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ORIGINAL ARTICLE

Occupational physical activity and mortality among Danish workers

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Abstract
Purpose The relationship between occupational physical activity (OPA) and mortality has mainly been studied among males and shows conflicting results. This study examines this relationship in a cohort of both male and female workers.
Methods OPA was determined by 4 self-reported questions in a representative sample of 5,839 Danish workers aged 18–59 years at baseline. A 19-year follow-up on mortality was assessed by linkage with the national death registry. Gender-stratified Cox regression models were used to determine the effect of high OPA on all-cause mortality while controlling for age, BMI, smoking, alcohol consumption, doctor-diagnosed disease, influence at work, and social class.
Results Two hundred and sixty-two males (8.6%) and 174 females (6.2%) died during follow-up. Being in the highest quartile of OPA predicted an increased risk for all-cause mortality among male workers (HR: 1.79, CI: 1.19–2.70), but not among female workers (HR: 0.99, CI: 0.65–1.49) compared with workers in the lowest quartile of OPA. Among females, indications of a u-shaped relationship between occupational physical activity and all-cause mortality were found.
Conclusions The findings indicate that high occupational physical activity increases the risk for all-cause mortality among male workers. Future studies need to further examine gender differences in the effects of OPA on mortality.

Keywords Physical work demands · Occupational health · All-cause mortality

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Introduction

The scientific literature on the relationship between occupational physical activity (OPA) and mortality is characterized by conflicting results. In some cohorts, high OPA was associated with a reduced risk of cardiovascular and all-cause mortality (Barengo et al. 2004; Lissner et al. 1996; Paffenbarger and Hale 1975; Salonen et al. 1988). In the Copenhagen Male Study consisting of middle-aged male workers, we have shown an increased risk for cardiovascular and all-cause mortality from high OPA (Holtermann et al. 2009, 2010a, b). A positive association between OPA and all-cause mortality is also found in a few other cohorts of male workers (Kristal-Boneh et al. 2000; Stender et al. 1993). However, the relationship between OPA and mortality has only been investigated in a few studies and needs further exploration in additional cohorts (Krause 2010).

The conflicting results on the relationship between OPA and mortality may have several explanations. One

explanation may be that the studies were conducted in occupational groups that differed regarding the type and intensity of occupational physical activities (Barengo et al. 2004; Holtermann et al. 2009; Kristal-Boneh et al. 2000; Lissner et al. 1996; Paffenbarger and Hale 1975; Salonen et al. 1988; Stender et al. 1993). Another explanation may be an inadequate control for psychosocial work factors in some previous studies (Barengo et al. 2004; Holtermann et al. 2009; Kristal-Boneh et al. 2000; Lissner et al. 1996; Paffenbarger and Hale 1975; Salonen et al. 1988; Stender et al. 1993). The conflicting findings may also be attributed to secular changes in occupational physical work demands over the past decades in western societies (Burr et al. 2003).

In addition, gender differences in the relationship between OPA and mortality have been previously reported (Andersen et al. 2000). However, the association between OPA and mortality has almost exclusively been studied among male workers. To address some of these research gaps, we investigated the association between OPA and mortality in a gender-stratified representative sample of the Danish workforce with adjustment for influence at work, a psychosocial occupational risk factor for cardiovascular disease (Kuper and Marmot 2003).

Methods and analysis

Study population

The 1990 survey of the Danish National Work Environment Cohort Study drew a random sample of 9,653 people aged 18–59 years from the national population register of all residents in Denmark. Of these, 8,664 agreed to be interviewed by telephone (response rate 90%), and the 6,067 respondents who were employed in 1990 were included in the study sample; 227 workers who had missing data on one or more questions, and one person who died before January 1,1991, were excluded, yielding a final study sample of 5,839 workers.

Variables

Data on age at baseline, gender, emigration, and mortality (between January 1, 1991, and December 31, 2009) were obtained from the national population register based on a unique personal identification number (Pedersen et al. 2006). All other variables were self-reported at baseline.

Occupational physical activity was assessed by four questions: 'Does your job require that you sit down?' (reverse scoring), 'Does your job require physically strenuous work which results in you breathing faster?', 'Does your job require that you kneel or squat?', and 'Do you lift loads that individually weigh more than 44 lb (20 kg) daily?' with the following response options (and score value) 'Almost all the time' (100), 'Approximately 3/4 of the time' (75), 'Approximately 1/2 of the time' (50), 'Approximately 1/4 of the time' (25), 'Rarely/very little' (6), 'Never' (0). Males and females were categorized in 4 categories of OPA based on quartiles from summarized average scores of all four questions calculated from the total population (no gender stratification).

Influence at work was assessed by average scores on a scale summarizing answers to the following questions 'Do you have the opportunity in your work to decide your own pace of work?' and 'Do you participate in the planning of your work? (for example, what needs to be done, how it will be accomplished, or who you will work with)?' with the same response options (and score values) described above for the first question and 'Always' (100), 'Usually' (66), 'Usually not' (33), and 'Never' (0) for the second question.

Body mass index (BMI) was calculated on the basis of the respondents' information on height and weight as kg/m^2 and was used as a continuous variable.

Smoking behavior was dichotomized into 'current' versus 'former' or 'never'.

Alcohol was based on the question 'Except for today, when was the last time you drank beer, wine or liquor?' and answers were collapsed into two categories 'Within the last week' and 'Not within the last week'.

The presence of *doctor-diagnosed disease* was assumed if participants reported having a disease being diagnosed by a medical doctor.

Five *social classes* were defined based on employment grade, job title, and education at baseline: Executives and/or academics (I), middle managers and/or people with 3 ± 4 years of secondary education (II), other white collar workers (III), skilled blue collar workers (IV), and semi- or unskilled blue collar workers (V).

Analyses

The proportionality risk assumption was confirmed using the scaled Schoenfeld residuals. Therefore, the semi-parametric Cox proportional hazard model (Cox 1972) was used for modeling the rate of death as a function of the age of a person in the follow-up period (Korn et al. 1997). The analyses were stratified on gender. Additional adjustments were made for smoking, alcohol consumption, body mass index, doctor-diagnosed disease, influence at work, and social class. The independent variable of interest was OPA.

Age was implicitly adjusted for in the construction of the model. Thus, the rate of death is expressed as $\lambda(t) = \lambda_0(t)\ \exp(\beta_{1i}1\ (\mathrm{OPA} = i))\ \exp(\Sigma_j\ \beta_{ji}\ z_{ji})$, where t is the age of a person, the z's are the factors adjusted for in

the analyses, and the β's are the effects of these on the linear scale. Then, $\exp(\beta_{1i})$ will be the hazard ratios representing the effects of OPA. Persons emigrating from Denmark during the follow-up period (between 1991 and 2009) were censored at time of emigration. Analyses were executed using the PHREG procedure of the statistical computer program SAS (version 9.2).

Results

A total of 261 (8.6%) males and 174 (6.2%) females died during the 19-year follow-up period. Moreover, 259 (4.4%) emigrated.

Table 1 summarizes demographic and lifestyle variables stratified by gender and 4 quartiles of OPA. Among the male workers, significant differences between the 4 quartiles of OPA were observed in age, current smoking, alcohol consumption during last week, influence at work, and low social class. Among the female workers, significant differences between the 4 quartiles of OPA were observed in BMI, current smoking, alcohol consumption during last week, influence at work, and low social class.

Table 2 shows the results of gender-stratified Cox proportional hazard analyses of the effect of OPA on all-cause mortality adjusted for age and also with additional adjustment for smoking, alcohol consumption, BMI, doctor-diagnosed disease, influence at work, and social class. Among the male workers, OPA increased the risk for all-cause mortality in a dose–response manner. Male workers in the highest quartile of OPA were 79% more likely to die at any time during follow-up compared with those in the lowest quartile of OPA. The mortality risk for men in the second highest quartile of OPA was 70% higher than for those in the lowest quartile. Among females, no significant increased risk was found among those with the highest quartile of OPA. Rather, a u-shaped relationship between OPA and all-cause mortality was found, with a non-significant reduced risk for the second and third quartiles of 21 and 28 percent. Therefore, a post hoc analysis on the relationship between OPA and all-cause mortality among the females was performed. Table 3 shows the Cox proportional hazard analyses of the effect of OPA on all-cause mortality among the females adjusted for age and also with additional adjustment for smoking, alcohol consumption, BMI, doctor-diagnosed disease, influence at work, and social class with the second and third quartiles collapsed (middle half) and set as reference. Although not reaching statistical significance, the lowest quartile had 33% and the highest quartile 31% excessive risk for mortality compared with the middle half of OPA.

Table 1 Demographic and lifestyle factors stratified by gender and level of occupational physical activity in the Danish National Work Environment Cohort Study, 1990, $N = 5{,}839$

Occupational physical activity	Males					Females				
	Lowest quartile $n = 750$	Second lowest quartile $n = 751$	Second highest quartile $n = 693$	Highest quartile $n = 855$	*P* value	Lowest quartile $n = 932$	Second lowest quartile $n = 585$	Second highest quartile $n = 692$	Highest quartile $n = 581$	*P* value
Age, years, mean (SD)	39.2 (10.7)	38.9 (10.4)	35.4 (11.7)	33.8 (11.3)	<0.0001	37.4 (10.6)	37.6 (10.4)	38.2 (11.4)	36.5 (10.5)	0.057
BMI, mean (SD)	24.4 (2.88)	24.5 (3.22)	24.6 (3.17)	24.6 (3.19)	0.36	22.2 (3.15)	22.1 (3.17)	22.5 (3.41)	22.8 (3.49)	0.0008
Current smokers, %	44.1	45.9	47.8	56.5	0.001	41.3	42.2	47.5	50.4	<0.0001
Any alcohol consumption during last week, %	90.3	89.1	85.7	85.7	0.01	81.7	80.5	74.0	71.4	<0.0001
Doctor-diagnosed disease, %	20.9	20.2	21.2	24.9	0.10	20.2	23.9	21.5	20.7	0.36
Influence at work, mean (SD)	83.5 (26.1)	81.5 (25.6)	72.2 (29.6)	68.3 (29.8)	<0.0001	73.3 (29.3)	73.4 (29.3)	68.5 (31.2)	65.7 (31.6)	<0.0001
Low social class (classes IV/V), %	13.3	20.8	53.5	66.7	<0.0001	11.9	13.0	35.3	28.7	<0.0001
Mortality, %	6.9	8.0	9.7	9.6	0.16	6.9	5.6	5.6	6.5	0.68

P values of test (ANOVA for continuous factors, i.e., age, BMI, and influence at work, and logistic regression for binary factors) for effect on occupational physical activity (nominal variable) in unadjusted analyses are provided

Table 2 Occupational physical activity and risk for all-cause mortality from 1990–2009 among male and female workers in the Danish National Work Environment Cohort Study

	Males		Females	
	Age-adjusted hazard ratio (95% CI)	Fully adjusted hazard ratio (95% CI)[b]	Age-adjusted hazard ratio (95% CI)	Fully adjusted hazard ratio (95% CI)[b]
Occupational physical activity				
Lowest quartile	1[a]	1[a]	1[a]	1[a]
Second lowest quartile	1.19 (0.82–1.73)	1.13 (0.77–1.65)	0.80 (0.53–1.22)	0.79 (0.51–1.20)
Second highest quartile	1.80 (1.25–2.59)*	1.70 (1.14–2.53)*	0.71 (0.48–1.06)	0.72 (0.48–1.09)
Highest quartile	2.05 (1.44–2.90)*	1.79 (1.19–2.70)*	1.03 (0.69–1.54)	0.99 (0.65–1.49)

The Cox proportional hazards model with age in years as the time scale for underlying hazard was applied for the analyses. Adjusted hazards ratios (HR) with 95% confidence intervals (95% CI) are presented

* $P \leq 0.01$

[a] Reference

[b] Adjusted for age, smoking, alcohol, BMI, chronic disease, influence at work and social class

Table 3 Occupational physical activity and risk for all-cause mortality from 1990–2009 among female workers in the Danish National Work Environment Cohort Study

	Age-adjusted hazard ratio (95% CI)	Fully adjusted hazard ratio (95% CI)[b]
Occupational physical activity		
Lowest quartile	1.33 (0.95–1.87)	1.33 (0.94–1.88)
Middle half	1[a]	1[a]
Highest quartile	1.37 (0.92–2.03)	1.31 (0.88–1.95)

The two middle quartiles of occupational physical activity are collapsed and set as reference. The Cox proportional hazards model with age in years as the time scale for underlying hazard was applied for the analyses. Adjusted hazards ratios (HR) with 95% confidence intervals (95% CI) are presented

[a] Reference

[b] Adjustment for age, smoking, alcohol, BMI, chronic disease, influence at work and social class

Discussion

The main finding of this study is the increased risk for all-cause mortality from high OPA among male workers. Although not reaching statistical significance, results among female workers indicate a u-shaped relationship between OPA and mortality.

The observed increased risk from high OPA on all-cause mortality among male workers in Denmark from 18 to 59 years of age is consistent with the previously observed association between OPA and all-cause mortality among middle-aged men in Denmark (Holtermann et al. 2009, 2010a, b). In the present study, the association found for males was not substantially reduced and remained significant after adjustment for influence at work, indicating that influence at work is not a significant confounder or modifying factor for the association between OPA and mortality.

The underlying causation for the increased risk for mortality from high OPA can be explained by the hemodynamic model of atherosclerosis (Glagov et al. 1988). Several hours per day of OPA will inevitably cause prolonged elevated heart rate, eliciting a higher fraction of the cardiac circle in the systolic phase with unfavorable intravascular turbulence and wall shear stress, leading to inflammatory processes in the arterial walls, which may result in atherosclerosis, cardiovascular disease, and death (Krause et al. 2007).

The nearly doubled risk for all-cause mortality among the half of the working male population with highest OPA indicates that OPA may have considerable influence on longevity among male workers. Moreover, because the data in this study are from a representative sample of Danish workers with a relatively recent baseline measure and follow-up (from 1990 to 2009), compared with other Danish studies on the relationship between OPA and mortality where OPA was assessed in the 1970s (Holtermann et al. 2009, 2010a, b), the findings are highly relevant for the present working population in Denmark.

Among the female workers, high OPA was not found to increase the risk for all-cause mortality. Although not

reaching statistical significance, the lowest quartile of OPA had 33% higher risk for mortality and the highest quartile of OPA had 31% higher risk for mortality compared with the middle half of OPA. This finding indicates a u-shaped relationship between OPA and all-cause mortality among females. Different associations between OPA and all-cause mortality among male and female workers have previously been reported (Andersen et al. 2000). Andersen and colleagues (Andersen et al. 2000) found a negative association between OPA and all-cause mortality among Danish adult females, but not among males. However, the underlying mechanisms behind this potentially different association between OPA and mortality among male and female workers remain unknown. A plausible explanation can be gender differences in type or physiological responses to OPA. However, because the u-shaped relationship between OPA and mortality among females did not reach statistical significance, this finding may be a result of chance. Additional studies investigating the association between specific occupational physical activities and mortality among both genders are therefore needed for further clarification.

Strengths and limitations

Strengths of the present study are the relatively long follow-up time, control for social class, and influence at work, and that the study population is representative for the working population in Denmark.

Limitations of the study include (1) the lack of observer-based measures of exposure, (2) a rather general measure of exposure and only measured once, likely to reduce the effect size because of regression to the mean over the 19-year follow-up, (3) the lack of control for other risk factors for mortality such as leisure time physical activity, (4) a general and unspecific outcome such as all-cause mortality can be considered a limitation of the study. The high correlation of OPA with socioeconomic conditions could indicate that OPA is not only a primary risk factor but also a marker for other risk factors associated with low socioeconomic status that were not measured, such as low levels of leisure time physical activity. However, control for social class plus three cardiovascular risk factors associated with social class (smoking, alcohol consumption, and influence at work) did not substantially alter the observed association. To better understand the specific pathways of the OPA effect on all-cause mortality, future studies should investigate cause-specific mortality, disease incidence including cardiovascular disease, and asymptomatic pre-clinical outcomes such as progression of atherosclerosis.

Conclusion

This study supports earlier findings from other cohorts that high OPA increases the all-cause mortality risk among male workers (Holtermann et al. 2009, 2010a, b; Kristal-Boneh et al. 2000; Stender et al. 1993) and that this relationship is independent of lifestyle factors, social class, and influence at work. However, no increased risk from high OPA was found among female workers. Instead, indications of a u-shaped relationship between OPA and all-cause mortality were found for females. The observed positive association between OPA and mortality among male, but not among female, workers may be explained by different physical work exposures or physiological responses to OPA between the genders. Future studies need to further examine gender differences in the effects of OPA on mortality.

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