or cooks); and hard physical work including lifting and pushing/pulling (eg, furniture movers or bricklayers). For all types of exposures, the respondent has to include a summation of their years of exposure.

Job Exposure Matrix

A job exposure matrix, the occupational physical activity matrix (OPA matrix), was applied to the dataset. The OPA matrix is based on an existing Danish job exposure matrix called the Knee-Hip Matrix [41] that is based on expert judgment of physical exposures associated with risk of osteoarthritis (eg, sitting, standing/walking, whole-body vibration, kneeling, and lifting of heavy objects). Firstly, all jobs in the D-ISCO classification considered more than minimally exposed to at least one of the exposures of interest were collapsed into homogeneous exposure groups (HEGs). Of the 2227 possible, 689 job titles were collapsed into 121 HEGs containing from 1-34 different occupational titles. For example, the HEG "people working in the printing industry" includes bookbinders, machine operators, and printers; "people working with food preparation in different kitchens" includes different types of cooks and managers in cafés and cafeterias.

Expert Rating

In keeping with international recommendations for expert ratings, a panel of five raters (experienced occupational physicians) independently assessed the 122 HEGs. They rated the duration of sitting, standing/walking, kneeling, and whole-body vibration throughout a normal working day. Furthermore, a rating of daily lifting (kg/day) and number of lifts over 20 kg per day were assigned to each HEG. A final consensus meeting was held to discuss outliers and discrepancies in the ratings and the method was validated internally and externally [41].

The OPA Matrix

The division of job titles in the HEGs and the average rating of the experts on physical activity (eg, hours standing/walking per day and lifting frequency and intensity per day) came from the Knee–Hip Matrix. Job groups not included in the HEGs were assigned as "unexposed." Years of exposure to standing and walking and lifting were calculated according to the following definitions: (1) standing year (SY) defined as 6 hours of standing and walking at work each day in 1 year; (2) lifting year (LY) defined as lifting more than 20 kg at least 10 times per day in 1 year; and (3) ton year (TY) defined as 1000 kg of heavy lifting per day in 1 year. Each participant's job history was converted to D-ISCO job titles covering the 0–5 previous longest occupations. Finally, data on exposure from the OPA matrix was assigned to the respective job titles and a summation of exposure was calculated.

Outcome Assessment

Test Protocol

Participants in CAMB attended an examination at the National Research Centre for the Working Environment (NRCWE), which involved a review of the previously completed questionnaire, measurement of weight and height, a battery of physical tests, cognitive tests, blood sampling, and information about health status with respect to some of the results of the examination. The battery of physical tests included tests of handgrip strength, trunk extension and flexion, jump height, flexibility, chair rise, and balance. General exclusion criteria for participation in the physical tests were high blood pressure, self-reported signs of angina pectoris, and use of prescribed heart/lung medication.

Objective Measures of Physical Function

Three signs of early musculoskeletal aging were used as outcome measures: handgrip strength, balance, and chair rise.

Handgrip strength was measured during a maximal voluntary isometric contraction with an electronic version of the Jamar dynamometer [42]. The participant sat upright on a chair with the elbow flexed 90 degrees and was instructed to squeeze the dynamometer as fast and as forcefully as possible. From a total of 3-5 attempts, the highest force value was used as the handgrip strength.

Balance was measured on an Advanced Mechanical Technology, Inc (AMTI) force platform during a one-legged stance with eyes open and arms across the chest [43,44]. The participant focused on a dot on the wall and stood as steady as possible for 30 seconds. Balance was defined as the sway area (95% confidence ellipse measured in cm^2). A lower sway area indicates better balance. Three 30-second attempts were given and the lowest sway area of the three attempts was used. Some participants were unable to maintain their balance for 30 seconds; therefore, the outcome was also dichotomized as a "yes/no" answer regarding completion of the test.

The ability to rise from a chair was determined by a chair rise test. Participants were instructed to rise and sit as many times as possible over 30 seconds [45]. Only one attempt was given because of the tiring nature of the test. An electronic switch placed under the seat of the chair counted the total number of chair rises.

Confounders and Intermediate Variables

Information about various confounders was available from the CAMB questionnaire:

1. Chronic diseases. Number of chronic diseases are registered and grouped into three groups: no chronic disease, one chronic disease, and two or more chronic diseases. Relevant diseases were asthma, diabetes, hypertension, angina pectoris, stroke, myocardial infarction, bronchitis, emphysema, osteoarthritis, cancer, anxiety, depression, other psychiatric diseases, and back pain.

2. Pain. A general pain score was calculated from answers about pain levels in 9 parts of the body.

3. Leisure-time physical activity. Information about weekly physical activity during leisure-time was reported in two ways. Duration of housing and gardening work plus walking and bicycling (including transportation to work) is summated and categorized as less than 3 hours per week, 3–6 hours per week, and more than 7 hours a week. Another question included a more specific description of the intensity of physical activity during leisure time and was categorized as low, medium, or high intensity.

4. Smoking. Smoking was reported as smoker/non-smoker including a smoking history in pack years (defined as 20 cigarettes or an equal amount of tobacco smoked each day for 1 year).

5. Alcohol consumption. Alcohol consumption was categorized in units of alcohol per week.

6. Education. School education was categorized into three groups: no exam, primary education, and secondary/higher education. Vocational education was categorized into five groups: unskilled, skilled manual worker, and short, medium, or long further education.

7. Occupational social class. Information about current occupation and education was used to categorize participants into eight socioeconomic classes.

8. Psychosocial work environment. Information about psychosocial work environmental factors (eg, demands, feedback, support, and influence) was also included in the analyses as confounders.

9. Physical measures. Height, weight, and lean body mass were measured at the examination. Body mass index (BMI) was categorized into four groups: <18.5, 18.5–25, 25–30, and >30 kg/m^2.

Statistical Analysis

The primary outcome is signs of early musculoskeletal aging, measured as performance in the three physical tests.

The following null-hypothesis will be tested: in 3 tests of physical function, there is no difference between middle-aged Danes according to their level of lifetime occupational physical activity.

Because prior studies hypothesized a positive association between manual workers and handgrip strength, we will analyze handgrip strength in a separate analysis. Analyses will be stratified for gender due to differences in physical capacity.

First univariate analyses of the cumulative exposures to standing and lifting and the associations with the three outcome measures will be calculated using logistic regression analyses. Analyses will be repeated using self-reports of exposure. Afterwards multiple regression analyses with stepwise forward selection of variables will be used.

Dropout analyses will be done with the CAMB database to study attrition by using information on socioeconomic status, health, and lifestyle factors from previous questionnaires and registers.

Power Calculation

The power calculation is based primarily on the studies of Kuh et al of a British birth cohort of comparable age and size (2797 individuals age 53 years) [29,46]. Work is included as a dichotomized covariate (manual/non-manual) in their multivariate regression analyses. We expect to find larger differences in our study using a more specific exposure assessment. The following power calculations were performed in SAS version 9.2 PROC POWER. It is assumed that 20% of the population has a job history that includes a moderate to high level of OPA, and we are aiming for a power of 90% (beta = .1) with a significance level of 5% (alpha = .05) in the following calculations.

Handgrip Strength

Kuh et al found a non-significant difference of 0.3 kg in handgrip strength between manual and non-manual male workers [29]. A significant difference of 4 kg between manual and non-manual workers was found in the Il SIRENTE study [14], in which hard physical work was a primary exposure but included older participants. Presuming a relevant difference of 4 kg and the previous assumptions, 2375 participants are needed to show a statistical difference.

Chair Rise Test

Kuh et al measured time to complete 10 chair rises and found a difference of 0.3 sec^{-1} (SD 3.3) between manual and non-manual workers. This is a small difference. A slightly larger difference of 0.5 sec^{-1} is more appropriate, so that manual and non-manual workers use 22 and 20 seconds, respectively. Given this and the other assumptions described previously, n is calculated to be 2870.

Balance

In the British birth cohorts, balance was tested at home and the results are not comparable to our test of balance using the AMTI platform.

From the power calculations in SAS PROC POWER, we will find significant differences (alpha = .05) between manual and non-manual workers in the three physical tests if we include at least 3000 persons.

Discussion

Prevention of decline in physical function due to working conditions is important to the individual worker and to society as a whole in order to maintain the ability to work and prevent disability later in life [47]. More knowledge is needed about the associations between lifetime workload and midlife physical function.

Measurements of physical function are more valid measures than self-reports of pain or disability. The three physical tests were chosen to study functional limitations instead of specific diseases. These outcome measures have been used mainly in gerontological studies [1,2]. There is an association between handgrip strength and mortality in elderly people and handgrip strength and mortality due to all causes in midlife have recently been shown to be associated [2].

Strengths and Limitations

CAMB is a population-based cohort and inclusion is not based on symptoms or diseases [24] which reduces the "healthy worker effect." Cohort members are invited and included regardless of their status in the labor market. Therefore, the cohort includes middle-aged Danes who are still working, on disability pension, unemployed, sick-listed, or have retired early. All have their occupational history recorded through the questionnaire. However, health and physical capacity during youth is not taken into account in our analyses. We hope to be able to include data on chronic diseases in youth in later analyses in order to study selection into jobs or into the labor market. A low participation in CAMB among those invited can lead to selection bias; therefore, dropout analyses are crucial.

We introduce an individual summation of exposure to occupational physical activity in working life using self-reports of job history and expert judgments of exposure to OPA and the exposure assessment is strengthened by a combination of dose (level of physical activity) and time (duration of occupation) [48]. However, there is a risk of misclassification due to generalization of physical demands in job groups (HEGs) in the JEM. By using the five longest-held jobs plus the present job in the exposure assessment, we take account of the fact that deterioration of physical function may be a chronic process and symptomatic workers are more likely to change jobs from high exposure to low exposure [22,49].

Changes in lifestyle factors and socioeconomics throughout life are not taken into account in this study, but historic data about exposures during childhood and adulthood will be included in future analyses. Because the participants did not have a physical examination during their youth, we cannot make conclusions about causal relationships with respect to changes in physical function.

Impact of Results

In Danish public opinion, OPA is considered to have detrimental effects on health. Work-related exposure is thought to be the primary cause of decline in physical function and ability to work in midlife. We hope to investigate this using the occupational life-course perspective on musculoskeletal aging and physical function. At the same time, it is important to prevent early exit from the labor market due to demographic changes in the Western world. This study will help pinpoint targets for such prevention strategies.

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The CAMB study was approved by the Regional Committee on Biomedical Research Ethics, Capital Region, Registration Number H-A-2008–126.

Authors' Contributions

AM was the first author of the manuscript and participated in the design of the study. OSM, JHA, PS, and SR designed the study in collaboration with KA. TSE and JHA participated in establishment of the job exposure matrix and in drafting and revision of the manuscript. LLA participated in collection of data in CAMB and was involved in the drafting and revision of the manuscript. KA, RL, MO, and AMH made substantial contributions to establishment of CAMB and to collection of data, and participated in drafting and revision of the manuscript. UC, RL, and MO contributed by administration of the two cohorts and participated in drafting and revision of the manuscript. All authors have read and approved the final manuscript and contributed to the revision of the manuscript.

Conflicts of Interest

None declared.

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Abbreviations

AKF: Anvendt Kommunal Forskning ("Danish Institute of Governmental Research")
AMTI: Advanced Mechanical Technology, Inc.
BMI: body mass index
CAMB: Copenhagen Aging and Midlife Biobank
D-ISCO: the Danish version of ISCO
HEG: homogeneous exposure groups
ISCO: International Standard Classification of Occupations
JEM: job exposure matrix
LY: lifting year (lifting more than 20 kg at least 10 times per day in a year)
NRCWE: National Research Centre for the Working Environment
OPA: occupational physical activity
SY: standing year (6 hours of standing and walking at work per day in a year)
TY: ton year (1000 kg of heavy lifting per day in a year)

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Appendix 7

Paper III

Møller A, Reventlow S, Hansen ÅM, Andersen LL, Siersma V, Lund R, Avlund K, Andersen JH, Mortensen OS. Does a history of physical exposures at work affect hand-grip strength in midlife? A retrospective cohort study in Denmark. Scandinavian Journal of Work Environment and Health. 2013; epub ahead of print. PMID 23665642

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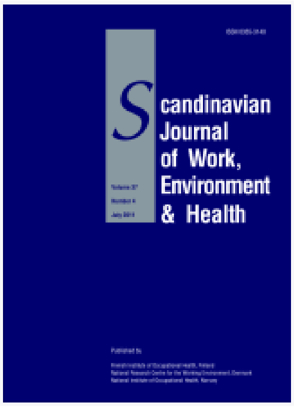

Original article

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Does a history of physical exposures at work affect hand-grip strength in midlife? A retrospective cohort study in Denmark

by Møller A, Reventlow S, Hansen ÅM, Andersen LL, Siersma V, Lund R, Avlund K, Andersen JH, Mortensen OS

This retrospective cohort study evaluates the associations between physical exposures throughout working life and late midlife hand-grip strength (HGS). Exposure to lifting, standing/walking, and kneeling were analyzed in multiple regression models. Physical exposures in working life were associated with a slightly higher HGS among men but no associations between physical exposures and HGS were seen among women.

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Key terms: cohort study; Denmark; ergonomics; hand-grip strength; muscle strength; musculoskeletal aging; occupational; physical activity; physical exposure; retrospective cohort study

Scand J Work Environ Health – online first. doi:10.5271/sjweh.3368

Does a history of physical exposures at work affect hand-grip strength in midlife? A retrospective cohort study in Denmark

by Anne Møller MD,[1, 2, 3] Susanne Reventlow DMSc,[3] Åse Marie Hansen PhD,[2, 4] Lars L Andersen PhD,[2] Volkert Siersma PhD,[3] Rikke Lund PhD, [4, 5] Kirsten Avlund DMSc, [4, 5, 6] Johan Hviid Andersen PhD,[7] Ole Steen Mortensen PhD [1, 2]

Møller A, Reventlow S, Hansen ÅM, Andersen LL, Siersma V, Lund R, Avlund K, Andersen JH, Mortensen OS. Does a history of physical exposures at work affect hand-grip strength in midlife? A retrospective cohort study in Denmark. *Scand J Work Environ Health* – online first. doi:10.5271/sjweh.3368

Objective The aim of this cohort study was to examine associations between physical exposures throughout working life and hand-grip strength (HGS) in midlife.

Methods The Copenhagen Aging and Midlife Biobank (CAMB) provided data about employment and HGS for 3843 Danes. Individual job histories, including duration of employment in specific jobs, were assigned exposures from a job exposure matrix. Exposures were standardized to ton-years (lifting 1000 kg each day in one year), stand-years (standing/walking for six hours each day in one year) and kneel-years (kneeling for one hour each day in one year). The effects of exposure-years on HGS were analyzed as linear effects and cubic splines in multivariate regression models, adjusted for potential confounders.

Results Mean age was 59 years among both genders and HGS was 49.19 kg [standard deviation (SD) 8.42] and 30.61 kg (SD 5.49) among men and women, respectively. Among men, exposure to kneel-years was associated with higher HGS (>0.030 kg (P=0.007) per exposure-year). Ton- and stand-years were not associated with HGS among either men or women in linear analyses. In spline regression analyses, associations between ton- and stand-years and HGS were non-linear and primarily positive among men. Among women, the associations were non-linear and, according to ton-years, primarily negatively associated with HGS but statistically insignificant.

Conclusion A history of physical exposures at work explained only a minor part of the variation in HGS, though exposure to kneeling throughout working life was associated with a slightly higher HGS among men. Exposure to lifting and standing/walking was not associated with HGS.

Key terms ergonomics; muscle strength; musculoskeletal aging; occupational; physical activity

The influence of work-related exposures on muscle strength has been discussed since the 1980s, where occupational physical activity was thought to strengthen manual workers (1). Since then the focus has been on the deteriorating effects of physical exposures, which are now known to be important risk factors in the development of musculoskeletal symptoms and diseases (2, 3). It has been suggested that exposure and musculoskeletal injury (or deterioration) follow a dose–response relationship (4), but threshold values for duration or intensity of exposure have not been established (3, 5). One explanation for this is the multi-factorial origin of musculoskeletal symptoms and diseases, including genetic, morphological, psychological, and biomechanical risk factors (4, 5). Theories about cumulative load suggest "wear and tear" as an important factor in the deterioration of the musculoskeletal system (4, 5), and the underlying musculoskeletal aging process also plays an important role (6).

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Few studies have used the objective outcomes of physical function as signs of occupational musculoskeletal deterioration though objective measures have been suggested to be less biased than self-reports (7). Hand-grip strength (HGS) is a simple objective measure of muscle strength and a well-known predictor of morbidity and disability among older people (8–10) and of mortality among both younger (11) and older age groups (8,12,13). A positive association between manual work and HGS was shown among men with a high workload compared to men with a lower workload in a cross-sectional study (14), suggesting a training effect. A few longitudinal studies have had contradictory results. Savinainen et al (15) found no association between perceived physical workload at baseline and HGS after 22 years of follow-up (mean age 67.3 at follow-up); while Stenholm et al (16) found that self-reports of physical work at baseline were associated with lower HGS at follow-up 22 years later (mean age 48 at follow-up). However, changes in exposure or total amount of exposure during the follow-up period were not taken into account in these studies. Torgen et al (17) included a retrospective assessment of exposures at work and found that HGS was higher among middle-aged manual workers with a history of physical work compared to non-manual workers (17). On the contrary Nygaard et al (18) found no association between current or lifetime physical occupational exposures and HGS among 19–64-year old workers.

The inconsistency of results, suggesting both the training and deteriorating effects of physical exposures on midlife HGS, could be due to differences in study design and lack of power in follow-up studies. The aim of this study was to evaluate the association between physical exposures throughout working life and midlife HGS in a large, population-based cohort in Denmark. More specifically, we wanted to study whether a history of physical exposures at work was associated with HGS when we took other determinants of HGS into account. Previous studies of associations between exposures at work and HGS are ambiguous and, based on these, we hypothesized that there would be no association between physical exposures and HGS in midlife.

Methods

Study design and participants

This population-based retrospective cohort study included a cross-sectional physical examination as part of the Copenhagen Aging and Midlife Biobank (CAMB) (19). CAMB was established to study signs of early aging among middle-aged Danes and was based on three existing Danish cohorts. In this study, we used data from two of the three cohorts in CAMB: the Metropolit Cohort (MP) and the Danish Longitudinal Study on Work, Unemployment and Health (DALWUH). In total, 12 656 middle-aged men and women were invited to take part (see figure 1).

The data collection in CAMB took place between April 2009 and March 2011 and included a postal questionnaire and a health examination at the National Research Centre for the Working Environment (NRCWE). This involved a review of the completed questionnaire, measurement of weight and height, physical tests including measurement of HGS, cognitive tests, blood sampling, and finally information about health status arising from some of the results of the examination. For details about the use of data from CAMB in this study see our research protocols (20). The selection of participants is illustrated in figure 1.

Exposure

The assessment of physical exposures at work was based on information about job history from the questionnaire combined with data from a job exposure matrix. Self-reports of physical exposures in the workplace derived from the questionnaire were not used since they had low reliability compared with similar information derived from a semi-structured interview (21). The CAMB questionnaire provided job titles and length of service for the participants' five longest-held occupations. Each participant's job history was coded according to the 1988 revision of the Danish version of the International Standard Classification of Occupations register (D-ISCO 88) (20). From an existing Danish job exposure matrix (the knee-hip matrix), information about physical exposures in Danish jobs (linked to D-ISCO-88 codes) was retrieved (22). The knee-hip matrix was based on expert judgments of physical exposures associated with risk of osteoarthritis in the lower limb: sitting, standing/walking, whole-body vibration, kneeling, and lifting (weight and number of heavy lifts) (20). In the present study, we used three physical exposures as proxy measures for occupational physical activity: (i) lifting, because lifting at work is the main physical exposure included in the definition of hard physical work (23); (ii) standing/walking, because standing/walking at work is a common exposure, even in jobs that do not include lifting but are still categorized as physical work, like cleaning; and (iii) kneeling, because kneeling is a specific exposure in physically demanding job types, like floor laying or plumbing.

The total amount of exposure for a study participant was expressed as the number of years a standard daily exposure incurred. Thus, the years of employment in each of the jobs retrieved from the questionnaire were multiplied by the corresponding daily amount of lifting, standing/walking, and kneeling retrieved from the

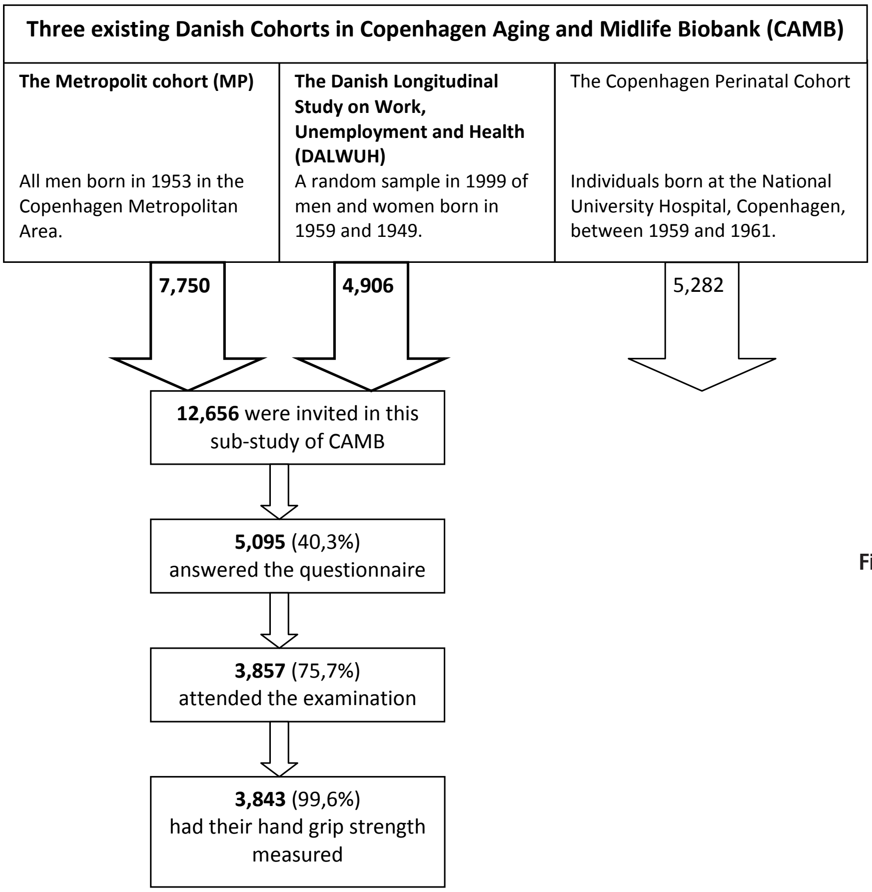

Figure 1. CAMB cohorts and participation.

knee-hip matrix, and then calculated for the participants' entire working life. In this way the exposures were standardized as ton-years (lifting 1000 kg each day in one year), stand-years (standing/walking at work for six hours each day in one year) and kneel-years (kneeling at work for one hour each day in one year).

Outcome

HGS was measured with a Jamar dynamometer (model G100, Biometrics Ltd, Newport, UK) wired to a computer's signal conditioning interface, enabling automatic recording of the grip strength force. Each participant sat upright in a chair with the elbow flexed at 90 ° and was instructed to squeeze the dynamometer as fast and as forcefully as possible (24). The maximum force value (kg) of five possible attempts was defined as the HGS.

Covariates and intermediate variables

From the CAMB questionnaire, we had information about age, height, weight, vocational education, chronic diseases, leisure-time physical activity (LTPA), and pain in hands and wrists.

Our theoretical model is seen in figure 2. Muscle strength declines over time, and age is an important confounder since it also influences length of exposure. Height and weight (among men) are strongly correlated to HGS (25) and therefore included in the models. Men were included from the MP and DALWUH cohorts therefore "cohort" was included as a covariate. Vocational education is associated with both exposure and outcome and therefore included as a confounder in the theoretical model. Vocational education was categorized into five groups: unskilled, skilled manual worker, and short-, medium-, or long-cycle further education. Chronic diseases influence exposure but could be a result of exposures, too, and therefore a potential mediator in the theoretical model. Number of chronic diseases was registered and grouped in three: 0, 1, and ≥2 chronic diseases. Diseases supposed to influence both exposure and outcome were asthma, diabetes, hypertension, angina pectoris, stroke, myocardial infarction, bronchitis, emphysema, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression/other psychiatric diseases, and back pain. LTPA influences physical capacity and thereby both exposure and outcome, however the level of physical activity at work likewise influences LTPA.

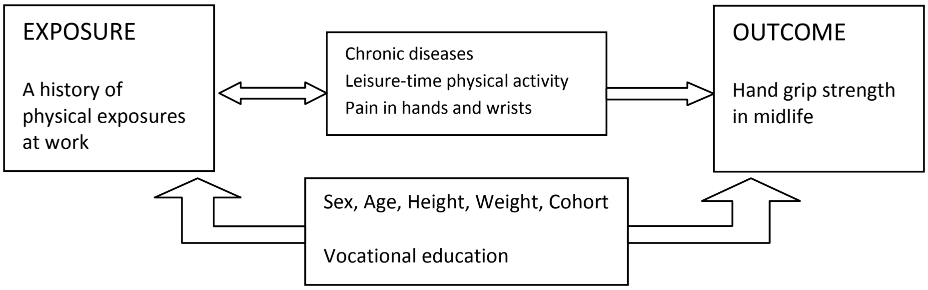

Figure 2. Theoretical model. Associations between exposure and outcome including covariates.

Information about the intensity of weekly physical activity during leisure-time was categorized as medium/hard=>4 hours a week, light=<4 hours a week, and sedentary=reading/watching television during leisure time. Pain was a potential mediator too, and pain in one or both hands and wrists was registered on a scale from 1 (no pain) to 9 (worst possible pain).

Statistical methods

Sex influences both exposures and muscle strength and all analyses were stratified by gender. The associations between exposure-years and HGS, adjusted for potential confounding, were estimated in multivariate linear regression models. Model 1 included age, height, and weight; model 2 included covariates from model 1 and vocational education. Chronic diseases, LTPA and pain in hands/wrists could both be mediators and confounders and thus were introduced separately to model 2 to study the effect on the associations. To evaluate how well the models predict HGS, we report the proportion of the variation explained by the regression models (R^2) (26). We analyzed for interaction between height and weight and between exposure-years and LTPA. Since the effect of physical exposures on HGS was hypothesized to be a combination of training, deterioration, and aging effects, a linear term may be too limited to characterize this association. Therefore we studied the shape of the association by modeling it as a restricted cubic spline function. The resulting spline functions were then plotted to show the expected increase in HGS attributed to each category of exposure, avoiding a linearity assumption (27, 28).

All analyses were performed using SAS 9.2 (SAS Institute, Cary, NC, USA), except the regression with spline functions which were done in the R system for statistical computation.

Results

The characteristics of the study population are presented in table 1. Mean age was 59 (53–64) years and men constituted 79.2% of the study population since the MP cohort included only male participants. Mean seniority in work based on the five longest-held employments registered in the CAMB questionnaire was 31.67 (SD 7.85) years among men and 30.10 (SD 8.82) years among women. Mean HGS was 1.6 times higher among men compared to women, and women had fewer exposure-years than men.

In the unadjusted analysis of the association between ton-years and HGS, a significant decline of 0.014 kg per ton-year was seen among men (P=0.045). However, when adjusting for age, height, and weight, the association between ton-years and HGS disappeared. In women no significant association was seen in either of the models (table 2). In all unadjusted analyses, the physical exposures explained less than 1% of the variation in HGS however the full model explained up to 24% of the variation.

Among men, exposure to kneel-years was positively associated with higher HGS in model 2, increasing HGS by 0.030 kg per exposure-year (P=0.007), see table 2.

In unadjusted analyses of associations between LTPA and HGS, we found that medium/high compared to sedentary LTPA increased HGS by 2.57 and 2.04 kg among women and men respectively (P=0.0025 and 0.0002). However, when LTPA was introduced to model 2, the association between kneel-years and HGS in men was attenuated only slightly. Having ≥2 chronic diseases decreased HGS by 1.29 and 1.28 kg among women and men respectively (P=0.0059 and P=0.0007) in unadjusted analyses. However, when included in model 2, chronic diseases affected the associations only slightly.

There was no significant interaction between height and weight, and only one statistically significant interaction term between ton-years and LTPA among men. Introducing the interaction term to model 2 attenuated the association between ton-years and HGS (from ß=-0.003 kg, P=0.653 to ß=0.0003 kg, P=0.9567).

The associations between each of the three physical exposures and HGS were evaluated visually (figure 3). Exposure to ton- and stand-years was slightly positively associated with HGS among men (figure 3, left column). The non-linear regression confirmed the positive asso-

Table 1. Characteristics of the study population, exposures and outcome. [MP=Metropolit Cohort; DALWUH=Danish Longitudinal Study on Work, Unemployment and Health; SD=standard deviation]

	Men				Women			
	N	%	Mean	SD	N	%	Mean	SD
Age	4035		58.99	2.32	1060		58.58	5.00
Height (cm)	3968		179.66	6.76	1045		166.58	6.15
Weight (kg)	3941		85.86	14.34	1029		69.79	13.26
Pain index [a]	3964		1.88	1.72	1044		2.44	2.20
Duration of working years [b]	3880		31.46	8.12	1016		29.69	8.94
Chronic diseases [c]	3993				1052			
No disease	1225	30.68			320	30.42		
1 disease	1326	33.21			311	29.56		
≥2 diseases	1442	36.11			421	40.02		
Vocational education	3964				1039			
Long cycle	738	18.6			131	12.6		
Medium cycle	857	21.6			313	30.1		
Short cycle	336	8.5			107	10.3		
Semi-skilled	1689	42.6			387	37.2		
Unskilled	344	8.7			101	9.7		
Intensity of leisure-time physical activity [d]	3957				1040			
Medium/hard	1253	31.7			255	24.5		
Light	2240	56.6			706	67.9		
Sedentary	464	11.7			79	7.6		
Labor market status	3953				1033			
Employed	3561	88.3			802	77.6		
Unemployed [e]	474	11.7			231	22.4		
Cohort [f]	4035				1060			
MP	3153	78.1			.	.		
DALWUH	882	21.9			1060	100.0		
Ton-years [g]	3880		12.90	23.15	1016		6.04	12.38
Stand-years [h]	3880		11.26	13.80	1016		7.43	11.44
Kneel-years [i]	3880		7.29	14.99	1016		1.14	2.99
Hand grip strength (kg)	3059		49.19	8.42	784		30.61	5.49

[a] Pain in hands and wrists. Score 1–9, where 1=no pain and 9=worst possible pain.
[b] Duration of working years: summation of years in the five longest employments registered in the questionnaire.
[c] Asthma, diabetes, hypertension, angina, stroke, bronchitis, chronic obstructive pulmonary disease, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression, psychiatric diseases, and back disease.
[d] Medium/hard = >4 hours a week, light=<4 hours a week, sedentary=reading/watching television during leisure-time.
[e] Unemployed=currently unemployed and early retirement, disability pensioners etc.
[f] Male participants were from two cohorts.
[g] Amount of lifting during working life. One ton-year is lifting 1000 kg each day in one year.
[h] Total exposure to standing/walking at work. One stand-year is standing/walking for six hours each day in one year
[i] Total exposure to kneeling at work. One kneel-year is kneeling at work one hour each day in one year.

ciations found in the linear models according to kneel-years among men, but the association was non-linear. Among women, the associations were non-linear and primarily negative, but all regressions were statistically insignificant (figure 3, right column).

Attrition analyses

Attrition analyses on the total CAMB study sample, including all three cohorts, showed that responders to the questionnaire (7191/17 938) and participants attending the physical examination (5576/17 938) had significantly higher education and were more likely to be employed compared to non-responders/non-participants (based on data from Danish registers). Use of the health-care system (ie, visits to the general practitioner during 2009) showed no statistically significant difference among the responders/participants and non-responders/non-participants, suggesting that participants and non-participants did not differ with regard to general health (19). Furthermore, using data from the two cohorts in the present study, we compared those who only completed the questionnaire (1238/5095) with those who took part in both the questionnaire study and the physical tests (3857/5095). We found that participants taking the physical tests were exposed to fewer physical exposures at work (11.7 versus 16.9 ton-years among men and 5.1 versus 9.0 ton-years among women), reflecting participants' higher educational attainment level.

Table 2. Multivariate linear regression models. Associations between exposure-years and hand-grip strength.

	Men				Women			
	N	Regression coefficient	P-value	R^{2} [a] (%)	N	Regression coefficient	P-value	R^{2} [a] (%)
Ton-years [b]								
Unadjusted	2986	-0.014	0.045	0.13	767	-0.016	0.317	0.13
Model 1 [c]	2945	-0.007	0.296	12.1	755	-0.011	0.454	21.9
Model 2 [d]	2911	-0.003	0.722	12.6	748	-0.004	0.812	23.2
Model 2 and leisure-time physical activity [e]	2896	-0.003	0.653	13.4	745	-0.001	0.928	24.9
Model 2 and chronic diseases [f]	2909	-0.001	0.864	13.0	748	-0.005	0.752	23.7
Model 2 and pain index [g]	2904	0.003	0.730	13.9	747	-0.004	0.803	24.4
Stand-years [h]								
Unadjusted	2986	-0.014	0.233	0.05	767	-0.008	0.667	0.02
Model 1 [c]	2945	0.010	0.339	12.1	755	-0.011	0.496	21.9
Model 2 [d]	2911	0.022	0.087	12.6	748	0.001	0.932	23.1
Model 2 and leisure-time physical activity [e]	2896	0.020	0.119	13.4	745	0.002	0.908	24.9
Model 2 and chronic diseases [f]	2909	0.024	0.063	13.1	748	0.001	0.955	23.7
Model 2 and pain index [g]	2904	0.030	0.021	14.0	747	0.001	0.936	24.4
Kneel-years [i]								
Unadjusted	2986	0.007	0.522	0.01	767	-0.053	0.453	0.07
Model 1 [c]	2945	0.024	0.017	12.3	755	-0.070	0.271	22.0
Model 2 [d]	2911	0.030	0.007	12.8	748	-0.025	0.696	23.2
Model 2 and leisure-time physical activity [e]	2896	0.026	0.021	13.5	745	-0.017	0.790	24.9
Model 2 and chronic diseases [f]	2909	0.031	0.005	13.3	748	-0.030	0.645	23.8
Model 2 and pain index [g]	2904	0.036	0.001	14.2	747	-0.030	0.641	24.4

[a] The proportion of the variation explained by the regression model in %.
[b] Amount of lifting during working life. One ton-year is lifting 1000 kg each day in one year.
[c] Adjusted for age, height, weight, and cohort.
[d] Adjusted for Model 1 + vocational education.
[e] Medium/hard=>4 hours a week, light=<4 hours a week, sedentary=reading/watching television during leisure-time.
[f] Chronic diseases in three groups: 0, 1 or ≥2 of the following diseases: asthma, diabetes, hypertension, angina, stroke, bronchitis, chronic obstructive pulmonary disease, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression, psychiatric diseases, and back disease.
[g] Pain in hands and wrists. Score 1–9, where 1=no pain and 9=worst possible pain.
[h] Total exposure to standing/walking at work. One stand-year is standing/walking for six hours each day in one year.
[i] Total exposure to kneeling at work. One kneel-year is kneeling at work one hour each day in one year.

Discussion

A history of physical exposures throughout working life explained only a minor part of the variation in HGS observed in this cohort. A positive association between exposures to kneeling and midlife HGS was seen among men, whereas exposure to lifting and standing/walking was not associated with HGS among men or women.

The effect of exposure to kneel-years in men was non-linear and most pronounced for exposure to 20–40 kneel-years (figure 3). Since the effects on HGS were different for the three outcome measures, one can speculate how jobs including lifting and standing/walking differ from jobs including kneeling according to exposures to the upper limb. It is well known that strong hand movements in vigorous activities increase HGS (25), and maybe the use of hand-held tools in workers kneeling at work (eg, carpenters, floor layers and plumbers) could explain part of the results. In fact, studies have shown that older power line technicians had higher HGS than expected for their age (29) and older waste collectors had higher shoulder strength compared to their younger colleagues (30), suggesting a task-specific training among older workers. Schibye et al (31) compared their results to studies of meat cutters who had lower HGS than waste collectors, maybe due to the lack of variety in job tasks among meat cutters compared to waste collectors (31). Workers with repetitive jobs are standing most of the day, and the jobs might include lifting, but seldom kneeling and thereby earning primarily “stand-years”. In our study, an expert judgment of repetitive work was not available from the job exposure matrix, but we found no association between self-reports of repetitive work and HGS in additional analyses (results not shown).

We found no association between physical exposures and HGS among women. This is in accordance with Rantanen et al (32) who found that a history of physical exposures had no association with muscle strength (including HGS) among older women (32). However in spline regressions, we found signs of deteriorative effects of ton-years on HGS among women. This is in contrast to the findings by Torgen et al (17) who found signs of a strengthening effect from the accumulated amount of physical work on HGS among both women and men. Few women had a history of physical exposures and almost no women were exposed to kneeling at work. There was a gender segregation in jobs in this age-

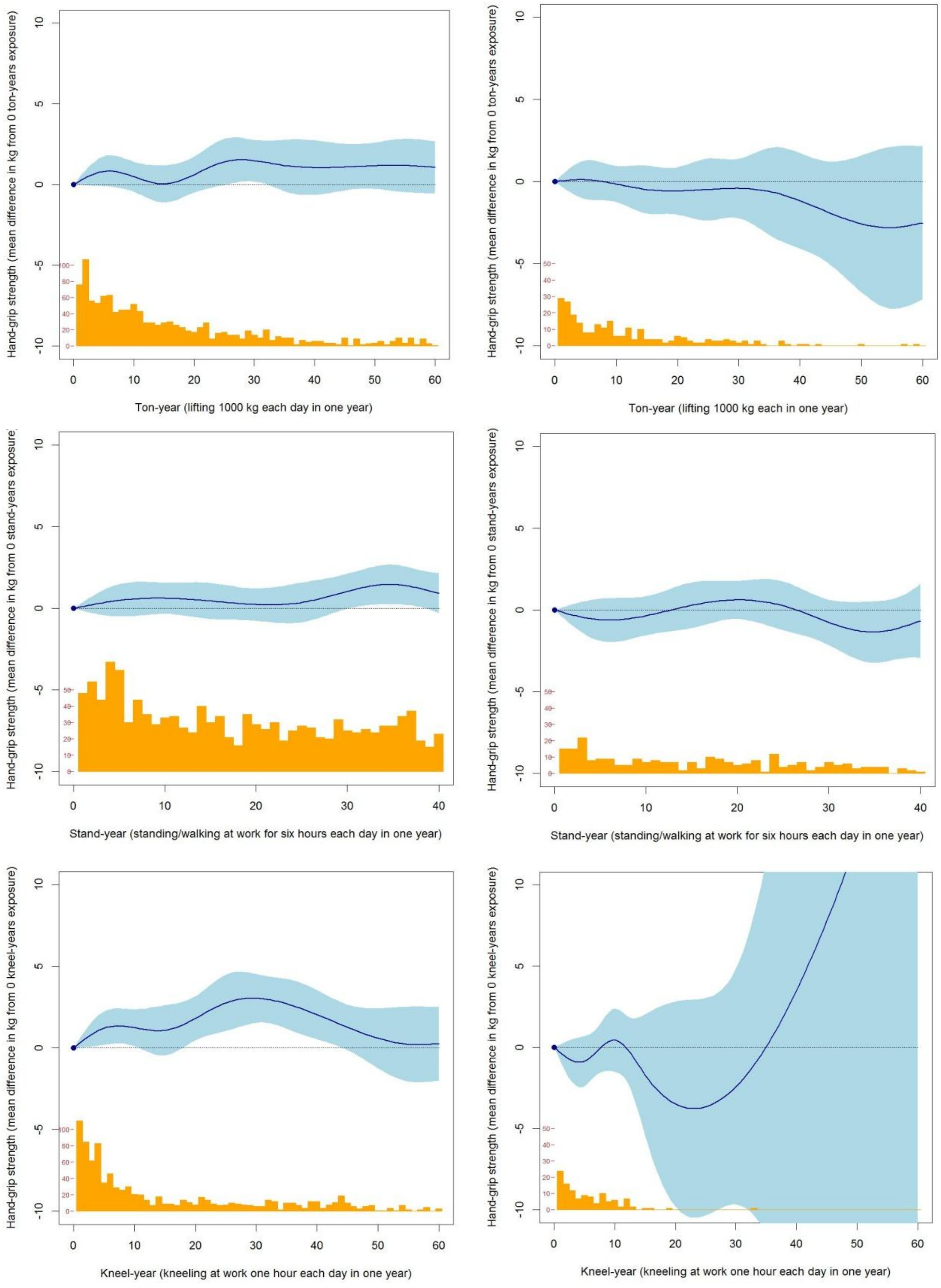

Figure 3. Multivariate spline regression analyses and confidence intervals (model 2 adjusted for height, weigth, age, cohort, and vocational education). Expsoure to ton-, stand-, and kneel-years in years at the x-axis, and hand grip strength (kg) in the y-axis. In men (left column) and women (right column). Participants are visualized in the bottom of each graph.

cohort since exposed women had mainly been employed as assistant nurses and cleaning assistants, whereas exposed men were employed in many different jobs with a variety of exposures. It is not known whether women would have had the same effect of exposure to kneeling if they had had the same jobs as men. Women have a higher relative workload if they perform the same tasks as men due to their lower muscle strength. Therefore, compared to men, women have another threshold and for example benefit from light physical activity in leisure-time like gardening (33). We found, however, that moderate-to-high activity in leisure-time increased HGS significantly among both men and women in unadjusted analyses. Existing evidence is limited by methodological problems due to categorization and misclassification of physical activity at work and during leisure-time, and also activity related to transportation and household work. Earlier studies have shown ambiguous results: LTPA was beneficial to HGS among middle-aged men (25) whereas no association was seen between baseline physical activity or persistent physical activity and HGS in midlife in a recent follow-up study (16). Interaction between physical exposures at work and physical activity during leisure-time is a possible bias, but we found no interaction between exposures and LTPA except in one exposure group among men. However, inclusion of this interaction term in the regression model did not change the relationship between the exposure and the outcome. Another possible bias, in studies of associations between LTPA and HGS, is participation in sports involving rackets and weight lifting (34). Unfortunately, we had no data on these types of sports in our study.

Introduction of chronic diseases to the models did not change the associations between exposure and outcome. Stenholm et al (16) found that the number of chronic diseases was not associated with HGS but, on the other hand, specific diseases (such as diabetes, hypertension, and asthma) increased the decline in HGS during follow-up. Including a variety of chronic diseases without weighting the diseases or analyzing them separately could be a bias in our study. On the other hand, Torgen et al (17) found that present musculoskeletal symptoms exerted a minor influence on the relationship between physical work and physical capacity. In this study, pain in hands and wrists was associated with lower HGS but explained only an additional 1% of the variance in HGS among both men and women when included in model 2.

The highest increase in HGS observed in this study (ie, among men with a history of kneeling) was 2 kg; according to our study protocol (20), we regarded a difference of 4 kg as clinically relevant. Therefore, though the non-linear analyses showed higher HGS among exposed men, the increase in HGS was not as high as expected and not equal among exposure groups. The low correlation between physical exposures and HGS in midlife indicates that occupational exposures play only a minor role in the variations of HGS in this age group. In studies that have shown clinically relevant differences in HGS among manual and non-manual workers, results could be biased due to inclusion of both mediators and confounders in the theoretical models [eg, in (35)]. The "healthy worker effect" also plays a role in these studies, since healthy workers remain in the labor market while workers who cannot meet the physical demands of their jobs change occupation or leave the labor market through early retirement or disability pension (29) or, in older cohorts, die during follow-up (36). Our results may also reflect a selection of stronger males taking up physically demanding occupations at an early age (17). We have no information about strength in youth but we do have information about birth weight in one of the CAMB cohorts (the MP cohort). Birth weight is known to be associated with HGS in middle-aged Britons, independently of later height and weight gain (37), however, the associations between physical exposures and HGS were unchanged when we included birth weight in the analyses (results not shown).

Differential drop-out could be another bias in this study since those responding to the questionnaire and attending the physical examination were better educated than non-responders and non-participants. Our attrition analyses showed that non-participants had more exposure-years than participants. It is not known, whether inclusion of the non-responders and non-participants would have changed the associations between exposures and HGS.

Strengths and limitations

A major strength of this study was the summation of exposures throughout working life based on information from a job exposure matrix. However, job exposure matrices have potential biases too, including the risk of misclassification of exposure (38). Exposures were assigned to job titles in homologous exposure groups, but variation between exposures in the groups could lead to non-differential bias. Changes in exposures over time were another possible bias in this study. Jobs in the 1970s were assigned the same exposures as the same job titles in the 1990s, even though physical exposures at work have declined in the last 40 years (39). However, we expect the effect of this potential bias to be small in this age-homogeneous cohort. Another possible bias is the standardization of exposure. Twenty ton-years can be "earned" in only 10 years of heavy work or 40 years of less heavy work. The physiological effect of these two types of exposure on muscle strength could be different, but is treated equally in our analyses. However, inclusion of seniority at work as a covariate did not change our results (results not shown).

The large sample size and recruitment from the general population were also strengths of this study and the mean HGS measured in this population corresponds well with recent findings in a Danish population-based cross-sectional study using a Jamar dynamometer (40).

Concluding remarks

A history of physical exposures at work explained only a minor part of the variation in HGS though exposure to kneeling throughout working life was associated with a slightly higher HGS among men. In future follow-up studies, the age-related decline in HGS in this cohort will be studied also from the perspective of lifetime occupational physical exposures.

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Appendix 8

Paper IV

Møller A, Reventlow S, Hansen ÅM, Andersen LL, Siersma V, Lund R, Avlund K, Andersen JH, Mortensen OS. Do Physical Exposures Throughout Working Life Influence Physical Function in Midlife? A Retrospective Cohort Study in Denmark. Submitted to Scandinavian Journal of Work Environment and Health June 2013

Do Physical Exposures Throughout Working Life Influence Physical Function in Midlife? A Retrospective Cohort Study in Denmark.

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Do Physical Exposures Throughout Working Life Influence Physical Function in Midlife?

Abstract

Objectives: Our aim was to study associations between physical exposures throughout working life and physical function in midlife. Methods: The Copenhagen Aging and Midlife Biobank (CAMB) provided data about employment and measures of physical function. Individual job histories were assigned exposures from a job exposure matrix. Exposures were standardized to ton-years (lifting 1000 kg each day in one year), stand-years (standing/walking for 6 hours each day in one year) and kneel-years (kneeling for one hour each day in one year). The associations between exposure-years, chair rise test (number in 30 seconds) and balance test (one legged sway area) were analyzed in multivariate linear and non-linear regression models adjusted for covariates. Results: Mean age among the 3,875 participants was 59 years in both genders, and on average, men achieved 21.58 (Standard deviation (SD)=5.69) and women 20.38 (SD=5.34) chair rises in 30 seconds. Lifting and standing/walking were negatively associated with chair rise performance in men (-0.020 chair-rises/ton-year and -0.024 chair-rises/stand-year, p<0.0001 and p=0.0091 respectively). Exposure to standing and kneeling was associated with poorer balance in women (+0.4% balance area per stand-year and +1.9% per kneel-year, p=0.0234 and p=0.0031 respectively). Spline regression analyses confirmed the findings and a maximum decrease in chair rise (-1.75 chair rises) was seen among men with 25-30 exposure-years. Conclusion: Exposure to lifting and standing/walking throughout working life is associated with poorer chair rise performance in men, but not in women. Exposure to standing and kneeling is associated with slightly poorer balance performance in women, but not in men.

Key words: hard work, occupational epidemiology, balance performance, chair rise test, middle-aged, job exposure matrix

60 words summary:

In this study a history of physical exposures in working life was associated with poorer chair rise performance in men and poorer balance performance in women. Physical exposures may accelerate musculoskeletal ageing; however in this cohort the proportion of the variation in physical function explained by exposures in working life was small.

Introduction

In the 1980s hard physical work was thought to strengthen workers (1). But since then a history of high workload has been associated with lower physical function. In retrospective studies, old men with a history of manual work had lower physical performance (2) and higher risk of physical disability (3) compared to former non-manual workers; and among retired miners, work strain was associated with impaired functional independence (4). Leino-Arjas et al. found increased risk of poor physical function after 28 years' follow up among those reporting high occupational physical strain at baseline (5). In middle aged Swedish workers long lasting physical demands were associated with poor dynamic muscle function, especially in women (6). However in a small follow up study among Finnish municipal workers, change in physical capacity over four years did not differ between different work groups: mental work, physical work, or mixed work (7).

Despite the lack of long prospective follow up studies in this field, there are signs of a negative association between lifetime physical exposures and midlife physical function. Underlying biological processes are the physiological explanation for this negative association, where acute changes in the musculoskeletal system become chronic because of insufficient recovery time (8,9). Prospective studies have shown associations between higher needs for recovery and development of sickness absence as a measure of disability (10). From life course epidemiology (11), theories of cumulative exposures throughout life could be applied to occupational epidemiology, addressing physical wear and tear throughout working life as an important factor in the musculoskeletal aging process.

In previous studies in this field, interviews (2), combined with questionnaires, (5,7), information from registers (3), and assessment by experts (4), have been used to categorize physical job strain, but few studies have included duration of exposure. Torgen et al. invented a physical workload score which was calculated annually for each individual and used to divide participants into three exposure groups (low, intermediate and high workload) (6). In this study we introduce a cumulative and continuous exposure assessment based on information from a Danish job exposure matrix (the knee-hip matrix). To our knowledge this is the first study to use lifetime exposures in an analysis of midlife physical function, specifically, the signs of early musculoskeletal aging.

The aging process can be studied at different levels, from impairment in specific body systems (e.g. muscle strength), through functional limitations, to disability (12). Performance tests, such as balance and chair rise tests, are independent of the surrounding environment and have been used worldwide to assess functional limitations in different age groups and settings (13,14). Performance tests have been shown to be important predictors of morbidity (14) and mortality in older age-groups (13). It has been established from previous studies that being overweight, having low socioeconomic status, and leading a sedentary lifestyle decrease physical performance in midlife (15).

Our study combines occupational epidemiology and exposure assessment with well known gerontological outcome measures in a large population based Danish cohort. In an earlier study we found that a history of physical exposures in working life had a minor but positive association with hand grip strength in middle-aged men (16). The aim of this study is to evaluate the influence of physical exposures in working life on two dynamic measures of physical function. According to previous studies in this field, a history of hard physical work was hypothesized to be associated with lower physical performance in midlife and thereby poorer performance in balance and chair rise tests.

Methods

This population based retrospective study included a cross-sectional physical examination as part of the Copenhagen Aging and Midlife Biobank (CAMB)(17). CAMB was established in 2009-2011 to study signs of early aging in middle aged Danes and was based on three existing Danish cohorts. In this study, we used data from two of the three cohorts in CAMB: ”The Metropolit Cohort” (MP) and “The Danish Longitudinal Study on Work, Unemployment and Health” (DALWUH), from which 12,656 middle aged men and women were invited to participate (see figure 1).

The data collection in CAMB took place between April 2009 and March 2011 and included a postal questionnaire together with a health examination at the National Research Centre for the Working Environment (NRCWE). For details about the use of data from CAMB in this study and a description of the cohorts, see our research protocol (18). The selection and attrition in the study is illustrated in figure 1.

Exposure

The assessment of physical exposures at work was based on information about job history from the questionnaire combined with data from a job exposure matrix (the knee-hip matrix). Self-reports of physical exposures in working life from the questionnaire were not used since they had low reliability compared with similar information derived from semi-structured interviews (19). The CAMB questionnaire provided job titles and length of service for the participants’ five longest held occupations. Each participant’s job history was coded according to the 1988 revision of the Danish version of the International Standard Classification of Occupations register (D-ISCO 88)(18). From an existing Danish job exposure matrix (the knee-hip matrix), information about physical exposures in Danish jobs (linked to D-ISCO-88 codes) was retrieved (20). The knee-hip matrix is based on expert judgments of physical exposures associated with risk of osteoarthritis in the lower limb: sitting, standing/walking, whole-body vibration, kneeling, and lifting (weight and number of heavy lifts)(20). In the present study we used information about three physical exposures: 1) Lifting; the main physical exposure included in the definition of hard physical work (21), 2) Standing/walking; a common exposure in jobs categorized as physically demanding jobs, but without lifting (e.g. cleaning assistants), and 3) Kneeling, because kneeling at work places demands on muscle power and strength in the lower limb.

The total amount of exposure for a study participant was expressed as the number of years incurred by a standard daily exposure. Thus, the years of employment in each of the jobs retrieved from the questionnaire were multiplied by the corresponding daily amount of lifting, standing/walking and kneeling retrieved from the knee-hip matrix, and then calculated for the participants' entire working life. In this way exposures were standardized as ton-years (lifting 1000 kg each day in one year), stand-years (standing/walking at work for six hours each day in one year) and kneel-years (kneeling at work for one hour each day in one year).

Outcomes

Balance

Balance was tested on a force platform (AMTI, model OR6-7-1000, Advanced Mechanical Technology, Watertown, MA). The stance was performed with eyes open and the subjects were instructed to look directly ahead at a small LED placed approximately 2 meters from the force platform at eye height. The subjects stood on the dominant foot and used earmuffs during the balance test to suppress any acoustic disturbances (22). Balance was defined as the postural sway area (95% confidence ellipse measured in mm^2), i.e., a lower sway area equals better balance. Three 30-second attempts were made by each participant, and the lowest sway area from the 3 attempts was used. Due to the non-normal distribution of the sway area, the variable was analyzed in logarithms ($\log_{10}$). Participants unable to fulfil the balance test were registered as missing according to sway area.

Chair rise

Functional lower limb capacity was measured as the number of chair rises performed during a 30 second test (23). Participants were instructed to perform as many chair rises as they could in a 30 second period. The test was performed using a chair (height 45 cm) with a mechanical contact in the seat, enabling automatic recording of the number of posture transitions and the number of cycles completed, e.g. 21.2 cycles in 30 seconds (17,22). Because the test was somewhat tiring each participant made only a single attempt. Participants unable to perform the chair rise test were included as missing in the analyses.

Covariates

From the CAMB questionnaire information about vocational education was categorized into five groups: Unskilled, skilled manual worker, and short cycle, medium cycle, or long cycle further education. Men were included from two cohorts (MP and DALWUH) and since the two cohorts differed according to scope and social background, “cohort” was included as a confounder.

The questionnaire provided information about the number of chronic diseases among participants, and these were grouped in three: 0, 1, and ≥2 or more chronic diseases. The diseases considered relevant for length of exposures in working life and physical function were asthma, diabetes, hypertension, angina pectoris, stroke, myocardial infarction, bronchitis, emphysema, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression/other psychiatric diseases, and back pain. Leisure-time physical activity (LTPA) was categorized as medium/hard: >4 hours a week, light: <4 hours a week, and sedentary: reading/watching television in leisure time. Smoking history was calculated as pack years (defined as twenty cigarettes or an equal amount of tobacco smoked each day for 1 year) and current alcohol consumption was categorized in units of alcohol per week. Pain in nine regions of the body was summarized (pain in neck, shoulders, upper part of back, elbows, lumbar region, hands/wrists, hips, knees, and ankles). The minimum score was 9 (no pain in any of the regions) and the maximum was 81 (worst possible pain in all nine regions). Work status was defined as employed or unemployed (currently unemployed and early or disability retirement).

Theoretical model

Age, height, cohort, and vocational education were seen as confounders in the theoretical model (figure 2). Chronic diseases influence physical function but could be both a confounder and a mediator since a chronic disease could be caused by the exposure, or, morbidity could influence the duration and intensity of exposure in working life. LTPA is beneficial to physical function generally, but the association with work exposures is less clear. Current LTPA could be a mediator in the association between physical exposures at work and physical function. But current LTPA, as a proxy of former LTPA, could also influence how many years a worker is able to meet the demands of a hard physical job and thereby influence the total amount of exposure. Alcohol and smoking were seen as mediators in the conceptual model together with pain and work status.

Statistical Analysis

As the effects of physical exposures were assumed to be gender-specific, all analyses were performed separately for each sex as suggested by Silverstein et al. (24). Both unadjusted and adjusted associations between exposures (summation of exposure-years) and outcomes (balance and chair rise tests) were assessed in general linear regression models. First, age, height, cohort, and vocational education were included with the exposure (model 1). Subsequently, chronic disease and LTPA were included in a second series of multivariable models to study their mediation effect. Finally, all mediators were included in a third series of multivariable models to study if an observed effect could be explained by the mediators. All analyses were performed in PROC GLM (SAS 9.2) To study how well the models predicted physical performance, we reported the proportion of the variation explained by the regression models (R^2) (25).

Since the effect of physical exposure on physical performance has been suggested to be both strengthening and deteriorating to physical function, a linear term may be too limited to characterize these associations (26). Therefore we studied the shape of the associations by modelling them as restricted cubic spline functions (Model 1). The resulting spline functions were then plotted to show the expected difference in outcome attributed to each category of exposure, avoiding a linearity assumption (26,27).

Attrition analyses were performed in the CAMB cohort (17), and in this study differences in exposure characteristics between participants and non-participants were analyzed with t-tests.

All analyses were performed using SAS 9.2, except the regression with spline functions, which were done in the R system for statistical computation (www.cran.r-project.org).

Power calculation

The power calculation was based on studies of a British birth cohort of comparable age and size (2797 individuals age 53 years) (15). See study protocol for details (18). Kuh et al. measured time to complete 10 chair rises and found a difference of 0.3 sec^{-1} (SD 3.3) between manual and non-manual workers. A slightly larger difference of 0.5 sec^{-1} was thought clinically relevant, which is to say that manual and non-manual workers spent 22 and 20 seconds respectively to perform 10 chair-rises. For the purposes of our study, this equates to 13.6 versus 15 chair-rises/30 seconds. We assumed that 20% of the population has a history of physical exposures during working life and we aimed for a power of 90% (beta=0.1) with a significance level of 5% (alpha= 0.05). To detect a difference of 0.5 sec^{-1}, n was calculated to be 2,870. The power calculations were performed in SAS version 9.2 PROC POWER. In the British birth cohorts, balance was tested at home and the results were not comparable to our balance tests using the AMTI platform.

Results

The characteristics of the study population are presented in table 1. Mean age is 59 years in both men and women and the MP cohort included only male participants; thus men constitute 79.2% of the study population. Women were exposed to fewer exposure-years compared to men, particularly with regard to kneel-years. Mean seniority in work based on the five longest held employments was almost similar, 31.46(SD=8.12) years in men and 29.69(SD=8.94) years in women, although fewer women were still in the labour market (77.0% vs. 88.0%). Women had better balance than men (mean area 25% less than mean area among men, primarily because women are smaller), and 3.3% women did not fulfil the balance test compared to 5.0% men. Women achieved, on average, one chair rise less than men in the 30 second test (20.38 vs. 21.58), but 94.4% of women completed the test compared to 88.4% of men. At the physical examination we noted if participants had a specific reason for not performing in the physical test. The most common reasons were recent surgery and disability in general. Men who did not fulfil the balance test were exposed to more ton-years than men who made at least 1 attempt (18.01 ton-years vs. 11.35 ton-years p=0.0054). In women balance performance was not statistically significant when associated to total physical exposures, but the analyses showed the same tendency as for men. From the results of the chair rise test, there were no statistically significant differences in exposures among participants and non-participants.

Attrition analyses

Attrition analyses on the total CAMB study sample, including all three cohorts, showed that questionnaire respondents (7191/17 938) and participants attending the physical examination (5576/17 938) had significantly higher education and were more likely to be employed compared to non-respondents/non-participants (based on data from Danish registers)(17). Use of the health-care system (i.e. visits to the general practitioner during 2009) showed no statistically significant difference among the respondents/participants and non-respondents/non-participants, suggesting that participants and non-participants did not differ with regard to general health (17). Further, using data from the two cohorts in the present study, we compared those who only filled out the questionnaire (1238/5095) with those who took part in both the questionnaire study and the physical tests (3857/5095). We found that participants taking part in the physical tests were exposed to fewer physical exposures at work (11.7 vs. 16.9 ton-years in men and 5.1 vs. 9.0 ton-years in women), possibly reflecting participants' higher educational attainment level.

Balance

In men exposure to ton-years was associated with a 0.1% increase in balance area per ton-year (p=0.0323) in the unadjusted analysis. However, when including confounders in model 1, the association disappeared (table 2). Stand and kneel-years were not associated with balance performance in men in any of the models. From spline regression analyses (model 1) the lack of associations between exposures and outcome was confirmed (see figure 3a). In women significant associations were seen between balance and exposure to stand and kneel-years in linear models. Balance area was increased by 0.4% per stand-year and 1.9% per kneel-year (p=0.0234 and p=0.0031 respectively) in model 1, although spline regressions indicated a slightly positive but non-linear association between these two exposures and balance in women (see figure 3a).

Introducing chronic diseases and LTPA to model 1 changed the associations between exposure years and balance slightly, but did not change the direction or strength of the associations (table 2). Including all covariates did not change the final conclusions, although the associations were attenuated in women (table 2).

Chair rise

In general, there was a negative association between exposure years and chair rise in men. Exposure to ton, stand, and kneel-years was associated with poorer chair rise performance in unadjusted analyses. Introducing age, height, cohort and vocational education attenuated the effect of ton- and stand-years, although it was still statistically significant, whereas the association between exposure to kneel-years and chair rise disappeared (table 2).

Spline regression analyses confirmed the findings from the linear analyses and an increasing negative effect of exposure to ton-years was observed in men (figure 3b). The effect reached a maximum decrease of -1.5

chair rises in men exposed to 30-40 ton-years compared to men without this occupational exposure. This association was non-linear and further exposure to ton-years did not decrease chair rise performance.

In women, exposure was associated with lower chair rise performance in unadjusted analyses but the associations disappeared when confounders were introduced in model 1 (see table 2). In spline regression analyses associations between exposure years and chair rise were non-linear and with broad confidence intervals due to few participants with higher exposures (figure 3b). However, the associations were not statistically significant in the non-linear analyses either.

Introducing chronic diseases to model 1 attenuated the negative effect of exposure years on chair rise performance in men and women, whereas introducing LTPA in model 1 increased the associations in men but not in women. Inclusion of all covariates attenuated the associations slightly.

Discussion

We hypothesized that a history of hard physical work was associated with lower physical function in midlife measured by chair rise and balance performance. We found that the effect of hard physical work varied between genders and also differed according to the tests.

Performance in the chair rise test was lower in women and men exposed to lifting and standing/walking in working life, but in women the associations were statistically insignificant and non-linear (figure 3b). In contrast to our findings, other studies in this field found that negative associations between workload and physical performance were more pronounced in women than in men (6,7). Female participants constitute only 20% of our study population and, in general, participating women had fewer exposure-years, which was reflected by the broad confidence intervals in the spline regressions (figure 3b). Furthermore, even in the same occupations the actual work tasks may differ between genders (28).

Chair rise, as a proxy measure of functional lower limb capacity, relies on muscle power in the lower limbs which is known to decrease due to musculoskeletal aging (29). We observed a decrease in chair rise performance in men with physical exposures, which could be a sign of accelerated musculoskeletal aging.

We found no association between physical exposures and balance in men, which was in contrast to our research hypothesis. Few other studies have evaluated the effect of occupational exposures on balance performance, and in a British cohort study manual occupational social class was associated with poorer balance in both men and women compared to non-manual occupational social class (15). In the CAMB cohort balance was poorer among men and women in the lowest social classes too (22). Interestingly the direction of the associations between stand- and kneel-years and balance in men changed from the unadjusted models to model 1. This indicates slightly better balance in men with physical exposures, as it was also seen in the spline regression plots (figure 3a). One study found better balance among workers with high demands on balancing at work (30) and a training effect in men could explain the findings.

Lack of balance has been categorized as an impairment of the neurologic system, but in our study it is seen as an integrated function and can therefore be used as a measure of functional limitation (31). Balancing on one leg requires muscle strength, as does chair rise, but it is also dependent on neurological and motor coordination (32), and therefore the central nervous system is important to balance performance. We have no obvious explanation for the differences in associations between men and women in this cohort relating to their performance in the balance test. However, more women than men completed the balance test.

One explanation could be gender segregation in the Danish labour market, since women with occupational exposures in this cohort had been working primarily as cleaning assistants or nursing assistants, whereas men had a variety of different jobs during their working life, such as carpentry, floor laying and plumbing. The primary aim of the knee-hip matrix was to study osteoarthritis in the lower limbs and it focused on exposures from lifting, kneeling, vibration and standing/walking at work. Cleaning assistants "earn" stand-years through working life, and not lift-years, whereas men in exposed jobs often earn both lift and stand-years. The job exposure matrix was not gender-specific as has been suggested by Solovieva et al. (28) and this could introduce misclassification bias due to differences in exposure between men and women with the same job-titles. However, due to the gender segregation in this age homogeneous cohort, this bias is less than could be expected in other cohorts.

Including all covariates in the linear regression models did not change the associations and the differences in performance were not explained by differences in lifestyle or health. The proportion of the variation explained by the models was small, and the proportion of the variance in outcome measures explained by the history of physical exposures was low, especially with regard to the association with balance in men. In linear models a loss of 0.02 chair rise/exposure-year was seen in men, which equals the loss of 0.6 chair rises in 30 years. The non-linear analyses showed higher effects: -1.5 chair-rises among those exposed to 30 ton-years. The question is, whether these findings are clinically relevant. The difference in linear and non-linear analyses equals 2.8% and 7.0% respectively of the average chair rise performance in men, and future studies of the consequences of this decreased function are needed, for instance in follow up studies of sickness absence or the work ability in this cohort.

In general, our results are in line with previous findings of poorer physical performance among men with a history of hard physical work (2,3,6), but our cohort included younger participants compared to the studies by Russo et al. (2) and Cassou et al. (3). Our study design is comparable to the retrospective cohort design of Torgen et al. (6) but it is larger and, compared to their results concerning squatting performance, we found more pronounced associations between physical exposures and chair rise in men in the non-linear associations.

Strengths and limitations

The exposure assessment was a strength of this study compared to other retrospective studies of lifetime physical workload, because the assessment included both intensity and duration of exposure. The use of a continuous measure of exposure could hypothetically lead to estimates of a threshold for exposure-years if a linear association was found. However our results indicate that the variation in physical function is caused by multiple risk factors, and exposures at work play a minor role. Furthermore, the associations turned out to be non-linear. Standardization of exposure to lifting could introduce measurement bias since twenty ton-years can be “earned” in only 10 years of heavy work or 40 years of less heavy work and intensity. Another possible bias in this study is the risk of misclassification of exposure in job exposure matrices, where exposures are assigned in exposure groups thought to be homogeneous. In the future, objective measures in bigger cohorts will be interesting for epidemiological studies (33).

The large study population was a strength, although the low response-rate in the CAMB study could have introduced bias due to selective drop-out. The attrition analyses, and analyses of those not participating in the tests, showed that participants had lower exposures which could attenuate the results in both genders. In a future study we will examine the associations between physical exposures in working life and self-reports of mobility among respondents to the CAMB questionnaire. In this way we will be able to compare mobility among participants and non-participants in the objective measures through a self-reported measure of physical function.

Another possible bias is the “healthy worker effect”, where those participants having “earned” the longest or highest exposures throughout working life could be a special sub-group of workers (27). The effect of the “healthy workers” is perhaps seen in the non-linear associations as the less pronounced deteriorating effect of maximum exposure.

Conclusion

In this cohort a history of physical exposures throughout working life was associated with poorer performance in a chair rise test in 59-year old men. However, we found no association between physical exposures and balance performance in men. In women a history of physical exposures was associated with slightly poorer balance performance. The effects of physical exposures on midlife physical function were numerically small and non-linear.

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Table 1. Characteristics of the study population, exposures and outcome. (MP=Metropolit Cohort; DALWUH=Danish Longitudinal Study on Work, Unemployment and Health; SD=standard deviation)

	Men					Women			
	N	%	Mean	SD		N	%	Mean	SD
Age	4035		58.99	2.32		1060		58.58	5.00
Height, cm	3968		179.66	6.76		1045		166.58	6.15
Smoking, pack-years	3842		20.68	26.72		999		10.52	14.76
Alcohol consumption, units/week	3973		14.82	14.02		1033		8.05	12.06
Pain index[a]	3990		19.90	10.87		1053		23.64	13.14
Chronic diseases[b]	3993					1052			
No disease	1225	30.7				320	30.4		
1 disease	1326	33.2				311	29.6		
2 or more diseases	1442	36.1				421	40.0		
Vocational education	3964					1039			
Long cycle	738	18.6				131	12.6		
Medium cycle	857	21.6				313	30.1		
Short cycle	336	8.5				107	10.3		
Semi-skilled	1689	42.6				387	37.2		
Un-skilled	344	8.7				101	9.7		
Intensity of leisure-time physical activity[c]	3957					1040			
Medium/hard	1253	31.7				255	24.5		
Light	2240	56.6				706	67.9		
Sedentary	464	11.7				79	7.6		

[a] Summation of pain in nine regions of the body. Minimum score is nine (no pain in any of the regions) and maximum is 81 (worst possible pain in all nine regions).

[b] Asthma, diabetes, hypertension, angina, stroke, bronchitis, chronic obstructive pulmonary disease, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression, psychiatric diseases, and back disease.

[c] Medium/ hard : > 4 hours a week, light: <4 hours a week, sedentary: reading/watching television in leisure-time.

Labor market status	3953					1033			
Employed	3479	88.0				802	77.6		
Unemployed[d]	474	12.0				231	22.4		
Cohort[e]	4035					1060			
MP	3153	78.14				.	.		
DALWUH	882	21.86				1060	100.0		
	N		Mean	Median		N		Mean	Median
Ton-years[f]	3880		12.90	2.32		1016		6.04	0
Stand-years[g]	3880		11.26	7.29		1016		7.43	0
Kneel-years[h]	3880		7.29	11.26		1016		1.14	0
Balance area, mm^2	2902		1206.70	901.0		762		902.62	734.5
Chair-rise, number in 30 sec	2700		21.58	21.4 (SD)		744		20.38	5.34 (SD)

[d] Unemployed=currently unemployed and early retirement, disability pensioners etc.
[e] Male participants were from two cohorts.
[f] Amount of lifting during working life. One ton year is lifting 1000 kg each day in one year.
[g] Total exposure to standing/walking at work. One stand-year is standing/walking for six hours each day in one year.
[h] Total exposure to kneeling at work. One kneel-year is kneeling at work for one hour each day in one year.

Table 2. Multivariate linear regression models. Associations between exposure-years and chair rise and balance performance.

Exposure	Model	Men			Women			Men			Women		
		Chair-rise Number in 30 seconds						Balance Log_{10} area					
		Regression coefficient	P value	R^{2a} (%)	Regression coefficient	P value	R^{2a} (%)	Regression coefficient	P value	R^{2a} (%)	Regression coefficient	P value	R^{2a} (%)
Ton-years[b]		-0.0374	<0.0001	2.1	-0.0345	0.0375	0.6	0.00043	0.0323	0.2	0.00061	0.3687	0.1
	Model 1[c]	-0.0204	0.0001	10.3	-0.0266	0.1138	14.9	0.00023	0.2914	3.2	0.00091	0.1957	7.5
	Model 1 and chronic diseases[d]	-0.0172	0.0010	13.1	-0.0266	0.1105	17.5	0.00017	0.4534	3.2	0.00093	0.1847	6.7
	Model 1 and leisure-time physical activity[e]	-0.0222	<0.0001	14.1	-0.0217	0.1899	19.4	0.00029	0.1893	2.2	0.00093	0.1820	5.9
	Final model[f]	-0.0156	0.0030	19.1	-0.0198	0.2485	24.1	0.00012	0.5901	5.3	0.00078	0.2652	11.3
Stand-years[g]		-0.0557	<0.0001	1.8	-0.0445	0.0179	0.8	0.00014	0.6660	0.007	0.00134	0.0677	0.4

[a] The proportion of the variation explained by the regression model in %.

[b] Amount of lifting in working life. One ton-year is lifting 1000 kg each day in one year.

[c] Adjusted for age, height, cohort, and vocational education.

[d] Chronic diseases in three groups: 0,1 or ≥2 of the following diseases: asthma, diabetes, hypertension, angina, stroke, bronchitis, chronic obstructive pulmonary disease, rheumatoid arthritis, osteoarthritis, cancer, anxiety, depression, psychiatric diseases, and back disease. Grouped in None, One, Two or more chronic diseases.

[e] Medium/ hard : > 4 hours a week, Light: <4 hours a week, Sedentary: reading/watching television in leisure-time.

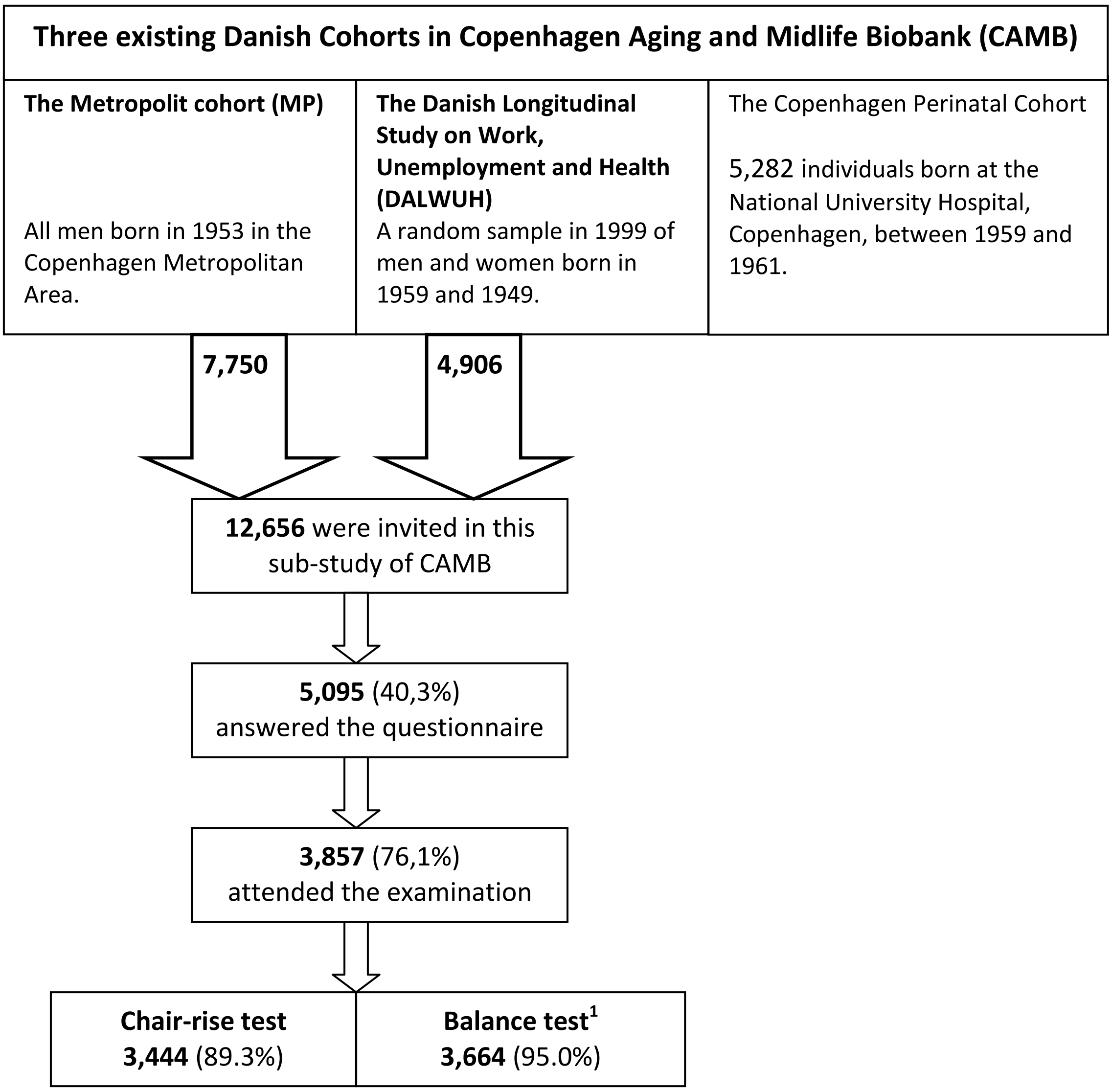
[f] Ajusted for age, height, cohort, vocational education, chronic diseases, leisure-time physical activity, smoking history, alcohol consumption, pain index.

[g] Total exposure to standing/walking at work. One stand-year is standing/walking for six hours each day in one year.

	Model 1[b]	-0.0239	0.0091	10.0	-0.0313	0.0911	15.0	-0.00041	0.2825	2.2	0.00172	0.0234	6.3
	Model 1 and chronic diseases[c]	-0.0204	0.0237	12.9	-0.0264	0.1506	17.4	-0.00052	0.1702	3.2	0.00162	0.0316	7.9
	Model 1 and leisure-time physical activity [d]	-0.0263	0.0035	13.8	-0.0304	0.0943	19.5	-0.00035	0.3549	3.2	0.00179	0.0177	7.2
	Final model[e]	-0.0207	0.0222	19.0	-0.0262	0.1548	24.2	-0.00043	0.2703	5.4	0.00140	0.0564	11.6
Kneel-years[h]		-0.0345	<0.0001	0.8	-0.1030	0.1450	0.3	0.00012	0.6982	0.005	0.00619	0.0259	0.7
	Model 1[b]	-0.0089	0.2539	9.8	-0.0743	0.2739	14.8	-0.00020	0.5464	2.2	0.00831	0.0031	6.8
	Model 1 and chronic diseases[c]	-0.0077	0.3167	12.8	-0.0675	0.3149	17.3	-0.00025	0.4553	3.2	0.00818	0.0034	8.4
	Model 1 and leisure-time physical activity [d]	-0.0137	0.0791	13.6	-0.0613	0.3551	19.3	-0.00016	0.6423	3.2	0.00849	0.0023	7.7
	Final model[e]	-0.0053	0.4961	18.9	-0.0708	0.2858	24.1	-0.0003	0.4075	5.3	0.00753	0.0048	12.2

[h] Total exposure to kneeling at work. One kneel-year is kneeling at work one hour each day in one year.

Figure 1. Copenhagen Aging and Midlife Biobank. Cohorts and participation.



1) Completed at least one attempt.

Figure 2. Theoretical model. Associations between exposure and outcomes including covariates.

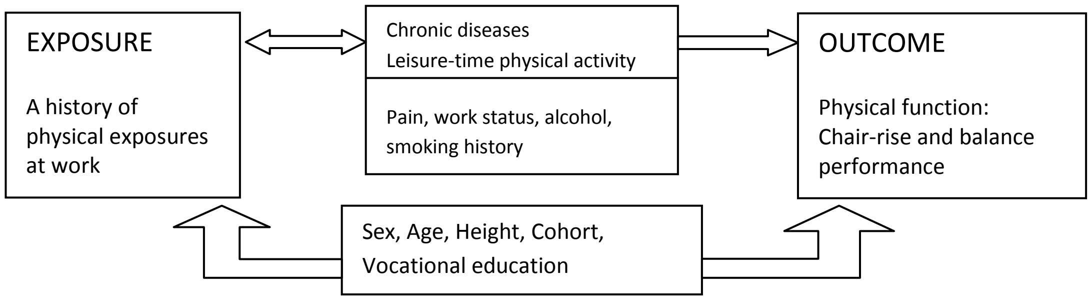


Figure 3a. Multivariate non-linear (spline) regressions including 95% confidence intervals. Associations between exposure-years and log 10 balance area. Model 1 including age, height, cohort, and vocational education. Upper row: Men, Lower row: Women. Along the x-axis is number of participants indicated.

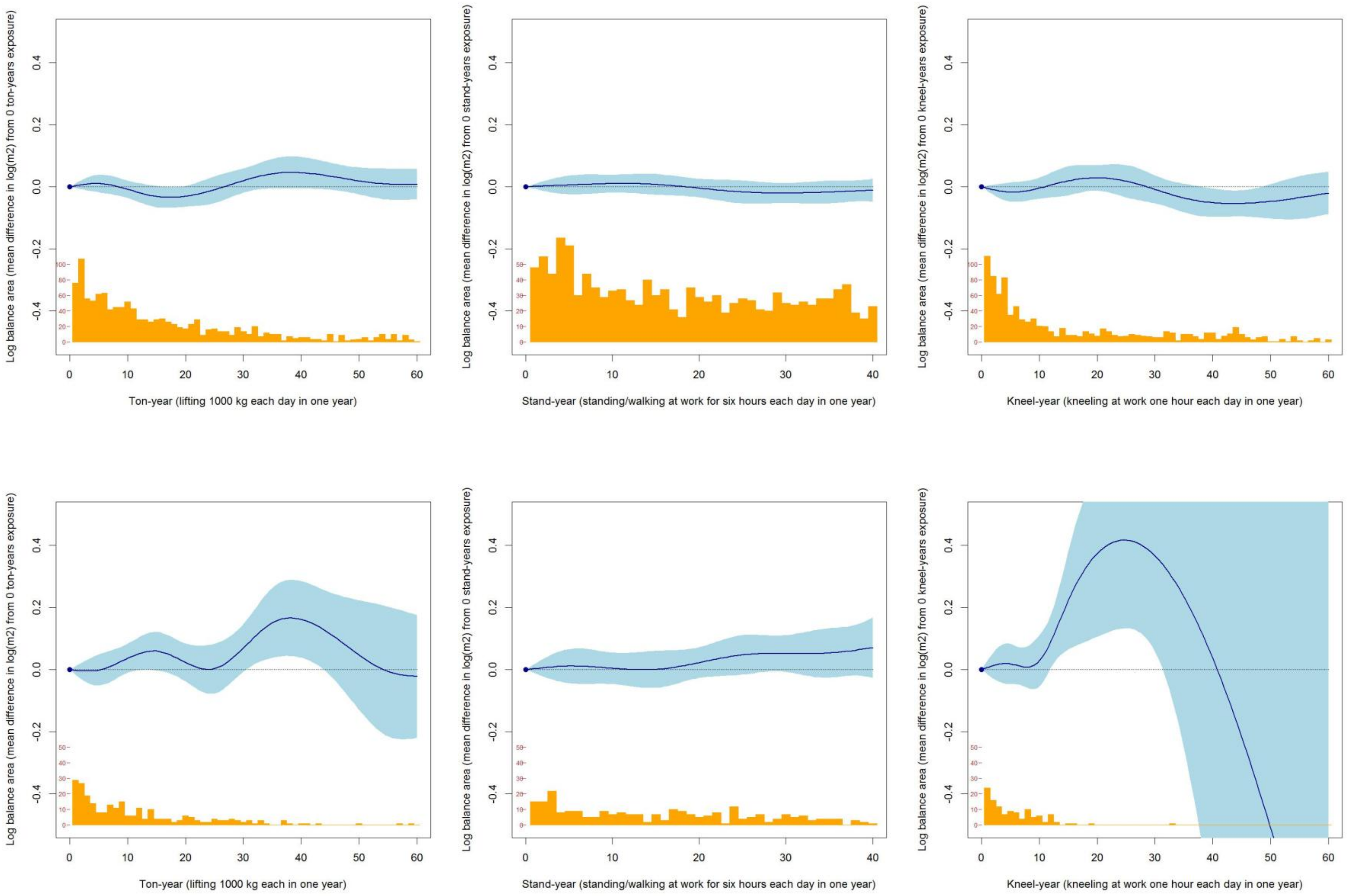


Figure 3b. Multivariate non-linear (spline) regressions including 95% confidence intervals. Associations between exposure-years and number of chair-rises/30 seconds. Model 1 including age, height, cohort, and vocational education. Upper row: Men, Lower row: Women. Along the x-axis is number of participants indicated.