BMJ Open

Do Physical Exposures throughout Working Life Influence Chair-Rise Performance in Midlife? A Retrospective Cohort Study of Associations between Work and Physical Function in Denmark.

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2015-009873
Article Type:	Research
Date Submitted by the Author:	03-Sep-2015
Complete List of Authors:	Møller, Anne; Copenhagen University Hospital Holbæk, Department of Occupational Medicine; The Research Unit for General Practice and Section of General Practice, Department of Public Health, University of Copenhagen Reventlow, Susanne; The Research Unit for General Practice and Section of General Practice, Department of Public Health, Copenhagen University Hansen, Åse; Section of Social Medicine, Department of Public Health, University of Copenhagen; National Research Centre for the Working Environment, Andersen, Lars; National Research Centre for the Working Environment, Siersma, Volkert; The Research Unit for General Practice and Section of General Practice, Department of Public Health, University of Copenhagen Lund, Rikke; Social Medicine Section, Department of Public Health, University of Copenhagen; Center for Healthy Aging, University of Copenhagen Avlund, Kirsten; Danish Aging Research Center, University of Southern Denmark; Section of Social Medicine, Department of Public Health, University of Copenhagen Andersen, Johan; Danish Ramazzini Center, Department of Occupational Medicine Mortensen, Ole; Copenhagen University Hospital Holbæk, Department of Occupational Medicine; National Research Centre for the Working Environment,
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Epidemiology, Public health
Keywords:	EPIDEMIOLOGY, OCCUPATIONAL & INDUSTRIAL MEDICINE, PUBLIC HEALTH

Do Physical Exposures throughout Working Life Influence Chair-Rise Performance in Midlife? A Retrospective Cohort Study of Associations between Work and Physical Function in Denmark.

Anne Møller PhD [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 [†], Johan Hviid Andersen PhD [6], Ole Steen Mortensen PhD [1,2]

1 Department of Occupational Medicine, Copenhagen University Hospital Holbæk, Denmark

2 National Research Centre for the Working Environment, Copenhagen, Denmark

3 The Research Unit for General Practice and Section of General Practice, Department of Public Health, University of Copenhagen, Denmark

4 Section of Social Medicine, Department of Public Health, University of Copenhagen, Denmark

5 Center for Healthy Aging, University of Copenhagen, Denmark

6 Danish Ramazzini Center, Department of Occupational Medicine, Regional Hospital West Jutland – University Clinic, Denmark

[†]Professor Kirsten Avlund passed away in September 2013, former affiliation [4,5]

§Corresponding author: Anne Møller, Department of Occupational Medicine, Copenhagen University Hospital Holbæk, Smedelundsgade 60, 4300 Holbæk, Denmark. Phone: +45 4732 2900. E-mail: annemoller1972@gmail.com

KEY WORDS: workload, occupational medicine, chair-rise performance, occupational exposure, physical fitness

WORD COUNT:

3286 words excluding title page, abstract, acknowledgements, contributor ship statement, competing interests, funding, data sharing statement, references, figures, and tables.

Figures: 3 in tiff-format

Tables: 2 included in the text file

References: 28

Additional files: 1 (Supplementary Information)

ABSTRACT

Objectives: Our aim was to study associations between physical exposures throughout working life and physical function measured as chair-rise performance 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 and chair-rise performance (number of chair-rises in 30 seconds) were analyzed in multivariate linear and non-linear regression models adjusted for covariates.

Results: Mean age among the 5,095 participants was 59 years in both genders, and, on average, men achieved 21.58 (standard deviation (SD)=5.60) and women 20.38 (SD=5.33) chair-rises in 30 seconds. Physical exposures were associated with poorer chair-rise performance in both men and women, however, only associations between lifting and standing/walking and chair-rise remained statistically significant among men in the final model. Spline regression analyses showed non-linear associations and confirmed the findings. **Conclusion:** Higher physical exposure throughout working life is associated with slightly poorer chair-rise performance. The associations between exposure and outcome were non-linear.

STRENGTHS AND LIMITATIONS OF THIS STUDY:

- Strenuous physical work has been considered both beneficial and detrimental to physical function, but there is a lack of evidence in this field.
- In this large cohort of middle-aged Danes, a history of physical exposures in working life was associated with slightly poorer chair-rise performance.
- Physical exposure may accelerate the age-related decrease in physical function; however, in this cohort, the proportion of the variation in physical function explained by exposures in working life was relatively small.
- The strength of this study is the exposure assessment that sums all physical exposures during working life; one limitation of this study is the cross-sectional measure of physical function.

INTRODUCTION

In the 1980s hard physical work was thought to strengthen workers, but later studies showed that hard physical work could not maintain physical function in middle-aged workers[1]. Since then, a history of hard physical work 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 physical function[4]. After 28 years follow-up Leino-Arjas et al. found increased risk of poor physical function among those reporting high occupational physical strain at baseline [5], and, in a retrospective study, Torgen et al. found that a history of hard physical work could be both beneficial and detrimental to physical function[6].

The inconsistency of results, suggesting both beneficial and detrimental effects of physical exposures on midlife physical function, could be due to differences in study designs. Few follow-up studies have been conducted in this field, but despite the lack of long follow-up studies, there are signs of a negative association between physical exposures throughout working life and midlife physical function. Underlying biological processes could be the physiological explanation of this negative association, where acute changes in the musculoskeletal system might become chronic because of insufficient recovery time[7,8]. In life-course epidemiology[9] theories of cumulative exposures throughout life could be applied to occupational epidemiology, addressing physical wear and tear throughout working life as a possible risk factor in the musculoskeletal ageing process.

The inconsistency of research results in this field could also be due to bias in the exposure assessment. In previous studies in this field, interviews[2], combined with questionnaires[3,6], 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. In this study, we introduce a cumulative and continuous exposure assessment based on information from a job exposure matrix. To our knowledge, this is the first study to use lifetime exposures in an analysis of midlife physical function assessing the influence of work on the musculoskeletal ageing process.

Inconsistency of research results in this field could also be due to the use of surrogate measures and the use of a variety of outcome measures. The musculoskeletal ageing process can be studied at different levels, from impairment in specific body systems (e.g. muscle strength), through functional limitations, to disability[10]. A test of chair-rise performance is independent of the surrounding environment and has been used worldwide to assess functional limitations in different age groups and settings, and performance tests are important predictors of morbidity[11] and mortality in older people[12]. However, chair-rise performance is seldom used in the occupational field as a dynamic measure.

Our study combines occupational epidemiology and exposure assessment with a well-known gerontological outcome measure in a large population-based cohort. This study was planned to include multiple outcome measures, but a literature review showed differences in associations between exposure and outcome measures: primarily a positive association between hard physical work and upper limb strength [13],and a negative association between hard physical work and lower limb strength/dynamic function [2-6]. The underlying mechanisms could vary between the upper and the lower limb/dynamic function, and, therefore, the outcome measures were separated in the analyses.

In the first paper, we found that physical exposures in working life had a minor but positive association with hand grip strength in middle-aged men[13].

The aim of this study is therefore to evaluate the influence of physical exposures in working life on a dynamic measure of physical function. According to previous studies in this field, a history of hard physical work was hypothesized to being associated with lower physical performance in midlife, and, thereby, with poorer performance in a chair-rise test.

METHODS

This population-based retrospective study included a cross-sectional physical examination as part of the Copenhagen Aging and Midlife Biobank (CAMB)[14]. CAMB was established in 2009-2011 to study signs of early ageing 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)[15].

The data collection in CAMB was made 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[15]. 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. Self-reports of physical exposures in working life from the questionnaire were not used, since we have found low reliability of that information in a previous study[16]. 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)[15]. From a Danish job exposure matrix (the Lower Body Job Exposure Matrix (Lower Body JEM)), information about physical exposures in Danish jobs (linked to D-ISCO-88 codes) was retrieved[17]. The Lower Body JEM 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)[17]. 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[18], 2) Standing/walking; a common exposure in jobs categorized as physically demanding, 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 Lower Body JEM, 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).

Outcome

Chair-rise performance was measured as the number of chair-rises performed during a 30-second test. 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[19]. As the test was somewhat tiresome each participant made only a single attempt.

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, the variable "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 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 activity: reading/watching television. 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 (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

A theoretical model was established based on the hypothesis of physical exposures during working life influencing chair-rise performance in combination with the effect of "wear and tear" and ageing. 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 in general, 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.[20]. Both unadjusted and adjusted associations between exposures (summation of exposure-years) and outcome (number of chair-rises) were assessed in general linear regression models. Unadjusted analyses were assessed, and, afterwards, age, height, cohort, and vocational education were included (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. Missing values in covariates led to a decrease in number of participants through the analyses of the three models, and numbers of individuals are reported in the tables. All analyses were performed in PROC GLM (SAS 9.2). In order to study how well the models predicted physical performance, we reported the proportion of the variation explained by the regression models (R^2)[21].

Since the effect of physical exposure on physical performance has been suggested to be both beneficial and detrimental to physical function, a linear term may be too limited to characterize these associations[22]. Exposure was therefore categorized in quartiles, and analyses were repeated. Based on those results, a statistician suggested a study of the shape of the associations by modelling them as restricted cubic spline functions in 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[22,23].

Attrition analyses were performed in the CAMB cohort[14], 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 was performed in the R system for statistical computation (www.cran.r-project.org).

Power calculation is found in "Supplementary information".

RESULTS

The characteristics of the study population are presented in Table 1. Mean age was 59 years in both men and women, and since the MP cohort included only male participants, 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 between the two sexes: 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 achieved, on average, 1.2 chair-rises less than men in the 30-second test (20.38 (SD=5.33) vs. 21.58 (SD=5.60)), but 94.4% of the women completed the test compared to 88.4% of men. At the physical examination, it was 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.

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; IQR=Inter quartile range)

	Men				Women		
	N (%)	Median(IQR)	Mean(SD)		N(%)	Median(IQR)	Mean(SD)
Age	4035	59(59-59)	59.0 (2.3)		1060	63(53-63)	58.6 (5.0)
Height, cm	3968	180(175-184)	179.7 (6.8)		1045	167(163-170)	166.6 (6.2)
Smoking, pack-years	3842	12.5(0-33)	20.7 (26.7)		999	2 (0-18)	10.5 (17.5)
Alcohol consumption, Units/Week	3973	12(6-20)	14.8 (14.0)		1033	6(2-10)	8.0(12.1)
Pain index[a]	3990	17(12-24)	19.9 (10.9)		1053	20(14-30)	23.6(13.1)
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)		
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 (78.1)				.		
DALWUH	882(21.9)				1060(100.0)		
Ton-years[f]	3880	2.3(0-16)	12.9(23.1)		1016	0.0(0-7.9)	6.0(12.4)
Stand-years[g]	3880	3.9(0-22)	11.3(13.8)		1016	0.0(0-13)	7.4(11.4)
Kneel-years[h]	3880	0.0 (0-0)	7.3(15.0)		1016	0.0(0-0)	1.1 (3.0)

[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.
[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.

In general, there was a negative association between exposure years and chair-rise in both men and women. 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 kneel-years in men, whereas the effect of physical exposures was slightly increased in women(Table 2).

Table 2.

Multivariable linear regression models. Associations between exposure-years and chair-rise performance.

Exposure	Model	Men				Women			
		Chair-rise Number in 30 seconds				Chair-rise Number in 30 seconds			
		Regression coefficient	P value	N	R^{2a} (%)	Regression coefficient	P value	N	R^{2a} (%)
Ton-years[b]	Unadjusted	-0.0401	<0.0001	2463	2.4	-0.0364	0.0426	666	0.6
	Model 1[c]	-0.0382	<0.0001	2463	10.24	-0.0454	0.0068	666	14.99
	Model 1 and chronic diseases[d]	-0.0328	<0.0001	2463	11.83	-0.0363	0.0271	666	18.81
	Model 1 and leisure-time physical activity[e]	-0.0388	<0.0001	2463	13.77	-0.419	0.0113	666	18.0
	Final model[f]	-0.0156	0.0030	2463	19.1	-0.0198	0.2485	666	24.1
Stand-years[g]	Unadjusted	-0.0596	<0.0001	2463	2.08	-0.0432	0.0271	666	0.7
	Model 1[c]	-0.0610	<0.0001	2463	10.2	-0.0470	0.0100	666	14.9
	Model 1 and chronic diseases[d]	-0.0523	<0.0001	2463	11.8	-0.0393	0.0278	666	18.8
	Model 1 and leisure-time physical activity[e]	-0.0610	<0.0001	2463	13.66	-0.0474	0.0083	666	18.1
	Final model[f]	-0.0207	0.0222	2463	19.0	-0.0262	0.1548	685	24.2
Kneel-years[h]	Unadjusted	-0.0365	<0.0001	2463	0.87	-0.1010	0.1618	666	0.29
	Model 1[c]	-0.0348	<0.0001	2463	8.89	-0.1477	0.0286	666	14.67
	Model 1 and chronic diseases[d]	-0.0268	0.0004	2463	10.75	-0.1408	0.0326	666	18.77
	Model 1 and leisure-time physical activity[e]	-0.0366	<0.0001	2463	12.43	-0.1421	0.0322	666	17.77
	Final model[f]	-0.0053	0.4961	2463	18.9	-0.0708	0.2858	666	24.1

[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] Adjusted 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.

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

Introducing chronic diseases in Model 1 attenuated the effect of exposure on chair-rise performance in men and women. Introducing LTPA in Model 1 did not change the associations in men, and only to a small extent in women. Inclusion of all covariates in the final model attenuated the associations, and only the associations between ton-years/stand-years and chair-rise in men remained statistically significant.

Spline regression analyses visualising Model 1 confirmed the findings from the linear analyses, and a negative association between exposure to ton-years/stand-years and chair-rise was observed in men (Figure 3). The effect reached a maximum decrease of -1.83 (95% confidence interval(CI): (-2.70;-0.95)) chair-rises in men exposed to 30 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, associations between exposure years and chair-rise were non-linear and with broad confidence intervals, due to few participants with higher exposures (Figure 3). An analysis of the association between exposure to ton-years and chair-rise indicates a negative association with a maximum in women exposed to 20 ton-years (-2.45 chair-rises CI:(-3.92;-0.98)).

DISCUSSION

We hypothesized that physical exposures throughout working life were associated with impaired physical function in midlife measured by chair-rise performance, and that the theoretical explanation could be wear and tear or accumulation of exposures during life. We found that the influence of physical exposures on physical function was relatively small and varied between genders.

The observed decrease in chair-rise performance in exposed men could hypothetically be a sign of an accelerated musculoskeletal ageing process, caused by exposures at work. However, the proportion of the variation explained by the models was low, and the proportion of the variance in outcome measures explained by the physical exposures was low, too. In linear models (Model 1), a loss of 0.04 chair-rise/ton-year was seen in men, which equals the loss of 1.2 chair-rises in 30 years and a loss of 0.045 chair-rise/ton-year in women, which equals the loss of 0.9 chair-rise in 20 years. The non-linear analyses showed higher effects: A loss of 1.8 chair-rises among those exposed to 30 ton-years compared to un-exposed and 2.5 chair-rises less among women exposed to 20 ton-years. In the final model, the results were attenuated, especially among women.

In general, our results are in line with previous findings of poorer physical performance among men with a history of hard physical work[2-6], 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], who found that long lasting physical demands were associated with poorer dynamic muscle function, though our study is larger. Chair-rise performance, as measure of dynamic function, relies on muscle power in the lower limbs, which is known to decrease due to musculoskeletal ageing[24]. Follow-up studies in this cohort should study the influence of physical performance on work ability, sickness absence, early retirement, or death, since a recent 13-year follow-up study in the British birth cohort showed a higher mortality rate among those with the lowest physical capability at age 53[25].

Covariates were introduced to the models separately, and it was discussed whether covariates were confounders or mediators. However, the overall conclusion in this study is that inclusion of all covariates in the linear regression models attenuated the associations. Chronic diseases and differences in physical activity in leisure time explained only slightly the differences in performance.

In general, performance in the chair-rise test was lower in women and men with physical exposures in working life. In contrast to our findings, other studies in this field found that negative associations between work load and physical performance were more pronounced in women than in men[6]. We have no obvious explanation of the observed differences in associations between men and women in this cohort, relating to their performance in the chair-rise test. Little is known about the gender difference in the influence of work on the musculoskeletal ageing process. The job exposure matrix was not gender-specific, as has been suggested by Solovieva et al.[26], and this could introduce misclassification bias due to differences in exposure between men and women with the same job-titles. However, this cohort included few women with a history of hard physical work (see the broad confidence intervals in Figure 3) and this could be part of the explanation of our results.

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. If a linear association was found, a threshold for exposure years could be calculated. However, our results indicate that the variation in physical function is caused by multiple factors, and exposures at work may 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. According to the exposure assessment, the use of a job exposure matrix was thought to improve the validity of exposure assessment, but it has not been studied. The primary aim of the Lower Body JEM was to study osteoarthritis in the lower limbs, and it focused on exposures from lifting, kneeling, vibration, and standing/walking at work. The aim of this study was to study physical function, and we have claimed that especially lifting and standing/walking at work could influence the musculoskeletal ageing and the chair-rise performance. However, this has not been studied by others, either.

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. Objective measures in bigger cohorts are preferable in future epidemiological studies in this field[27].

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 showed that participants had lower exposures compared to non-participants[13]. Furthermore, sub-group analyses showed that participants not attending the chair-rise test had a lower socioeconomic status and more exposure-years compared to the participants fulfilling this test. This could attenuate the results further. 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 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[28]. The effect of the "healthy workers" is perhaps seen in the non-linear associations as the less pronounced detrimental effect of maximum exposure.

Conclusion

In this cohort, greater duration of physical exposures throughout adult life was associated with poorer chair-rise performance in men with a mean age of 59. In women, exposures were associated with poorer chair-rise performance in unadjusted analyses, but few female participants had physical exposures in working life. The influence of physical exposure on midlife physical function was numerically small and non-linear.

ACKNOWLEDGEMENTS

Authors thank Helle Bruunsgaard, Nils-Erik Fiehn, Poul Holm-Pedersen, Erik Lykke Mortensen and Merete Osler who initiated and established the Copenhagen Aging and Midlife Biobank from 2009-2011 together with Kirsten Avlund, Åse Marie Hansen and Rikke Lund. The authors acknowledge the crucial role of the initiators and steering groups of the Metropolit Cohort, The Copenhagen Perinatal Cohort and The Danish Longitudinal Study on Work Unemployment and Health. The authors gratefully acknowledge the contributions of Willy Karlslund and Drude Molbo (data handling processing). We acknowledge Tine Steen Rubak and her supervisors for their important contribution in the establishment of the Lower Body JEM.

CONTRIBUTORSHIP STATEMENT

AM planned the project together with SR, OSM, JHA and KA. AM wrote the draft of the article, and all authors have contributed by commenting on the manuscript. VS assisted in the power calculation and made the spline regression analyses. LLA and AMH are responsible for designing and implementing the physical tests in CAMB. KA was the PI, and RL was the main co-PI of the CAMB study, and, after the death of KA, RL is the PI of CAMB. AM has revised the article together with VS. All authors have approved the final manuscript.

COMPETING INTERESTS

The authors have no competing interests to declare.

FUNDING

This study was supported by a grant from The Research Foundation for the Working Environment, Denmark. The foundation has no influence on the data handling or manuscript approval. The Copenhagen Aging and Midlife Biobank has been supported by a generous grant from the VELUX FOUNDATION.

DATA SHARING STATEMENT

The CAMB steering group welcomes collaboration and the interest of national and international colleagues. External researchers can get access to data by a collaboration agreement with the CAMB steering committee. For more information on how to apply, please contact the principal investigator Rikke Lund [camb@sund.ku.dk]. The CAMB home page [www.camb.ku.dk/Collaboration/] provides further information.

REFERENCE LIST

1. Nygård C, Luopajärvi T, Ilmarinen, J. Musculoskeletal capacity and its changes among aging municipal employees in different work categories. Scand J Work Environ Health 1991;17:110–7.

2. Russo A, Onder G, Cesari M, et al. Lifetime occupation and physical function: a prospective cohort study on persons aged 80 years and older living in a community. Occup Environ Med 2006;63:438–42.

3. Cassou B, Derriennic F, Iwatsubo Y, et al. Physical diability after retirement and occupational risk factors during working life: a cross sectional epidemiological study in the Paris area. J Epidemiol Community Health 1992;46:506–11.

4. Calmels P, Ecochard R, Blanchon MA,et al. Relation between locomotion impairment, functional independence in retirement, and occupational strain resulting from work carried out during working life. Study of a sample population of 350 miners in the Loire valley in France. Epidemiol Community Health 1998;52:283–8.

5. Leino-Arjas P, Solovieva S, Riihimäki H, et al. Leisure time physical activity and strenuousness of work as predictors of physical functioning: a 28 year follow up of a cohort of industrial employees. Occup Environ Med 2004;61:1032–8.

6. Torgén M, Punnett L, Alfredsson L, et al. Physical capacity in relation to present and past physical load at work: a study of 484 men and women aged 41 to 58 years. Am J Ind Med 1999;36:388–400.

7. Mohren DC, Jansen NW, Kant I. Need for recovery from work in relation to age: a prospective cohort study. Int Arch Occup Environ Health 2010;83:553–61.

8. De Croon EM, Sluiter JK, Frings-Dresen MHW. Need for recovery after work predicts sickness absence: a 2-year prospective cohort study in truck drivers. J Psychosom Res 2003;55:331–9.

9. Kuh D, Ben-Shlomo Y. A Life Course Approach to Chronic Diseases Epidemiology. Oxford Medical Publishers 2004.

10. Verbrugge LM, Jette AM. The disablement process. Soc Sci Med 1994;38:1–14.

11. Cooper R, Kuh D, Cooper C, Gale C, et al. Objective measures of physical capability and subsequent health: a systematic review. Age ageing 2011;40:14–23.

12. Cooper R, Kuh D, Hardy R. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. BMJ 2010;341:c4467–c4467

13. Møller A, Reventlow S, Hansen Å, et al. Does a history of physical exposures at work affect hand-grip strength in strength in midlife ? A retrospective cohort study in Denmark. Scand J Work Environ Health 2013;39:599-608.

14. Avlund K, Osler M, Mortensen EL, et al. Copenhagen Aging and Midlife Biobank (CAMB). An introduction. J Aging Health 2014;26:5-20.

15. Møller A, Mortensen OS, Reventlow S, et al. Lifetime occupational physical activity and musculoskeletal aging in middle-aged men and women in denmark: retrospective cohort study protocol and methods. JMIR Res Protoc 2012;1:e7.

16. Møller A, Reventlow S, Andersen JH,et al.. Validity of Workers' Self-Reports. Evaluation of a Question Assessing Lifetime Exposure to Occupational Physical Activity. Br J Med Med Res 2012;2:536–52.

17. Rubak T, Svendsen S, Andersen J, et al. An expert-based job exposure matrix for large scale epidemiologic studies of primary hip and knee osteoarthritis: the Lower Body JEM. BMC Musculoskelet Disord 2014;15:204.

18. Mateson L. The functional capacity evaluation. In: Anderson G, Demeter S, Smith G, editors. Disability Evaluation. Mosby Year. Chicago 2003.

19. Hansen Å, Andersen L, Skotte J, et al. Social class differences in physical functions in middle-aged men and women. J Aging Health 2013; 26:88-105.

20. Silverstein B, Fan Z, Smith C, et al. Gender adjustment or stratification in discerning upper extremity musculoskeletal disorder risk? Scand J Work Environ Health 2009;35:113–26.

21. Altman DG. Practical Statistics for Medical Research. London: Chapman & Hall 1999.

22. Greenland S. Dose-response and trend analysis in epidemiology: alternatives to categorical analysis. Epidemiology 1995;6:356–65.

23. Steenland K, Deddens J. A practical guide to dose-response analyses and risk assessment in occupational epidemiology. Epidemiology 2004;15:63–70.

24. Reid KF, Fielding RA. Skeletal muscle power: a critical determinant of physical functioning in older adults. Exerc Sport Sci Rev 2012;40:4–12.

25. Cooper R, Strand B, Hardy R, et al. Physical capability in mid-life and survival over 13 years of follow-up: British birth cohort study. Bmj. 2014;348:g2219-g2219.

26. Solovieva S, Pehkonen I, Kausto J, et al. Development and validation of a job exposure matrix for physical risk factors in low back pain. PloS one 2012;7:e48680.

27. Skotte J, Korshøj M, Kristiansen J, et al. Detection of Physical Activity Types Using Triaxial Accelerometers. J Phys Act Health 2014;11:76-84.

28. Kenny G, Yardley J, Martineau L, et al. Physical work capacity in older adults: implications for the aging worker. Am J Ind Med 2008;51:610–25.

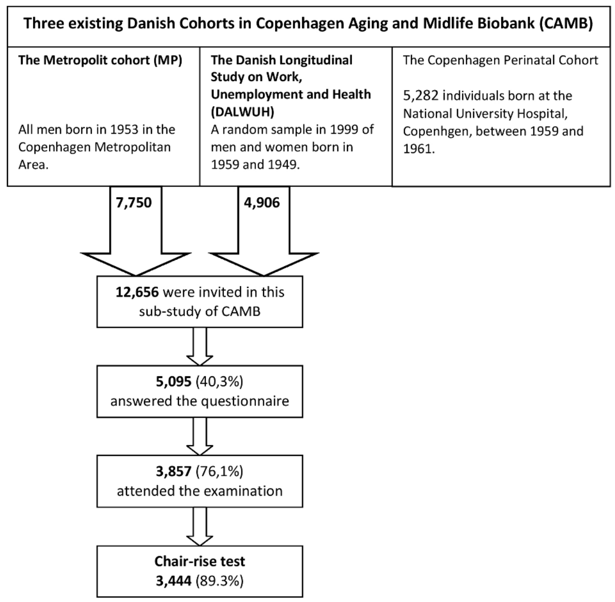
LEGENDS

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

Figure 2. Theoretical model. Associations between exposure and outcome including covariates. Gender is not included in the model since each gender is analyzed separately.

Figure 3. Multivariable 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 in orange bars.

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



210x297mm (300 x 300 DPI)

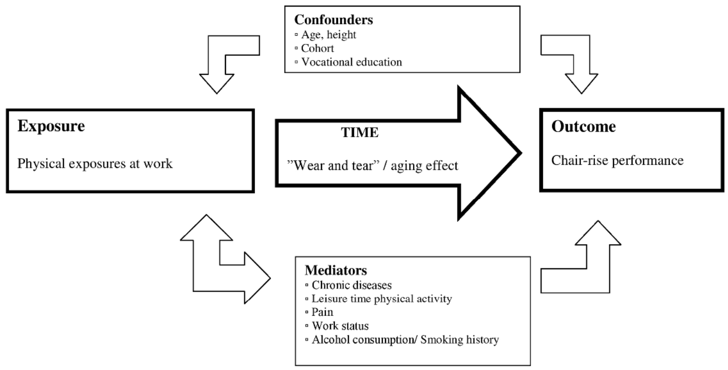
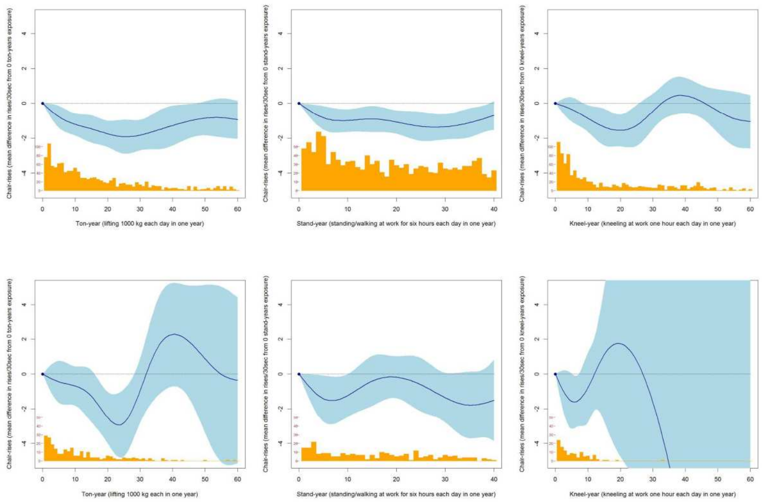


Figure 2. Theoretical model. Associations between exposure and outcome including covariates. Gender is not included in the model since each gender is analyzed separately.

297x210mm (300 x 300 DPI)

Figure 3. 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 in orange bars.



297x210mm (300 x 300 DPI)

Supplementary information

Power calculation

The power calculation was based on studies of a British birth cohort of comparable age and size (2797 individuals aged 53 years)[1]. See study protocol for details[2]. 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.

[1] Kuh D, Bassey E, Butterworth S, et al. Grip strength, postural control, and functional leg power in a representative cohort of British men and women: associations with physical activity, health status, and socioeconomic conditions. J Gerontol A Biol Sci Med Sci 2005;60:224–31.

[2] Møller A, Mortensen OS, Reventlow S, et al. Lifetime occupational physical activity and musculoskeletal aging in middle-aged men and women in denmark: retrospective cohort study protocol and methods. JMIR Res Protoc 2012;1:e7.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	✓
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	✓
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	✓
Objectives	3	State specific objectives, including any prespecified hypotheses	✓
Methods			
Study design	4	Present key elements of study design early in the paper	✓
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	✓
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	✓
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	✓
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	✓
Bias	9	Describe any efforts to address potential sources of bias	✓
Study size	10	Explain how the study size was arrived at: FIGUR 1	✓
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	✓
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	✓
		(*b*) Describe any methods used to examine subgroups and interactions	✓
		(*c*) Explain how missing data were addressed	✓
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	✓
		(*e*) Describe any sensitivity analyses	

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	✓
		(b) Give reasons for non-participation at each stage	✓
		(c) Consider use of a flow diagram	✓
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	✓
		(b) Indicate number of participants with missing data for each variable of interest	✓
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	✓
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	✓
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	✓
		(*b*) Report category boundaries when continuous variables were categorized	✓
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	✓
Discussion			
Key results	18	Summarise key results with reference to study objectives	✓
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	✓
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	✓
Generalisability	21	Discuss the generalisability (external validity) of the study results	✓
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	✓

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Do Physical Exposures throughout Working Life Influence Chair-Rise Performance in Midlife? A Retrospective Cohort Study of Associations between Work and Physical Function in Denmark.

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2015-009873.R1
Article Type:	Research
Date Submitted by the Author:	18-Sep-2015
Complete List of Authors:	Møller, Anne; Copenhagen University Hospital Holbæk, Department of Occupational Medicine; The Research Unit for General Practice and Section of General Practice, Department of Public Health, University of Copenhagen Reventlow, Susanne; The Research Unit for General Practice and Section of General Practice, Department of Public Health, Copenhagen University Hansen, Åse; Section of Social Medicine, Department of Public Health, University of Copenhagen; National Research Centre for the Working Environment, Andersen, Lars; National Research Centre for the Working Environment, Siersma, Volkert; The Research Unit for General Practice and Section of General Practice, Department of Public Health, University of Copenhagen Lund, Rikke; Social Medicine Section, Department of Public Health, University of Copenhagen; Center for Healthy Aging, University of Copenhagen Avlund, Kirsten; Danish Aging Research Center, University of Southern Denmark; Section of Social Medicine, Department of Public Health, University of Copenhagen Andersen, Johan; Danish Ramazzini Center, Department of Occupational Medicine Mortensen, Ole; Copenhagen University Hospital Holbæk, Department of Occupational Medicine; National Research Centre for the Working Environment,
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Epidemiology, Public health
Keywords:	EPIDEMIOLOGY, OCCUPATIONAL & INDUSTRIAL MEDICINE, PUBLIC HEALTH

Do Physical Exposures throughout Working Life Influence Chair-Rise Performance in Midlife? A Retrospective Cohort Study of Associations between Work and Physical Function in Denmark.

Anne Møller PhD [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 [†], Johan Hviid Andersen PhD [6], Ole Steen Mortensen PhD [1,2]

1 Department of Occupational Medicine, Copenhagen University Hospital Holbæk, Denmark

2 National Research Centre for the Working Environment, Copenhagen, Denmark

3 The Research Unit for General Practice and Section of General Practice, Department of Public Health, University of Copenhagen, Denmark

4 Section of Social Medicine, Department of Public Health, University of Copenhagen, Denmark

5 Center for Healthy Aging, University of Copenhagen, Denmark

6 Danish Ramazzini Center, Department of Occupational Medicine, Regional Hospital West Jutland – University Clinic, Denmark

[†]Professor Kirsten Avlund passed away in September 2013, former affiliation [4,5]

§Corresponding author: Anne Møller, Department of Occupational Medicine, Copenhagen University Hospital Holbæk, Smedelundsgade 60, 4300 Holbæk, Denmark. Phone: +45 4732 2900. E-mail: annemoller1972@gmail.com

KEY WORDS: workload, occupational medicine, chair-rise performance, occupational exposure, physical fitness

WORD COUNT:

3268 words excluding title page, abstract, acknowledgements, contributor ship statement, references, figures and tables.

Figures: 3 in tiff-format

Tables: 2 included in the text file

References: 28

Additional files: 1 (Supplementary Information)

ABSTRACT

Objectives: Our aim was to study associations between physical exposures throughout working life and physical function measured as chair-rise performance 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 and chair-rise performance (number of chair-rises in 30 seconds) were analyzed in multivariate linear and non-linear regression models adjusted for covariates.

Results: Mean age among the 5,095 participants was 59 years in both genders, and, on average, men achieved 21.58 (standard deviation (SD)=5.60) and women 20.38 (SD=5.33) chair-rises in 30 seconds. Physical exposures were associated with poorer chair-rise performance in both men and women, however, only associations between lifting and standing/walking and chair-rise remained statistically significant among men in the final model. Spline regression analyses showed non-linear associations and confirmed the findings. **Conclusion:** Higher physical exposure throughout working life is associated with slightly poorer chair-rise performance. The associations between exposure and outcome were non-linear.

STRENGTHS AND LIMITATIONS OF THIS STUDY:

- Few studies evaluate the influence of exposures in working life on the musculoskeletal aging process; therefore, this study contributes to new knowledge in the field.
- In this study, we have access to data from a large population-based cohort of middle-aged Danes.
- The strength of this study is the exposure assessment that sums all physical exposures during working life.
- One limitation of this study is the cross-sectional measure of physical function.
- Another limitation is the "healthy worker"-effect that might be a bias in the study.

INTRODUCTION

In the 1980s hard physical work was thought to strengthen workers, but later studies showed that hard physical work could not maintain physical function in middle-aged workers[1]. Since then, a history of hard physical work 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 physical function[4]. After 28 years follow-up Leino-Arjas et al. found increased risk of poor physical function among those reporting high occupational physical strain at baseline [5], and, in a retrospective study, Torgen et al. found that a history of hard physical work could be both beneficial and detrimental to physical function[6].

The inconsistency of results, suggesting both beneficial and detrimental effects of physical exposures on midlife physical function, could be due to differences in study designs. Few follow-up studies have been conducted in this field, but despite the lack of long follow-up studies, there are signs of a negative association between physical exposures throughout working life and midlife physical function. Underlying biological processes could be the physiological explanation of this negative association, where acute changes in the musculoskeletal system might become chronic because of insufficient recovery time[7,8]. In life-course epidemiology[9] theories of cumulative exposures throughout life could be applied to occupational epidemiology, addressing physical wear and tear throughout working life as a possible risk factor in the musculoskeletal ageing process.

The inconsistency of research results in this field could also be due to bias in the exposure assessment. In previous studies in this field, interviews[2], combined with questionnaires[3,6], 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. In this study, we introduce a cumulative and continuous exposure assessment based on information from a job exposure matrix. To our knowledge, this is the first study to use lifetime exposures in an analysis of midlife physical function assessing the influence of work on the musculoskeletal ageing process.

Inconsistency of research results in this field could also be due to the use of surrogate measures and the use of a variety of outcome measures. The musculoskeletal ageing process can be studied at different levels, from impairment in specific body systems (e.g. muscle strength), through functional limitations, to disability[10]. A test of chair-rise performance is independent of the surrounding environment and has been used worldwide to assess functional limitations in different age groups and settings, and performance tests are important predictors of morbidity[11] and mortality in older people[12]. However, chair-rise performance is seldom used in the occupational field as a dynamic measure.

Our study combines occupational epidemiology and exposure assessment with a well-known gerontological outcome measure in a large population-based cohort. This study was planned to include multiple outcome measures, but a literature review showed differences in associations between exposure and outcome measures: primarily a positive association between hard physical work and upper limb strength [13],and a negative association between hard physical work and lower limb strength/dynamic function [2-6]. The underlying mechanisms could vary between the upper and the lower limb/dynamic function, and, therefore, the outcome measures were separated in the analyses.

In the first paper, we found that physical exposures in working life had a minor but positive association with hand grip strength in middle-aged men[13].

The aim of this study is therefore to evaluate the influence of physical exposures in working life on a dynamic measure of physical function. According to previous studies in this field, a history of hard physical work was hypothesized to being associated with lower physical performance in midlife, and, thereby, with poorer performance in a chair-rise test.

METHODS

This population-based retrospective study included a cross-sectional physical examination as part of the Copenhagen Aging and Midlife Biobank (CAMB)[14]. CAMB was established in 2009-2011 to study signs of early ageing 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)[15].

The data collection in CAMB was made 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[15]. 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. Self-reports of physical exposures in working life from the questionnaire were not used, since we have found low reliability of that information in a previous study[16]. 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)[15]. From a Danish job exposure matrix (the Lower Body Job Exposure Matrix (Lower Body JEM)), information about physical exposures in Danish jobs (linked to D-ISCO-88 codes) was retrieved[17]. The Lower Body JEM 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)[17]. 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[18], 2) Standing/walking; a common exposure in jobs categorized as physically demanding, 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 Lower Body JEM, 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).

Outcome

Chair-rise performance was measured as the number of chair-rises performed during a 30-second test. 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[19]. As the test was somewhat tiresome each participant made only a single attempt.

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, the variable "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 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 activity: reading/watching television. 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 (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

A theoretical model was established based on the hypothesis of physical exposures during working life influencing chair-rise performance in combination with the effect of "wear and tear" and ageing. 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 in general, 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.[20]. Both unadjusted and adjusted associations between exposures (summation of exposure-years) and outcome (number of chair-rises) were assessed in general linear regression models. Unadjusted analyses were assessed, and, afterwards, age, height, cohort, and vocational education were included (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). In order to study how well the models predicted physical performance, we reported the proportion of the variation explained by the regression models (R^2)[21].

Since the effect of physical exposure on physical performance has been suggested to be both beneficial and detrimental to physical function, a linear term may be too limited to characterize these associations[22]. Exposure was therefore categorized in quartiles, and analyses were repeated. Based on those results, a statistician suggested a study of the shape of the associations by modelling them as restricted cubic spline functions in 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[22,23].

Attrition analyses were performed in the CAMB cohort[14], 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 was performed in the R system for statistical computation (www.cran.r-project.org).

Power calculation is found in "Supplementary information".

RESULTS

The characteristics of the study population are presented in Table 1. Mean age was 59 years in both men and women, and since the MP cohort included only male participants, 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 between the two sexes: 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 achieved, on average, 1.2 chair-rises less than men in the 30-second test (20.38 (SD=5.33) vs. 21.58 (SD=5.60)), but 94.4% of the women completed the test compared to 88.4% of men. At the physical examination, it was 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.

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; IQR=Inter quartile range)

	Men				Women		
	N (%)	Median(IQR)	Mean(SD)		N(%)	Median(IQR)	Mean(SD)
Age	4035	59(59-59)	59.0 (2.3)		1060	63(53-63)	58.6 (5.0)
Height, cm	3968	180(175-184)	179.7 (6.8)		1045	167(163-170)	166.6 (6.2)
Smoking, pack-years	3842	12.5(0-33)	20.7 (26.7)		999	2 (0-18)	10.5 (17.5)
Alcohol consumption, Units/Week	3973	12(6-20)	14.8 (14.0)		1033	6(2-10)	8.0(12.1)
Pain index[a]	3990	17(12-24)	19.9 (10.9)		1053	20(14-30)	23.6(13.1)
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)		
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 (78.1)				.		
DALWUH	882(21.9)				1060(100.0)		
Ton-years[f]	3880	2.3(0-16)	12.9(23.1)		1016	0.0(0-7.9)	6.0(12.4)
Stand-years[g]	3880	3.9(0-22)	11.3(13.8)		1016	0.0(0-13)	7.4(11.4)
Kneel-years[h]	3880	0.0 (0-0)	7.3(15.0)		1016	0.0(0-0)	1.1 (3.0)

[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.
[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.

In general, there was a negative association between exposure years and chair-rise in both men and women. 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 kneel-years in men, whereas the effect of physical exposures was slightly increased in women(Table 2).

Table 2.

Multivariable linear regression models. Associations between exposure-years and chair-rise performance.

Exposure	Model	Men[a]			Women[b]		
		Chair-rise Number in 30 seconds			Chair-rise Number in 30 seconds		
		Regression coefficient	P value	R^{2c} (%)	Regression coefficient	P value	R^{2c} (%)
Ton-years[d]	Unadjusted	-0.0401	<0.0001	2.4	-0.0364	0.0426	0.6
	Model 1[e]	-0.0382	<0.0001	10.24	-0.0454	0.0068	14.99
	Model 1 and chronic Diseases[f]	-0.0328	<0.0001	11.83	-0.0363	0.0271	18.81
	Model 1 and leisure-time physical activity[g]	-0.0388	<0.0001	13.77	-0.419	0.0113	18.0
	Final model[h]	-0.0156	0.0030	19.1	-0.0198	0.2485	24.1
Stand-years[i]	Unadjusted	-0.0596	<0.0001	2.08	-0.0432	0.0271	0.7
	Model 1[e]	-0.0610	<0.0001	10.2	-0.0470	0.0100	14.9
	Model 1 and chronic Diseases[f]	-0.0523	<0.0001	11.8	-0.0393	0.0278	18.8
	Model 1 and leisure-time physical activity[g]	-0.0610	<0.0001	13.66	-0.0474	0.0083	18.1
	Final model[h]	-0.0207	0.0222	19.0	-0.0262	0.1548	24.2
Kneel-years[j]	Unadjusted	-0.0365	<0.0001	0.87	-0.1010	0.1618	0.29
	Model 1[e]	-0.0348	<0.0001	8.89	-0.1477	0.0286	14.67
	Model 1 and chronic Diseases[f]	-0.0268	0.0004	10.75	-0.1408	0.0326	18.77
	Model 1 and leisure-time physical activity[g]	-0.0366	<0.0001	12.43	-0.1421	0.0322	17.77
	Final model[h]	-0.0053	0.4961	18.9	-0.0708	0.2858	24.1

[a] N for all models for men is 2463

[b] N for all models for women is 666

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

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

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

[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. Grouped in None, One, Two or more chronic diseases.

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

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

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

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

Introducing chronic diseases in Model 1 attenuated the effect of exposure on chair-rise performance in men and women. Introducing LTPA in Model 1 did not change the associations in men, and only to a small extent in women. Inclusion of all covariates in the final model attenuated the associations, and only the associations between ton-years/stand-years and chair-rise in men remained statistically significant.

Spline regression analyses visualising Model 1 confirmed the findings from the linear analyses, and a negative association between exposure to ton-years/stand-years and chair-rise was observed in men (Figure 3). The effect reached a maximum decrease of -1.83 (95% confidence interval(CI): (-2.70;-0.95)) chair-rises in men exposed to 30 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, associations between exposure years and chair-rise were non-linear and with broad confidence intervals, due to few participants with higher exposures (Figure 3). An analysis of the association between exposure to ton-years and chair-rise indicates a negative association with a maximum in women exposed to 20 ton-years (-2.45 chair-rises CI:(-3.92;-0.98)).

DISCUSSION

We hypothesized that physical exposures throughout working life were associated with impaired physical function in midlife measured by chair-rise performance, and that the theoretical explanation could be wear and tear or accumulation of exposures during life. We found that the influence of physical exposures on physical function was relatively small and varied between genders.

In general, our results are in line with previous findings of poorer physical performance among men with a history of hard physical work[2-6], 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], who found that long lasting physical demands were associated with poorer dynamic muscle function, though our study is larger. Chair-rise performance, as measure of dynamic function, relies on muscle power in the lower limbs, which is known to decrease due to musculoskeletal ageing[24]. The observed decrease in chair-rise performance in exposed men could hypothetically be a sign of an accelerated musculoskeletal ageing process, caused by exposures at work. However, the proportion of the variation explained by the models was low, and the proportion of the variance in outcome measures explained by the physical exposures was low, too. In linear models (Model 1), a loss of 0.04 chair-rise/ton-year was seen in men, which equals the loss of 1.2 chair-rises in 30 years and a loss of 0.045 chair-rise/ton-year in women, which equals the loss of 0.9 chair-rise in 20 years. The non-linear analyses showed higher effects: A loss of 1.8 chair-rises among those exposed to 30 ton-years compared to un-exposed and 2.5 chair-rises less among women exposed to 20 ton-years. In the final model, the results were attenuated, especially among women. The question is whether these findings are clinically relevant, and follow-up studies in this cohort should study the influence of physical performance on work ability, sickness absence, early retirement, or death. A recent 13-year follow-up study in the British birth cohort showed a higher mortality rate among those with the lowest physical capability at age 53[25].

Covariates were introduced to the models separately, and it was discussed whether covariates were confounders or mediators. However, the overall conclusion in this study is that inclusion of all covariates in the linear regression models attenuated the associations. Chronic diseases and differences in physical activity in leisure time explained only slightly the differences in performance.

In general, performance in the chair-rise test was lower in women and men with physical exposures in working life. In contrast to our findings, other studies in this field found that negative associations between work load and physical performance were more pronounced in women than in men[6]. We have no obvious explanation of the observed differences in associations between men and women in this cohort, relating to their performance in the chair-rise test. Little is known about the gender difference in the influence of work on the musculoskeletal ageing process. The job exposure matrix was not gender-specific, as has been suggested by Solovieva et al.[26], and this could introduce misclassification bias due to differences in exposure between men and women with the same job-titles. However, this cohort included few women with a history of hard physical work (see the broad confidence intervals in Figure 3) and this could be part of the explanation of our results.

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. If a linear association was found, a threshold for exposure years could be calculated. However, our results indicate that the variation in physical function is caused by multiple factors, and exposures at work may 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. According to the exposure assessment, the use of a job exposure matrix was thought to improve the validity of exposure assessment, but it has not been studied. The primary aim of the Lower Body JEM was to study osteoarthritis in the lower limbs, and it focused on exposures from lifting, kneeling, vibration, and standing/walking at work. The aim of this study was to study physical function, and we have claimed that especially lifting and standing/walking at work could influence the musculoskeletal ageing and the chair-rise performance. However, this has not been studied by others, either.

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. Objective measures in bigger cohorts are preferable in future epidemiological studies in this field[27].

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 showed that participants had lower exposures compared to non-participants[13]. Furthermore, sub-group analyses showed that participants not attending the chair-rise test had a lower socioeconomic status and more exposure-years compared to the participants fulfilling this test. This could attenuate the results further. 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 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[28]. The effect of the “healthy workers” is perhaps seen in the non-linear associations as the less pronounced detrimental effect of maximum exposure.

Conclusion

In this cohort, greater duration of physical exposures throughout adult life was associated with poorer chair-rise performance in men with a mean age of 59. In women, exposures were associated with poorer chair-rise performance in unadjusted analyses, but few female participants had physical exposures in working life. The influence of physical exposure on midlife physical function was numerically small and non-linear.

ACKNOWLEDGEMENTS

Authors thank Helle Bruunsgaard, Nils-Erik Fiehn, Poul Holm-Pedersen, Erik Lykke Mortensen and Merete Osler who initiated and established the Copenhagen Aging and Midlife Biobank from 2009-2011 together with Kirsten Avlund, Åse Marie Hansen and Rikke Lund. The authors acknowledge the crucial role of the initiators and steering groups of the Metropolit Cohort, The Copenhagen Perinatal Cohort and The Danish Longitudinal Study on Work Unemployment and Health. The authors gratefully acknowledge the contributions of Willy Karlslund and Drude Molbo (data handling processing). We acknowledge Tine Steen Rubak and her supervisors for their important contribution in the establishment of the Lower Body JEM.

FUNDING

This study was supported by a grant from The Research Foundation for the Working Environment, Denmark. The foundation has no influence on the data handling or manuscript approval. The Copenhagen Aging and Midlife Biobank has been supported by a generous grant from the VELUX FOUNDATION.

CONTRIBUTOR SHIP STATEMENT

AM planned the project together with SR, OSM, JHA and KA. AM wrote the draft of the article, and all authors have contributed by commenting on the manuscript. VS assisted in the power calculation and made the spline regression analyses. LLA and AMH are responsible for designing and implementing the physical tests in CAMB. KA was the PI, and RL was the main co-PI of the CAMB study, and, after the death of KA, RL is the PI of CAMB. AM has revised the article together with VS. All authors have approved the final manuscript.

COMPETING INTERESTS

No, there are no competing interests.

DATA SHARING

No additional data available.

REFERENCE LIST

1. Nygård C, Luopajärvi T, Ilmarinen, J. Musculoskeletal capacity and its changes among aging municipal employees in different work categories. Scand J Work Environ Health 1991;17:110–7.

2. Russo A, Onder G, Cesari M, et al. Lifetime occupation and physical function: a prospective cohort study on persons aged 80 years and older living in a community. Occup Environ Med 2006;63:438–42.

3. Cassou B, Derriennic F, Iwatsubo Y, et al. Physical diability after retirement and occupational risk factors during working life: a cross sectional epidemiological study in the Paris area. J Epidemiol Community Health 1992;46:506–11.

4. Calmels P, Ecochard R, Blanchon MA,et al. Relation between locomotion impairment, functional independence in retirement, and occupational strain resulting from work carried out during working life. Study of a sample population of 350 miners in the Loire valley in France. Epidemiol Community Health 1998;52:283–8.

5. Leino-Arjas P, Solovieva S, Riihimäki H, et al. Leisure time physical activity and strenuousness of work as predictors of physical functioning: a 28 year follow up of a cohort of industrial employees. Occup Environ Med 2004;61:1032–8.

6. Torgén M, Punnett L, Alfredsson L, et al. Physical capacity in relation to present and past physical load at work: a study of 484 men and women aged 41 to 58 years. Am J Ind Med 1999;36:388–400.

7. Mohren DC, Jansen NW, Kant I. Need for recovery from work in relation to age: a prospective cohort study. Int Arch Occup Environ Health 2010;83:553–61.

8. De Croon EM, Sluiter JK, Frings-Dresen MHW. Need for recovery after work predicts sickness absence: a 2-year prospective cohort study in truck drivers. J Psychosom Res 2003;55:331–9.

9. Kuh D, Ben-Shlomo Y. A Life Course Approach to Chronic Diseases Epidemiology. Oxford Medical Publishers 2004.

10. Verbrugge LM, Jette AM. The disablement process. Soc Sci Med 1994;38:1–14.

11. Cooper R, Kuh D, Cooper C, Gale C, et al. Objective measures of physical capability and subsequent health: a systematic review. Age ageing 2011;40:14–23.

12. Cooper R, Kuh D, Hardy R. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. BMJ 2010;341:c4467–c4467

13. Møller A, Reventlow S, Hansen Å, et al. Does a history of physical exposures at work affect hand-grip strength in strength in midlife ? A retrospective cohort study in Denmark. Scand J Work Environ Health 2013;39:599-608.

14. Avlund K, Osler M, Mortensen EL, et al. Copenhagen Aging and Midlife Biobank (CAMB). An introduction. J Aging Health 2014;26:5-20.

15. Møller A, Mortensen OS, Reventlow S, et al. Lifetime occupational physical activity and musculoskeletal aging in middle-aged men and women in denmark: retrospective cohort study protocol and methods. JMIR Res Protoc 2012;1:e7.

16. Møller A, Reventlow S, Andersen JH,et al.. Validity of Workers' Self-Reports. Evaluation of a Question Assessing Lifetime Exposure to Occupational Physical Activity. Br J Med Med Res 2012;2:536–52.

17. Rubak T, Svendsen S, Andersen J, et al. An expert-based job exposure matrix for large scale epidemiologic studies of primary hip and knee osteoarthritis: the Lower Body JEM. BMC Musculoskelet Disord 2014;15:204.

18. Mateson L. The functional capacity evaluation. In: Anderson G, Demeter S, Smith G, editors. Disability Evaluation. Mosby Year. Chicago 2003.

19. Hansen Å, Andersen L, Skotte J, et al. Social class differences in physical functions in middle-aged men and women. J Aging Health 2013; 26:88-105.

20. Silverstein B, Fan Z, Smith C, et al. Gender adjustment or stratification in discerning upper extremity musculoskeletal disorder risk? Scand J Work Environ Health 2009;35:113–26.

21. Altman DG. Practical Statistics for Medical Research. London: Chapman & Hall 1999.

22. Greenland S. Dose-response and trend analysis in epidemiology: alternatives to categorical analysis. Epidemiology 1995;6:356–65.

23. Steenland K, Deddens J. A practical guide to dose-response analyses and risk assessment in occupational epidemiology. Epidemiology 2004;15:63–70.

24. Reid KF, Fielding RA. Skeletal muscle power: a critical determinant of physical functioning in older adults. Exerc Sport Sci Rev 2012;40:4–12.

25. Cooper R, Strand B, Hardy R, et al. Physical capability in mid-life and survival over 13 years of follow-up: British birth cohort study. Bmj. 2014;348:g2219-g2219.

26. Solovieva S, Pehkonen I, Kausto J, et al. Development and validation of a job exposure matrix for physical risk factors in low back pain. PloS one 2012;7:e48680.

27. Skotte J, Korshøj M, Kristiansen J, et al. Detection of Physical Activity Types Using Triaxial Accelerometers. J Phys Act Health 2014;11:76-84.

28. Kenny G, Yardley J, Martineau L, et al. Physical work capacity in older adults: implications for the aging worker. Am J Ind Med 2008;51:610–25.

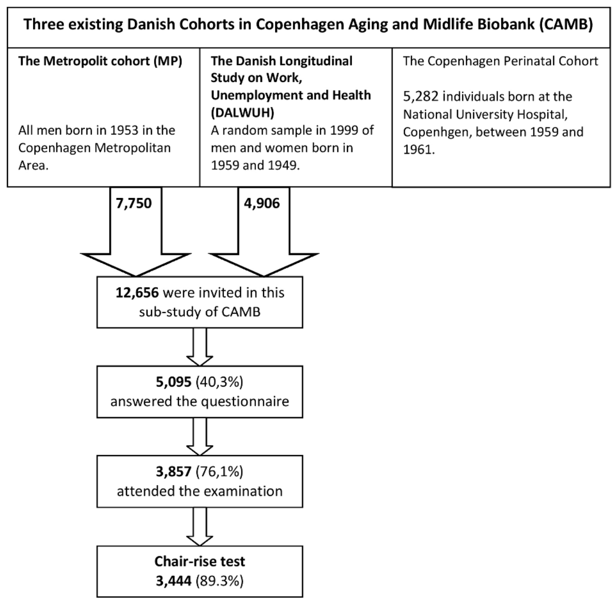
LEGENDS

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

Figure 2. Theoretical model. Associations between exposure and outcome including covariates. Gender is not included in the model since each gender is analyzed separately.

Figure 3. Multivariable 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 in orange bars.

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



210x297mm (300 x 300 DPI)

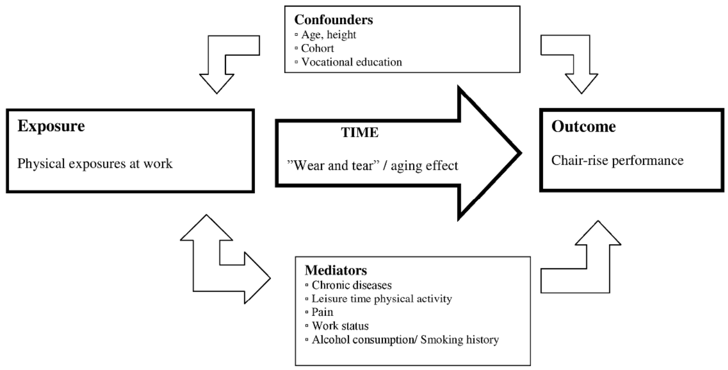
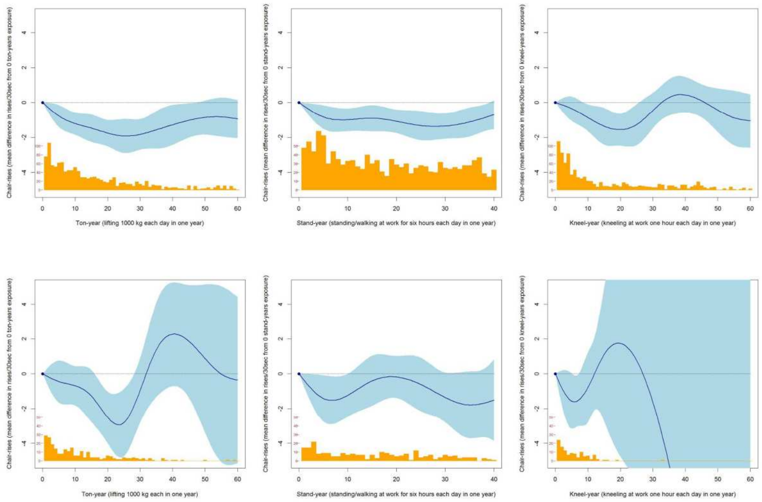


Figure 2. Theoretical model. Associations between exposure and outcome including covariates. Gender is not included in the model since each gender is analyzed separately.

297x210mm (300 x 300 DPI)

Figure 3. 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 in orange bars.



297x210mm (300 x 300 DPI)

Supplementary information

Power calculation

The power calculation was based on studies of a British birth cohort of comparable age and size (2797 individuals aged 53 years)[1]. See study protocol for details[2]. 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.

[1] Kuh D, Bassey E, Butterworth S, et al. Grip strength, postural control, and functional leg power in a representative cohort of British men and women: associations with physical activity, health status, and socioeconomic conditions. J Gerontol A Biol Sci Med Sci 2005;60:224–31.

[2] Møller A, Mortensen OS, Reventlow S, et al. Lifetime occupational physical activity and musculoskeletal aging in middle-aged men and women in denmark: retrospective cohort study protocol and methods. JMIR Res Protoc 2012;1:e7.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8/9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*8*
Bias	9	Describe any efforts to address potential sources of bias	9
Study size	10	Explain how the study size was arrived at: FIGUR 1	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9/10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9/10
		(*b*) Describe any methods used to examine subgroups and interactions	9/10
		(*c*) Explain how missing data were addressed	10
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	10
		(*e*) Describe any sensitivity analyses	

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	Fig_1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table_1
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	*Table_1*
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Table 2
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Figure_3
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.