Safety Science 184 (2025) 106768

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Occupational physical activity and mortality risk among 756 377 adults: A prospective cohort register-based study with 13 years follow-up☆

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ARTICLE INFO

Keywords:
Occupational medicine
Occupational hazards
Occupational health
Epidemiology

ABSTRACT

Background: Recent research from Nordic countries observed higher levels of occupational physical activity (OPA) to increase mortality risk. However, research is required to clarify generalizability to other countries as several studies have found no or even an inverse association for certain subgroups.
Objectives: We aimed to investigate the association between OPA and mortality, retrieving administrative data from a Spanish population.
Methods: In a prospective cohort study, individuals from the Continuous Working Life Sample (CWLS), a representative sample with administrative registers of the workforce in Spain were followed up from baseline (January 1, 2006) to either death date or end of follow-up (September 1, 2019).
Results: During 13.6 years from baseline to the end of follow-up, 23,975 (3.2 %) of the participants died. The full adjusted model showed significant associations for men aged 18–36 years in moderate (HR, 1.54; 95 % CI, 1.26–1.88), high (HR, 1.26; 95 % CI 1.01–1.58), and very high OPA (HR, 1.44; 95 % CI, 1.15–1.80). Men aged 37–64 years solely showed a significant HR for moderate OPA (HR, 1.10; 95 % CI, 1.04–1.16), whereas no significant association was found in women.
Conclusion: These results warrant preventative measures to address early mortality among young working men in highly demanding physical jobs.

1. Introduction

Overall levels of physical activity has been observed to protect against early mortality in a dose–response fashion (Ekelund et al. 2019; Gebel et al. 2015). However, different physical activity domains appear to differ regarding effects on general health; a recent *meta*-analysis by Raza et al.(Raza et al. 2020) observed significant risk reductions of critical conditions such as myocardial infarction (18 %) and type II diabetes (22 %) for commuting physical activity, and myocardial infarction (22 %), cardiovascular disease (26 %), heart failure (27 %), stroke (23 %), type II diabetes (22 %), colon cancer (15 %), and breast cancer (7 %) for leisure-time physical activity. In contrast, two Danish cohort studies observed higher risk of atrial fibrillation (55 %) and cardiovascular disease (57 %) from higher occupational physical activity (OPA) (Holtermann et al. 2021; Skielboe et al. 2016). These domain specific effects of physical activity also appear to exist for mortality; particularly, leisure-time physical activity and OPA have shown opposite outcomes, reducing and increasing mortality risk, respectively. (Holtermann et al. 2021) Prior research showed similar results, although important differences concerning sex have also been identified (Coenen et al. 2018a; Wanner et al. 2019). On the other hand, recent research from Norway presented completely different results where higher OPA protected against early mortality in men (Dalene et al. 2021). Nevertheless, current research on the topic is mainly based on self-reporting,

☆ This article is part of a special issue entitled: 'Human-Focused Perspectives' published in Safety Science.

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https://doi.org/10.1016/j.ssci.2024.106768
Received 8 November 2022; Received in revised form 9 November 2024; Accepted 23 December 2024
Available online 29 December 2024

and a number of studies lack population representativeness. Furthermore, Shephard suggested a potential lack of rigour in the previous analyses associating higher OPA with higher mortality risk (Shephard 2019).

Nevertheless, increasing research is adding evidence to this topic, contributing to support the notion of detrimental effects of OPA on health from different perspectives; a large study by Pega et al. identified higher risks of stroke and ischemic heart disease from long working hours (≥55 h/week vs 35–40 h/week) (Pega et al. 2021), whereas higher age appeared to worsen the consequences of high physical work demands for the risk of long-term sickness absence (Andersen et al. 2021). Partially in agreement, a recent umbrella review on 23 different health outcomes in relation to OPA found both favourable and unfavourable effects, suggesting the need for higher quality evidence to provide an unequivocal conclusion on the effects of OPA over health (Cillekens et al. 2020). Moreover, prior research has suggested that, owing to the better working conditions and lifestyle in countries such as Denmark, the observed harmful health associations from OPA might be even stronger in Eastern and South European countries (Eurofound 2019). Finally, work constitutes the main domain of physical activity for a large portion of the adult population, although until recently not closely examined than other domains such as leisure or overall physical activity (Strain et al. 2020).

Previous research on occupational physical activity (OPA) has highlighted significant disparities in its impact on health outcomes. For instance, Coenen et al. (2018a) conducted a systematic review with *meta*-analysis that explored the association between high levels of OPA and mortality. The results indicated that workers with intense OPA had an increased risk of all-cause mortality, suggesting that physical exertion at work might not confer the same protective health benefits as leisure-time physical activity. This finding was supported by further analysis showing differential mortality risk between OPA and leisure-time activity, challenging the common belief that all physical activity is beneficial for health.

In contrast, Holtermann et al. (2021) examined the so-called "physical activity paradox," which refers to the contradictory effects of OPA compared to non-occupational physical activity. Their research, based on a large population cohort, suggested that OPA could indeed increase the risk of cardiovascular disease and overall mortality. This paradox may stem from the nature of occupational activities, which often involve repetitive, high-intensity tasks without the recovery periods typically associated with recreational physical activity. Unlike structured physical exercise, OPA often lacks variation and may contribute to chronic physical strain, limited recovery, and adverse long-term health effects.

These contrasting findings underscore the complexity of OPA impact on health, influenced by factors such as intensity, duration, and context. They emphasize the need for nuanced research, such as the present study, to further understand the diverse outcomes of OPA and its role in occupational health policy development. By analyzing a large, representative sample over an extensive follow-up period, our study aims to bridge gaps in understanding the nuanced relationship between OPA and mortality.

2. Methods

2.1. Study design and participants

This prospective cohort with register follow-up retrieved data from the Continuous Working Life Sample (CWLS) (Gómez et al. 2016), an annual random sample comprising 4 % of the social security affiliated in Spain. The representativeness of the sample is ensured using four variables: sex, age, geographical regions, and nationality. Eligibility criteria for being part of this cohort is having a registered Personal Identification Code (PIC) derived from a governmental document and having any social security affiliation register during the considered year. The population consists of contributors and beneficiaries of social security, and comprises wage-earners, self-employed workers, early retirees (<65 years) and unemployed people receiving benefits. Around 95 % of workers in formal employment are registered in the social security system. Randomised sequences of numbers were matched to parts of the PIC to select the initial sample. To ensure follow-ups, individuals remain in the sample if they continue active in the social security system. By contrast, individuals lost because of death or administrative inactivity are randomly replaced to reach 4 % of the reference population following a panel study methodology. More details of the CWLS have been described elsewhere (Gómez et al. 2016).

Individual data from the 2006 round of CWLS was used to describe features of the participants at baseline, whereas data from 2007 to 2018 rounds were linked to the 2006 round via PIC and used to follow-up mortality status. From an initial randomly selected sample of 1 170 895 participants that constituted the cohort, those with no legal age to work without parent consent and those over the retirement age in Spain (i.e., <18 to > 65 years) were removed from the study sample (n = 249 430). Moreover, participants with missing data on any covariate or replicated participants (n = 163 612) or with no score available to their economic activity and level of education (n = 1476) were also removed from the analytical sample, which finally comprised 756 377 participants. See Fig. 1 for more details on the study cohort selection. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (von Elm et al. 2007). The study received the approval of the Ethics Committee of Research in Humans of the University of Valencia (register code 1510464).

2.2. Exposure

Working trajectories dating as far back as 1981 to 2006 were analysed. Among all the available registers for each participant, the first three numbers of the economic activity code linked to the register involving longer time were used. For ties, the more recent registration was selected. Economic activity codes from the 2006 round of CWLS are based on the first version of the standard Statistical Classification of Economic Activities in the European Community (NACE),(Eurostat 2008) which describes the activity of the company or administration the participants were working for. Group-level OPA was estimated using as proxy the physical work demand index created by Andersen et al. (Andersen et al. 2021). Each participant was assigned their corresponding index score based on economic activity and education level (eTable 1).

2.3. Outcome

Participants were prospectively followed up from baseline (Jan 1, 2006) until death date or end of follow-up on Sept 1, 2019, whichever came first. Data regarding all-cause mortality were obtained during follow-up from the social security registers included in CWLS.

2.4. Covariates

Age and sex for each individual were drawn from social security registers of CWLS. The first was estimated using difference between date of birth registered from social security in CWLS and baseline date. Moreover, the highest level of education attained in the 2006 round of CWLS was considered as a potential confounder (Dalene et al. 2021; Luy et al. 2019). Data on education level in CWLS stems from municipal registers and is classified into 4 main categories: (1) Illiterate; (2) lower than primary education (1–9 years of education); (3) uncompleted to completed secondary education and/or vocational training (10–16 years of education); (4) higher education comprising from general certificate of education or certificate of higher education to a university degree (>16 years of education). To better adjust estimations of physical work

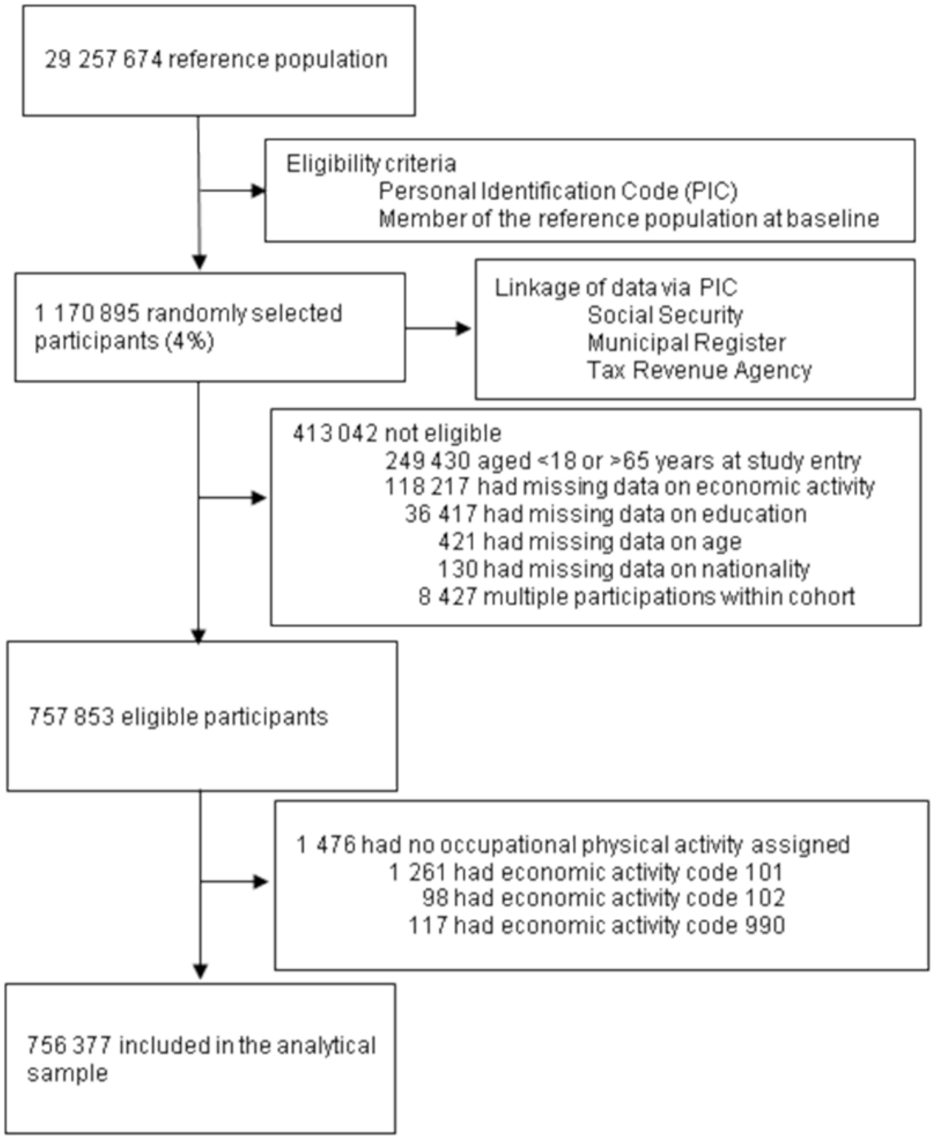

Fig. 1. Cohort profile.

demands for potentially different roles within economic activities, categories 1,2, and 3, of the education attainment level were grouped as low level of education, whereas category 4 was considered as high level of education. Because nationality has been found to be associated with job demands as well as mortality, this was considered a potential confounder (Bhopal et al. 2018; Fila et al. 2017); such variable was retrieved from the social security registers of CWLS and categorized into Spanish or not Spanish. Finally, due to the potential cohort effect over both OPA and mortality (Borodulin et al. 2008; Ocaña-Riola et al. 2015), the participants were categorized into five birth cohorts depending on their birth decade: (1) 1941–1949; (2) 1950–1959; (3) 1960–1969; (4) 1970–1979; (5) 1980–1988. Information on other potential confounders for the studied association that are lacking in the CWLS dataset have been detailed in the Supplement (eFig. 1) and comprise health-related habits concerning smoking, alcohol consumption leisure-time physical activity, diet and body mass index.

2.5. Statistical analyses

Statistical analyses were conducted with Stata version 16.1 (StataCorp, Texas, USA). The Cox proportional hazard model was used to estimate the hazard ratios (HRs) of mortality during follow-up with OPA as the exposure variable, and low category of OPA as reference. Graphical inspections of the proportional-hazards assumption in the conducted models showed no infringement (stphplot command). Time-on-study in months was used as the timescale. Because preliminary analyses detected a significant interaction between both age and sex with OPA (chunk test), analyses were stratified by age and sex subgroups. Consequently, the age variable was categorized into two groups using the median as a cut-off point (37 years), which also coincide with the median age of affiliated to the social security system in 2006. Using a priori directed acyclic graphs (eFigure), we explored the potential causal and confounding pathways between OPA and mortality. The confounding effect of education, birth cohort, and nationality was examined using the model including the three potential confounders with the two interactions as a reference, having more accurate estimations when nationality variable was removed from the reference model (confound command). Collinearity between OPA and education was assessed through the variance inflation factor. Thus, a model without confounders (model A) and the full model (model B) including education and birth cohort as confounders were examined. The effect of the models is shown as forest plots for all age and sex subgroups. Results are reported as HRs with 95 % CIs. Levels of significance were set at $p < 0.05$.

2.6. Sensitivity analyses

Due to the substantial loss of participants out of the selected age range, analyses were repeated including individuals between 15 and 74 years that might respectively have an early beginning or a prolonged working life, as well as the opposite, a more restricted age-range comprising 30–50 years, to circumvent a substantial number of participants potentially experiencing a contributory pension over the follow-up period, as well as relevant changes in working trajectories for those aged < 30 years and ≥ 30 years. Reverse causation from unknown disease in mortality was estimated by excluding the first 5 years of follow-up. Unmeasured confounding was assessed through E-Values in subgroups with significant associations.

2.7. Additional analyses

We also conducted additional analyses using adjusted restricted cubic splines with knots placed at first and second tertiles to check for non-linearity of the examined association.

3. Results

The final sample included 436 660 men and 319 617 women, with a median age of 37.0 years (IQR 28.8–47.3) at baseline (Table 1). During the follow-up period of 13·6 years from baseline to the end of follow-up, 23 975 (3.2 %) of the participants died due to all-causes.

In men aged 18–36 years and 37–64 years, crude analysis (model A) showed that higher levels of OPA significantly increased mortality risk, although no dose–response relationship was observed (Fig. 2). For women aged 37–64 years, similar significant associations were found for moderate, high, and very high OPA categories, whereas no associations were observed for women aged 18–36 years.

In the fully adjusted model (model B) (Fig. 3), men aged 37–64 years showed higher mortality risk for moderate OPA category solely, whereas either women aged 18–36 years or aged 37–64 years showed no association with mortality. Results remained consistent with model A for men aged 18–36 years, which showed the highest significant risk of mortality for moderate OPA (HR, 1.54; 95 % CI, 1.26–1.88) when compared with the low OPA referent. By contrast, the results did not show significant associations between OPA and mortality in the rest of subgroups except for men aged 37–64 years exposed to moderate OPA (HR, 1.10; 95 % CI, 1.04–1.16), which remained similar to model A. Besides, slight attenuations and accentuations of effect size were observed in the sensitivity analyses when increasing and reducing the target age-range, (eTable 2, eTable 3), as well as removing the first five years of follow-up to avoid causal-reversion, though the overall patterns remained similar as in the original sample. Sensitivity analyses indicated slight attenuations in effect size when varying age ranges and excluding the first five years of follow-up, suggesting robustness against reverse causation. Unmeasured confounding was assessed with E-values, underscoring potential bias in certain subgroups, particularly men aged 37–64 years (eTable 4). Additional analyses showed a curvilinear association between OPA and all-cause mortality (p for non-linearity < 0.001) (eFig. 2).

4. Discussion

In 757 377 participants from the CWLS sample with 23 975 deaths due to all causes during 13·7 years of follow-up, we observed significant higher mortality risk for men aged 18–36 years in both crude and fully adjusted models, with slight differences depending on OPA exposure. Moreover, a significant effect was also identified for men aged 37–64 years exposed to moderate OPA in the fully adjusted model. Education and birth cohort importantly attenuated the examined association in women aged 37–64 years, neutralising the effects of OPA. These results partially support our initial hypothesis and highlight the different effects that OPA provides depending on sex and age. These findings were supported in sensitivity analyses varying the study sample in relation to age inclusion criterion.

Our additional analyses showing a curvilinear association of OPA with all-cause mortality align with findings from Hermansen et al. (2019), who identified a U-shaped relationship between OPA and cardiovascular disease and all-cause mortality. This suggests that both low and very high OPA levels may contribute to increased mortality risk due to different underlying health mechanisms, including chronic diseases or extreme work strain.

The fact that both extremes of the curve suggest higher mortality risk in our study may reflect two different situations; the initial part of the

Table 1
Baseline characteristics of study participants by sex. No.(%).

	Men				Women			
	Low OPA	Moderate OPA	High OPA	Very high OPA	Low OPA	Moderate OPA	High OPA	Very high OPA
No. of participants	71 994 (16.5)	132 969 (30.5)	83 706 (19.0)	148 041 (34.0)	63 047 (19.7)	101 600 (31.8)	57 735 (18.1)	97 335 (30.4)
Age								
18–36 years	31 052 (14.9)	59 874 (28.1)	38 856 (18.7)	78 030 (37.6)	34 899 (20.3)	51 344 (29.8)	32 649 (19.0)	53 247 (30.9)
37–64 years	40 892 (17.9)	73 095 (31.9)	44 850 (19.6)	70 011 (30.6)	28 148 (19.1)	50 256 (34.1)	25 086 (17.0)	44 088 (29.9)
Education length[a]								
≤16 years	6 733 (2.3)	71 009 (24.6)	64 833(22.5)	146 273 (12.8)	6 716 (3.7)	49 547 (27.1)	32 203 (17.6)	94 611 (51.7)
>16 years	65 211 (44.1)	61 960 (41.9)	18 873 (12.8)	1 768 (1.2)	56 331 (41.2)	52 053 (38.1)	25 532 (18.7)	2 724 (2.0)
Birth cohort								
1941–1949	6 819 (14.7)	14 506 (31.2)	11 027 (23.7)	14 192 (30.5)	2 583 (12.2)	7 381 (34.9)	3 651 (17.3)	7 539 (35.6)
1950–1959	13 985 (1.1)	24 030 (31.1)	15 729 (20.4)	23 414(30.4)	8 172 (16.3)	16 961 (33.9)	9 006 (18.0)	15 952 (31,9)
1960–1969	20 088 (19.1)	34 559 (32.9)	18 094 (17.2)	32 405 (30.8)	17 393 (22.8)	25 914 (34.0)	12 429 (6.3)	20 597 (27.0)
1970–1979	24 972 (19.2)	41 105 (31.5)	22 704 (17.4)	41 586 (31.9)	26 991 (25.5)	33 744 (31.9)	19 157 (18.1)	25 886 (24.5)
1980–1988	6 080 (7.9)	18 769 (24.2)	16 152 (20.9)	36 444 (47.1)	7 908 (11.9)	17 600 (26.5)	13 492 (20.3)	27 381 (41.3)
Nationality								
Spanish	69 088 (17.2)	124 083 (31.0)	78 564 (19.6)	129 217 (32.2)	60 691 (20.2)	97 449 (32.4)	53 418 (17.7)	89 609 (29.8)
Not Spanish	2 856 (8.0)	8 886 (24.9)	5 142 (14.4)	18 824 (52.7)	2 356 (12.7)	4 151 (22.4)	4 317 (23.3)	7 726 (41.7)

Abbreviation: OPA, occupational physical activity.
[a] Highest level attained at baseline Jan 1, 2006.

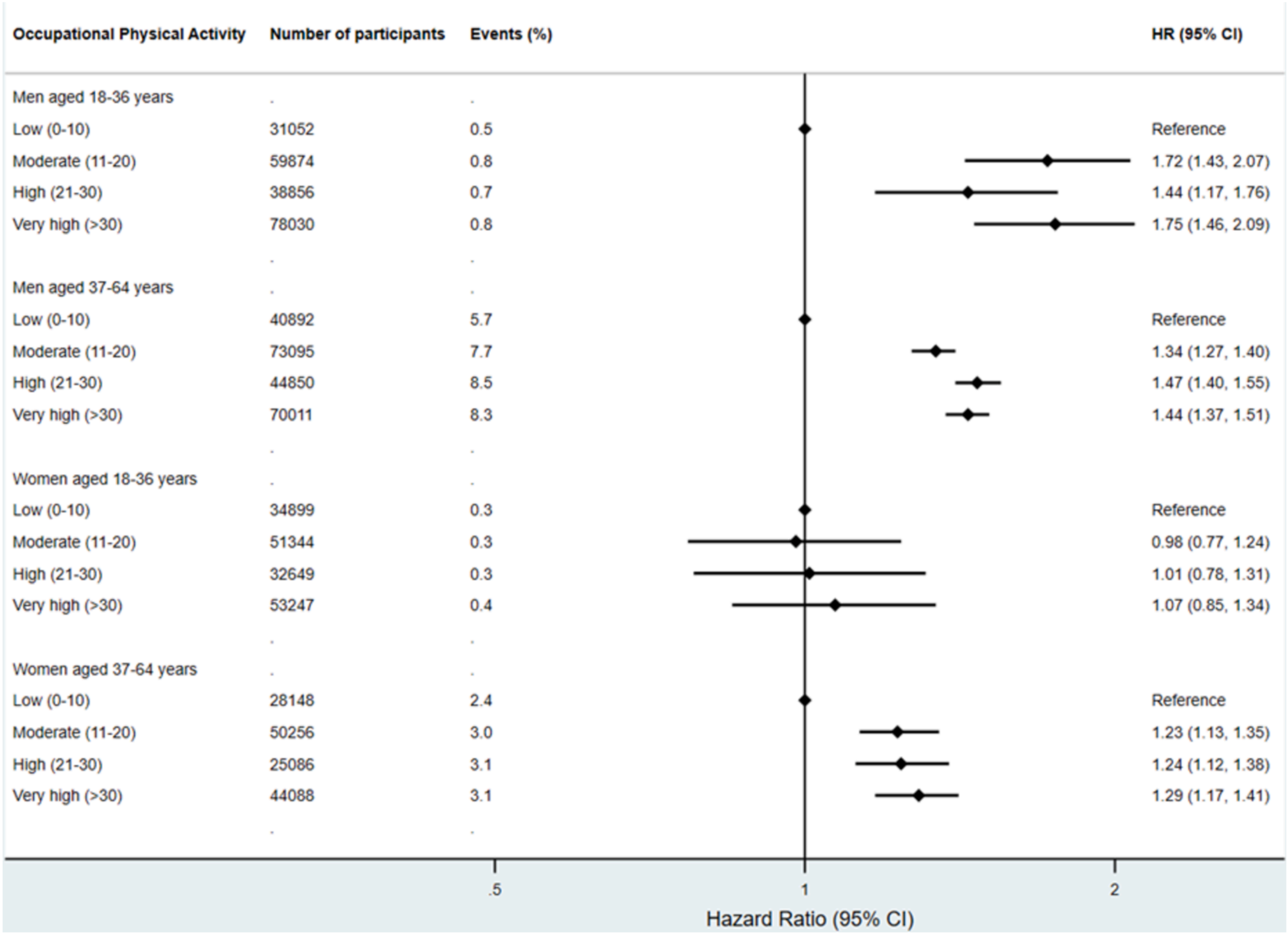

Fig. 2. Prospective associations between occupational physical activity and all-cause mortality among sex and age subgroups (Model A Crude) Occupational Physical Activity has been divided in four categories (Low, Moderate, High, and Very High) according to a physical activity index ranging from 0 to > 30.

curve, which reflects low OPA levels, may be related with individuals experiencing any type of chronic disease, which impedes to perform higher levels of OPA. By contrast, very high levels of OPA represented in the ending extreme of the curve may be related to physically-extenuating works that worsen overall health as well as involve other concomitant occupational hazards such as accidents or poisoning (Won et al. 2011).

The explanation underlying the detrimental effects that OPA can have over health, eventually increasing mortality risk in specific population subgroups, is being currently examined in the literature. A plausible cause for this is related to an equalisation mechanism observing that higher levels of OPA are usually associated with lower leisure-time physical activity, which might be detrimental for health in the long term; a systematic review on the topic observed white-collar showing the highest leisure-time physical activity compared to blue-collar workers (Kirk and Rhodes 2011). More detailed studies examining biological reasons underpinning OPA contribution to worse health have investigated the effect of different physical activity domains over hypertension, finding higher commuting and leisure-time physical activity but not OPA significantly associated with lower blood pressure and lower hypertension risk at all ages, although these associations were stronger in older adults (Byambasukh et al. 2020). Moreover, despite that we found no higher mortality risk for women with higher OPA, higher risk for both strokes and transient ischemic attack have been recently found among women residing in the United States (Hall et al. 2019), which indicates clear deterioration of cerebrovascular health. In addition, another study involving a South Korean population observed that female workers with work-related physical activity are at higher risk of oversleeping; this finding suggests that physical activity might have distinct associations with sleep duration according to the physical activity domains which might affect overall health.(Beak et al. 2021) Even faster epigenetic aging has been found for OPA in young adult and older twin pairs (Kankaanpää et al. 2021). Thus, in the light of these studies, there seems to be different pathways involved in the explanation of the effects of OPA over mortality, although further investigations might add more evidence to the current knowledge.

Our results endorse those found in prior research regarding differences between sex groups since men, particularly those younger, showed higher significant mortality risk when exposed to higher levels of OPA, whereas women did not (Coenen et al. 2018a; Holtermann et al. 2012; Wanner et al. 2019). Differences of the effects of OPA over mortality according to sex have been also observed in recent research, but the direction of the association was different than that found in the present study; for example, a Norwegian prospective cohort study using a wide-range of potential confounders such as socioeconomic status or health markers observed no association of higher levels of OPA with longevity in women, but that was identified as a protective factor for men (Dalene et al. 2021). Such differences among studies could be explained in relation to a diverse composition of the workforce, different selection criteria of the sample, or differences concerning the assessment of OPA, among others. A case in point is the late entry that Spanish women had in the workforce in comparison with the North European countries,

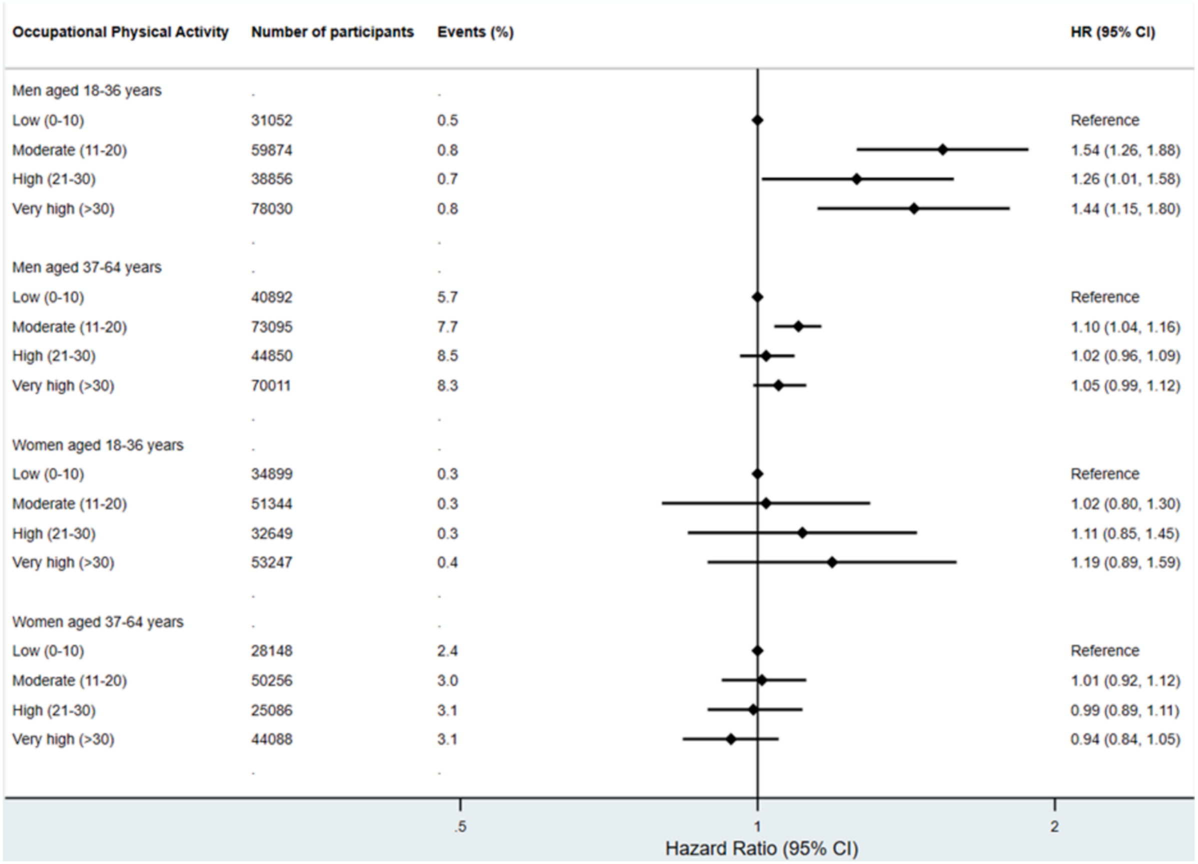

Fig. 3. Prospective associations between occupational physical activity and all-cause mortality among sex and age subgroups (Model B Full) Adjusted for education length, birth cohort. Occupational Physical Activity has been divided in four categories (Low, Moderate, High, and Very High) according to a physical activity index ranging from 0 to > 30.

which might have contributed to higher levels of both unemployment and household physical activity, which, in turn, could have contributed to reduce their mortality risk during the examined period (Huerta et al. 2016). In addition, working life of women, particularly those included in our study, probably had shorter duration than men, and involved lighter physical demands (Guner et al. 2014).

Moreover, the role of age in this study is vital since an early exposure to higher levels of OPA significantly increased mortality risk. This finding might partially be explained by survivorship bias, where older workers exposed to higher OPA are not as affected because of having any individual characteristic (e.g., biological, or job-related) that younger workers exposed to higher OPA do not have or viceversa. In fact, Dalene et al.(Dalene et al. 2021) acknowledged the possible effect of the so-called healthy worker bias (Li and Sung 1999), which might have been pronouncedly exacerbated by an excessive health-selection requirements for participants at baseline. Additionally, Holtermann et al. (Holtermann et al. 2021) carried out a profound examination of a list of 20 potential lifestyle, health, living condition, and socioeconomic confounders in the association between OPA and mortality, finding similar estimates in their models showing higher mortality risk for higher OPA even after adjustment for all these confounders. Another possibility for explaining age differences found for higher mortality risk in the examined sample is early retirement due to any developed physical/mental condition, strengthening the notion of a survival bias possibly blurring the effect of OPA on mortality, particularly in older workers; a study by Ervasti et al.(Ervasti et al. 2019) supports this argument since it found that 8 to 10 years of exposure to heavy physical effort at work was strongly associated with disability pension due to musculoskeletal disorders for men and women, and premature mortality specially among men.

Cultural, socioeconomic, and policy differences may also play a significant role in influencing the association between OPA and mortality risk. There is ongoing research to understand how socioeconomic health differences can be explained by physical activity at work and during leisure time (Coenen et al. 2018b). Socioeconomic factors like education, occupation, and income have been found to have independent effects on mortality risk, even when mutually adjusted (Khang and Kim 2005). Moreover, policy differences can impact the relationship between OPA and mortality. For instance, the type of occupation, such as sitting occupations, has been associated with increased risks of all-cause and cancer mortality, particularly in women (Stamatakis et al. 2013). Policies that promote physical activity in the workplace and during leisure time may have varying effects on mortality risk depending on the nature of the activities and the overall physical activity levels of individuals (Holtermann et al. 2013). To prevent problems derived from physically demanding work, it is essential to implement effective intervention strategies that focus on maintaining physical capacity and preventing physical deterioration among employees in job groups with high physical demands (Holtermann et al. 2010a). These strategies should include initiatives to allow workers to perform physical exercise during working hours, especially for those with physically demanding jobs and older workers, to increase physical capacity to meet job demands (Bláfoss et al. 2019). Additionally, programs aimed at maintaining functional capacity, such as health surveillance programs, flexible work practices, and workplace health-enhancing physical activity strategies, should be implemented to manage the health and functional capacity of workers in physically demanding occupations (Kenny et al. 2016). It is crucial to prioritize the physical work environment in physically demanding occupations, particularly among senior workers, to prolong working life and prevent work limitations due to pain (Skovlund et al. 2020). Furthermore, high physical work demands can have worse consequences for older workers, emphasizing the need to consider age-related changes in individual physical capacity when addressing physical work demands (Andersen et al. 2021).

The observed age-specific risk in younger men may be attributed to cumulative strain and insufficient recovery, as highlighted by Kenny et al. (2016). These workers may also lack adaptations to workplace demands, increasing vulnerability to adverse health outcomes. To reduce early mortality among young working men in physically demanding jobs, a multifaceted approach may be necessary. Research by Holtermann et al. (2010b) suggests a dual prevention strategy involving fitness-enhancing physical exercise and tailoring physical work demands based on employees' fitness levels, which together could reduce the risk of ischemic heart disease and all-cause mortality. Furthermore, the same study highlights the significance of leisure-time physical activity in preventing physical deterioration and reducing premature cardiovascular and all-cause mortality among young men with high physical work demands (Holtermann et al. 2010b).

To mitigate the observed risk among young men in highly demanding jobs, we recommend workplace policies such as mandatory health surveillance, ergonomic training, and programs that balance physical workloads. Previous interventions, such as those suggested by Holtermann et al. (2010b), which involve physical exercises tailored to fitness levels, have demonstrated efficacy in reducing mortality risks. The observed age-specific risk in younger men may be attributed to cumulative strain and insufficient recovery, as highlighted by Kenny et al. (2016). These workers may also lack adaptations to workplace demands, increasing vulnerability to adverse health outcomes.

Strengths of the present study comprise a representative large sample retrieved from governmental administrative registers, which hold a high degree of completeness and reliability (Gómez et al. 2016). The data also allowed wide sensitivity analysis which strengthened our findings. Finally, estimations of OPA were made in accordance with NACE, an international standard for economic activities making comparisons with future studies easier.

Nevertheless, we also underscore several limitations. First, information of occupational physical work demands is based on average index values from another country from prior research, which may lead to a certain degree of misclassification bias. The physical demand index used, based on the NACE classification, is standardized across Europe, enhancing its applicability in cross-national research (Eurostat 2008). However, this reliance introduces a potential bias, which we acknowledge as a limitation, alongside the unavailability of cause-specific mortality data. By contrast, NACE has been observed to match with specific economic activities, particularly those which are more sedentary (Andersen et al. 2021). Second, there is an obvious lack of further examination of other relevant confounders, particularly those related to health outcomes, that were not included in the CWLS dataset. However, the included confounders might account for a relevant part of such health-related habits effect (Raghupathi and Raghupathi 2020). Also, when possible, a more refined design setting including potential competing risks such as specific mortality causes would be desirable. Third, the use of cause-specific mortality, which was not available in the used dataset, may contribute to better understand the observed associations in the present study. Fourth, the fact that the association between OPA and all-cause mortality may be non-linear need further investigation in order to explain the potential reasons behind this phenomenon. Finally, to understand the broader applicability of our results, we reference studies from Nordic countries, such as Dalene et al. (2021), which highlight protective associations between OPA and mortality. These findings contrast with those observed in Spain, potentially due to differences in occupational health policies and working conditions.

Our results indicate that higher exposition to OPA is associated with increased risk for mortality in men aged 18 to 36 years, and partially in men aged 37 to 64 years. No significant association between OPA and higher risk of mortality was found in women. These findings warrant labour policies implementing preventive measures aiming at young men performing high OPA.

Data sharing

The data used in this study is available upon formal request to the National Institute of Social Security of Spain.

CRediT authorship contribution statement

Rubén López-Bueno: Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Joaquín Calatayud:** Writing – review & editing, Validation, Investigation, Funding acquisition. **Ai Koyanagi:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis. **Lee Smith:** Writing – review & editing, Validation, Methodology, Investigation. **José Casaña:** Writing – review & editing, Validation, Funding acquisition, Conceptualization. **Lars Louis Andersen:** Writing – review & editing, Supervision, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Dr.Rubén López-Bueno is supported by the European Union-NextGeneration EU.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssci.2024.106768.

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