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Retrospectively assessed physical work environment during working life and risk of sickness absence and labour market exit among older workers

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ABSTRACT

Objective To determine the prospective association between retrospectively assessed physical work environment during working life and prospectively assessed sickness absence and labour market exit among older workers.

Methods Using Cox regression analyses we estimated the 4-year to 6-year prospective risk of register-based long-term sickness absence (LTSA), disability pension, early retirement and unemployment from exposure to different physical work environmental factors during working life among 5076 older workers (age 49–63 at baseline) from the Copenhagen Aging and Midlife Biobank cohort.

Results Very hard physical work throughout working life was a risk factor for LTSA (HR 1.66,95% CI 1.32 to 2.07), disability pension (HR 2.21,95% CI 1.04 to 4.72) and early retirement (HR 1.57,95% CI 1.13 to 2.17). Both short-term (<10 years) and long-term (≥20 years) exposures to lifting or carrying of heavy burdens predicted the risk of LTSA (HRs 1.49–1.56) and disability pension (HRs 2.26–3.29). In contrast, exposure to dust was associated with LTSA and disability pension only following 20 or more exposure years.

Conclusions Retrospectively assessed hard physical work during working life and exposure to several factors in the physical work environment, especially heavy lifting, were important for labour market exit and sickness absence. This study underscores the importance of reducing physical work exposures throughout the working life course for preventing sickness absence and premature exit from the labour market.

What this paper adds

- ► While previous studies on risk factors in the physical working environment for development of ill health have focused on the current job, a long history of different physical work demands and exposures characterises most working lives, all of which may contribute to health status later in life.
- ► Our study shows that retrospectively assessed hard physical work during working life and exposure to several other factors in the physical working environment—in particular heavy lifting, vibration, noise and dust—increase the risk for premature exit from the labour market and sickness absence in older age.
- ► Dose–response analyses showed that exposure to heavy lifting for both less than 10 and more than 20 years, and exposure to dust for more than 20 years, were related to long-term sickness absence and disability pension.
- ► Work environment professionals and authorities should use this knowledge for early identification of workers at risk for premature exit from the labour market and for assisting in the development of practical guidelines and policy regulations—both in regard to exposure time and exposure to different types of physical work factors throughout life.

INTRODUCTION

Demographic changes in many industrialised countries reflect a growing proportion of older people. A focus of many Western societies is therefore to create a better framework for keeping older workers in the labour market.[1] Consequently, many governments across the European Union are increasing statutory retirement age and making it more difficult to retire early from the labour market. Despite attempts to keep older workers in the labour market, their ability to sustain employment may be constrained by their work histories and their prolonged exposure to physical workload.[2 3] To prevent premature exit of older workers from the labour market, knowledge on risk factors in the physical work environment for leaving paid employment is needed.

The physical work environment constitutes the tangible workplace environment that comprises the working conditions of employees. In the present study physical work environment is defined as covering both exposure to physical work demands (such as heavy lifting and whole body vibration) and exposure to putative hazardous indoor work environmental agents (such as dust, noise and toxic substances). Poor health, including musculoskeletal disorders, has been associated with several aspects of the physical work environment, and previous research has established physical work demands as an independent risk factor for early retirement,[4 5] long-term sickness absence (LTSA),[3 6–8] unemployment[5] and disability pension.[9 10] In addition,

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exposure to specific physical work demands—such as lifting, bending or twisting of the back, squatting and kneeling, standing and repetitive arm/hand movements—is a risk factor for LTSA.[3 6 8] In a prospective study of employees from the Helsinki Health Study cohort, Lahelma *et al*[9] found that physical workload was among the primary risk factors for all-cause disability pension. Using data from the same cohort, Laaksonen *et al*[7] showed that both heavy physical demands and hazardous exposures (comprising exposures to dirt and dust, dampness and wetness, noise, solvents or other irritating substances, and problems with lighting or temperature) were strongly associated with both short-term and long-term sickness absence. Hence, other factors in the physical working environment in addition to physical work demands seem to increase the risk of poor health and absence from work. This is in agreement with other studies showing associations between exposure to physical factors such as noise, air pollution, cleaning agents or disinfectants and disability pension.[11 12] In addition, occupational exposures to dust have been associated with increased risk of poor health, such as chronic obstructive pulmonary disease.[13]

Previous studies have mainly focused on the association between physical work demands in participants' latest job function or within a relative short time period (eg, within the last year) and the risk for sickness absence or other health outcomes. However, working lives for older workers can often be described by a long history of different physical work demands and exposures, all of which may contribute to health status in older age, stressing the need for assessing cumulative work demands when assessing risk factors for loss of labour market attachment in older age. Therefore, the present study will investigate the association between years of exposure to multiple factors in the physical work environment during working life and labour market attachment in older age. Such knowledge is relevant for the early identification of individuals at risk for premature exit from the labour market and for assisting in the development of practical guidelines and policy regulations—both in regard to exposure time and exposure to different types of physical work factors throughout life. Overall, the study aims to add to the existing knowledge base on the working experience of older workers, and aims to offer an explanation for why they may leave employment.

The relation between specific physical exposures and labour market attachment might differ between different pathways of leaving the workforce (ie, through LTSA, disability pension, unemployment and early retirement). Premature exit from the labour market reflects a complex interaction of health and work characteristics, and can be a consequence of the scenario where requirements at work exceed individual resources. Specifically, poor health is a risk factor for labour force exit as demonstrated by studies showing that sickness absence predicts disability pension.[14 15] In addition, some studies have reported sickness absence to be associated with unemployment and early retirement,[4 16] whereas others have not.[17] Generally, disability pension seems to be preceded by sickness absence, whereas early retirement and unemployment to a larger extent could be entitled to other causes than poor health such as economic and social factors. In the present study, we therefore aim to investigate the association between the physical environment during working life and the risk of fully or partially leaving the workforce, due to disability pension, unemployment, early retirement and LTSA. We hypothesise that high physical work demands throughout life are associated with increased risk of loss of labour market attachment due to poor health, which is expressed as LTSA or disability pension. Additionally, we hypothesise that long-term exposure to indoor environmental factors such as noise and dust is associated with increased risk of loss of labour market attachment due to poor health. Unemployment and early retirement were included in the study as exploratory outcomes.

MATERIALS AND METHODS

Study design

The project is a 4-year to 6-year prospective register follow-up study that uses data from the Copenhagen Aging and Midlife Biobank (CAMB) and the Danish Register for Evaluation of Marginalization (DREAM). Using participants' social security number, we linked CAMB survey data that retrospectively assessed work environment during working life with DREAM data that prospectively assessed all social transfer payments. The STROBE checklist was followed to ensure transparent and standardised reporting of the study. Further details on design and methods of the study are published elsewhere.[18]

Study population

Data on work environment and health were obtained from the CAMB, which was established in 2009–2011 by researchers from the Department of Public Health, University of Copenhagen, in collaboration with the National Research Centre for the Working Environment.[19] The CAMB database contains data on biological, psychological and social factors for individuals in the age range between 49 and 63 years from the merging of three established cohorts: the Metropolit Cohort,[20] the Copenhagen Perinatal Cohort[21] and the Danish Longitudinal Study on Work, Unemployment and Health.[22] A total of 17 937 individuals were invited for the CAMB data collection, and 7190 completed a questionnaire while 5575 attended the clinical examination. For the present study, we only included currently employed wage earners at baseline, yielding a study sample of 5076 older employees. Individuals not affiliated with the labour market at the point of data collection were ineligible for this study, which investigated the risk of fully or partially leaving the workforce due to disability pension, unemployment, early retirement and LTSA. Hence, the study population consists of a homogeneous group representing currently employed wage earners in Denmark, as previously described in the published protocol article.[18] Because not all participants answered all the survey questions, the exact number for each analysis varies. Baseline characteristics of the study population are presented in table 1.

Ethical approval

The present study was approved by the Danish Data Protection Agency (j.nr. 2015-41-4232). The local ethical committee and Danish Data Protection Agency have previously approved the CAMB as a database combining three cohorts: approval no H-A-2008–126 and no 2013-41-1814, respectively.[19] Participants were informed about the content and purpose of the CAMB study and gave written informed consent to participate.[19]

Predictor variables

Physical work environment during working life

Physical work environment during the working life was evaluated by a general question about physical work demands from the CAMB questionnaire: 'Looking back on your entire working life: For how many years of your working life have you had…, 1) mostly sedentary work without physical strain?, 2) mostly standing or walking work without major physical strain?, 3) mostly standing or walking work with some lifting and carrying?, 4) mostly heavy, fast or physically demanding

Table 1 Characteristics of the study population

	N	%	Mean	SD
Age, years	5076		54.3	3.8
Body mass index (kg/m²)	5076		26.0	4.1
Gender				
Men	3537	70		
Women	1539	30		
Smoking (yes/no)				
Yes and ex-smoker	1102	22		
No	3922	78		
Physical work environment during working life				
Sedentary work	2618	53		
Moderate physical work	1072	22		
Hard physical work	827	17		
Very hard physical work	414	8		
Psychosocial work environment				
Quantitative demands				
Often to always	1041	21		
Never to sometimes	3964	79		
Influence/Decision authority				
Often to always	3740	75		
Never to sometimes	1270	25		
Emotional demands				
Often to always	1531	31		
Never to sometimes	3477	69		
Work pace				
Often to always	2206	44		
Never to sometimes	2807	56		
Role conflicts				
To a high to very high degree	521	10		
Poor to partly degree	4459	90		
Possibilities for development				
To a high to very high degree	4007	80		
Poor to partly degree	1003	20		
Rewards/Appreciation				
To a high to very high degree	2832	57		
Poor to partly degree	2119	43		
Chronic diseases				
Back disease (have or have had)	1306	26		
No back disease	3705	74		
Cancer inclusive leukaemia (have or have had)	212	4		
No cancer inclusive leukaemia	4799	96		
Chronic depression or anxiety (have or have had)	516	10		
No chronic depression or anxiety	4497	90		

Values are percentage of participants or mean and SD.

work?' These four response categories were based on a question from the Copenhagen Male Study.[23] For each response category respondents listed the number of years of working life (cumulative exposure assessment) with the specific effort level.[24] For further analyses, the data on exposure years in each of the four categories were transformed to a number between 0 and 100, where 0 indicates that all exposure years belong to category 1 (seated work) and 100 indicates that all exposure years belong to category 4 (very hard work), and anything in between was linearly scaled. The categories were defined as 'low physical work demands' (0–24.99), 'moderate physical work demands' (25–49.99), 'high physical work demands' (50–74.99) and 'very high physical work demands' (75–100).

The main question on physical work environment was supplemented by questions on single physical exposures during working life (both concerning physical work demands and other physical exposures): 'In your current or previous job are/were you often exposed to the following in your daily work (several times a week or more)… (1) noise so loud that you must raise your voice to talk to other people?, (2) hand tools vibrations?, (3) lift or move heavy things or persons?, (4) pull or push heavy burdens?, (5) work in stooping posture without leaning on hands or arms?, (6) work in which you have to twist or bend your back several times per hour?, (7) work where you repeat the same movements several times per minute during a large part of the working hours?, (8) dust? (cement, demolitions, mineral fibers, wood, animals or plants), (9) toxic substances?, (10) welding smoke?, and (11) diesel fumes?' The following response categories were available: 'no', 'yes' and 'if yes, indicate number of years'. For further analyses, each of the 11 physical exposure variables was transformed into four categories of exposure years: (1) no exposure, (2) less than 10 years of exposure, (3) more than 10 and less than 20 years of exposure and (4) 20 or more years of exposure.

Outcome variables

The DREAM register contains information on all types of social transfer payments (including sickness absence, early retirement, government education, unemployment benefits and so on) and other basic personal data on all Danish residents on a weekly basis.[25] In Denmark, the current state pension age is 65 years but will gradually increase to 68 years by the year 2030. The average actual age of retirement in Denmark (in the period 2009–2014) was 63.0 years among men and 60.6 years among women.[26] In the present study, outcome variables were labour market attachment to varying degrees: LTSA, disability pension, early retirement and unemployment.

Long-term sickness absence

In DREAM, sickness absence is recorded on a weekly basis when the employer is entitled to reimbursement of the sickness pay. During our follow-up, the period during which the employer received no reimbursement changed from 21 days of sickness absence to 30 days (January 2012). To define LTSA consistently throughout this period, we defined it as sickness absence >30 calendar days, corresponding to ≥6 consecutive weeks in DREAM.

Disability pension

Participants receiving a disability benefit were classified as being on disability pension. In Denmark, a disability pension (in Danish: 'førtidspension') is a social benefit for people with a significant and permanent loss of work ability. The disability pension is permanent with a compensation period lasting until retirement age. To be qualified for disability pension, an attempt to increase work ability must have been carried out without success. Individuals with a permanent loss of work ability and working on special terms, such as 'light jobs' (in Danish 'skånejob': work on special terms with a wage subsidy offered to people on disability pension) and 'flexible jobs' (in Danish 'flex-job': a job offer on special terms for people with permanently reduced work ability), or vacancy benefit for individuals with flexible job, were also classified as receiving disability pension.[27]

Early retirement

Early retirement (in Danish: 'efterløn') is a voluntary retirement scheme for people who are members of an unemployment insurance fund and have paid retirement contributions for 30 years, which allows for withdrawal from the labour market before official retirement age. Additionally, to be applicable for early retirement, people must meet a number of other criteria such as having reached the early retirement age, having the right to unemployment benefits, being available for the labour market and not being sick or unable to take on a job. With the adoption of the early retirement reform in 2011, this limit is gradually shifted to 64 years for individuals born in 1959 and forth and 65 years for individuals born in 1963 and forth.

Unemployment

Participants being unemployed, but available for the labour market, were classified as unemployed.

Covariates

Covariates at baseline included age, gender, psychosocial work environment during working life (described below), physical activity level during leisure, body mass index (BMI), smoking, chronic diseases (described below), socioeconomic position (described below) and previous LTSA. Previous LTSA was derived from the DREAM register and defined as at least one episode of LTSA (at least six consecutive weeks) over the preceding 2 years prior to baseline.

Psychosocial work environment during working life was assessed retrospectively by seven scales: (1) quantitative demands, (2) influence/decision authority, (3) emotional demands, (4) work pace, (5) role conflicts, (6) possibilities for development and (7) recognition/appreciation. Each scale included one single-item question from the Copenhagen Psychosocial Questionnaire,[28] which was modified to retrospectively cover the participants' entire working life. The scales, items and associated response categories are presented in the online supplementary appendix table s1.

Chronic diseases were assessed by the following question: 'Do you have or have you had any of the following diseases?' with the response options 'yes, have now', 'yes, previously' or 'no'. We included three diseases—back disease, cancer including leukaemia, and chronic anxiety or depression, because these were the only diseases that predicted LTSA in a previous analysis of Danish employees.[29]

Socioeconomic position was evaluated by level of education. Education was categorised into five groups: unskilled, skilled, and short, medium and long education.[30] Skilled labour refers to labour that requires workers who have specialised training or a learnt skill-set to perform the work. These workers can be either blue-collar or white-collar workers, with varied levels of training or education. Unskilled labour refers to labour that requires no other education or professional qualifications than primary school education. Short, medium and long education refer to short, medium or long cycle further education than a high school education.

Statistical methods

Using the PHREG procedure in SAS V.9.4, the Cox proportional hazard model was used for modelling the probability of LTSA, disability pension, early retirement and unemployment during the follow-up period of 4–6 years from the baseline measurements. Specifically, we evaluated the HR of the different outcome events (ie, LTSA, disability pension, early retirement and unemployment) by conducting four separate analyses, where we censored for all competing events of permanent labour market dropout based on the DREAM register within the follow-up period. For instance, in the analysis with LTSA as outcome, we censored for statutory retirement, early retirement, disability pension, immigration or death. When individuals had an onset of LTSA, disability pension, early retirement or unemployment within the follow-up period, the survival times were non-censored and referred to as event times. In addition, trend tests were performed by including the predictor variables (ie, physical work environment) as continuous variables in the Cox proportional hazard model. Hence, it was possible to statistically test dose–response relations. The estimation method was maximum likelihood and the results are reported as HR with 95% CI.

The first set of analyses, presented in table 2, concerns the associations between physical work demands throughout working life and degree of labour market attachment (ie, LTSA, disability pension, early retirement and unemployment). The minimally adjusted model 1 was adjusted for age and gender. The fully adjusted model 2 was additionally adjusted for psychosocial work environment throughout life, lifestyle factors (physical activity level, BMI, smoking), chronic diseases, socioeconomic position and LTSA prior to baseline. To provide an estimate of how age affected the different labour market outcomes, we extracted the risk estimates for age in the fully adjusted statistical model.

The second set of analyses, presented in table 3, concerns the associations between duration of exposure to different types of factors in the physical work environment throughout life and labour market attachment to a varying degree (ie, LTSA, disability pension, early retirement and unemployment). The analyses were adjusted according to the models mentioned above.

Correlation analyses

Previous analyses including a small sample (n=68) of the CAMB participants showed that the higher the level of occupational physical activity in the work history, the lower the agreement between self-reports and interviews.[24] However, self-reports are less time-consuming and resource-consuming, whereas it seems relevant to determine whether a single question on retrospectively physical exposure can actually give an estimate of the physical working environment during an occupational career. Because the previous analysis included only a small sample size, we performed an additional exploratory analysis based on the full data set, where we determined the strength of the association between retrospectively assessed physical exposure from the CAMB questionnaire and cumulative occupational mechanical exposures from the lower body Job Exposure Matrix (JEM). As described elsewhere,[31] the lower body JEM is based on expert judgements of mechanical exposures in 121 homogeneous exposure groups and provides estimates of total load lifted per day. In brief, job history for each participant from the CAMB study was coded according to the 1988 revision of the Danish version of the International Standard Classification of Occupations register (D-ISCO 88) and linked to the lower body JEM, providing cumulative exposure variables: one ton-year was standardised as lifting one ton per working day for 1 year.[30] For the present study, Spearman correlation coefficient was used to determine the correlation between the general question about physical work demands from the CAMB questionnaire (predictor variable) and ton-years from the JEM. Spearman correlation

Table 2 Physical work demands throughout working life and risk for long-term sickness absence (LTSA), disability pension, early retirement and unemployment

			Model 1	Model 2
	N	%	HR (95% CI)	HR (95% CI)
LTSA				
Sedentary work	2618	53.1	1	1
Moderate physical work	1072	21.7	1.30 (1.10 to 1.54)	1.21 (1.01 to 1.44)
Hard physical work	827	16.8	1.93 (1.63 to 2.28)	1.36 (1.13 to 1.64)
Very hard physical work	414	8.4	2.75 (2.25 to 3.35)	1.66 (1.32 to 2.07)
Disability pension				
Sedentary work	2618	53.1	1	1
Moderate physical work	1072	21.7	1.88 (1.00 to 3.55)	1.55 (0.79 to 3.03)
Hard physical work	827	16.8	3.83 (2.15 to 6.80)	1.95 (1.02 to 3.71)
Very hard physical work	414	8.4	5.00 (2.61 to 9.55)	2.21 (1.04 to 4.72)
Early retirement				
Sedentary work	2618	53.1	1	1
Moderate physical work	1072	21.7	1.36 (1.09 to 1.69)	1.26 (1.00 to 1.58)
Hard physical work	827	16.8	2.27 (1.81 to 2.86)	1.74 (1.35 to 2.25)
Very hard physical work	414	8.4	2.21 (1.65 to 2.95)	1.57 (1.13 to 2.17)
Unemployment				
Sedentary work	2618	53.1	1	1
Moderate physical work	1072	21.7	1.24 (1.05 to 1.48)	1.19 (0.99 to 1.42)
Hard physical work	827	16.8	1.64 (1.38 to 1.95)	1.15 (0.95 to 1.40)
Very hard physical work	414	8.4	2.09 (1.69 to 2.59)	1.23 (0.96 to 1.57)

Model 1: adjusted for age and gender
Model 2: model 1 + psychosocial work environment, lifestyle, chronic diseases, socioeconomic position, previous LTSA

coefficient was additionally used to determine the correlation between the 11 single physical exposures. The following interpretation of the strengths of the correlation was used: 0.00–0.30=weak, 0.31–0.50=moderate, 0.51–0.80=strong and 0.81–1.00=very strong.

RESULTS

Outcome data

During the follow-up period of 4–6 years, the following number of outcome events occurred: 970 participants (19.3%) had at least one episode of LTSA; 933 participants (18.5%) had at least one episode of unemployment; 85 participants (1.7%) received disability pension; 538 participants (10.7%) received early retirement benefit; 529 participants (10.4%) received state pension; and 60 (1.2%) died.

Physical work environment throughout life

Table 2 shows the prospective association between physical work demands throughout working life and LTSA, disability pension, early retirement and unemployment. A highly statistically significant dose–response association between increasing physical demands at work and LTSA and disability pension was observed (trend test with physical work demands as continuous variable $p<0.001$). In the fully adjusted model with physical work demands as a categorical variable, being exposed to 'Hard physical work' and 'Very hard physical work' for the entire working life was statistically significant associated with LTSA, disability pension and early retirement. In addition, 'Moderate physical work' for the entire working life was associated with LTSA and early retirement. No association was found between physical work demands throughout working life and unemployment in the fully adjusted model. The risk estimate for age in the fully adjusted model was only statistically significant for the outcome early retirement (HR 1.66, 95% CI 1.59 to 1.74), whereas age did not predict disability pension (HR 1.06, 95% CI 0.98 to 1.03), sickness absence (HR 1.00, 95% CI 0.98 to 1.03) and unemployment (HR 0.98, 95% CI 0.95 to 1.00).

Table 3 shows the prospective associations between duration of specific physical exposures throughout working life and LTSA and disability pension (ie, outcomes related to poor health). In the fully adjusted model, both short-time (<10 years) and long-time (≥20 years) exposures to noise, lifting/carrying of heavy burdens, pushing/pulling of heavy burdens and frequently working with the back twisted/bended statistically significant increased the risk for LTSA. By contrast, exposure to vibration, working with the back severely bended/twisted and dust were statistically significant associated with LTSA only after 20 or more exposure years. In the fully adjusted model, both short-time (<10 years) and long-time (≥20 years) exposures to vibration, lifting/carrying of heavy burdens and working with the back severely bended/twisted statistically significant increased the probability for disability pension. In contrast, exposure to dust and noise was statistically significant associated with disability pension only following 20 or more exposure years and less than 20 years of exposure, respectively.

In the fully adjusted model for the risk of early retirement (not shown in the table), being exposed to noise (HR 1.34, 95% CI 1.07 to 1.67), lifting/carrying of heavy burdens (HR 1.40, 95% CI 1.11 to 1.78) and dust (HR 1.52, 95% CI 1.12 to 2.05) for more than 20 years were statistically significant risk factors. None of the remaining physical exposures were associated with early retirement in the fully adjusted model. In the fully adjusted model, both short-time (HR 1.52, 95% CI 1.20 to 1.93) and long-time (HR 1.22, 95% CI 1.00 to 1.49) exposures to repetitive frequent movements were statistically significant associated with unemployment (not shown in the table). Likewise, both short-time (HR 1.53, 95% CI 1.20 to 1.95) and long-time (HR 1.40, 95% CI 1.09 to 1.79) exposures to dust were statistically

Table 3 Associations between duration of different physical exposures throughout working life and long-term sickness absence (LTSA) and disability pension

			Long-term sickness absence		Disability pension	
			Model 1	Model 2	Model 1	Model 2
	N	%	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Noise: no exposure	3198	66.0	1	1	1	1
Noise: less than 10 years of exposure	495	10.2	1.62 (1.33 to 1.97)	1.32 (1.08 to 1.62)	2.62 (1.38 to 4.99)	1.83 (0.94 to 3.55)
Noise: less than 20 years of exposure	395	8.2	1.80 (1.45 to 2.24)	1.23 (0.98 to 1.55)	3.34 (1.75 to 6.35)	2.19 (1.10 to 4.32)
Noise: 20 or more years of exposure	757	15.6	1.75 (1.48 to 2.07)	1.34 (1.13 to 1.60)	2.57 (1.46 to 4.53)	1.73 (0.94 to 3.19)
Vibration: no exposure	4089	83.7	1	1	1	1
Vibration (hand tool): less than 10 years of exposure	251	5.1	1.18 (0.87 to 1.60)	1.03 (0.75 to 1.41)	2.98 (1.46 to 6.09)	2.24 (1.05 to 4.77)
Vibration (hand tool): less than 20 years of exposure	185	3.8	1.65 (1.20 to 2.27)	1.15 (0.82 to 1.61)	2.35 (0.92 to 5.96)	1.53 (0.58 to 4.02)
Vibration (hand tool): 20 or more years of exposure	361	7.4	1.70 (1.36 to 2.12)	1.39 (1.10 to 1.76)	2.35 (1.18 to 4.70)	2.11 (1.01 to 4.40)
Lifting/carrying of heavy burdens: no exposure	3001	62.1	1	1	1	1
Lifting/carrying of heavy burdens: less than 10 years of exposure	501	10.4	1.82 (1.49 to 2.22)	1.56 (1.26 to 1.91)	4.48 (2.40 to 8.36)	3.29 (1.71 to 6.34)
Lifting/carrying of heavy burdens: less than 20 years of exposure	422	8.7	2.28 (1.86 to 2.80)	1.39 (1.12 to 1.73)	4.11 (2.09 to 8.10)	2.00 (0.97 to 4.14)
Lifting/carrying of heavy burdens: 20 or more years of exposure	910	18.8	1.99 (1.70 to 2.34)	1.49 (1.26 to 1.77)	3.69 (2.10 to 6.47)	2.26 (1.20 to 4.26)
Pushing/pulling of heavy burdens: no exposure	3338	69.1	1	1	1	1
Pushing/pulling of heavy burdens: less than 10 years of exposure	403	8.3	1.64 (1.31 to 2.04)	1.36 (1.08 to 1.71)	3.41 (1.84 to 6.35)	2.16 (1.13 to 4.14)
Pushing/pulling of heavy burdens: less than 20 years of exposure	337	7.0	2.04 (1.63 to 2.55)	1.22 (0.96 to 1.56)	2.68 (1.29 to 5.59)	1.08 (0.48 to 2.40)
Pushing/pulling of heavy burdens: 20 or more years of exposure	753	15.6	1.81 (1.54 to 2.14)	1.29 (1.08 to 1.55)	2.50 (1.43 to 4.37)	1.36 (0.73 to 2.55)
Back severely bended/twisted: no exposure	3646	75.1	1	1	1	1
Back severely bended/twisted: less than 10 years of exposure	328	6.8	1.61 (1.27 to 2.04)	1.21 (0.95 to 1.54)	4.71 (2.47 to 8.98)	3.03 (1.55 to 5.95)
Back severely bended/twisted: less than 20 years of exposure	272	5.6	2.04 (1.60 to 2.60)	1.21 (0.93 to 1.57)	4.98 (2.51 to 9.90)	2.35 (1.10 to 5.02)
Back severely bended/twisted: 20 or more years of exposure	612	12.6	1.84 (1.55 to 2.19)	1.26 (1.05 to 1.53)	4.23 (2.46 to 7.28)	2.72 (1.50 to 4.92)
Back twisted/bended frequently: no exposure	3445	71.1	1	1	1	1
Back twisted/bended frequently: less than 10 years of exposure	337	7.0	1.77 (1.40 to 2.23)	1.34 (1.05 to 1.71)	2.65 (1.28 to 5.50)	1.79 (0.83 to 3.85)
Back twisted/bended frequently: less than 20 years of exposure	333	6.9	1.89 (1.51 to 2.38)	1.12 (0.87 to 1.43)	2.98 (1.48 to 6.00)	1.41 (0.65 to 3.05)
Back twisted/bended frequently: 20 or more years of exposure	733	15.1	1.79 (1.52 to 2.11)	1.28 (1.07 to 1.53)	3.06 (1.81 to 5.15)	1.61 (0.88 to 2.96)
Repetitive frequent movements: no exposure	3701	76.6	1	1	1	1
Repetitive frequent movements: less than 10 years of exposure	295	6.1	1.57 (1.24 to 1.99)	1.26 (0.99 to 1.62)	2.95 (1.53 to 5.69)	1.91 (0.93 to 3.91)
Repetitive frequent movements: less than 20 years of exposure	263	5.4	1.46 (1.12 to 1.90)	0.98 (0.75 to 1.30)	1.82 (0.78 to 4.24)	1.05 (0.43 to 2.57)
Repetitive frequent movements: 20 or more years of exposure	573	11.9	1.38 (1.14 to 1.67)	0.99 (0.81 to 1.22)	1.91 (1.05 to 3.47)	1.04 (0.52 to 2.07)
Dust: no exposure	4134	84.8	1	1	1	1
Dust: less than 10 years of exposure	268	5.5	1.61 (1.25 to 2.09)	1.21 (0.92 to 1.58)	2.42 (1.14 to 5.12)	1.56 (0.71 to 3.43)
Dust: less than 20 years of exposure	152	3.1	1.61 (1.12 to 2.32)	1.11 (0.77 to 1.60)	1.14 (0.28 to 4.70)	0.61 (0.14 to 2.57)
Dust: 20 or more years of exposure	321	6.6	2.15 (1.72 to 2.68)	1.64 (1.30 to 2.08)	3.22 (1.68 to 6.14)	2.03 (1.00 to 4.10)
Toxic substances: no exposure	4209	86.3	1	1	1	1
Toxic substances: less than 10 years of exposure	261	5.4	1.45 (1.12 to 1.87)	1.02 (0.78 to 1.33)	2.20 (1.05 to 4.63)	1.32 (0.61 to 2.85)
Toxic substances: less than 20 years of exposure	161	3.3	1.44 (1.04 to 1.99)	0.99 (0.70 to 1.38)	1.80 (0.65 to 4.98)	1.08 (0.38 to 3.10)
Toxic substances: 20 or more years of exposure	247	5.1	1.50 (1.15 to 1.95)	1.28 (0.97 to 1.69)	1.47 (0.59 to 3.67)	1.27 (0.49 to 3.25)
Welding smoke: no exposure	4529	92.5	1	1	1	1

continued

Table 3 continued

			Long-term sickness absence		Disability pension	
			Model 1	Model 2	Model 1	Model 2
	N	%	HR (95% CI)	HR (95% CI)	HR (95% CI)	HR (95% CI)
Welding smoke: less than 10 years of exposure	169	3.5	1.38 (0.98 to 1.95)	0.98 (0.69 to 1.39)	2.07 (0.82 to 5.19)	1.63 (0.64 to 4.20)
Welding smoke: less than 20 years of exposure	80	1.6	1.70 (1.10 to 2.64)	1.09 (0.69 to 1.71)	1.78 (0.43 to 7.36)	0.89 (0.21 to 3.85)
Welding smoke: 20 or more years of exposure	119	2.4	1.37 (0.94 to 2.00)	1.03 (0.69 to 1.55)	0.59 (0.08 to 4.26)	0.42 (0.06 to 3.11)
Diesel fumes: no exposure	4420	90.4	1	1	1	1
Diesel fumes: less than 10 years of exposure	152	3.1	1.19 (0.81 to 1.74)	0.91 (0.62 to 1.33)	1.48 (0.46 to 4.76)	0.75 (0.22 to 2.50)
Diesel fumes: less than 20 years of exposure	121	2.5	1.91 (1.32 to 2.77)	1.22 (0.83 to 1.80)	4.65 (2.09 to 10.33)	1.75 (0.72 to 4.25)
Diesel fumes: 20 or more years of exposure	196	4.0	1.72 (1.28 to 2.29)	1.29 (0.96 to 1.75)	0.77 (0.19 to 3.18)	0.49 (0.12 to 2.06)

Model 1: adjusted for age and gender
Model 2: model 1 + psychosocial work environment, lifestyle, chronic diseases, socioeconomic position, previous LTSA

significant associated with unemployment. Additionally, working with the back twisted/bended frequently was statistically significant associated with unemployment only following less than 10 years of exposure (HR 1.56, 95% CI 1.24 to 1.95). None of the remainder of the physical exposures was associated with unemployment in the fully adjusted model.

Correlation analyses

The Spearman correlation coefficient revealed a strong correlation between retrospectively assessed physical activity throughout working life and years with heavy lifting (ton-years) from the JEM (rs=0.66, p<0.0001).

The correlation analyses between the 11 different physical exposures revealed that lifting/carrying of heavy burdens, pushing/pulling of heavy burdens and working with the back severely bended/twisted were strongly or very strongly correlated (correlation coefficients ≥0.51). None of the remaining physical exposures were strongly or very strongly correlated (correlation coefficients <0.51).

DISCUSSION

Hard physical work during working life and exposure to several other factors in the physical working environment (heavy lifting, vibration, noise and dust) were important risk factors for sickness absence and premature exit from the labour market. However, their relative significance varied by the labour market outcome. For instance, hard and very hard physical work during working life was prospectively associated with LTSA, disability pension and early retirement, but not related to unemployment. Both short-term (<10 years) and long-term (≥20 years) exposures to lifting or carrying of heavy burdens increased the probability of LTSA and disability pension, whereas exposure to dust was only related to LTSA and disability pension following 20 or more years of exposure. The following discussion will primarily focus on the health-related outcomes, that is, LTSA and disability pension.

A dose–response relationship between higher physical work demands during working life and increased risk of LTSA and disability pension was observed. In the fully adjusted model, both 'hard physical work' and 'very hard physical work' during working life were associated with LTSA, disability pension and early retirement. Specifically, 'very hard physical work' increased risk of LTSA, disability pension and early retirement with 66%, 121% and 57%, respectively. It may be argued that controlling for previous LTSA (model 2) in the analysis with disability pension as outcome is an overadjustment, that is, sickness absence may be on the causal pathway from physical work demands (exposure) to disability pension (outcome). In spite of this, model 2 will form the base for all work-related outcomes for the discussion, but the reader should be aware of the possible bias associated with overadjustment in the analyses on disability pension. Analysing the study data without adjusting for previous LTSA (results not presented) did not change the results to any significant extent for any of the labour market outcomes. However, a small increase was observed for most of the risk estimates. Importantly, adjusting for previous LTSA in the analyses with LTSA as outcome changes the outcome from future sickness absence to future sickness absence that is independent of previous sickness absence, corresponding to the change in LTSA from baseline to follow-up.[32]

The overall results on physical work demands partially agree with previous studies investigating the relation between labour market attachment and shorter term exposures to high physical workload. For instance, Ropponen *et al*[10] showed, in a prospective cohort study, that high physical workload was associated with increased risk of disability pension (HR 2.21) due to musculoskeletal disorders. In addition, a prospective cohort study among waste collectors and municipal workers in Denmark showed that pushing of heavy loads and extreme bending of the back were associated with unemployment, whereas only extreme bending of the back was associated with early retirement.[5] However, in that study, no association between any of the physical work demands investigated and disability pension or LTSA was observed. The present study elaborates on the existing knowledge base by showing that physical work demands during the course of a working life are associated with premature labour market exit and sickness absence at older age.

Real working lives consist of a multitude of different physical exposures of different durations of time. In the dose–response analysis of accumulated physical exposures during working life, we investigated the association between years exposed to specific factors in the physical work environment and attachment to the labour market. The results show that short-term (<10 years) and long-term (≥20 years) exposures during working life to lifting or carrying of heavy burdens increase the probability of LTSA and disability pension. In addition, both short-term and long-term exposures to vibration and working with the back severely bended or twisted increased the risk for disability pension. Our results suggest that being engaged in work that involves these specific physical work demands during working life increases the risk for leaving the labour market due to ill health (ie, through LTSA or disability pension). Reducing these risk factors early in the working life should therefore be prioritised as an early preventative action to maintain a longer and healthier working life among older workers engaged in physically demanding work.

In addition to physical work demands, Laaksonen *et al*[7] found that hazardous exposures (comprising dust and noise among other factors) were consistently associated with increased sickness absence episodes (both short and long term). In the present study, exposure to dust was only associated with LTSA and disability pension following 20 or more exposure years, suggesting an accumulated exposure profile—that is, the longer time engaged in work that involves exposure to dust, the higher the risk for leaving the labour force due to ill health. Interestingly, of the factors associated with early retirement (ie, noise, lifting or carrying of heavy burdens and dust), only long-term exposure (≥20 years) to these factors increased this risk. It could be speculated that participants who did not get sick and/or permanently lost work ability due to lifelong exposure to these factors, but were still engaged in a job leading to physical deterioration, would choose this more voluntary pathway of leaving the workforce. This result might be biased by the healthy worker effect, where older workers engaged in physically demanding jobs are leaving the labour market before the age of 50 years due to ill health.

The present findings provide evidence of how years on the labour market can impact work outcomes later in life. Hence, there should be a greater consideration for work history with regard to the physical work environment when developing programme and policies aimed at older workers. Policy makers should use this knowledge as they continue to strategise ways to keep older workers employed. In particular, a continuous effort to mitigate physical work exposures throughout the working life course should be prioritised, and especially a reduction of the physical demands is needed to prevent loss of labour market attachment among older workers.[3 6 9] Even though hard physical work has become less common during recent decades, many industries still involve high physical work demands. Thus, there is a need to think about creative ways to keep older workers employed, especially if they have been working in physically demanding jobs their entire life. In a workplace setting, reduced exposure time to these physical factors could for example be achieved by organising the work in a different way (eg, by incorporating micro-breaks or job rotation to less physically demanding job tasks) or by using technical aids, for example, lifting devices, when appropriate. Overall, the present study provides evidence for both upstream and downstream interventions to support the employment of older workers.

Strengths and limitations

Some strengths and limitations to the study need to be addressed. The physical work environment during working life was retrospectively assessed by self-reports at mid-life and not prospectively assessed throughout the lives of the participants. Therefore, we were not able to analyse the physical work environment throughout an entire working life, as we measured physical work environment only once when we asked the participants in retrospect to assess exposure years during their working career. The type and exposure time of the physical workloads may therefore be prone to recall bias. It is possible that past exposure to physical workloads influences labour market participation less than current exposure, but the present study did not have sufficiently detailed labour history information to differentiate between effects of current and previous exposure.

It has previously been stated that information on physical workload assessed through questionnaire surveys depends on participants' memory, understanding and interpretation,[33] which could have caused wider CIs of the risk estimates in the present study, and thus increased the probability of statistical type II errors. In spite of this, we observed clear associations between hard physical work throughout working life and labour market attachment, indicating that the questionnaire data were less prone to bias due to type II error. Importantly, levels of physical work demands during working life retrospectively assessed by a question from the CAMB questionnaire have previously been shown to have low reliability.[24] In that study, it was concluded that self-reports of lifetime exposure to sedentary work were valid in the CAMB cohort, whereas the validity of self-reports of exposure to high levels of occupational physical activity was questionable.[24] However, self-reports are less time-consuming and resource-consuming, and therefore it is important to determine whether a single question on retrospectively physical exposure can actually give an estimate of the physical working environment throughout an occupational career. In the exploratory analysis, we observed a strong correlation between the predictor variable of the present study (general question on physical work demands throughout working life) and cumulative occupational heavy lifting from the JEM (correlation coefficient of 0.66). Hence, it seems that asking participants to retrospectively evaluate physical work demands throughout an entire occupational career, despite potential biases, can be used as a proxy measure to analyse the physical work environment during the course of a working life. In addition, questionnaire information on several physical exposures seems to be systematically biased by factors such as disease and socioeconomic status—for example, current health status may affect the retrospective assessment of earlier working conditions.[34 35] However, this probability was reduced in the present study by adjusting for several factors that potentially could lead to bias. Overall, the addition of control variables thought to be potential confounders (eg, psychosocial working environment, chronic disease, lifestyle and socioeconomic position) is a strength of the study. Another strength of the study is the use of register-based data on the different states of labour market attachment. The DREAM register has high validity as it contains weekly information on all social transfer payments for all Danish residents.[25] A limitation is that, due to Danish law, the DREAM register contains no information regarding the cause of sickness absence, disability pension, early retirement and unemployment. Thus, even though several factors in the physical working environment were associated with different routes of leaving paid employment, we have no information about the specific cause leading to these events (such as musculoskeletal disorders or specific chronic diseases).

A possible bias is the healthy worker effect. It is likely that those with the heaviest work could either be selected out of the labour market earlier, or the most robust employees could continue for more than 20 years in spite of the physically heavy work. Kaila-Kangas *et al*[36] observed that a long history of handling heavy objects and bending was related to sciatica among non-working women, suggesting that those with the longest history of physically demanding work could already be outside the workforce when the present study began.[36] This could have led to bias on the assessment of the contribution of long-term physical exposure to labour attachment.

Further, the study holds no data on the proportion of participants who were members of an unemployment insurance fund and had paid retirement contribution. Therefore, there was no information on who had the possibility to withdraw from the labour market before official retirement age (ie, early retirement). However, at the time of the baseline measurements, approximately 80% of older Danish employees were members of an early retirement scheme that provided partly compensation for loss of income if they retired before the statutory retirement age of 65.[37] In addition, it has previously been suggested that people between 50 and 60 years with declining health may choose to wait for early retirement pension instead of applying for disability pension, which could cause an overestimation of the probability of sickness absence in the present study.[27,38]

The large sample size and the recruitment of older workers from the general population are a strength of the study. However, the low response rate could have introduced selection bias. Participants and non-participants of the CAMB study have previously been compared by linking the CAMB database with Danish registers.[19] That analysis revealed that educational level of the participants did not differ substantially compared with non-participants. In contrast, a larger proportion of the participants in the CAMB study were employed compared with non-participants, which could suggest that the participants of the CAMB study represent a socially selected group. However, this does not seem to influence the present study results as we only included currently employed wage earners. In addition, when using number of contacts with general practitioners during year 2009 as a proxy measure for general health, there was no difference between participants and non-participants.[19]

In regard to generalisability of the results, it should also be mentioned that the study population consisted of workers between 49 and 63 years and that the definition of older workers is not agreed on in the literature.[39] Different agencies, organisations and researchers are using a broad spectrum of ages, ranging from 40 to 65 years, or more.[39,40] Therefore, the generalisability of the study applies to older individuals on the labour market in the age range 49–63 years.

CONCLUSIONS

In conclusion, retrospectively assessed hard physical work during working life was prospectively associated with register-based LTSA, disability pension and early retirement, but not related to unemployment. Both short-term (<10 years) and long-term (≥20 years) exposures to lifting or carrying of heavy burdens significantly increased the risk of LTSA and disability pension, whereas exposure to dust was only related to LTSA and disability pension following 20 or more years of exposure. Reducing physical work demands—for example by organising the work in a different way or by using technical aids when appropriate—may contribute to reducing premature exit from the labour market.

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Contributors LLA obtained the funding. LLA and ES designed the study and performed the statistical analyses. ÅMH and ELM initiated and established the Copenhagen Aging and Midlife Biobank. ÅMH, ELM, OMP, TC, RR and AM provided feedback to the study design and interpretation of the results. ES drafted the manuscript. All authors approved and critically reviewed the final version of the manuscript.

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