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Associations of occupational and leisure-time physical activity with all-cause mortality: an individual participant data meta-analysis

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ABSTRACT

Objective Health effects of different physical activity domains (ie, during leisure time, work and transport) are generally considered positive. Using *Active Worker consortium* data, we assessed independent associations of occupational and leisure-time physical activity (OPA and LTPA) with all-cause mortality.

Design Two-stage individual participant data meta-analysis.

Data source Published and unpublished cohort study data.

Eligibility criteria Working participants aged 18–65 years.

Methods After data harmonisation, we assessed associations of OPA and LTPA with all-cause mortality. In stage 1, we analysed data from each study separately using Cox survival regression, and in stage 2, we pooled individual study findings with random-effects modelling.

Results In 22 studies with up to 590 497 participants from 11 countries, during a mean follow-up of 23.1 (SD: 6.8) years, 99 743 (16%) participants died. Adjusted for LTPA, body mass index, age, smoking and education level, summary (ie, stage 2) hazard ration (HRs) and 95% confidence interval (95% CI) for low, moderate and high OPA among men (n=2 96 134) were 1.01 (0.99 to 1.03), 1.05 (1.01 to 1.10) and 1.12 (1.03 to 1.23), respectively. For women (n=2 94 364), HRs (95% CI) were 0.98 (0.92 to 1.04), 0.96 (0.92 to 1.00) and 0.97 (0.86 to 1.10), respectively. In contrast, higher levels of LTPA were inversely associated with mortality for both genders. For example, for women HR for low, moderate and high compared with sedentary LTPA were 0.85 (0.81 to 0.89), 0.78 (0.74 to 0.81) and 0.75 (0.65 to 0.88), respectively. Effects were attenuated when adjusting for income (although data on income were available from only 9 and 6 studies, for men and women, respectively).

Conclusion Our findings indicate that OPA may not result in the same beneficial health effects as LTPA.

WHAT IS ALREADY KNOWN ON THE TOPIC

⇒ Physical activity is important for the prevention of many non-communicable diseases and health effects of different physical activity domains (ie, leisure time, work, household and transport) are generally considered to be positive.

⇒ Some studies indicate that high occupational physical activity is associated with adverse health outcomes, although the quality of the current evidence on this topic is moderate.

⇒ In the Active Worker study, we addressed some of the previous limitations in the literature with an individual participant data meta-analysis.

WHAT THIS STUDY ADDS

⇒ Even after adjusting for the other domain of physical activity, body mass index, age, smoking and education level, we found higher levels of leisure-time physical activity were associated with a lower risk of all-cause mortality, while higher levels of occupational physical activity were associated with a higher risk of mortality in men but not in women.

⇒ Our findings suggest that public health messages, stating that daily physical activity can be accrued as part of any domain, may not be adequate for adults obtaining most of their physical activity at work.

⇒ As the evidence base on this topic develops, more tailored advice for those with physically active occupations, including in work safety regulations and training of occupational health professionals, might be required.

INTRODUCTION

Physical activity is of importance for the prevention of many non-communicable diseases.[1] The health effects of different physical activity domains (ie, leisure time, work, household and transport)[2] are generally considered to be positive. This can be seen in physical activity guidelines that advocate daily engagement in aerobic physical activity of moderate-to-vigorous intensity as part of leisure, transportation, work and/or household activities.[3]

High levels of leisure-time physical activity (LTPA) are associated with lower risk of several non-communicable diseases.[4] Yet, emerging evidence indicates that high levels of occupational physical activity (OPA) are associated with adverse health outcomes. This phenomenon, referred to as the *physical activity paradox*,[5] has been addressed in recent systematic reviews on all-cause mortality,[6] cardiovascular disease[7 8] and cancer.[9] Evidence on the topic is conflicting, as in an umbrella review, high levels of OPA had favourable effects for multiple cancer outcomes, stroke, coronary heart disease and mental health, while unfavourable effects were reported for all-cause mortality in men, mental well-being, osteoarthritis and sleep quality.[10] Workers with lower socioeconomic status are often inactive during leisure time,[11] while accumulating most of their daily physical activity at work.[12] The possible existence of a *physical activity paradox,* therefore, implies that workers with a lower socioeconomic status may be exposed to ambiguous health consequences of OPA, while only benefiting to a limited extent from positive health consequences of LTPA (as engagement in such activities is often limited).

The quality of the current evidence is moderate at best,[10] with residual (unmeasured) confounding a considerable concern and socioeconomic status and smoking believed to be key confounding variables not or insufficiently addressed in many previous studies.[13] Other limitations include uneven geographical coverage of the evidence-base, mainly originating from high income Western-European countries, and biases associated with (self-reported) assessments of physical activity.[13] More high-quality evidence on the possible differential health effects of OPA versus LTPA is needed. An individual participant data (IPD) meta-analysis can reduce some previous limitations, since variable definitions and analytic strategies, including those for confounding, can be harmonised. The value of an IPD meta-analysis is further enhanced if additional unpublished data can be located, harmonised and analysed. Using IPD from the *Active Worker study*, we aimed to assess the association of OPA and LTPA with all-cause mortality.

METHODS

The *Active Worker* study protocol[14] was a-priori registered.[15] We conducted and reported our study using methods described by the Cochrane IPD Meta-analysis Methods Group[16] and the Preferred Reporting Items for Systematic Review and Meta-Analyses of Individual Participant Data (PRISMA-IPD) statement.[17]

Data collection

We identified cohort studies (with published and unpublished data on the topic) using literature searches in electronic databases and scoping searches through personal communication with experts, collaborators and colleagues. The literature search has been described in detail elsewhere.[14] Briefly, we conducted a systematic search for original prospective studies with data on at least OPA and LTPA, socioeconomic status indicators and all-cause and/or cardiovascular mortality among adult part-time or full-time workers (aged 18–65 years at baseline). Data from these cohort studies were eligible regardless of whether associations of physical activity with health outcomes had been previously published from these cohorts or not. Corresponding authors of eligible studies were invited to collaborate, asked to complete our data request form, providing more study details (regarding the design and available data) and sign a policy document. Hereafter, collaborators were asked to transfer their anonymised and encrypted cleaned datasets with complete cases only (ie, with data on at least physical activity and mortality variables) or to conduct the analyses remotely (in cases IPD could not be shared) using the harmonisation and analysis plan described below.

Data harmonisation

Data on OPA and LTPA and relevant additional variables (all measured at baseline) and all-cause mortality were retrieved from all participating studies (see the list of requested variables in online supplemental appendix 1). Data of all studies were harmonised according to definitions that were published in our study protocol,[14] which were further developed in an iterative process of Active Worker core group consensus meetings, seeking verification by data contributors. Our final definitions are described in more detail in a codebook (available on request). Definitions were also shared with collaborators that analysed their data remotely, so that they could follow similar harmonisation procedures. The most detailed level of data available (eg, continuous rather than categorical) was used for harmonisation. However, the level of detail after the harmonisation procedure depended on the study with the least detailed data. If a study consisted of multiple data collection waves, the wave with the longest follow-up period was chosen for harmonisation, to obtain more events.[18] Data were checked for consistency, which included identifying outliers and missing data. Queries were discussed and resolved with the study collaborator. No imputation on missing data was performed.

Physical activity

Physical activity (during work and leisure time—the latter sometimes also incorporating transportation) from categorical and continuous variables was harmonised into four categories along the physical activity continuum.[19] OPA categories roughly reflect: mainly sitting work (sedentary), work that mainly involves standing or walking, without lifting or carrying (low level), work that involves carrying light objects or walking stairs (moderate level) and physically demanding work involving frequent carrying or lifting heavy loads (high level). LTPA categories roughly reflect: almost no regular physical activity, spending most leisure-time sitting (sedentary), occasionally engaging in leisure-time activities such as slow walking or household activities (low level), engaging in activities such as brisk walking or dancing (moderate level) and regular engagement in activities such as jogging or cycling (high level). Although we requested device-based and self-reported data on physical activity, only the latter were provided to us and used for harmonisation. OPA assessment methods included self-reported OPA (eg, in terms of tasks conducted, physical activity intensity or self-perceived load). One study assessed relative aerobic workload taking objectively measured cardiorespiratory fitness into account[20] and one study used self-reported occupational classification codes, which were further categorised into OPA exposures[21] (online supplemental appendix 2).

If possible, we recoded existing categorical variables into the four aforementioned categories. Continuous data were categorised using tertiles or quartiles, with arbitrary cut-off points, since established cut-off points were not available or could not be feasibly used for all measurement tools. This was done on a study level, but not on a gender level. The above was determined in an iterative process in which we sought consensus among the Active Worker core group members, using input from the data contributors.

All-cause mortality

Outcome ascertainment was registry-based or hospital record-based (online supplemental appendix 3). All-cause mortality was harmonised as dichotomous variable depicting incidence (yes/no) and time-to-event (in days).

Additional variables

We differentiated low (preprimary/primary/lower secondary), moderate (upper secondary) and high (postsecondary) education, using the ISCED-97 classification. Income (in most studies: household income) was harmonised using predefined income categories or tertiles of continuous variables to categorise low/moderate/high income. Age and gender were harmonised as a continuous (in years) and dichotomous (man/woman) variable, respectively. We used body mass index (BMI; in kg/m^2) as a measure of adiposity, with other measures of adiposity (eg, waist circumference and skinfold thickness) being insufficiently available across studies. Data were restricted to BMI values >14 or <48[22] (<1% of the total sample). Smoking was dichotomised into current smokers and non-smokers (including those who smoked in the past).

Risk of bias assessment

Risk of bias (RoB) was assessed by two reviewers independently (PC/MH/BC) based on the original articles (see table 1 for references), using a scoring system[23] with criteria regarding: (1) participation, (2) attrition, (3) exposure assessment (scoring OPA and LTPA together, with the score depending on the weakest assessment method) and (4) outcomes. Conflicts were resolved during a consensus meeting (with authors PC/BC/MH/AJvdB/WvM).

Data analysis

We performed a two-stage meta-analysis where in the first stage, each study was analysed separately. In the second stage, the results per study were statistically pooled using Stata's *admetan* function. Due to high statistical heterogeneity in some of the models (I^2>70%), random-effect models were used.

We used Cox proportional hazards models, estimating HRs with 95% CI, to assess associations of OPA and LTPA with all-cause mortality. Per our study protocol,[14] we a-priori decided to consider man and woman separately, as gender differences in health outcomes of OPA have previously been reported.[6] Clustering was assessed using random intercepts. Correlations between variables were assessed on the data available to the core team. As all correlation coefficients were below our prespecified threshold of <0.70 (ie, <0.35; online supplemental appendix 4) multicollinearity was rendered unlikely. Models were not used if (1) <25 data points were available in any of the exposure variable categories (with ≥5 participants per covariate)[24] or (2) models had imprecise effect sizes (with a beta SE >3); for example, for a point estimate of HR=1.50, this translates to a (0.17 to 12.88) 95% CI.

Based on directed acyclic graphs (DAG) drawn using Daggity software (dagitty.net; online supplemental appendix 5), analyses were done with several levels of adjustment. First, we estimated unadjusted associations. Second, we adjusted for BMI, age, smoking and the other domain of physical activity. In a third set of models, we additionally adjusted for education level. The role of education was additionally considered by stratifying on education level. Data on income were not available from more than half of the cohorts, yet since it is unclear whether it is a confounder or mediator or both (online supplemental appendix 5), we chose to adjust for income in a sensitivity analysis. Analyses were performed on the subset of participants for which relevant data were available.

With these models, we deviated from our original meta-analysis protocol[14] for various reasons. Data on diet, medication use, coffee use and alcohol intake could not be harmonised due to the large heterogeneity in definitions and measurement methods across studies. The following variables could also not be used due to insufficient information (with data from <50% of studies) being available: ethnicity (available in 41% of studies), self-reported health (47%), psychosocial work demands (47%), history of non-communicable diseases (<35%), blood markers (eg, cholesterol, triglycerides, haemoglobin, insulin or thyroglobulin <35%), sleep quality (41%), healthcare utilisation (35%), parental socioeconomic status (24%), social support (29%) and neighbourhood conditions (12%). Finally, we did not adjust for blood pressure, glucose, diabetes or marital status as these variables were not deemed confounders according to our DAGs (online supplemental appendix 5).

In sensitivity analyses assessing the role of RoB on the association of OPA with all-cause mortality, we compared findings from studies with low versus moderate/high RoB. Only RoB considering participation, attrition and exposure measurements were assessed. The item on outcome measurements provided insufficient variation between studies (all, except one,[25] were appraised low RoB). Since the level of OPA changed during the last decades,[26] we assessed the role of baseline assessment moment on our findings, by comparing studies with baseline assessment before and after 1990. We assessed the role of individual study findings by subsequently leaving individual study findings out of the analyses. Funnel plots were generated to assess publication bias (using visual inspection). We also performed a sensitivity analysis, in which we excluded participants who died within the first 3 years of follow-up. Because the health effects of LTPA are well established,[4] abovementioned sensitivity analyses were only conducted on OPA models. All sensitivity analyses were performed on model 3.

Equity, diversity and inclusion statement

In this study, we compared people with various levels of LTPA and OPA, who are by definition from a variety of socioeconomic positions. We performed gender-specific analyses. Also, we intended to collect published and unpublished data, and thereby include authors, from across the globe. Despite our efforts, most included cohorts (and authors) were from Western European countries. Our author team, however, shows diversity in gender and age groups.

Patient and public involvement

An advisory group of public and occupational health professionals provided, in multiple meetings, their input on the design and results of this study to secure practical relevance. In particular, the advisory group helped developing

Table 1 Overview of included studies, their main characteristics and risk of bias

			Sample information							Risk of bias			
Reference	Study name	Country	n	Age at baseline	Females	Sample	Baseline	FU	Incidence	1	2	3	4
Clays *et al*[27]	BELFIT study	Belgium	2351	47.2 (4.4)	0%	Industry	1976	16.7 (3.5)	306 (13%)	Mod	Mod	Mod	Low
Saidj *et al*[64]	Health 2006 (H2006)*	Denmark	2663	45.9 (11.6)	54%	Gen pop	2006	10.5 (1.0)	53 (2%)	Mod	Mod	Low	Low
Sjøl *et al*[65]	MONICA Denmark	Denmark	6576	44.4 (11.1)	50%	Gen Pop	1976	9.5 (3.5)	395 (6%)	Mod	Mod	Mod	Low
Krause *et al*[20]	KIHD study	Finland	1883	51.8 (5.0)	0%	Gen Pop	1984	24.6 (7.9)	923 (49%)	Low	Low	Low	Low
Pulsford *et al*[31]	Whitehall II study	UK	3160	52.2 (4.2)	29%	Civil servants	1997	16.9 (2.0)	221 (7%)	Mod	Mod	High	Low
Eaton *et al*[25]	IIHDS study	Israel	9379	49.0 (6.6)	0%	Civil servants	1963	28.2 (11.3)	7878 (84%)	Low	Low	Mod	Mod
Autenrieth *et al*[66]	MONICA/KORA Augsburg	Germany	2628	42.6 (10.3)	38%	Gen Pop	1989	18.3 (2.7)	263 (10%)	Mod	Low	Mod	Low
Rosengren and Wilhelmsen[29]	Primary Prevention Study	Sweden	7317	51.6 (2.3)	0%	Gen Pop	1970	27.2 (10.5)	6366 (87%)	Mod	Low	Mod	Low
Richard *et al*[21]†	NHANES study	USA	8984	40.4 (13.1)	47%	Gen Pop	2005	5.9 (1.7)	180 (2%)	Low	Low	Mod	Low
Moe *et al*[67]	HUNT study	Norway	41 161	40.9 (11.5)	52%	Gen Pop	1995	20.1 (4.4)	2881 (7%)	Mod	Low	Mod	Low
Franzon *et al*[68]	ULSAM study	Sweden	2106	49.6 (0.6)	0%	Gen Pop	1970	30.1 (10.5)	1959 (93%)	Low	Low	Mod	Low
Huerta *et al*[69]	EPIC Spain study	Spain	13 752	46.8 (6.3)	66%	Gen Pop	1992	18.7 (2.2)	963 (7%)	High	Low	Low	Low
Johnsen *et al*[32]	WOLF study	Sweden	10 333	42.1 (10.7)	31%	60 companies	1992	23.5 (3.3)	310 (3%)	Low	Low	Mod	Low
Bahls *et al*[70]	SHIP-START1 study	Germany	1502	44.3 (9.5)	53%	Gen Pop	2002	8.2 (1.4)	30 (2%)	Mod	Mod	Low	Low
Bahls *et al*[70]	CARLA study	Germany	386	53.7 (4.3)	39%	Gen Pop	2002	11.7 (1.3)	19 (5%)	Mod	Mod	Low	Low
Wanner *et al*[71]	The Swiss MONICA study	Switzerland	8487	45.2 (10.0)	50%	Gen Pop	1984	24.5 (6.9)	1782 (21%)	Low	Low	Mod	Low
Wanner *et al*[71]	NRP 1A study	Switzerland	4602	39.4 (11.8)	37%	Gen Pop	1977	31.9 (9.9)	1703 (37%)	Mod	Low	Mod	Low
Petersen *et al*[72]	Danish National Health Interview Surveys*	Denmark	15 466	40.6 (13.3)	50%	Gen Pop	1987	11.9 (4.1)	763 (5%)	Low	Low	Mod	Low
Dalene *et al*[38]	Norwegian study*	Norway	404 239	41.3 (5.9)	52%	Gen Pop	1974	26.7 (6.6)	57 332 (14%)	Mod	Low	Low	Low
Holtermann *et al*[73]	Copenhagen City Heart Study*	Denmark	10 934	52.1 (10.2)	58%	Gen Pop	1976	18.4 (7.6)	8615 (79%)	Mod	Low	Mod	Low
Holtermann *et al*[37]	Copenhagen General Population Study*	Denmark	69 652	52.2 (10.7)	55%	Gen Pop	2003	10 (3.1)	2001 (3%)	Mod	Low	Mod	Low
Holtermann *et al*[30]	Copenhagen male study*	Denmark	5082	48.7 (5.3)	0%	Working pop	1970	28.9 (1.6)	4801 (92%)	Mod	Low	Mod	Low
	Total		632 643	43.1 (7.9)	49%			23.1 (6.8)	99 743 (16%)				

Data from 16 studies were combined in one dataset and data from an additional 6 studies (denoted with a * sign) were analysed remotely and combined in the second stage of the two-stage meta-analysis.
Age in years (mean (SD)).1=study participation; 2=study attrition; 3=predictive variable assessment; 4=outcome ascertainment. Risk of bias was assessed according to established criteria.[23] See online supplemental appendix 7 for more details on the risk of bias assessment.
*Studies that were analysed remotely.
†Although a reference is made to the paper by Richard and colleagues (which is the only paper we identified on the topic using NHANES data), different measurement waves were included for our meta-analysis. Measurements of the following waves were used in which all dependent and confounding variables were assessed: 2005–2006, 2007–2008, 2009–2010 and 2011–2012. For outcomes the 2015 follow-up measurements were used.
FU, follow-up period in years (mean (SD)); Gen pop, general population; Working pop, working population.

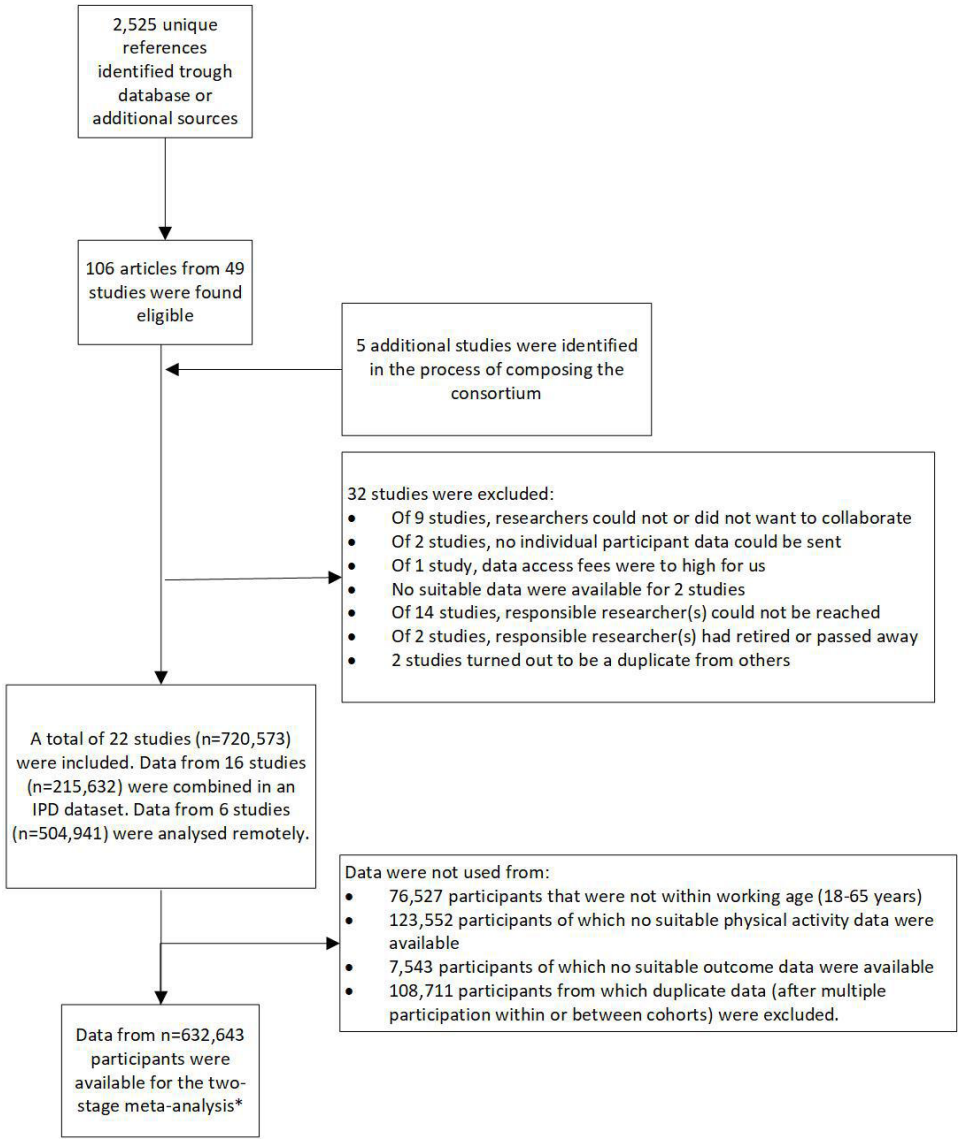

Figure 1 Flowchart showing the process of the composition of our individual participant data (IPD) two-stage meta-analysis. *Although the full dataset has data on 632 643 participants, note that the number of participants varies between the various models. Please refer to tables 3 and 4 for the number of participants per model.

our models, which were based on the DAGs (online supplemental appendix 5), using their expertise. Also they helped to interpret our findings and its implications for practice. Patients nor members of the general public were involved in this research project.

RESULTS

Our data collection procedure is shown in figure 1. Through contacting researchers from 49 eligible studies, we identified five additional studies. Data from 32 studies could not be used for various reasons (online supplemental appendix 6). Data from 22 studies were included in our study (table 1). Data from 16 studies (n=1 24 607) were combined in one dataset and data from an additional six studies (n=5 09 524) were analysed remotely and combined in the second stage of the two-stage meta-analysis. Excluding participants who were outside predefined age ranges had missing data for physical activity and/or all-cause mortality, or were duplicates, a final dataset of 632 643 participants was composed. Hereof, 590 497 (97%) and 597 002 (97%) were included in the final adjusted models for OPA and LTPA, respectively.

Table 2 and online supplemental appendix 3 describe the characteristics of the study sample and protocol, respectively. All but one study from Israel[25] were from Western Europe and the USA. Seventeen studies included men and women, five included men only.[25 27–30] Most studies used population-based samples; one study—an industry sample,[27] two studies—samples of civil servants[25 31] and two studies—sampled workers from selected occupational sectors.[30–32] Mean age at baseline was 43.1 (SD: 7.9) years, and 99 743 (16%) participants died during an average 23.1 years (SD: 6.8) follow-up period.

RoB regarding participation (ie, participation rates being low) and attrition was noted for 14 studies (table 1; online supplemental appendix 7). Six studies had a low risk of exposure assessment bias, they all used questionnaires with established validity and/or reliability (see online supplemental

Table 2 Descriptive characteristics of the individual participant dataset comprising data from n=22 cohort studies

		N	n	%	Mean	SD
Total		22	632 643			
Occupational physical activity*	Sedentary	22	217 504	34		
	Low	22	227 453	36		
	Medium	22	130 524	21		
	High	22	55 242	9		
Leisure-time physical activity*	Sedentary	22	123 311	19		
	Low	22	304 905	48		
	Medium	22	157 357	25		
	High	22	47 056	7		
Education level	Low	21†	129 736	21		
	Medium	21†	309 613	50		
	High	21†	181 528	29		
Gender	Men	22	320 523	51		
	Women	22	311 714	49		
Smoking	No	22	404 430	64		
	Yes	22	224 179	36		
Age (years)		22			43.1	7.9
BMI (kg/m^2)		22			25.2	3.8

*Physical activity levels (during work and at leisure time) reflect the physical activity continuum, ie, sedentary, low, moderate and high. For leisure-time physical activity, these categories roughly indicate: spending most leisure time sitting (sedentary), occasionally engaging in light intensity physical activities during leisure time such as slow walking or household activities (low), engaging in physical activities of moderate intensity such as intense household activities or brisk walking (moderate), regular engagement in high intensity physical activities such as jogging or cycling, thereby meeting physical activity guidelines (high). For occupational physical activity, categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), highly physically demanding works involving frequent carrying or lifting heavy loads (high).
†No data on this metric provided by Primary Prevention Study.[29]
BMI, body mass index; N, number of studies from which this variable is available; n, number of participants.

appendix 2). Except for one study,[25] all studies used register data to ascertain mortality (low RoB).

Association of occupational and LTPA with all-cause mortality

The associations of OPA and LTPA with all-cause mortality are shown for men and women in tables 3 and 4.

Occupational physical activity

For men, higher levels of OPA were associated with higher risks of all-cause mortality in all models. Adjustment for confounders, especially adding education in model 3, attenuated risks to adjusted HRs of 1.01 (95% CI 0.99 to 1.03), 1.05 (95% CI 1.01 to 1.10) and 1.12 (95% CI 1.03 to 1.23) for low, moderate and high OPA, respectively, when compared with sedentary. Associations using low level OPA as reference category showed a similar trend, although with a slightly stronger attenuation (online supplemental appendix 8). These analyses were based on a slightly different set of studies as not all studies had data on all four physical activity categories. Forest plots are shown in online supplemental appendix 9. In sensitivity analyses, additionally adjusting for income, estimates were further attenuated yielding null findings (online supplemental appendix 10). When stratifying by educational level, estimates in the moderate and high education strata were similar to estimates from model 3, but no association was observed in the low education stratum (online supplemental appendix 11).

Funnel plots (online supplemental appendix 12) showed some degree of publication bias. Moreover, we found stronger associations among studies with low compared with moderate/high RoB regarding attrition, and the opposite for RoB regarding participation. Studies with different levels of RoB regarding exposure assessment were comparable (online supplemental appendix 13). Associations did vary somewhat when testing for the impact of individual studies (online supplemental appendix 14). We showed comparable HRs for studies with baseline assessment before/after 1990 (online supplemental appendix 15), and when only analysing participants that survived the first 3 years after baseline (online supplemental appendix 16).

For women, unadjusted estimates suggested higher levels of OPA were associated with higher risks of all-cause mortality. Estimates were substantially attenuated in models 2–3. Model 3 yielded HRs of 0.98 (95% CI 0.92 to 1.04), 0.96 (95% CI 0.92 to 1.00) and 0.97 (95% CI 0.86 to 1.10) for low, moderate and high OPA, respectively. Associations were not substantially impacted by individual studies. Associations remained relatively unchanged when stratifying for educational level, when additionally adjusting for income, for studies with baseline assessment before/after 1990, when assessing the role of RoB and when only analysing participants who survived the first 3 years after baseline.

Leisure-time physical activity

Unadjusted and adjusted analyses consistently showed lower risks of all-cause mortality with higher LTPA levels across all models. For men, model 3 indicated an inverse association for low (HR: 0.87, 95% CI 0.83 to 0.92), moderate (HR: 0.79, 95% CI 0.73 to 0.86) and high (HR: 0.79, 95% CI 0.72 to 0.86), compared with sedentary LTPA. For women, comparable associations were found for low (HR: 0.85, 95% CI 0.81 to 0.89), moderate (HR: 0.78, 95% CI 0.74 to 0.81) and high (HR: 0.75, 95% CI 0.65 to 0.88), compared with sedentary LTPA. Associations were not substantially impacted by stratification on education level (online supplemental appendix 11) nor by individual studies (online supplemental appendix 14).

DISCUSSION

In line with harmonised analyses on large datasets, using self-reported[33] or device-based physical activity,[34] we consistently found higher levels of LTPA to be associated with lower risks of all-cause mortality. OPA did not show such associations, as higher levels of OPA were associated with higher all-cause mortality in men and with null effects in women. Results for both OPA and LTPA remained mostly unchanged in sensitivity analyses. Our findings indicate that LTPA is associated with lower risk of mortality while OPA is not and, to the contrary, is associated with higher mortality risk among men in some of our models. These findings could be highly relevant for large parts of the working population, in particular, those who accrue most of their daily physical activity at work.[12] OPA is still prevalent in our working societies, in both affluent Western and low and middle-income countries. For example, in the USA, in 2010, approximately 20% of the jobs consisted of a combination of tasks with a metabolic equivalent, indicating at least moderate intensity-level physical activity.[26] However, in several low to middle-income countries, OPA makes up most of daily physical activity.[35] For example, a study across 22 African countries revealed that only 5% of physical activity was accrued during leisure time,[36] despite the vast

Table 3 Association of occupational (left panels) and leisure-time physical activity (right panels) with all-cause mortality in men

	Occupational physical activity			Leisure-time physical activity		
Model 1*	n	N	HR (95% CI)	n	N	HR (95% CI)
Sedentary	122 419	20	1.00 (reference)	64 306	19	1.00 (reference)
Low	84 029	18	1.12 (1.07 to 1.17)	131 670	19	0.81 (0.77 to 0.85)
Moderate	65 449	20	1.21 (1.13 to 1.30)	86 317	19	0.66 (0.55 to 0.79)
High	38 514	18	1.36 (1.22 to 1.51)	27 938	17	0.53 (0.36 to 0.79)
Model 2†						
Sedentary	119 487	19	1.00 (reference)	63 534	19	1.00 (reference)
Low	83 441	18	1.08 (1.05 to 1.10)	128 470	19	0.87 (0.83 to 0.91)
Moderate	64 841	19	1.17 (1.15 to 1.20)	85 677	19	0.77 (0.71 to 0.84)
High	38 317	18	1.23 (1.15 to 1.31)	27 546	17	0.77 (0.70 to 0.85)
Model 3‡						
Sedentary	116 316	18	1.00 (reference)	61 375	18	1.00 (reference)
Low	79 957	17	1.01 (0.99 to 1.03)	126 414	18	0.87 (0.83 to 0.92)
Moderate	62 564	18	1.05 (1.01 to 1.10)	83 892	18	0.79 (0.73 to 0.86)
High	37 297	17	1.12 (1.03 to 1.23)	26 538	16	0.79 (0.72 to 0.86)

Physical activity levels (during work and at leisure time) reflect the physical activity continuum, ie, sedentary, low, moderate and high. For occupational physical activity, categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high). For leisure-time physical activity, these categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure time activities such as slow walking or household activities (low), engaging in activities such as intense household activities or brisk walking (moderate), regular engagement in activities such as jogging or cycling (high).
Note that the number of studies (N) differs across comparisons, as not all occupational and leisure-time physical activity categories were available from all studies (see online supplemental appendix 2 for an overview).
*Model 1: Unadjusted model.
†Model 2: Adjusted for the other domain of physical activity, body mass index, age and smoking.
‡Model 3: Additionally adjusted for education level.
N, number of studies; n, number of participants.

Table 4 Association of occupational (left panels) and leisure-time physical activity (right panels) with all-cause mortality in women

	Occupational physical activity			Leisure-time physical activity		
Model 1*	n	N	HR (95% CI)	n	N	HR (95% CI)
Sedentary	94 114	14	1.00 (reference)	58 946	13	1.00 (reference)
Low	137 007	13	1.11 (1.03 to 1.20)	169 993	13	0.73 (0.61–0.88)
Moderate	62 129	12	1.06 (0.98 to 1.14)	59 877	13	0.56 (0.39–0.81)
High	6744	11	1.35 (1.07 to 1.70)	16 910	11	0.49 (0.31–0.78)
Model 2†						
Sedentary	93 254	14	1.00 (reference)	58 110	13	1.00 (reference)
Low	136 244	13	1.01 (0.94 to 1.08)	168 007	13	0.83 (0.78–0.88)
Moderate	61 536	12	1.02 (0.98 to 1.06)	59 265	13	0.74 (0.71–0.77)
High	6623	11	1.06 (0.98 to 1.14)	16 624	11	0.74 (0.62–0.88)
Model 3‡						
Sedentary	92 215	14	1.00 (reference)	57 812	13	1.00 (reference)
Low	135 154	13	0.98 (0.92 to 1.04)	167 175	13	0.85 (0.81–0.89)
Moderate	60 482	12	0.96 (0.92 to 1.00)	58 332	13	0.78 (0.74–0.81)
High	6512	11	0.97 (0.86 to 1.10)	15 464	11	0.75 (0.65–0.88)

Physical activity levels (during work and at leisure time) reflect the physical activity continuum, ie, sedentary, low, moderate and high. For occupational physical activity, categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high). For leisure-time physical activity, these categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure time activities such as slow walking or household activities (low), engaging in activities such as intense household activities or brisk walking (moderate), regular engagement in activities such as jogging or cycling (high).
Note that the number of studies (N) differs across comparisons, as not all occupational and leisure-time physical activity categories were available from all studies (see online supplemental appendix 2 for an overview).
*Model 1: Unadjusted model.
†Model 2: Adjusted for the other domain of physical activity, body mass index, age and smoking.
‡Model 3: Additionally adjusted for education level.
N, number of studies; n, number of participants.

majority of individuals in these countries (ie, 84% among men) meeting physical activity guidelines.

Interpretation of findings

Our findings on differential health effects of LTPA and OPA are in line with an earlier systematic review[6] and with some individual studies published after that review (including studies incorporated in this meta-analysis).[37] Findings are, however, in contrast with a Norwegian study, also incorporated in our meta-analyses, that showed beneficial health effects of OPA.[38] Other studies, such as those based on the NIH-AARP Diet and Health Study[39] and the UK Biobank,[40] which were not part of this meta-analysis, showed null findings in the association of OPA and mortality.

Both methodological[13] and physiological[41] explanations have been raised for these conflicting findings. Methodological limitations of the evidence include study selection bias (with most evidence originating from Western European countries), misclassification of physical activity in original assessment and during analysis, insufficient control of confounding,[13] healthy worker selection bias and heterogeneity of methods. While in this IPD meta-analysis, we addressed some of these issues (most notably dealing with heterogeneity in methods), for others, our results still do not provide an unequivocal resolution. Despite our efforts to include studies from across the globe and incorporating unpublished data to address study selection bias, our database still originates mainly from affluent Western countries. Thirty-two eligible studies, including several from low-to-middle income countries (eg, Iran[42] and China)[43] or from non-Western countries (eg, Japan),[44] could unfortunately not be incorporated (online supplemental appendix 6), and some degree of publication bias was seen in our funnel plots. As associations of physical activity and health may differ between countries,[45] with OPA making up most of daily physical activity in low-to-middle income countries,[35] our results may not be generalisable to those countries. Providing evidence from such countries should be a research priority. Moreover, this research field has shown to be rapidly emerging and since the start of this study, several studies that could be relevant to include in a future IPD meta-analysis have been published.[46 47]

All studies included in our meta-analysis relied on self-reports of physical activity, possibly resulting in exposure misclassification bias.[48] Emerging evidence from studies with accelerometer assessed (total) physical activity indicate stronger associations with health than earlier studies that assessed (leisure time) physical activity with self-reports.[34] The harmonisation procedure, in which we categorised physical activity measures (even those on a continuous scale) in four crude categories, has also introduced misclassification bias. Nevertheless, we were able to provide some insights into the association of OPA and LTPA with all-cause mortality across four levels of physical activity. This is an advantage of our study over earlier systematic reviews in which only the health effects of low and high level OPA were compared.[6] Nonetheless, in harmonising OPA, information was inevitably lost due to categorising different modalities (eg, tasks, physical activity intensity or self-perceived load) and using tertiles or quartiles to categorise continuous data. Our harmonised categories did not allow for inferring intensity, frequency and duration of physical activity. Moreover, the arbitrary cut-off points that stem from our methodology of using tertiles or quartiles for continuous data may have resulted in unbalanced categories. Future studies should ideally combine device-measured physical activity data with self-reports, not accruing it in crude categories, to obtain detailed and accurate assessments of OPA and LTPA (eg, regarding life-time exposures and the duration, frequency and intensity of physical activity). Measurements on, for example, muscle activity, heart rate or postures of specific body regions can provide additional insights into modalities of OPA, of which the health effects should be explored in future research.

We asked for an array of (sub-)constructs (online supplemental appendix 1) from contributing researchers to enable adjustment for as much relevant confounding as possible. Unfortunately, due to the limited data provided and the harmonising process, only few variables were available from all studies (ie, gender, age, BMI, smoking and education level). Additional variables were available from few studies and used in sensitivity analyses. While IPD meta-analyses have the potential to deal with limitations in the literature, for example, by unlocking evidence on previously unmeasured confounding variables, unfortunately our study does not add evidence beyond what is already available in the literature on this aspect. This asks for more carefully designed cohort studies with standardised measurements, or even other research designs, in the future. Nonetheless, in our study, associations between OPA and mortality remained mostly unchanged across these and other sensitivity analyses but were substantially attenuated when additionally adjusting for income (online supplemental appendix 11). This might indicate residual socioeconomic confounding. However, income may also be on the pathway from OPA to all-cause mortality (online supplemental appendix 5). There is insufficient evidence to determine which of these two pathways is most likely, which has been further complicated by the fact that the variable income in our dataset consists of a combination of household and individual income. Nonetheless, income cannot only be viewed as confounder that one needs to adjust for but also a mediator that one should not adjust for. Other potential confounders such as alcohol use, psychosocial work demands and other work characteristics could unfortunately not be incorporated in the analyses, while available variables were crudely categorised during the harmonisation procedure. Additional adjustment for confounding has not shown to substantially affect the association of OPA and health in some studies.[37] However, it has resulted in substantially different[39 40] (and even opposite[38] association in others). As we cannot rule out residual confounding, future studies on the topic should strive for better ways to consider confounding. Evidence from experimental studies and alternative research designs (eg, analyses on natural experiments)[49] may help to address this issue, providing better insights in the causality of the association.

When stratifying by education level, associations between LTPA and all-cause mortality remained consistent across strata, but associations for OPA changed in both directions, for example, among men, estimates for the moderate and high education strata were similar to estimates in non-stratified analyses, but no association was observed in the low education strata. Among women in the high education stratum, high OPA levels were associated with up to 18% higher mortality risks in contrast to zero risks in non-stratified analyses. These effect moderation patterns may be due to the reference category of 'sitting work' being rather physically demanding among people with low education level (performing demanding upper extremity work while sitting). In our analyses where low OPA was used as reference category, we see a slight attenuation of the associations, potentially since the 'low' category 'mainly standing with some walking' might be associated with a higher risk of adverse health outcomes in itself.[50] On the other hand, evidence from LTPA has shown that, compared with none, already low-intensity physical activity can

bring benefits to health.[4] For OPA, such associations should be explored further in future research.

Despite methodological issues, it is possible that the different nature and characteristics of OPA and LTPA explain differential health effects.[41] High levels of OPA commonly involve lifting, manual handling, repetitive work and prolonged static postures performed over long time periods (ie, multiple hours/day, multiple days/week). LTPA is voluntary and typically carried out in short bouts with moderate or high intensity, accompanied by long recovery periods. Because of these differences, OPA and LTPA could differ in their acute and chronic physiological responses. For example, in a sample of cleaners who were highly active at work in terms of the number of steps taken at work, OPA did not reach intensity levels that may be required to achieve substantial cardiorespiratory fitness improvements.[51] In a prospective study, LTPA was associated with a reduced age-related decline in cardiorespiratory fitness, while OPA was not.[52] Also, whereas high levels of OPA have been suggested to cause chronic exhaustion and elevated resting blood pressure[53] and heart rate,[54] which are established risk factors for cardiovascular diseases,[55 56] aerobic exercise (eg, brisk walking, jogging, cycling) and strength training have shown to improve these cardiometabolic risk factors.[3] Another explanation for the differential health effects of OPA and LTPA is that physical activities at work are known to be associated with higher levels and longer duration of exhaustion[57] and additional mental (and thus physical) stress[58] than similar but usually much shorter self-determined activities during leisure time. This may be reinforced by the phenomenon of status inconsistency, which is the mismatch of education level and work status. For example, for those with a moderate or high education level and a physically demanding job, the mismatch may cause them to experience high levels of occupational stress and lack of social support impacting their health.[59 60] Future studies should further build the evidence base on these mechanisms to better understand potential differential health effects of OPA and LTPA. Such studies should also explore why we found adverse health effects for men and null effects for women regarding the association of OPA and all-cause mortality. One explanation for these gender differences is that physically demanding jobs are typically men dominated,[61] while we combined men and women with different relative levels of OPA into the same crude categories. Other potential explanations are differential reporting bias across genders, or that women who engage in high levels of OPA are more healthy and/or fit than men doing the same OPA. As women are more likely to work in part-time jobs than men,[62] shorter working hours and longer recovery periods could also explain gender differences. However, no data on working hours were available in our study.

Implications for practice

Current physical activity guidelines state that adults should engage in ≥150–300 min of moderate intensity, or ≥75–150 of vigorous intensity, aerobic physical activity per week.[3] As evidence has been insufficient to determine whether specific health benefits vary by physical activity domain, guidelines state that this physical activity can be accrued as part of leisure, household, transportation and work activities.[3] As the evidence on the topic develops with emerging studies such as ours, this message may not be adequate for men in physically demanding jobs, as many types of OPA (eg, standing, walking, carrying and lifting or other manual handling activities) may not be health enhancing. High levels of OPA might discourage these workers from engaging in sufficient amounts of LTPA due to fatigue and physical exertion at work,[63] or because they believe they get sufficient physical activity through work.[40] As the evidence-base on this topic develops, more tailored and gender-specific advice for those with physically active occupations, including in work safety regulations and training of occupational health professionals, might be required.

Methodological strengths and limitations

Our study has several methodological strengths, including the preregistered protocol (to address reporting bias), combining and harmonising a range of variables, uncovering unpublished data to address publication bias and assessing various sources of bias (eg, the role of single studies, RoB, and pre-existing conditions).

The use of IPD allows harmonisation of variables and statistical analysis and increases statistical power. However, the harmonisation procedure also reduced the level of detail of variables for some constructs. The costs of increased misclassification bias due to harmonisation may outweigh the benefits of IPD analyses as long as there are few studies with high-quality fine-grained data. This loss of detailed information is an inherent implication when harmonising data from various studies and can only be addressed if future studies make use of generic variables and construct operationalisations. Additionally, not all variables were available in all studies, with only nine and six studies (men and women, respectively) providing data on income that we used in our sensitivity analysis (online supplemental appendix 10). The main models reported in tables 3 and 4, however, are for a fair share based on similar samples with only 3% missing data in model 3 compared with model 1.

The associations of OPA with all-cause mortality had larger HRs for studies with low compared with moderate/high RoB regarding attrition, but reversely for participation and exposure variable measurement. A limitation of the RoB assessment for exposure measurement is that we assessed RoB based on the exposure (either LTPA or OPA) with the highest RoB. RoB for studies where the measurement methods for the two domains of physical activity differed, for example, in the Whitehall study where LTPA was by measuring time in certain intensity activities while OPA was assessed in two crude categories,[31] which may thus not be accurate.

In contrast to our a-priori registered[15] and published protocol,[14] we did not conduct a one-stage meta-analysis, since a single analysis on the full IPD dataset did not converge due to the complexity of the model. This was mainly due to the multilevel structure of the data, with clustering at the level of studies, and sometimes clustering within studies (ie, one study used clustered sampling).[21] Moreover, a two-stage approach allowed us to incorporate aggregated data from studies of which collaborators were unable to send us IPD (but used the same analysis plan). One study consisted of multiple waves of data, for which the wave with the longest follow-up period was chosen, to obtain more endpoints.[18] This procedure could, however, lead to misclassification, and future studies should strive to incorporate repeated measurements to get a better insight into the health effects of OPA and LTPA.

CONCLUSION

This IPD meta-analysis showed higher risks of all-cause mortality to be associated with higher levels of LTPA, but not

for OPA. Higher levels of occupational were associated with higher mortality risks in men in some models and showed no such association among women. These findings indicate that OPA may not have the health-enhancing effects of LTPA in men but not women. These findings could be relevant to large parts of the working population, in particular, those who accrue most of their daily physical activity at work.

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Author note The authors confirm that that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained.

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REFERENCES

1 Lee I-M, Shiroma EJ, Lobelo F, *et al*. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 2012;380:219–29.
2 Sallis JF, Owen N, Fisher EB. Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K, eds. *Health behavior and health education: theory, research, and practice*. 4th edn. San Francisco, CA: Jossey-Bass, 2008: 465–82.
3 World Health Organization. *WHO guidelines on physical activity and sedentary behaviour*. Geneva: World Health Organization, 2020.
4 Bull FC, Al-Ansari SS, Biddle S, *et al*. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med* 2020;54:1451–62.
5 Holtermann A, Krause N, van der Beek AJ, *et al*. The physical activity paradox: six reasons why occupational physical activity (OPA) does not confer the cardiovascular health benefits that leisure time physical activity does. *Br J Sports Med* 2018;52:149–50.
6 Coenen P, Huysmans MA, Holtermann A, *et al*. Do highly physically active workers die early? A systematic review with meta-analysis of data from 193 696 participants. *Br J Sports Med* 2018;52:1320–6.
7 Cillekens B, Huysmans MA, Holtermann A, *et al*. Physical activity at work may not be health enhancing. A systematic review with meta-analysis on the association between occupational physical activity and cardiovascular disease mortality covering 23 studies with 655 892 participants. *Scand J Work Environ Health* 2022;48:86–98.
8 Li J, Loerbroks A, Angerer P. Physical activity and risk of cardiovascular disease: what does the new epidemiological evidence show? *Curr Opin Cardiol* 2013;28:575–83.
9 Rana B, Hu L, Harper A, *et al*. Occupational Physical Activity and Lung Cancer Risk: A Systematic Review and Meta-Analysis. *Sports Med* 2020;50:1637–51.
10 Cillekens B, Lang M, van Mechelen W, *et al*. How does occupational physical activity influence health? An umbrella review of 23 health outcomes across 158 observational studies. *Br J Sports Med* 2020;54:1474–81.
11 van Dommelen P, Coffeng JK, van der Ploeg HP, *et al*. Objectively Measured Total and Occupational Sedentary Time in Three Work Settings. *PLoS One* 2016;11:e0149951.
12 Beenackers MA, Kamphuis CBM, Giskes K, *et al*. Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults: a systematic review. *Int J Behav Nutr Phys Act* 2012;9:9.
13 Shephard RJ. Is there a 'recent occupational paradox' where highly active physically active workers die early? Or are there failures in some study methods? *Br J Sports Med* 2019;53:1557–9.
14 Coenen P, Huysmans MA, Holtermann A, *et al*. Can socioeconomic health differences be explained by physical activity at work and during leisure time? Rationale and protocol of the active worker individual participant meta-analysis. *BMJ Open* 2018;8:e023379.
15 Coenen P, Huysmans MA, Holtermann A, *et al*. Can socio-economic health differences be explained by physical activity? The active worker consortium; an individual participant meta-analysis. *Prospero* 2018;CRD42018085228.
16 Cochrane Individual Participant Data (IPD) Meta-analysis Methods Group. Individual participant data meta-analysis. A handbook for healthcare research.2022. Available: http://ipdmamg.cochrane.org/2022
17 Stewart LA, Clarke M, Rovers M, *et al*. Preferred Reporting Items for Systematic Review and Meta-Analyses of individual participant data: the PRISMA-IPD Statement. *JAMA* 2015;313:1657–65.
18 Andersen LB. Relative risk of mortality in the physically inactive is underestimated because of real changes in exposure level during follow-up. *Am J Epidemiol* 2004;160:189–95.
19 Sedentary Behaviour Research Networ. Letter to the Editor: standardized use of the terms 'sedentary' and 'sedentary behaviours.' *Appl Physiol Nutr Metab* 2012;37:540–2.
20 Krause N, Arah OA, Kauhanen J. Physical activity and 22-year all-cause and coronary heart disease mortality. *Am J Ind Med* 2017;60:976–90.
21 Richard A, Martin B, Wanner M, *et al*. Effects of leisure-time and occupational physical activity on total mortality risk in NHANES III according to sex, ethnicity, central obesity, and age. *J Phys Act Health* 2015;12:184–92.
22 Miller Y. Recommendations for the truncation of body mass index in population data: NSW centre for physical activity and health. Report no. CPAH03-0005. 2003.
23 Hayden JA, van der Windt DA, Cartwright JL, *et al*. Assessing bias in studies of prognostic factors. *Ann Intern Med* 2013;158:280–6.
24 Peduzzi P, Concato J, Kemper E, *et al*. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol* 1996;49:1373–9.
25 Eaton CB, Medalie JH, Flocke SA, *et al*. Self-reported physical activity predicts long-term coronary heart disease and all-cause mortalities. Twenty-one-year follow-up of the Israeli Ischemic Heart Disease Study. *Arch Fam Med* 1995;4:323–9.
26 Church TS, Thomas DM, Tudor-Locke C, *et al*. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One* 2011;6:e19657.
27 Clays E, Lidegaard M, De Bacquer D, *et al*. The combined relationship of occupational and leisure-time physical activity with all-cause mortality among men, accounting for physical fitness. *Am J Epidemiol* 2014;179:559–66.
28 Krause N, Brand RJ, Arah OA, *et al*. Occupational physical activity and 20-year incidence of acute myocardial infarction: results from the Kuopio Ischemic Heart Disease Risk Factor Study. *Scand J Work Environ Health* 2015;41:124–39.
29 Rosengren A, Wilhelmsen L. Physical activity protects against coronary death and deaths from all causes in middle-aged men. Evidence from a 20-year follow-up of the primary prevention study in Göteborg. *Ann Epidemiol* 1997;7:69–75.
30 Holtermann A, Mortensen OS, Burr H, *et al*. The interplay between physical activity at work and during leisure time--risk of ischemic heart disease and all-cause mortality in middle-aged Caucasian men. *Scand J Work Environ Health* 2009;35:466–74.
31 Pulsford RM, Stamatakis E, Britton AR, *et al*. Associations of sitting behaviours with all-cause mortality over a 16-year follow-up: the Whitehall II study. *Int J Epidemiol* 2015;44:1909–16.
32 Johnsen AM, Alfredsson L, Knutsson A, *et al*. Association between occupational physical activity and myocardial infarction: a prospective cohort study. *BMJ Open* 2016;6:e012692.
33 Ekelund U, Steene-Johannessen J, Brown WJ, *et al*. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. *Lancet* 2016;388:1302–10.
34 Ekelund U, Tarp J, Steene-Johannessen J, *et al*. Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ* 2019;366:l4570.
35 Atkinson K, Lowe S, Moore S. Human development, occupational structure and physical inactivity among 47 low and middle income countries. *Prev Med Rep* 2016;3:40–5.
36 Guthold R, Louazani SA, Riley LM, *et al*. Physical activity in 22 African countries: results from the World Health Organization STEPwise approach to chronic disease risk factor surveillance. *Am J Prev Med* 2011;41:52–60.
37 Holtermann A, Schnohr P, Nordestgaard BG, *et al*. The physical activity paradox in cardiovascular disease and all-cause mortality: the contemporary Copenhagen General Population Study with 104 046 adults. *Eur Heart J* 2021;42:1499–511.
38 Dalene KE, Tarp J, Selmer RM, *et al*. Occupational physical activity and longevity in working men and women in Norway: a prospective cohort study. *Lancet Public Health* 2021;6:e386–95.
39 Martinez Gomez D, Coenen P, Celis-Morales C, *et al*. Lifetime high occupational physical activity and total and cause-specific mortality among 320 000 adults in the NIH-AARP study: a cohort study. *Occup Environ Med* 2022;79:147–54.
40 Pearce M, Strain T, Wijndaele K, *et al*. Is occupational physical activity associated with mortality in UK Biobank? *Int J Behav Nutr Phys Act* 2021;18:102.

41 Holtermann A, Coenen P, Krause N. The paradoxical health effects of occupational versus leisure-time physical activity. In: Theorell T, ed. *Handbook of socioeconomic determinants of occupational health - from macro-level to micro-level evidence*. Springer, 2020: 1–27.
42 Etemadi A, Abnet CC, Kamangar F, *et al*. Impact of body size and physical activity during adolescence and adult life on overall and cause-specific mortality in a large cohort study from Iran. *Eur J Epidemiol* 2014;29:95–109.
43 Hu G-C, Chien K-L, Hsieh S-F, *et al*. Occupational versus leisure-time physical activity in reducing cardiovascular risks and mortality among ethnic Chinese adults in Taiwan. *Asia Pac J Public Health* 2014;26:604–13.
44 Kikuchi H, Inoue S, Odagiri Y, *et al*. Occupational sitting time and risk of all-cause mortality among Japanese workers. *Scand J Work Environ Health* 2015;41:519–28.
45 Lear SA, Hu W, Rangarajan S, *et al*. The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. *Lancet* 2017;390:2643–54.
46 Bonekamp NE, Visseren FLJ, Ruigrok Y, *et al*. Leisure-time and occupational physical activity and health outcomes in cardiovascular disease. *Heart* 2023;109:686–94.
47 Luo M, Gupta N, Holtermann A, *et al*. Revisiting the "physical activity paradox" in a Chinese context: Occupational physical activity and mortality in 142,302 urban working adults from the China Kadoorie Biobank study. *Lancet Reg Health West Pac* 2022;23:100457.
48 Prince SA, Adamo KB, Hamel ME, *et al*. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act* 2008;5:56.
49 Schlevis RM, Oude Hengel KM, Burdorf A, *et al*. Evaluation of occupational health interventions using a randomized controlled trial: challenges and alternative research designs. *Scand J Work Environ Health* 2015;41:491–503.
50 Hall C, Ritz B, Heck JE, *et al*. Occupational physical activity and 7-year incidence of stroke and transient ischemic attack in women. *Scand J Work Environ Health* 2019;45:267–79.
51 Korshøj M, Krustrup P, Jespersen T, *et al*. A 24-h assessment of physical activity and cardio-respiratory fitness among female hospital cleaners: a pilot study. *Ergonomics* 2013;56:935–43.
52 Bahls M, Ittermann T, Ewert R, *et al*. Physical activity and cardiorespiratory fitness—A ten-year follow-up. *Scand Med Sci Sports* 2021;31:742–51.
53 Clays E, De Bacquer D, Van Herck K, *et al*. Occupational and leisure time physical activity in contrasting relation to ambulatory blood pressure. *BMC Public Health* 2012;12:1002.
54 Jakobsen MD, Sundstrup E, Persson R, *et al*. Is Borg's perceived exertion scale a useful indicator of muscular and cardiovascular load in blue-collar workers with lifting tasks? A cross-sectional workplace study. *Eur J Appl Physiol* 2014;114:425–34.
55 Palatini P. Elevated heart rate: a 'new' cardiovascular risk factor? *Prog Cardiovasc Dis* 2009;52:1–5.
56 Xie X, Atkins E, Lv J, *et al*. Effects of intensive blood pressure lowering on cardiovascular and renal outcomes: updated systematic review and meta-analysis. *Lancet* 2016;387:435–43.
57 Wolff MB, O'Connor PJ, Wilson MG, *et al*. Associations Between Occupational and Leisure-Time Physical Activity With Employee Stress, Burnout and Well-Being Among Healthcare Industry Workers. *Am J Health Promot* 2021;35:957–65.
58 de-Pedro-Jiménez D, Meneses-Monroy A, de Diego-Cordero R, *et al*. Occupational and Leisure-Time Physical Activity Related to Job Stress and Job Satisfaction: Correspondence Analysis on a Population-Based Study. *Int J Environ Res Public Health* 2021;18:11220.
59 Smith P, Frank J. When aspirations and achievements don't meet. A longitudinal examination of the differential effect of education and occupational attainment on declines in self-rated health among Canadian labour force participants. *Int J Epidemiol* 2005;34:827–34.
60 Honjo K, Iso H, Inoue M, *et al*. Socioeconomic status inconsistency and risk of stroke among Japanese middle-aged women. *Stroke* 2014;45:2592–8.
61 Kjellsson S. Do working conditions contribute differently to gender gaps in self-rated health within different occupational classes? Evidence from the Swedish Level of Living Survey. *PLoS One* 2021;16:e0253119.
62 Beham B, Drobnič S, Präg P, *et al*. Part-time work and gender inequality in Europe: a comparative analysis of satisfaction with work–life balance. *Eur Soc* 2019;21:378–402.
63 Rasmussen CL, Palarea-Albaladejo J, Bauman A, *et al*. Does Physically Demanding Work Hinder a Physically Active Lifestyle in Low Socioeconomic Workers? A Compositional Data Analysis Based on Accelerometer Data. *Int J Environ Res Public Health* 2018;15:1306.
64 Saidj M, Jørgensen T, Jacobsen RK, *et al*. Separate and joint associations of occupational and leisure-time sitting with cardio-metabolic risk factors in working adults: a cross-sectional study. *PLoS One* 2013;8:e70213.
65 Sjøl A, Thomsen KK, Schroll M, *et al*. Secular trends in acute myocardial infarction in relation to physical activity in the general Danish population. *Scandinavian Med Sci Sports* 2003;13:224–30.
66 Autenrieth CS, Baumert J, Baumeister SE, *et al*. Association between domains of physical activity and all-cause, cardiovascular and cancer mortality. *Eur J Epidemiol* 2011;26:91–9.
67 Moe B, Mork PJ, Holtermann A, *et al*. Occupational physical activity, metabolic syndrome and risk of death from all causes and cardiovascular disease in the HUNT 2 cohort study. *Occup Environ Med* 2013;70:86–90.
68 Franzon K, Zethelius B, Cederholm T, *et al*. Modifiable midlife risk factors, independent aging, and survival in older men: report on long-term follow-up of the Uppsala Longitudinal Study of Adult Men cohort. *J Am Geriatr Soc* 2015;63:877–85.
69 Huerta JM, Chirlaque MD, Tormo MJ, *et al*. Work, household, and leisure-time physical activity and risk of mortality in the EPIC-Spain cohort. *Prev Med* 2016;85:106–12.
70 Bahls M, Groß S, Baumeister SE, *et al*. Association of domain-specific physical activity and cardiorespiratory fitness with all-cause and cause-specific mortality in two population-based cohort studies. *Sci Rep* 2018;8:16066.
71 Wanner M, Tarnutzer S, Martin BW, *et al*. Impact of different domains of physical activity on cause-specific mortality: a longitudinal study. *Prev Med* 2014;62:89–95.
72 Petersen CB, Eriksen L, Tolstrup JS, *et al*. Occupational heavy lifting and risk of ischemic heart disease and all-cause mortality. *BMC Public Health* 2012;12:1070.
73 Holtermann A, Marott JL, Gyntelberg F, *et al*. Occupational and leisure time physical activity: risk of all-cause mortality and myocardial infarction in the Copenhagen City Heart Study. A prospective cohort study. *BMJ Open* 2012;2:e000556.

Appendix 1. Overview of all variables that were requested from eligible studies.

Variable group	**Variables**
Predicting variables	● Occupational physical activity ● Leisure-time physical activity
Socioeconomic status	● Education level ● Occupational class ● Income
Primary outcomes	● All-cause mortality
Secondary outcomes	● Cardiovascular mortality ● Cardiovascular diseases in general ● Specific cardiovascular diseases (e.g., ischaemic heart disease, myocardial infarction or stroke)
Health status	● Adiposity (e.g., BMI, waist circumference or fat percentage) ● Blood pressure (systolic and diastolic) and/or hypertension ● Blood lipids, cholesterol and/or glucose ● Cardiorespiratory fitness ● Self-reported health ● Other non-communicable diseases (e.g., diabetes, cancer, pulmonary diseases, mental health condition)
Other factors	
Demographic factors	● Gender ● Age ● Ethnicity ● Marital status
Lifestyle factors	● Smoking ● Alcohol use ● Diet (e.g., consumption of fruit and vegetables, sweets, snacks and sugary drinks) ● Sleep duration/quality ● Coffee use ● Other (e.g., transport and/or household) domains of physical activity
Psychosocial factors	● Stress ● Social support ● Psychosocial work demands (e.g., decision authority, effort-rewards imbalance, job strain)
Material factors	● Health care utilisation ● Medication use ● Neighbourhood conditions

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Appendix 2. Overview of harmonization criteria used for physical activity, resembling the Saltin-Grimby physical activity scales[1]. Occupational physical activity categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, without lifting or carrying (low level), work that involves carrying light objects or walking stairs (moderate level), and physically demanding work involving frequent carrying or lifting heavy loads (high level). For leisure-time physical activity the categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure-time activities such as slow walking or household activities (low level), engaging in activities such as brisk walking or dancing (moderate level), regular engagement in activities such as jogging or cycling (high level)

			Leisure-time physical activity		**Occupational physical activity**	
Reference	**Study name**	**Assessment**	**Original variable**	**Harmonized**	**Original variable**	**Harmonized**
Clays, 2014[2]	BELFIT study	Occupational physical activity was assessed with a specific questionnaire, asking about attitudes, movement and postures in a regular working day. Leisure-time physical activity was assessed with the Minnesota Leisure Time Physical Activity Questionnaires. Results from both questionnaires were expressed in caloric expenditure.	Leisure-time physical activity in kcal accumulated in the last 12 months, calculated into MET-hrs/week. Using quartiles to categorise continuous variable into sedentary, low, moderate and high	Sedentary Mean (SD): 2.3 (2.3), range: [0.0 6.7]	Occupational physical activity in kcal/working hour	White collar occupations were determined as sedentary, tertiles were taken from remaining occupations to categorise low, moderate and high occupational physical activity.
				Low Mean (SD): 11.6 (3.2), range: [6.8 17.5]		
				Moderate Mean (SD): 25.1 (4.7), range: [17.5 34.6]		
				High Mean (SD): 60.3 (25.2), range: [34.6 186.9]		
Saidj, 2013[3]	Health 2006 (H2006)	Physical activity (at work and during leisure-time) assessed with two items from the questionnaire developed by Saltin & Grimby[27] was analysed for the purpose of this meta-analysis. This is in contrast to the PAS2	Mainly sedentary	Sedentary	Mainly sedentary	Sedentary
			Some low to moderate physical activity – e.g., walking/biking at least 4 hours per week	Low	Some standing, walking (e.g., kitchen, light industrial work, teaching – no heavy lifting)	Low
			Sports and exercise or equivalent heavy	Moderate	Mainly walking, stairclimbing, some lifting	Moderate

		questionnaire that was reported on in the Saidj et al. (2013) paper.	gardening etc. at least 3 times per week			
			Competitive sports/long distance running/athletics several times per week	High	Strenuous physical work	High
Sjøl, 2003[4]	MONICA Denmark	Occupational and leisure-time physical activity were assessed using single questions with four outcome categories.	Sedentary: almost completely inactive, e.g., reading, watching TV, going to movie.	Sedentary	Sedentary: predominantly sedentary: e.g., desk worker, watch-maker, seated assembly-line worker (light goods).	Sedentary
			Moderate active: some physical activity during at least 4h per week, e.g., walking, bicycling, or skiing, gardening.	Low	Moderate active: mainly sitting or standing, some walking, e.g., cashier, general office worker, light tool and machinery worker, foreman.	Low
			Highly active: Regular activity at least 3h a week, e.g., heavy gardening, running, calisthenics, tennis etc.	Moderate	Highly active: walking, some handling of material, e.g., post-man waiter, construction worker, heavy tool and machinery worker.	Moderate
			Sports: Regular hard physical training for competition in running events, soccer, European handball, etc. several times a week.	High	Heavy manual work: e.g., lumberjack, dockworker, stone mason and farm worker, ditch digger.	High
Krause, 2017[5]	KIHD study	Occupational physical activity was assessed with interviews in which participants were asked about their activities during a regular workday. Leisure-time physical activity was assessed using the	Total leisure-time physical activity (MET-hrs/year), with a 7d recall. Using quartiles to categorise continuous	Sedentary Mean (SD): 7.3 (3.9), range: [0.0 13.4]	Relative aerobic workload defined as %VO2max. Using quartiles to categorise continuous variable into	Sedentary Mean (SD): 18.2 (2.4), range: [9.9 21.6]
				Low		Low

		Minnesota Leisure Time Physical Activity Questionnaire.	variable into sedentary, low, moderate and high	Mean (SD): 19.2 (3.4), range: [13.4 25.2]	sedentary, low, moderate and high	Mean (SD): 24.7 (1.8), range: [21.7 28.0]
				Moderate Mean (SD): 33.0 (4.8), range: [25.2 41.7]		Moderate Mean (SD): 32.4 (2.8), range: [28.0 37.5]
				High Mean (SD): 71.4 (36.6), range: [41.7 472.7]		High Mean (SD): 49.4 (12.3), range: [37.0 119.0]
Pulsford, 2015[6]	Whitehall II study	Leisure-time physical activity was assessed using the Minnesota Leisure Time Physical Activity Questionnaire. Occupational physical activity was obtained from job classification.	Mild, moderate and vigorous physical activity (MET-hrs/wk). Using quartiles to categorise continuous variable into sedentary, low, moderate and high	Sedentary Mean (SD): 14.4 (5.1), range: [0.0 21.5]	Professional / intermediate / non-manual skilled	Sedentary
					-	Low
					Manual skilled / semi-skilled / unskilled	Moderate
					-	High
				Low Mean (SD): 26.6 (2.9), range: [21.5 31.6]		
				Moderate Mean (SD): 37.7 (3.7), range: [31.6 44.7]		
				High Mean (SD): 60.3 (14.5),		

				range: [44.7 146.2]		
Eaton, 1995[7]	IIHDS study	Participants were interviewed regarding their occupational and leisure-time physical activity, with answer options into four outcome categories.	Almost no daily physical activity	Sedentary	Sit or drive	Sedentary
			Low-to-moderate but not daily physical activity	Low	Stand (including all the teachers)	Low
			Light intensity daily physical activity such as a daily walk of 3 km	Low	Walk (postmen, jail wardens and many more)	Moderate
			Moderate-to-heavy daily physical exertion (swimming, gardening, etc.)	Moderate	Manual labour	High
Autenrieth, 2011[8]	MONICA/KORA Augsburg	The MOSPA questionnaire was used to assess different domains of physical activity, asking participants to report the time usually spent on being physically active during work, transportation (walking or biking), household and/or leisure time, during a normal week over the past year. Based upon the subjects' indications, metabolic equivalents (METs, expressed in minutes per week) were calculated by means of a standardized program derived from the Compendium of Physical Activities and provided by the Centers for Disease Control and Prevention (CDC). For the present analysis, METs were only used for leisure-time physical activity. Occupational physical activity was graded on a four point scale based on participants' self-report.	Total leisure-time physical activity (MET-mins/wk). Using quartiles to categorise continuous variable into sedentary, low, moderate and high	Sedentary Mean (SD): 2.6 (2.4), range: [0.0 6.7]	No noteworthy occupational physical activity	Sedentary
					Low occupational physical activity	Low
					Moderate occupational physical activity	Moderate
					Heavy occupational physical activity	High
				Low Mean (SD): 12.0 (3.2), range: [6.7 18.0]		
				Moderate Mean (SD): 26.9 (5.5), range: [18.0 38.2]		
				High Mean (SD): 75.3 (46.1),		

				range: [38.2 490.0]		
Rosengren, 1997[9]	Primary Prevention Study	Occupational and leisure-time physical activity was graded on a four point scale	Mainly sedentary (e.g., reading or watching television)	Sedentary	Mainly sedentary	Sedentary
			Moderate activity (e.g., walking, riding a bicycle, light garden work at least 4 hours per week)	Low	Predominantly walking on one level but no heavy lifting	Low
			Regular exercise (e.g., running, swimming, tennis, heavy gardening at least 2 to 3 hours per week)	Moderate	Mainly walking, including climbing stairs, or walking uphill or lifting heavy objects	Moderate
			Athletic training or participation in competitive sports regularly and several times per week	High	Heavy physical labour	High
Richard, 2015[10]*	NHANES study	IPAQ questionnaire to assess physical activity. Single item question to assess occupational physical activity (in the 2005-2006 wave). Classification scheme according to profession and using Ainsworth tables[1] to assess occupational physical activity (only in the 2007-2008, 2009-2010 and 2011 and 2012 wave)	Leisure-time physical activity items were used to assess METs. Using quartiles to categorise continuous variable into sedentary, low, moderate and high	Sedentary	Professions were expressed in MET according to Ainsworth tables[1.] Using quartiles to categorise continuous variable into sedentary, low, moderate and high (in the 2007-2008, 2009-2010 and 2011 and 2012 wave)	Sedentary Mean (SD): 1.7 (0.1), range: [1.5 1.8]
				Low		Low Mean (SD): 2.2 (0.2), range: [2.0 2.5]
				Moderate		Moderate Mean (SD): 2.5 (0.0), range: [2.5 2.6]
				High		High Mean (SD): 3.4 (0.6), range: [2.7 4.3]
Moe, 2013[11]	HUNT study		None	Sedentary	Mostly sedentary work	Sedentary

		Occupational and leisure-time physical activity were assessed using questions (one question for leisure-time physical activity and two for occupational physical activity) with four outcome categories	Less than 1 hour	Low	Much walking at work	Low
			1-2 hours	Moderate	Much walking or lifting at work	Moderate
			3 hours or more	High	Heavy physical work	High
Franzon, 2015[12]	ULSAM study	Occupational and leisure-time physical activity were assessed with a single question with four outcome categories	Sedentary	Sedentary	Chiefly sedentary	Sedentary
			Moderate	Low	Mostly standing or walking	Low
			Regular	Moderate	Heavy lifting (>10kg)	Moderate
			Athletic	High	Physically demanding work	High
Huerta, 2016[13]	EPIC Spain study	EPIC-PAQ questionnaire was used to assess occupational and leisure-time physical activity. Occupational physical activity was classified into four categories, leisure-time physical activity was MET-hrs/week and then categorised into four outcome categories using WHO cut-off values	<7,5 MET-hrs/week	Sedentary	-	Sedentary
			7,5-15 MET-hrs/week	Low	Sedentary	Low
			15-30 MET-hrs/week	Moderate	-	Moderate
			>=30 MET-hrs/week	High	Non-sedentary	High
Johnsen, 2016[14]	WOLF study	Both occupational and leisure-time physical activity were measured with few questions, categorising participants in four physical activity categories	Never exercise	Sedentary	Very, very light	Sedentary
			Very little exercise. Take occasional walks.	Low	Very light / Quite light	Low
			Exercise now and then	Moderate	Somewhat strenuous / Strenuous	Moderate
			Exercise regularly	High	Very strenuous / Very, very strenuous	High
Bahls, 2018[15]	SHIP-START1 study	Baecke questionnaire with 16 questions from different domains of physical activity, expressing physical activity in arbitrary units, was used	Arbitrary leisure-time physical activity units with values ranging from 1 to 5. Using quartiles to categorise continuous	Sedentary Mean (SD): 2.1 (0.2), range: [1.1 2.4]	Arbitrary occupational physical activity units with values ranging from 1 to 5. Using quartiles to categorise continuous variable into	Sedentary Mean (SD): 1.8 (0.2), range: [1.0 2.1]
				Low		Low

			variable into sedentary, low, moderate and high	Mean (SD): 2.6 (0.1), range: [2.5 2.7]	sedentary, low, moderate and high	Mean (SD): 2.5 (0.1), range: [2.3 2.7]
				Moderate Mean (SD): 3.0 (0.1), range: [2.9 3.1]		Moderate Mean (SD): 3.1 (0.2), range: [2.9 3.4]
				High Mean (SD): 3.5 (0.3), range: [3.3 4.6]		High Mean (SD): 3.9 (0.3), range: [3.6 4.9]
Bahls, 2018[15]	CARLA study	Baecke questionnaire with 16 questions from different domains of physical activity, expressing physical activity in arbitrary units, was used	Arbitrary leisure-time physical activity units with values ranging from 1 to 5. Using quartiles to categorise continuous variable into sedentary, low, moderate and high	Sedentary Mean (SD): 2.0 (0.2), range: [1.3 2.3]	Arbitrary occupational physical activity units with values ranging from 1 to 5. Using quartiles to categorise continuous variable into sedentary, low, moderate and high	Sedentary Mean (SD): 1.8 (0.2), range: [1.3 2.0]
				Low Mean (SD): 2.5 (0.1), range: [2.4 2.6]		Low Mean (SD): 2.3 (0.1), range: [2.1 2.5]
				Moderate Mean (SD): 2.9 (0.1), range: [2.7 3.1]		Moderate Mean (SD): 2.9 (0.2), range: [2.6 3.3]
				High Mean (SD): 3.5 (0.3), range: [3.3 4.6]		High Mean (SD): 3.7 (0.3), range: [3.4 4.5]
			-	Sedentary	Mostly sitting	Sedentary

Wanner, 2014[16]	The Swiss MONICA study	Single questions were used to assess occupational (4 outcome categories) and leisure-time physical activity (3 outcome categories)	Light intensity physical activity, mostly sedentary	Low	Mostly standing and walking frequently, but not lifting or carrying heavy objects	Low
			Frequent walking/cycling; other frequent activities (e.g., gardening)	Moderate	Often having to take stairs and carrying light objects	Moderate
			Regular vigorous physical activity	High	A lot of physical effort and frequently carrying heavy objects	High
Wanner, 2014[16]	NRP 1A study	Single questions were used to assess occupational (4 outcome categories) and leisure-time physical activity (3 outcome categories). Those without work were excluded from the OPA assessment	-	Sedentary	Sedentary (taking stairs of <5 floors or walking <800m per day)	Sedentary
			Sedentary	Low	-	Low
			Medium (walking, cycling, gardening, dancing, gymnastics, table tennis, badminton, skiing)	Moderate	Medium (taking stairs of 5 to 20 floors or walking 800m to 3km per day at work	Moderate
			High (soccer, cycling in the mountains, swimming, wood chopping, digging, rowing, cross-country skiing)	High	High (taking stairs of >20 floors or walking >3km per day at work	High
Petersen, 2012[17]	Danish National Health Interview Surveys	Occupational physical activity was estimated from the self-administrated questionnaire by the question: "Which description most precisely covers your level of physical activity at work?" Participants were asked to state their typical level of physical activity in leisure time during the last 12 months	sedentary activities (reading, TV-watching or other sedentary activities)	Sedentary	Mainly sedentary work	Sedentary
			low physical activity (walking, bicycling or other light intensity activities for a minimum of four hours a week)	Low	Work that require quite a bit of standing or walking activities	Low
			moderate physical activity (exercise, endurance training or	Moderate	Standing and walking most of the time with	Moderate

			heavy gardening for at least four hours a week)		quite a bit of carrying or lifting heavy burdens	
			vigorous physical activity (strenuous activities usually involving competition or endurance training performed regularly or several times a week)	High	Work that requires vigorous or strenuous physical activity	High
Dalene, 2021[18]	Norwegian study	Occupational and leisure-time physical activity was assessed by *the Saltin-Grimby Physical Activity Level Scale*	Reading, watching television, or engaging in sedentary activities	Sedentary	Mostly sedentary work (e.g., desk work, work including assembling of minor parts)	Sedentary
			At least 4 hours a week walking, bicycling, or engaging in other types of physical activity	Low	Work characterized by some walking (e.g., light industrial work, non-sedentary office work, inspection and the like)	Low
			At least 4 hours a week exercising to keep fit and participating in recreational athletics	Moderate	Work characterized by walking and lifting (e.g., mail delivery and construction work)	Moderate
			Regular, vigorous training or participating in competitive sports several times a week	High	Work characterized by heavy manual labour (for example, work including digging and shovelling)	High
Holtermann, 2012[19]	Copenhagen City Heart Study	A single question with four categories was used for self-reporting leisure-time and occupational physical activity. For occupational physical activity 'Which description most precisely covers your pattern of physical	Being almost entirely sedentary (e.g., reading, watching television or movies, engaging in light intensity physical activity such as walking or biking <2 h/week)	Sedentary	Predominantly sedentary work	Sedentary

		activity at work? For leisure time physical activity: 'Which description most precisely covers your pattern of physical activity during leisure time?	Engaging in light intensity physical activity for 2-4 h/week.	Low	Sedentary or standing, sometimes walking work	Low
			Engaging in light intensity physical activity for more than 4 h/week or more vigorous activity for 2-4 h/week (e.g., brisk walking, fast biking, heavy gardening, sports that cause perspiration or exhaustion).	Moderate	Walking, sometimes lifting work	Moderate
			Engaging in highly vigorous physical activity for more than 4 h/week or regular heavy exercise or competitive sports several times per week.	High	Heavy manual work	High
Holtermann, 2021[20]	Copenhagen General Population Study	Participants self-reported their occupational and leisure time physical activity, from an earlier used questionnaire. Occupational physical activity was quantitated using the following question: Which description most precisely covers your pattern of physical activity at work? Leisure time physical activity was quantitated by the following question: Which description most precisely covers your pattern of physical activity at leisure time?	You are mainly sedentary, e.g., you read, watch television, go to the cinema. In general, you spend most of your leisure time performing sedentary tasks.	Sedentary	Predominantly sedentary work	Sedentary
			You go for a walk, use your bicycle a little or perform activity for at least 4 hours per week, e.g., light gardening, leisure-time building activity, table tennis and bowling.	Low	Sedentary or standing, sometimes walking work	Low
			You are an active athlete, run, play tennis or badminton for at least 3	Moderate	Walking, sometimes lifting work	Moderate

			hours/week. If you frequently perform heavy gardening, you also belong to this group.			
			You take part in competitive sports, swim, play European football, handball or run long distances regularly several times per week.	High	Heavy manual work	High
Holtermann, 2009[21]	Copenhagen male study	Occupational physical activity at work was estimated by the question: "Which description most precisely covers your pattern of physical activity at work?" To assess leisure-time physical activity the following question was asked "Which description most precisely covers your pattern of physical activity at leisure time?" Both questions had four answer options of which the highest two were combined.	-	Sedentary	-	Sedentary
			You are mainly sedentary, for example, you read, watch television, go to the cinema. In general you spend most of your leisure time performing sedentary tasks	Low	You are mainly sedentary and do not walk much around at your workplace, e.g., desk work, and work including assembling of minor parts	Low
			You go for a walk, use your bicycle a little or perform activity for at least 4 hours per week, for example, light gardening, leisure-time building activity, table tennis and bowling	Moderate	You walk around quite a bit at your workplace but do **not** have to carry heavy items, e.g., light industrial work, non-sedentary office work, inspection and the like	Moderate
			You are an active athlete, run, play tennis or badminton for at least 3 hours/week. If you frequently perform heavy gardening, you also belong to this group. You take part in competitive sports, swim, play European football,	High	Most of the time you walk, and you often have to walk up stairs and lift various items. Examples include mail delivery and construction work. You do heavy physical work. You carry heavy burdens and carry out physically	High

			handball or run long distances regularly several times per week		strenuous work, e.g., work including digging and shovelling	

[1]Ainsworth et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011; 43(8):1575-81.
MET = Metabolic equivalent of task
* Although a reference is made to the paper by Richard and colleagues (which is the only paper we identified on the topic using NHANES data), different measurement waves were included for our meta-analysis. Measurements of the following waves were used in which all dependent and confounding variables were assessed: 2005-2006, 2007-2008, 2009-2010, and 2011-2012. For outcomes the 2015 follow-up measurements were used.

References

1. Saltin B, Grimby G. Physiological analysis of middle-aged and old former athletes. Comparison with still active athletes of the same ages. *Circulation* 1968 38(6):1104-15. doi: 10.1161/01.cir.38.6.1104
2. Clays E, Lidegaard M, De Bacquer D, et al. The combined relationship of occupational and leisure-time physical activity with all-cause mortality among men, accounting for physical fitness. *American journal of epidemiology* 2014;179(5):559-66. doi: 10.1093/aje/kwt294
3. Saidj M, Jorgensen T, Jacobsen RK, et al. Separate and joint associations of occupational and leisure-time sitting with cardio-metabolic risk factors in working adults: a cross-sectional study. *PloS one* 2013;8(8):e70213. doi: 10.1371/journal.pone.0070213
4. Sjøl A, Thomsen KK, Schroll M, Andersen LB. Secular trends in acute myocardial infarction in relation to physical activity in the general Danish population. *Scandinavian journal of medicine & science in sports* 2003;13(4):224-30.
5. Krause N, Arah OA, Kauhanen J. Physical activity and 22-year all-cause and coronary heart disease mortality. *American Journal of Industrial Medicine* 2017;60(11):976-90. doi: 10.1002/ajim.22756
6. Pulsford RM, Stamatakis E, Britton AR, et al. Associations of sitting behaviours with all-cause mortality over a 16-year follow-up: the Whitehall II study. . *International journal of epidemiology* 2015;44(6):1909-16.
7. Eaton CB, Medalie JH, Flocke SA, et al. Self-reported physical activity predicts long-term coronary heart disease and all-cause mortalities. Twenty-one-year follow-up of the Israeli Ischemic Heart Disease Study. *Archives of family medicine* 1995;4(4):323-29.
8. Autenrieth CS, Baumert J, Baumeister SE, et al. Association between domains of physical activity and all-cause, cardiovascular and cancer mortality. *European journal of epidemiology* 2011;26(2):91-99. doi: 10.1007/s10654-010-9517-6
9. Rosengren A, Wilhelmsen L. Physical activity protects against coronary death and deaths from all causes in middle-aged men. Evidence from a 20-year follow-up of the primary prevention study in Goteborg. *Annals of Epidemiology* 1997;7(1):69-75.
10. Richard A, Martin B, Wanner M, et al. Effects of leisure-time and occupational physical activity on total mortality risk in NHANES III according to sex, ethnicity, central obesity, and age. *Journal of physical activity & health* 2015;12(2):184-92. doi: 10.1123/jpah.2013-0198
11. Moe B, Mork PJ, Holtermann A, Nilsen TI. Occupational physical activity, metabolic syndrome and risk of death from all causes and cardiovascular disease in the HUNT 2 cohort study. *Occupational and Environmental Medicine* 2013;70(2):86-90. doi: 10.1136/oemed-2012-100734
12. Franzon K, Zethelius B, Cederholm T, Kilander L. Modifiable midlife risk factors, independent aging, and survival in older men: report on long-term follow-up of the Uppsala Longitudinal Study of Adult Men cohort. *Journal of the American Geriatrics Society* 2015;63(5):877-85. doi: 10.1111/jgs.13352
13. Huerta JM, Chirlaque MD, Tormo MJ, et al. Work, household, and leisure-time physical activity and risk of mortality in the EPIC-Spain cohort. *Preventive medicine* 2016;85:106-12. doi: 10.1016/j.ypmed.2016.02.009
14. Johnsen AM, Alfredsson L, Knutsson A, et al. Association between occupational physical activity and myocardial infarction: a prospective cohort study. *BMJ Open* 2016;6(10):e012692. doi: 10.1136/bmjopen-2016-012692
15. Bahls M, Groß S, Baumeister SE, et al. Association of domain-specific physical activity and cardiorespiratory fitness with all-cause and cause-specific mortality in two population-based cohort studies. *Sci Rep* 2018;8(1):16066. doi: 10.1038/s41598-018-34468-7

16. Wanner M, Tarnutzer S, Martin BW, et al. Impact of different domains of physical activity on cause-specific mortality: a longitudinal study. *Preventive medicine* 2014;62:89-95. doi: 10.1016/j.ypmed.2014.01.025
17. Petersen CB, Eriksen L, Tolstrup JS, et al. Occupational heavy lifting and risk of ischemic heart disease and all-cause mortality. *BMC Public Health* 2012;12:1070. doi: 10.1186/1471-2458-12-1070
18. Dalene KE, Tarp J, Selmer RM, et al. Occupational physical activity and longevity: A prospective cohort study of 437 378 Norwegian working men and women. *Lancet Public Health* 2021;6(6):e386-e95. doi: 10.1016/S2468-2667(21)00032-3
19. Holtermann A, Marott JL, Gyntelberg F, et al. Occupational and leisure time physical activity: risk of all-cause mortality and myocardial infarction in the Copenhagen City Heart Study. A prospective cohort study. *BMJ Open* 2012;2(1):e000556. doi: 10.1136/bmjopen-2011-000556
20. Holtermann A, Schnohr P, Nordestgaard BG, Marott JL. The physical activity paradox in cardiovascular disease and all-cause mortality: the contemporary Copenhagen General Population Study with 104,046 adults. *European Heart Journal* 2021:ehab087. doi: 10.1093/eurheartj/ehab087
21. Holtermann A, Mortensen OS, Burr H, et al. The interplay between physical activity at work and during leisure time--risk of ischemic heart disease and all-cause mortality in middle-aged Caucasian men. *Scandinavian Journal of Work, Environment & Health* 2009;35(6):466-74.

Appendix 3. Detailed information on sample and outcome ascertainment of cohort studies.

	Reference	Study name	Type of sample	Outcome ascertainment
1	Clays, 2014[1]	BELFIT study	All male industry workers (age 40-55 years) who were regularly employed by a selection of organisations were invited, of which 75% participated.	Mortality was ascertained from the national registry and death certificates from the National Institute of Statistics were used to assess cause of death.
2	Saidj, 2013[2]	Health 2006 (H2006)	Working participants from a population-based cohort, a random sample of the population aged 18–69 years and living in the South-Western part of the greater Copenhagen area	Mortality was ascertained through the national register (information obtained after personal communication with the researchers).
3	Sjøl, 2003[3]	MONICA Denmark	Selection of three surveys of the general population in 11 suburban municipalities in the Copenhagen county. Random sample were drawn among participants aged 30, 40, 50 and 60 years. Mean participation rate was 79%.	Mortality was ascertained through the national register (information obtained after personal communication with the researchers).
4	Krause, 2017[4]	KIHD study	Random ethnically homogeneous sample of Eastern Finnish men, residing in the city of Kuopio or its surrounding rural communities.	Data from the National Death registry were used to ascertain mortality. At the National Center of Statistics of Finland, cause of mortality was assessed using ICD codes.
5	Pulsford, 2015[5]	Whitehall II study	All London-based civil servants 35-55 years were invited to participate. There was a 73% participation rate.	Mortality was ascertained through the national mortality register.
6	Eaton, 1995[6]	IIHDS study	A sample (using purposeful sampling to ensure an adequate sample from all regions of origin) of Israeli male government employees was conducted.	Hospital records, death certificates and autopsy reports were used to ascertain mortality and determine cause of death.
7	Autenrieth, 2011[7]	MONICA/KORA Augsburg	A random sample from all residents (age 25-74 years) of the city of Augsburg and adjacent counties	Population registries inside and outside the study area were used to ascertain mortality. Death certificates were obtained from local authorities to assess cause of death (using ICD classifications).
8	Rosengren, 1997[8]	Primary Prevention Study	All men born in the city of Götenborg between 1915 and 1925 were invited. There was a 755 response rate.	National registry was used to ascertain mortality and cause of death.
9	Richard, 2015[9]*	NHANES study	Population-based study, which used a multistage probability sampling of the noninstitutionalized US population	Mortality was ascertained from the follow-up data of NHANES, with death certificate records from the National Death Index (NDI)
10	Moe, 2013[10]	HUNT study	Population-based health survey in Nord-Trøndelag County. All inhabitants ≥20 years were invited (70% response rate).	Cause of Death Registry in Norway was used to ascertain mortality and cause of mortality using ICD classification.
11	Franzon, 2015[11]	ULSAM study	All men born between 1920 and 1924 living in Uppsala were invited, of which 82% participated.	National Swedish Death Registry was used to ascertain mortality.

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12	Huerta, 2016[12]	EPIC Spain study	Participants were 29 to 69 year old and were recruited from five regions in Spain. Participants were blood donors, civil servants and from the general population.	Mortality was ascertained with registry information from the Spanish National Statistics Institute, with cause of death assessed using ICD classification.
13	Johnsen, 2016[13]	WOLF study	Workers were recruited through 33 out of 36 occupational health services in the counties of Stockholm, Jämtland and Västernorrland, serving 60 companies.	Mortality was ascertained with national registers (personal communication with researchers)
14	Bahls, 2018[14]	SHIP-START1 study	Random sample of the inhabitants of the region of West-Pomerania	Death certificates were requested from the local health authorities and were coded by two certified physicians according to the ICD classification
15	Bahls, 2018[14]	CARLA study	Representative sample of the citizens of the city of Halle	Death certificates were requested from the local health authorities and were coded by a certified according to the ICD classification
16	Wanner, 2014[15]	The Swiss MONICA study	Conducted in three waves among participants from French and Italian language regions in Switzerland.	Mortality ascertained from Swiss National Cohort data (94% of participants could be linked).
17	Wanner, 2014[15]	NRP 1A study	Combination of a random and convenience sample among participants in the three main language regions in Switzerland; i.e., a random sample from a population registry plus a convenience sample from volunteers (often family members of sampled participants).	Mortality ascertained from Swiss National Cohort data (97% of participants could be linked).
18	Petersen, 2012[16]	Danish National Health Interview Surveys	A national representative random sample of the Danish population aged 16 or above selected from the Danish Civil Registration System	Data were linked to nation-wide registers by using the unique personal identification number. Information on cause-specific mortality was obtained from the Danish Register of Causes of Death
19	Dalene, 2021[17]	Norwegian study	Data from the Norwegian population-based health examination surveys were used. The surveys cover all parts of and sub-populations in Norway.	Data on all-cause mortality during follow-up were obtained from the Norwegian Cause of Death Registry.
20	Holtermann, 2012[18]	Copenhagen City Heart Study	The Copenhagen City Heart Study is a prospective cardiovascular population study comprising a random sample of men and women aged 20-101 years, drawn from the Copenhagen Population Register as of 1 January 1976.	Subjects were followed in national registers. Episodes of non-fatal myocardial infarction were retrieved from the National Hospital Discharge Register. Deaths were obtained from the Civil Registration System and causes of death from the National Register of Causes of Death.
21	Holtermann, 2021[19]	Copenhagen General Population Study	In the Copenhagen General Population Study, women and men aged 20-100 years were randomly invited from the general population of the greater Copenhagen area including both high and low income areas, using the Danish Central Person	Outcomes were identified by linkage to the national Danish Patient Registry covering all Danish hospitals and to the national Danish Cause of Death Registry

			Registration number, which uniquely identifies all individuals living in Denmark.	
22	Holtermann, 2009[20]	Copenhagen male study	The Copenhagen Male Study comprised of male employees, aged 40–59 years, from 14 companies in the railway, public road construction, military, postal and telephone services, customs, national banking, and medical industries.	Data on death diagnoses were obtained from official national registers.
* Although a reference is made to the paper by Richard and colleagues (which is the only paper we identified on the topic using NHANES data), different measurement waves were included for our meta-analysis. Measurements of the following waves were used in which all dependent and confounding variables were assessed: 2005-2006, 2007-2008, 2009-2010, and 2011-2012. For outcomes the 2015 follow-up measurements were used.				

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References

1. Clays E, Lidegaard M, De Bacquer D, et al. The combined relationship of occupational and leisure-time physical activity with all-cause mortality among men, accounting for physical fitness. *American journal of epidemiology* 2014;179(5):559-66. doi: 10.1093/aje/kwt294
2. Saidj M, Jorgensen T, Jacobsen RK, et al. Separate and joint associations of occupational and leisure-time sitting with cardio-metabolic risk factors in working adults: a cross-sectional study. *PloS one* 2013;8(8):e70213. doi: 10.1371/journal.pone.0070213
3. Sjøl A, Thomsen KK, Schroll M, Andersen LB. Secular trends in acute myocardial infarction in relation to physical activity in the general Danish population. *Scandinavian journal of medicine & science in sports* 2003;13(4):224-30.
4. Krause N, Arah OA, Kauhanen J. Physical activity and 22-year all-cause and coronary heart disease mortality. *American Journal of Industrial Medicine* 2017;60(11):976-90. doi: 10.1002/ajim.22756
5. Pulsford RM, Stamatakis E, Britton AR, et al. Associations of sitting behaviours with all-cause mortality over a 16-year follow-up: the Whitehall II study. . *International journal of epidemiology* 2015;44(6):1909-16.
6. Eaton CB, Medalie JH, Flocke SA, et al. Self-reported physical activity predicts long-term coronary heart disease and all-cause mortalities. Twenty-one-year follow-up of the Israeli Ischemic Heart Disease Study. *Archives of family medicine* 1995;4(4):323-29.
7. Autenrieth CS, Baumert J, Baumeister SE, et al. Association between domains of physical activity and all-cause, cardiovascular and cancer mortality. *European journal of epidemiology* 2011;26(2):91-99. doi: 10.1007/s10654-010-9517-6
8. Rosengren A, Wilhelmsen L. Physical activity protects against coronary death and deaths from all causes in middle-aged men. Evidence from a 20-year follow-up of the primary prevention study in Goteborg. *Annals of Epidemiology* 1997;7(1):69-75.
9. Richard A, Martin B, Wanner M, et al. Effects of leisure-time and occupational physical activity on total mortality risk in NHANES III according to sex, ethnicity, central obesity, and age. *Journal of physical activity & health* 2015;12(2):184-92. doi: 10.1123/jpah.2013-0198
10. Moe B, Mork PJ, Holtermann A, Nilsen TI. Occupational physical activity, metabolic syndrome and risk of death from all causes and cardiovascular disease in the HUNT 2 cohort study. *Occupational and Environmental Medicine* 2013;70(2):86-90. doi: 10.1136/oemed-2012-100734
11. Franzon K, Zethelius B, Cederholm T, Kilander L. Modifiable midlife risk factors, independent aging, and survival in older men: report on long-term follow-up of the Uppsala Longitudinal Study of Adult Men cohort. *Journal of the American Geriatrics Society* 2015;63(5):877-85. doi: 10.1111/jgs.13352
12. Huerta JM, Chirlaque MD, Tormo MJ, et al. Work, household, and leisure-time physical activity and risk of mortality in the EPIC-Spain cohort. *Preventive medicine* 2016;85:106-12. doi: 10.1016/j.ypmed.2016.02.009
13. Johnsen AM, Alfredsson L, Knutsson A, et al. Association between occupational physical activity and myocardial infarction: a prospective cohort study. *BMJ Open* 2016;6(10):e012692. doi: 10.1136/bmjopen-2016-012692
14. Bahls M, Groß S, Baumeister SE, et al. Association of domain-specific physical activity and cardiorespiratory fitness with all-cause and cause-specific mortality in two population-based cohort studies. *Sci Rep* 2018;8(1):16066. doi: 10.1038/s41598-018-34468-7
15. Wanner M, Tarnutzer S, Martin BW, et al. Impact of different domains of physical activity on cause-specific mortality: a longitudinal study. *Preventive medicine* 2014;62:89-95. doi: 10.1016/j.ypmed.2014.01.025

16. Petersen CB, Eriksen L, Tolstrup JS, et al. Occupational heavy lifting and risk of ischemic heart disease and all-cause mortality. *BMC Public Health* 2012;12:1070. doi: 10.1186/1471-2458-12-1070
17. Dalene KE, Tarp J, Selmer RM, et al. Occupational physical activity and longevity: A prospective cohort study of 437 378 Norwegian working men and women. *Lancet Public Health* 2021;6(6):e386-e95. doi: 10.1016/S2468-2667(21)00032-3
18. Holtermann A, Marott JL, Gyntelberg F, et al. Occupational and leisure time physical activity: risk of all-cause mortality and myocardial infarction in the Copenhagen City Heart Study. A prospective cohort study. *BMJ Open* 2012;2(1):e000556. doi: 10.1136/bmjopen-2011-000556
19. Holtermann A, Schnohr P, Nordestgaard BG, Marott JL. The physical activity paradox in cardiovascular disease and all-cause mortality: the contemporary Copenhagen General Population Study with 104,046 adults. *European Heart Journal* 2021:ehab087. doi: 10.1093/eurheartj/ehab087
20. Holtermann A, Mortensen OS, Burr H, et al. The interplay between physical activity at work and during leisure time--risk of ischemic heart disease and all-cause mortality in middle-aged Caucasian men. *Scandinavian Journal of Work, Environment & Health* 2009;35(6):466-74.

Appendix 4. Correlation of variables from the 17 studies that were combined in the individual participant dataset.

	OPA	**LTPA**	**Edu**	**Gender**	**Smoking**	**BMI**	**Age**
OPA	1						
LTPA	0.071	1					
Edu	-0.293	0.136	1				
Gender	0.037	0.071	0.013	1			
Smoking	0.067	-0.127	-0.133	-0.041	1		
BMI	0.064	-0.069	-0.138	-0.016	-0.089	1	
Age	-0.014	-0.141	-0.250	-0.105	0.023	0.165	1

OPA = Occupational physical activity; LTPA = Leisure-time physical activity;
Edu = Education level; BMI = Body mass index

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Appendix 5. Directed acyclic graphs (DAG) describing the potential causal pathways of occupational and leisure-time physical activity with all-cause mortality. Based on these DAGs, analyses were done with several levels of adjustment.

We drew an initial DAG describing the association of occupational physical activity and all-cause mortality (Figure 1), to derive the causal association of occupational physical activity and all-cause mortality. Based on this DAG it appears to be relevant to adjust for education, age, gender, lifestyle factors (including leisure-time physical activity) and health outcomes. Variables that could also be relevant to adjust for, such as occupation and work characteristics were, however, unfortunately not available in the database (grey dots).

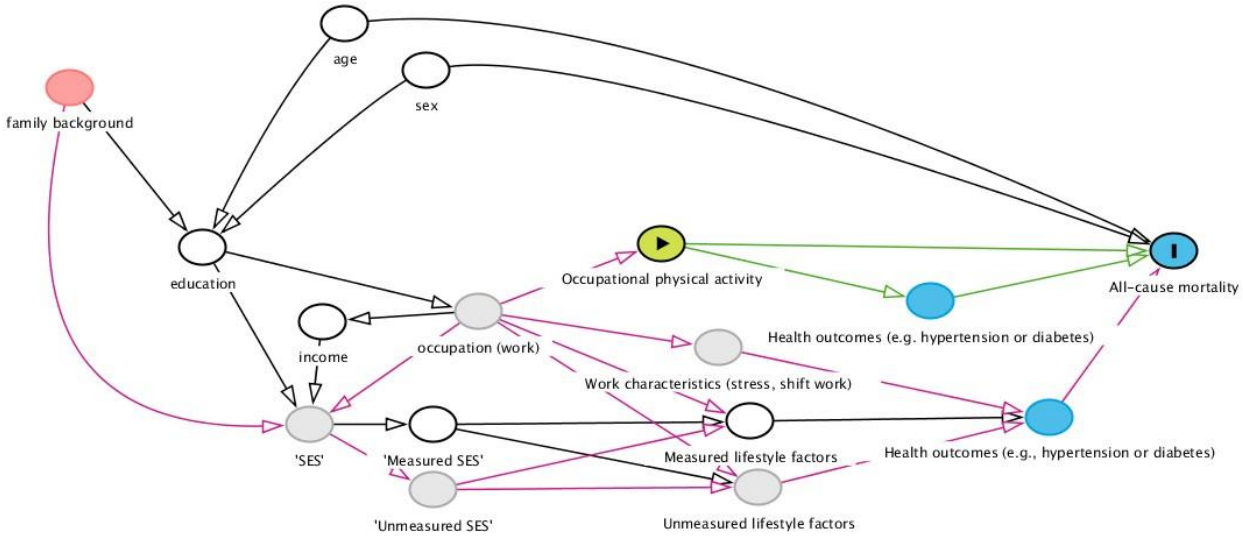

Figure 1. Initial DAG describing the association of occupational physical activity and all-cause mortality.

It may not be needed (or could even lead to bias) to adjust for income because income can be considered a mediator in that being or not being able to work in a physically demanding job over time may likely impact income (Figure 2). The other way around (i.e., income leading to a job with a certain degree of occupational physical activity) is less likely, but is conceivable. To add to the complexity, the variable income in our dataset consists of a combination of household and individual income.

Also lifestyle factors can be considered a mediator; e.g. one's occupational physical activity level could influence one's leisure-time physical activity level since engagement in high levels of occupational physical activity could, due to fatigue, prevent workers from engaging in leisure-time physical activity (Figure 3). As shown in Figure 4, a last option is that both income and lifestyle factors can be on the directed path between occupational physical activity and all-cause mortality, in which case one should not adjust for them.

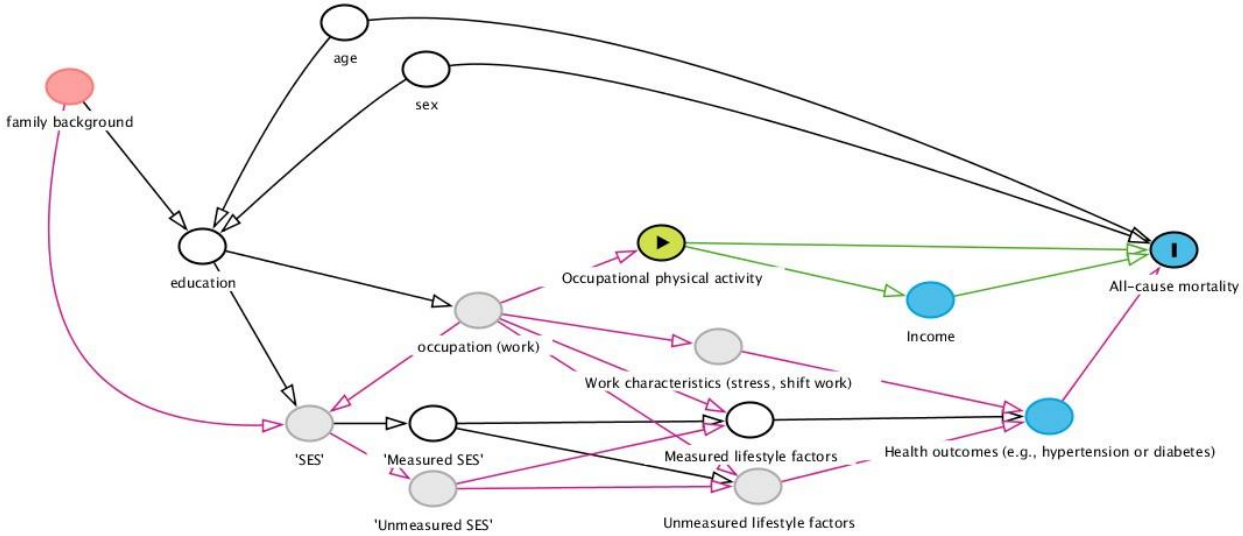

Figure 2. DAG describing the association of occupational physical activity and all-cause mortality with income being a potential mediator.

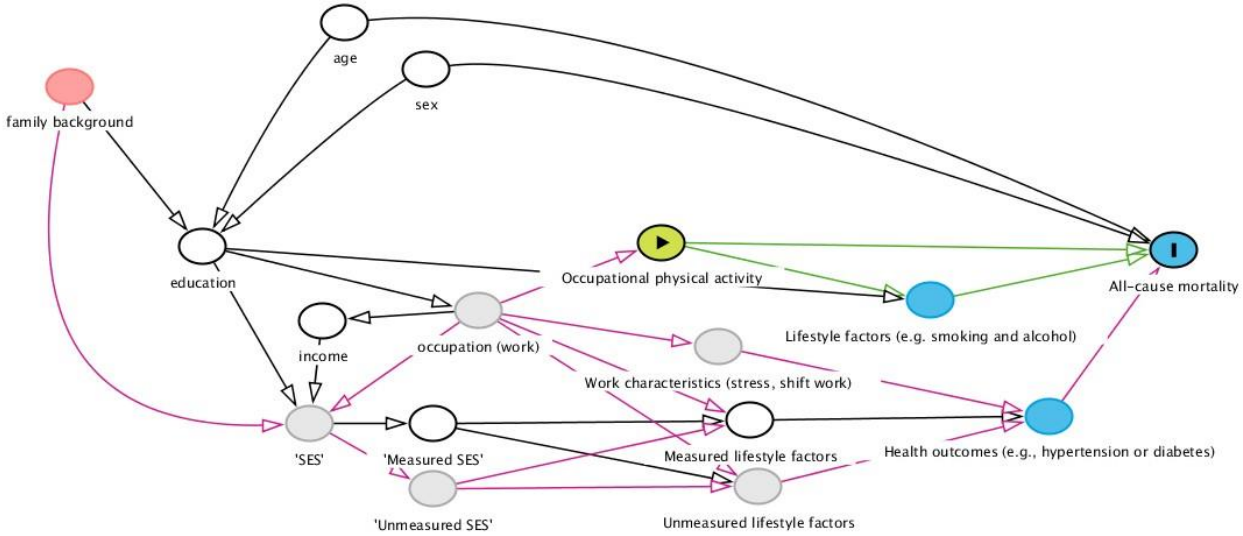

Figure 3. DAG describing the association of occupational physical activity and all-cause mortality with lifestyle factors (including leisure-time physical activity) being potential mediators .

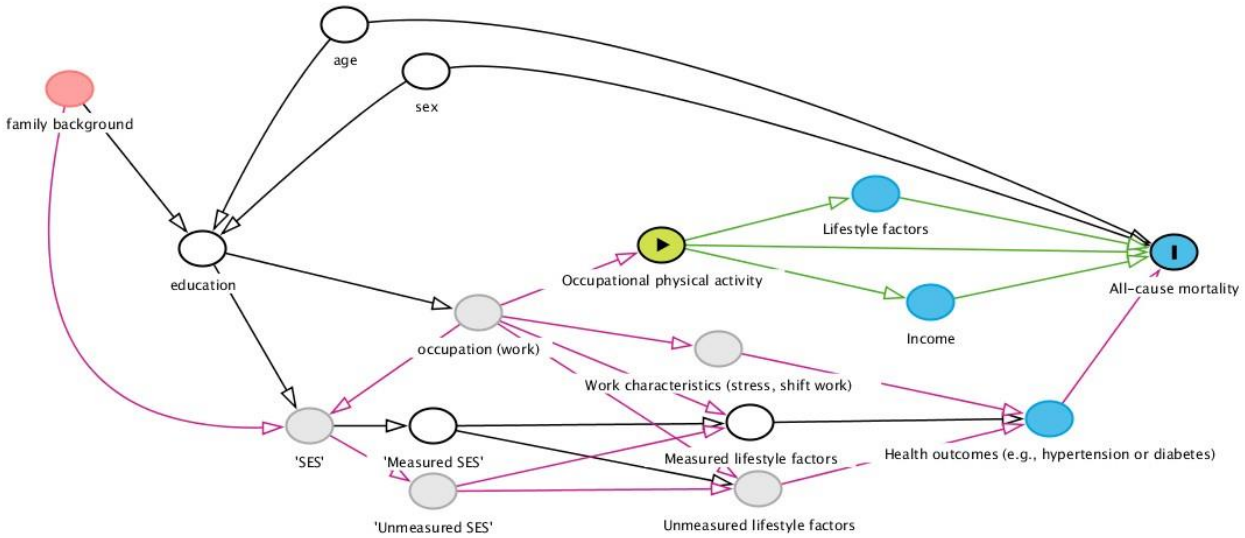

Figure 4. DAG describing the association of occupational physical activity and all-cause mortality with both lifestyle factors (including leisure-time physical activity) and income being potential mediators .

Appendix 6. Excluded studies after contacting researchers.

n	Reference	Study name	Reason for exclusion
1	Graff-Iversen S, Selmer R, Sørensen M, Skurtveit S. Occupational physical activity, overweight, and mortality: a follow-up study of 47,405 Norwegian women and men. Res Q Exerc Sport, 2007; 78(3):151-161.	-	Could not or did not want to collaborate
2	Harari G, Green MS, Zelber-Sagi S. Combined association of occupational and leisure-time physical activity with all-cause and coronary heart disease mortality among a cohort of men followed-up for 22 years. Occup Environ Med, 2015; 72(9):617-624.	CORDIS study	Could not or did not want to collaborate
3	Etemadi A, Abnet CC, Kamangar F, Islami F, Khademi H, Pourshams A, Poustchi H, Bagheri M, Sohrabpour AA, Aliasgar A, Khoshnia M, Wacholder S, Matthews CC, Pharoah PD, Brennan P, Boffetta P, Malekzadeh R, Dawsey SM. Impact of body size and physical activity during adolescence and adult life on overall and cause-specific mortality in a large cohort study from Iran. Eur J Epidemiol, 2014; 29(2):95-109.	Golestan Cohort Study	Could not or did not want to collaborate
4	Lissner L, Bengtsson C, Björkelund C, Wedel H. Physical activity levels and changes in relation to longevity. A prospective study of Swedish women. Am J Epidemiol, 1996; 143(1):54-62.	Gothenburg Prospective Study of Women	Could not or did not want to collaborate
5	Padyab M, Blomstedt Y, Norberg M. No association found between cardiovascular mortality, and job demands and decision latitude: experience from the Västerbotten Intervention Programme in Sweden. Soc Sci Med, 2014; 117:58-66.	Linnaeus database	Could not or did not want to collaborate
6	Lear SA, Hu W, Rangarajan S, Gasevic D, Leong D, Iqbal R, Casanova A, Swaminathan S, Anjana RM, Kumar R, Rosengren A, Wei L, Yang W, Chuangshi W, Huaxing L, Nair S, Diaz R, Swidon H, Gupta R, Mohammadifard N, Lopez-Jaramillo P, Oguz A Zatonska K, Seron P, Avezum A, Poirier P, Teo K, Yusuf S. The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. Lancet, 2017; 390(10113):2643-2654.	Prospective Urban Rural Epidemiologic (PURE) study with pooled data from 17 countries.	Could not or did not want to collaborate
7	Kikuchi H, Inoue S, Odagiri Y, Inoue M, Sawada N, Tsugane S. Occupational sitting time and risk of all-cause mortality among Japanese workers. Scand J Work Environ Health, 2015; 41(6):519-528.	Japan Public Health Centre-based prospective study (JPHC study)	Could not or did not want to collaborate
8	Dorn JP, Cerny FJ, Epstein LH, Naughton J, Vena JE, Winkelstein W, Schisterman E, Trevisan M. Work and leisure time physical activity and mortality in men and women from a general population sample. Ann Epidemiol, 1999; 9(6):366-373	The Buffalo Blood Pressure Study	Could not or did not want to collaborate
9	Hall C, Heck JE, Sandler DP, Ritz B, Chen H, Krause N. Occupational and leisure-time physical activity differentially predict 6-year incidence of stroke and transient ischemic attack in women. Scand J Work Environ Health. 2019; 45(3):267-279.	US sister study	Could not or did not want to collaborate
10	Holtermann A, Burr H, Hansen JV, Krause N, Søgaard K, Mortensen OS. Occupational physical activity and mortality among Danish workers. Int Arch Occup Environ Health, 2012; 85(3):305-310.	Danish Work Environment Cohort Study	Were not able to share individual participant data,

			nor to conduct data analysis remotely
11	Besson H, Ekelund U, Brage S, Luben R, Bingham S, Khaw KT, Wareham NJ. Relationship between subdomains of total physical activity and mortality. Med Sci Sports Exerc, 2008; 40(11):1909-1915.	European Prospective Investigation into Cancer (EPIC) study	Were not able to share individual participant data, nor to conduct data
12	Chasland LC, Knuiman MW, Divitini ML, Chan YX, Handelsman DJ, Naylor LH, Green DJ, Yeap BB. Greater physical activity and higher androgen concentrations are independently associated with lower cardiometabolic risk in men. Clin Endocrinol, 2017; 87(5):466-474.	Busselton Health Survey	Data access fees were too high for us
13	Emberson JR, Whincup PH, Morris RW, Walker M. Social class differences in coronary heart disease in middle-aged British men: implications for prevention. Int J Epidemiol. 2004; 33(2): 289-296	British Regional Heart Study	No suitable data were available
14	Crespo CJ, Garcia-Palmieri MR, Smit E, Lee IM, McGee D, Muti P, Figueroa Valle NR, Ramierez-Marrero FA, Freudenheim JL, Sorlie P. Physical activity and prostate cancer mortality in Puerto Rican men. J Phys Act Health 2008; 5(6):918-929	The Puerto Rico Heart Health Program	No suitable data were available
15	Hu GC, Chien KL, Hsieh SF, Chen CY, Tsai WH, Su TC. Occupational Versus Leisure-Time Physical Activity in Reducing Cardiovascular Risks and Mortality Among Ethnic Chinese Adults in Taiwan. Asia Pac J Public Health, 2014; 26(6): 604-613.	Chin-Shan Community Cardiovascular Cohort study	Responsible researcher(s) could not be reached
16	Stamatakis E, Chau JY, Pedisic Z, Bauman A, Macniven R, Coombs N, Hamer M. Are sitting occupations associated with increased all-cause, cancer, and cardiovascular disease mortality risk? A pooled analysis of seven British population cohorts. PLoS One, 2013; 8(9):e73753.	Health Survey for England (HSE) and the Scottish Health Survey (SHS)	Responsible researcher(s) could not be reached
17	Hu G, Eriksson J, Barengo NC, Lakka TA, Valle TT, Nissinen A, Jousilahti P, Tuomilehto J. Occupational, commuting, and leisure-time physical activity in relation to total and cardiovascular mortality among Finnish subjects with type 2 diabetes. Circulation, 2004; 110(6):666-673.	Six cross-sectional surveys (within the North Karelia Project and the FINMONICA/Finrisk studies)	Responsible researcher(s) could not be reached
18	Salonen JT, Slater JS, Tuomilehto J, Rauramaa R. Leisure time and occupational physical activity: risk of death from ischemic heart disease. Am J Epidemiol, 1988; 127(1):87-94.	North Karelia Project	Responsible researcher(s) could not be reached
19	Johnson JV, Stewart W, Hall EM, Fredlund P, Theorell T. Long-term psychosocial work environment and cardiovascular mortality among Swedish men. Am J Public Health, 1996; 86(3): 324–331.	Random sample of the entire Swedish population obtained by Statistics Sweden	Responsible researcher(s) could not be reached
20	Lapidus L, Bengtsson C. Socioeconomic factors and physical activity in relation to cardiovascular disease and death. A 12 year follow up of participants in a population study of women in Gothenburg, Sweden. Br Heart J, 1986; 55(3):295-301.	Revenue Office Register	Responsible researcher(s) could not be reached
21	Li Y, Sato Y, Yamaguchi N. Lifestyle factors as predictors of general cardiovascular disease: use for early self-screening. Asia Pac J Public Health, 2014; 26(4):414-424.	SAKUCESS (Saku Cancer Etiology Surveillance Study)	Responsible researcher(s) could not be reached
22	Śmigielski J, Ruszkowska J, Piotrowski W, Polakowska W, Bielecki W, Hanke W, Drygas W. The relationship between physical activity level and selected cardiovascular risk factors and	National Multicentre Health Survey (WOBASZ)	Responsible researcher(s) could not be reached

	mortality of males ≥ 50 years in Poland – The results of follow-up of participants of national multicentre health survey Wobasz. Int J Occup Med Environ Health, 2016;29(4): 633–648		
23	Hayashi R, Iso H, Cui R, Tamakoshi A, JACC Study Group. Occupational physical activity in relation to risk of cardiovascular mortality: The Japan Collaborative Cohort Study for Evaluation for Cancer Risk (JACC Study). Prev Med, 2016; 89:286-291.	The Japan Collaborative Cohort Study for Evaluation for Cancer Risk (JACC Study)	Responsible researcher(s) could not be reached
24	Hrafnkelsdóttir SM, Torfadóttir JE, Aspelund T, Magnusson KT, Tryggvadóttir L, Gudnason V, Mucci LA, Stampfer M, Valdimarsdóttir UA. Physical Activity from Early Adulthood and Risk of Prostate Cancer: A 24-Year Follow-Up Study among Icelandic Men. Cancer Prev Res, 2015; 8(10):905-911.	Reykjavik Study	Responsible researcher(s) could not be reached
25	Rahman I, Bellavia A, Wolk A. Relationship between physical activity and heart failure risk in women. Circ Heart Fail, 2014; 7(6):877-881.	the Swedish Mammography Cohort	Responsible researcher(s) could not be reached
26	Turi BC, Codogno JS, Fernandes RA, Sui X, Lavie CJ, Blair SN, Monteiro HL. Association of Different Physical Activity Domains on All-Cause Mortality in Adults Participating in Primary Care in the Brazilian National Health System: 4-Year Follow-up. J Phys Act Health, 2017; 14(1):45-51.	-	Responsible researcher(s) could not be reached
27	Kim Y, Wilkens LR, Park SY, Goodman MT, Monroe KR, Kolonel LN. Association between various sedentary behaviours and all-cause, cardiovascular disease and cancer mortality: the Multiethnic Cohort Study. Int J Epidemiol, 2013; 42(4):1040-1056.	Multiethnic Cohort Study	Responsible researcher(s) could not be reached
28	Orsini N, Bellocco R, Bottai M, Pagano M, Michaelsson K, Wolk A. Combined effects of obesity and physical activity in predicting mortality among men. J Intern Med, 2008; 264(5):442-451	The Cohort of Swedish Men (COSM)	Responsible researcher(s) could not be reached
29	Yu S, Yarnell JW, Sweetnam PM, Murray L; Caerphilly study. What level of physical activity protects against premature cardiovascular death? The Caerphilly study. Heart, 2003; 89(5):502-506.	Caerphilly collaborative heart disease study	Responsible researcher(s) retired or passed away
30	Holme I, Helgeland A, Hjermann I, Leren P, Lund-Larsen PG. Physical activity at work and at leisure in relation to coronary risk factors and social class. A 4-year mortality follow-up. The Oslo study. Acta Med Scand, 1981; 209(4):277-283.	Oslo study	Responsible researcher(s) retired or passed away
31	Stender M, Hense HW, Doring A, Keil U. Physical Activity at Work and cardiovascular disease risk: results from the MONICA Augsburg Study. Int J Epidemiol, 1993; 22(4): 644-650	MONICA Augsburg study	Duplicate study
32	Padyab M, Blomstedt Y, Norberg M. No association found between cardiovascular mortality, and job demands and decision latitude: experience from the Vasterbotten Intervention Programme in Sweden. Soc Sci Med, 2014; 117:58-66	Longitudinal integration database for health insurance and labor market studies (LISA)	Duplicate study

Appendix 7. Risk of bias (RoB) of the studies included in the individual participant data meta-analysis.

Reference	**Study name**	**Study participation**		**Study attrition**		**Predicting variable measurement**		**Outcome**	
		RoB	**Explanation**	**RoB**	**Explanation**	**RoB**	**Explanation**	**RoB**	**Explanation**
Clays, 2014[1]	BELFIT study	Moderate risk	Unclear how participating companies were selected. Also, a substantial part of the selected participant (25%) did not participate	Moderate risk	Of 2,363 eligible workers, 1456 were analysed. Loss to follow-up is unclear	Moderate risk	Accuracy of the occupational physical activity questionnaire is unclear. The Minnesota Leisure Time Physical Activity Questionnaire has shown reasonable accuracy[2]	Low risk	Ascertainment through registry seems adequate
Saidj, 2013[3]	Health 2006 (H2006)	Moderate risk	Participation rate was only 44% (although it was a random sample of the source population)	Moderate	Of 3,471 eligible workers, 2.544 were included. Unclear loss to follow-up	Low risk	PAS2 questionnaire was used which has shown reasonable validity[4]	Low risk	Ascertainment through registry seems adequate (based on personal communicatio n with researchers – not reported in the referred paper)
Sjøl, 2003[5]	MONICA Denmark	Moderate risk	Participation rate was below 80% (i.e., 79%)	Moderate	Unclear loss to follow-up	Moderate risk	Although reproducibility has been assessed, validity of the l physical	Low risk	Ascertainment through registry seems adequate

							activity questionnaire is unclear		
Krause, 2017[6]	KIHD study	Low risk	There was an 83% participation rate and an adequate description of the sample (Table 1)	Low risk	There was no loss of follow-up. All working participants were included and National Finnish death registries have complete data for all Finnish residents	Low risk	Occupational physical activity questionnaire showed good reliability (test-retest correlation 0.69[7]). The Minnesota Leisure Time Physical Activity Questionnaire has shown reasonable accuracy[2]	Low risk	Ascertainment through registry seems adequate
Pulsford, 2015[8]	Whitehall II study	Moderate risk	Participation rate was below 80% (i.e., 73%).	Moderate risk	Unclear how many participant were lost to follow-up and there appear to be differences between those who did and did not participate in the follow-up measurements	High risk	The Minnesota Leisure Time Physical Activity Questionnaire has shown reasonable accuracy (justifying a lower risk of bias score). However occupational physical activity assessment	Low risk	Ascertainment through registry seems adequate

							based on job classification is prone to a high risk of bias (based on personal communication with the study		
Eaton, 1995[9]	IIHDS study	Low risk	Authors report no significant differences between participant who did and did not participate	Low risk	Approximately 8463/10059=84% were followed up (although the percentage may be slightly different for those with physical activity reporting)	Moderate risk	Unclear accuracy of the used questionnaires (two single questions and source of these questions is unclear)	Moderate risk	Multiple ways of ascertainment were used, showing high agreement
Autenrieth, 2011[10]	MONICA/KORA Augsburg	Moderate risk	A random sample of the population was drawn and adequate description of the sample is provided (Table 1). 77% participated	Low risk	20 out of 6637 participants were lost to follow-up	Moderate risk	MOSPA questionnaire was used which has shown reasonable accuracy[11]	Low risk	Ascertainment through registry and death certificate (for reason of mortality) seems adequate
Rosengren, 1997[12]	Primary Prevention Study	Moderate risk	Participation rate was below 80% (i.e., 75%)	Low risk	All participants in the study were followed up	Moderate risk	Unclear accuracy of the used questionnaires. For leisure-time physical activity a reference is provided[13]	Low risk	Ascertainment through registry seems adequate

Richard, 2015[14]*	NHANES study	Low risk	NHANES has shown to be generalizable to the US population	Low risk	Only 26 participants did not have follow-up data	Moderate risk	Classification scheme according to profession and using Ainsworth tables to assess occupational physical activity	Low risk	Mortality was ascertained from registries
Moe, 2013[15]	HUNT study	Moderate risk	Participation rate was below 80% (i.e., 70%)	Low risk	All participants were followed up	Moderate risk	Accuracy of questions used is unclear (two questions were used to assess occupational physical activity, with unclear source)	Low risk	Ascertainment through registry seems adequate
Franzon, 2015[16]	ULSAM study	Low risk	All eligible participants were invited and 82% participated	Low risk	11 out of 2322 participants were lost to follow-up	Moderate risk	Accuracy of questionnaire used is unclear	Low risk	Ascertainment through registry seems adequate
Huerta, 2016[17]	EPIC Spain study	High risk	Source population of the sample and its representativeness regarding that population is unclear. Participation rate is also unclear	Low risk	Approximately 3k participants out of 41k were lost to follow-up (7%)	Low risk	EPIC-PAQ questionnaire was used which has shown reasonable accuracy[18].	Low risk	Ascertainment through registry seems adequate
Johnsen, 2016[19]	WOLF study	Low risk	There was an 82% response rate. Adequate description of the	Low risk	9,961/10,416=96 % were followed.	Moderate risk	Accuracy of questions is unclear	Low risk	Ascertainment through registry seems adequate

			sample is provided (Table 1)						
Bahls, 2018[20]	SHIP-START1 study	Moderate risk	A random sample of the population was drawn, with 68% response rate. Adequate description of the sample is provided (Table 1)	Moderate risk	Unclear how many participants were lost to follow-up	Low risk	Baecke questionnaire was used which has shown reasonable accuracy[21]	Low risk	Ascertainment through registry seems adequate
Bahls, 2018[20]	CARLA study	Moderate	A random sample of the population was drawn with unclear response rate. Adequate description of the sample is provided (Table 2)	Moderate risk	Unclear how many participants were lost to follow-up	Low risk	Baecke questionnaire was used which has shown reasonable accuracy[21]	Low risk	Ascertainment through registry seems adequate
Wanner, 2014[22]	The Swiss MONICA study	Low risk	A two-stage sampling procedure was used drawing a sample of 51 out of 651 communities after stratification according to their size; and drawing a random sample from the resident population files of these communities (for more details see Bopp et al.: BMC	Low risk	99% of participants were followed up (while another 165 participants were excluded due to missing data)	Moderate risk	Accuracy (i.e., validity) of questions is unclear	Low risk	Ascertainment through national registry seems adequate

			Public Health 2010 10:562)						
Wanner, 2014[22]	NRP 1A study	Moderate risk	Sampling procedure is unclear (with a combination of a random and convenience sample used).	Low risk	93% of participants were followed up (while another 500 participants were excluded due to missing data)	Moderate risk	Accuracy (i.e., validity) of questions is unclear	Low risk	Ascertainment through national registry seems adequate
Petersen, 2012[23]	Danish National Health Interview Surveys	Low risk	National representative sample, in which at least 80% of the eligible participants took part. Good description of the sample	Low risk	143 participants (~1%) were lost due to unknown vital status, and 1946 because they did not provide physical activity data (~16 drop out in total)	Moderate risk	Questionnaire is well describe. But its origin and accuracy are unclear	Low risk	Ascertainment through registry seems adequate
Dalene, 2021[24]	Norwegian study	Moderate risk	National representative sample and good description of the sample. However, 71% of the eligible participants took part in the study	Low risk	Due to registry data used, the vast majority of participants appeared to be followed up (2% drop out).	Low risk	Saltin-Grimby Physical Activity Level with known accuracy was used.	Low risk	Ascertainment through registry seems adequate
Holtermann, 2012[25]	Copenhagen City Heart Study	Moderate risk	Representative sample for the Copenhagen area, with good description of the sample. However, only 70-74% of eligible participants took part in the study	Low risk	Due to registry data used, the vast majority of participants appeared to be followed up.	Moderate risk	The questionnaire was earlier used and well described. However, its origin and accuracy is unclear.	Low risk	Ascertainment through registry seems adequate

Holtermann, 2021[26]	Copenhagen General Population Study	Moderate risk	Representative sample for the Copenhagen area, with good description of the sample. However, only 43% of eligible participants took part in the study	Low risk	Due to registry data used, the vast majority of participants appeared to be followed up.	Moderate risk	The questionnaire was earlier used. However, its origin and accuracy is unclear.	Low risk	Ascertainment through registry seems adequate
Holtermann, 2009[27]	Copenhagen male study	Moderate risk	High response rate (87%) and good description of the sample. Sample of workers from various companies.	Low risk	Only nine men had missing answers, and 14 had emigrated during the follow-up	Moderate risk	The questionnaire was earlier used. However, its origin and accuracy is unclear.	Low risk	Ascertainment through registry seems adequate
* Although a reference is made to the paper by Richard and colleagues (which is the only paper we identified on the topic using NHANES data and based on which the current risk of bias assessment has been conducted), different measurement waves were included for our meta-analysis. Measurements of the following waves were used in which all dependent and confounding variables were assessed: 2005-2006, 2007-2008, 2009-2010, 2011-2012. For outcomes the 2015 follow-up measurements were used.									

References

1. Clays E, Lidegaard M, De Bacquer D, et al. The combined relationship of occupational and leisure-time physical activity with all-cause mortality among men, accounting for physical fitness. *American journal of epidemiology* 2014;179(5):559-66. doi: 10.1093/aje/kwt294
2. Taylor HL, Jacobs Jr DR, Schucker B, et al. A questionnaire for the assessment of leisure time physical activities. *Journal of Chronic Diseases* 1978;31(12):741-55. doi: 10.1016/0021-9681(78)90058-9
3. Saidj M, Jorgensen T, Jacobsen RK, et al. Separate and joint associations of occupational and leisure-time sitting with cardio-metabolic risk factors in working adults: a cross-sectional study. *PloS one* 2013;8(8):e70213. doi: 10.1371/journal.pone.0070213
4. Andersen LG, Groenvold M, Jørgensen T, Aadahl M. Construct validity of a revised Physical Activity Scale and testing by cognitive interviewing. *Scandinavian journal of public health* 2010;38(7):707-14. doi: 10.1177/1403494810380099
5. Sjøl A, Thomsen KK, Schroll M, Andersen LB. Secular trends in acute myocardial infarction in relation to physical activity in the general Danish population. *Scandinavian journal of medicine & science in sports* 2003;13(4):224-30.
6. Krause N, Arah OA, Kauhanen J. Physical activity and 22-year all-cause and coronary heart disease mortality. *American Journal of Industrial Medicine* 2017;60(11):976-90. doi: 10.1002/ajim.22756
7. Lakka TA, Salonen JT. Intra-person variability of various physical activity assessments in the kuopio ischaemic heart disease risk factor study. *International journal of epidemiology* 1992;21(3):467–72. doi: 10.1093/ije/21.3.467
8. Pulsford RM, Stamatakis E, Britton AR, et al. Associations of sitting behaviours with all-cause mortality over a 16-year follow-up: the Whitehall II study. . *International journal of epidemiology* 2015;44(6):1909-16.
9. Eaton CB, Medalie JH, Flocke SA, et al. Self-reported physical activity predicts long-term coronary heart disease and all-cause mortalities. Twenty-one-year follow-up of the Israeli Ischemic Heart Disease Study. *Archives of family medicine* 1995;4(4):323-29.
10. Autenrieth CS, Baumert J, Baumeister SE, et al. Association between domains of physical activity and all-cause, cardiovascular and cancer mortality. *European journal of epidemiology* 2011;26(2):91-99. doi: 10.1007/s10654-010-9517-6
11. Iqbal R, Rafique G, Badruddin S, et al. Validating MOSPA questionnaire for measuring physical activity in Pakistani women. *Nutr J* 2006;5:18. doi: 10.1186/1475-2891-5-18
12. Rosengren A, Wilhelmsen L. Physical activity protects against coronary death and deaths from all causes in middle-aged men. Evidence from a 20-year follow-up of the primary prevention study in Goteborg. *Annals of Epidemiology* 1997;7(1):69-75.
13. Wilhelmsen L, Tibblin G, Aurell M, et al. Physical activity, physical fitness and risk of myocardial infarction. *Advances in Cardiology* 1976;18(0):217-30. doi: 10.1159/000399526
14. Richard A, Martin B, Wanner M, et al. Effects of leisure-time and occupational physical activity on total mortality risk in NHANES III according to sex, ethnicity, central obesity, and age. *Journal of physical activity & health* 2015;12(2):184-92. doi: 10.1123/jpah.2013-0198
15. Moe B, Mork PJ, Holtermann A, Nilsen TI. Occupational physical activity, metabolic syndrome and risk of death from all causes and cardiovascular disease in the HUNT 2 cohort study. *Occupational and Environmental Medicine* 2013;70(2):86-90. doi: 10.1136/oemed-2012-100734

16. Franzon K, Zethelius B, Cederholm T, Kilander L. Modifiable midlife risk factors, independent aging, and survival in older men: report on long-term follow-up of the Uppsala Longitudinal Study of Adult Men cohort. *Journal of the American Geriatrics Society* 2015;63(5):877-85. doi: 10.1111/jgs.13352
17. Huerta JM, Chirlaque MD, Tormo MJ, et al. Work, household, and leisure-time physical activity and risk of mortality in the EPIC-Spain cohort. *Preventive medicine* 2016;85:106-12. doi: 10.1016/j.ypmed.2016.02.009
18. Peters T, Brage S, Westgate K, et al. Validity of a short questionnaire to assess physical activity in 10 European countries. *European journal of epidemiology* 2012;27(1):15-25. doi: 10.1007/s10654-011-9625-y
19. Johnsen AM, Alfredsson L, Knutsson A, et al. Association between occupational physical activity and myocardial infarction: a prospective cohort study. *BMJ Open* 2016;6(10):e012692. doi: 10.1136/bmjopen-2016-012692
20. Bahls M, Groß S, Baumeister SE, et al. Association of domain-specific physical activity and cardiorespiratory fitness with all-cause and cause-specific mortality in two population-based cohort studies. *Sci Rep* 2018;8(1):16066. doi: 10.1038/s41598-018-34468-7
21. Philippaerts RM, Westerterp KR, Lefevre J. Doubly labelled water validation of three physical activity questionnaires. . *International Journal of Sports Medicine* 1999;20:284–89. doi: https://doi.org/10.1055/s-2007-971132
22. Wanner M, Tarnutzer S, Martin BW, et al. Impact of different domains of physical activity on cause-specific mortality: a longitudinal study. *Preventive medicine* 2014;62:89-95. doi: 10.1016/j.ypmed.2014.01.025
23. Petersen CB, Eriksen L, Tolstrup JS, et al. Occupational heavy lifting and risk of ischemic heart disease and all-cause mortality. *BMC Public Health* 2012;12:1070. doi: 10.1186/1471-2458-12-1070
24. Dalene KE, Tarp J, Selmer RM, et al. Occupational physical activity and longevity: A prospective cohort study of 437 378 Norwegian working men and women. *Lancet Public Health* 2021;6(6):e386-e95. doi: 10.1016/S2468-2667(21)00032-3
25. Holtermann A, Marott JL, Gyntelberg F, et al. Occupational and leisure time physical activity: risk of all-cause mortality and myocardial infarction in the Copenhagen City Heart Study. A prospective cohort study. *BMJ Open* 2012;2(1):e000556. doi: 10.1136/bmjopen-2011-000556
26. Holtermann A, Schnohr P, Nordestgaard BG, Marott JL. The physical activity paradox in cardiovascular disease and all-cause mortality: the contemporary Copenhagen General Population Study with 104,046 adults. *European Heart Journal* 2021:ehab087. doi: 10.1093/eurheartj/ehab087
27. Holtermann A, Mortensen OS, Burr H, et al. The interplay between physical activity at work and during leisure time--risk of ischemic heart disease and all-cause mortality in middle-aged Caucasian men. *Scandinavian Journal of Work, Environment & Health* 2009;35(6):466-74.

Appendix 8. Association of occupational and leisure-time physical activity with all-cause mortality, with low physical activity as the reference category.

The association of occupational physical activity (left panels) and leisure-time physical activity (right panels) with all-cause mortality in males, using low physical activity as the reference category.

	Occupational physical activity			Leisure-time physical activity		
Model 1[1]	**n**	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Sedentary	121,424	18	0.89 [0.85-0.93]	64,306	19	1.23 [1.18-1.30]
Low	87,322	20	1.00 (reference)	132,592	22	1.00 (reference)
Moderate	66,687	19	1.06 [1.01-1.12]	94,012	22	0.81 [0.74-0.89]
High	41,782	19	1.17 [1.08-1.28]	29,559	20	0.64 [0.52-0.79]
Model 2[2]						
Sedentary	118,500	18	0.93 [0.91-0.95]	63,534	19	1.15 [1.10-1.20]
Low	86,734	20	1.00 (reference)	131,375	22	1.00 (reference)
Moderate	66,095	19	1.09 [1.07-1.12]	93,334	22	0.89 [0.84-0.94]
High	41,590	19	1.13 [1.07-1.20]	29,159	20	0.87 [0.81-0.93]
Model 3[3]						
Sedentary	115,367	17	0.99 [0.97-1.01]	61,375	18	1.14 [1.09-1.20]
Low	83,215	19	1.00 (reference)	126,414	21	1.00 (reference)
Moderate	63,869	18	1.02 [0.99-1.04]	91,450	21	0.90 [0.85-0.95]
High	39,474	18	1.06 [0.99-1.13]	28,122	19	0.87 [0.81-0.92]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval.

Note that the number of studies (N) differs across comparisons, as not all occupational and leisure-time physical activity categories were available from all studies (see Appendix 2 for an overview).

[1] Model 1: Unadjusted model

[2] Model 2: Adjusted for the other domain of physical activity, body mass index, age and smoking

[3] Model 3: Additionally adjusted for education level

Physical activity levels (during work and at leisure time) reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. For occupational physical activity, categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high). For leisure-time physical activity these categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure time activities such as slow walking or household activities (low), engaging in activities such as intense household activities or brisk walking (moderate), regular engagement in activities such as jogging or cycling (high).

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Association of occupational physical activity (left panels) and leisure-time physical activity (right panels) with all-cause mortality in females, using low physical activity as the reference category.

	Occupational physical activity			Leisure-time physical activity		
Model 1[1]	**n**	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Sedentary	93,528	13	0.90 [0.83-0.97]	58,946	13	1.36 [1.14-1.63]
Low	140,101	14	1.00 (reference)	172,135	15	1.00 (reference)
Moderate	61,377	11	0.89 [0.75-1.05]	63,244	15	0.78 [0.71-0.85]
High	12,829	11	1.32 [1.06-1.65]	17,313	13	0.60 [0.52-0.70]
Model 2[2]						
Sedentary	90,773	13	0.99 [0.93-1.06]	58,110	13	1.20 [1.13-1.28]
Low	139,029	14	1.00 (reference)	170,064	15	1.00 (reference)
Moderate	60,456	11	0.98 [0.95-1.01]	62,467	15	0.88 [0.82-0.94]
High	12,258	11	1.06 [0.93-1.20]	17,014	13	0.82 [0.73-0.93]
Model 3[3]						
Sedentary	89,512	13	1.02 [0.96-1.09]	57,812	13	1.18 [1.13-1.24]
Low	137,691	14	1.00 (reference)	169,189	15	1.00 (reference)
Moderate	59,244	11	0.96 [0.93-0.99]	61,433	15	0.91 [0.88-0.94]
High	12,158	11	1.00 [0.88-1.14]	15,849	13	0.85 [0.75-0.95]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval.

Note that the number of studies (N) differs across comparisons, as not all occupational and leisure-time physical activity categories were available from all studies (see Appendix 2 for an overview).

[1] Model 1: Unadjusted model

[2] Model 2: Adjusted for the other domain of physical activity, body mass index, age and smoking

[3] Model 3: Additionally adjusted for education level

Physical activity levels (during work and at leisure time) reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. For occupational physical activity, categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high). For leisure-time physical activity these categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure time activities such as slow walking or household activities (low), engaging in activities such as intense household activities or brisk walking (moderate), regular engagement in activities such as jogging or cycling (high).

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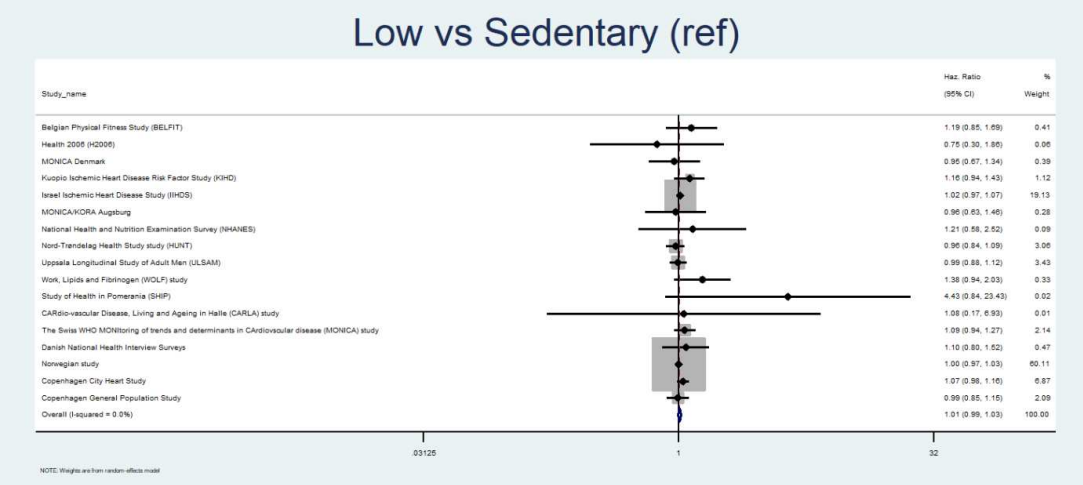
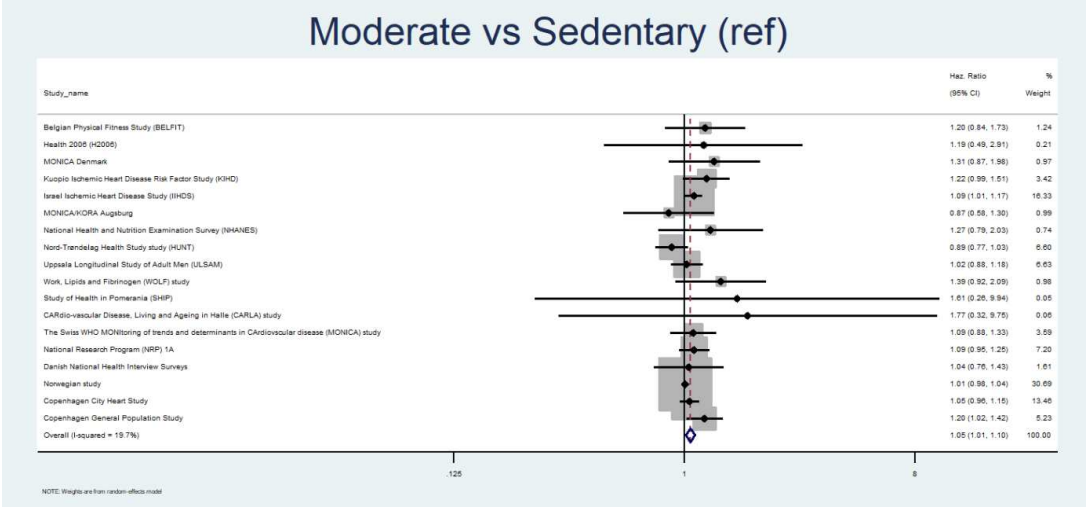
Appendix 9. Forest plots showing the individual study and pooled association of occupational and leisure-time physical activity with all-cause mortality. We report individual study effect sizes (HR with 95% confidence interval), their weight in the pooled effect size, and the pooled effect size (i.e., diamonds).

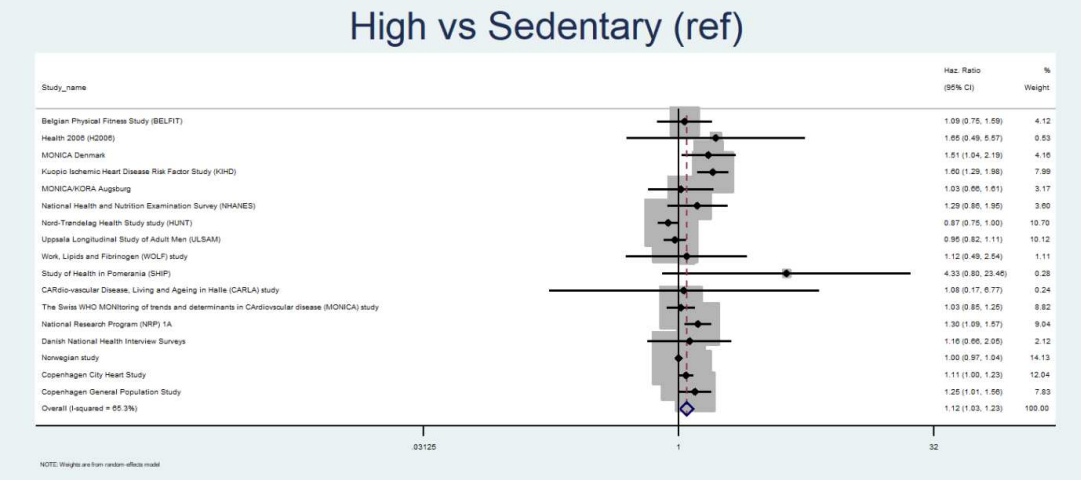
Forest plot showing the association of low versus sedentary occupational physical activity with all-cause mortality among males from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).



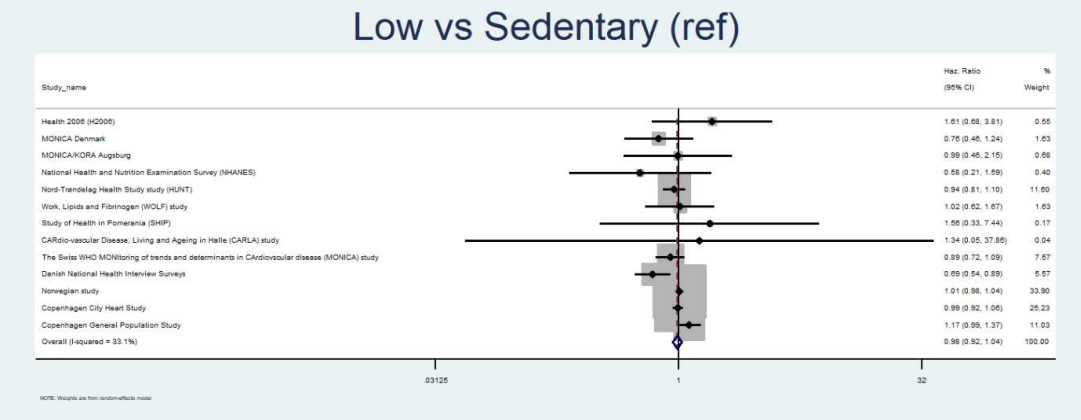
Forest plot showing the association of moderate versus sedentary occupational physical activity with all-cause mortality among males from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).


Moderate vs Sedentary (ref)
Study_name
Haz. Ratio (95% CI)
% Weight
Belgian Physical Fitness Study (BELFIT) 1.20 (0.84, 1.73) 1.24
Health 2006 (H2006) 1.19 (0.49, 2.91) 0.21
MONICA Denmark 1.31 (0.87, 1.98) 0.97
Kuopio Ischemic Heart Disease Risk Factor Study (KIHD) 1.22 (0.99, 1.51) 3.42
Israel Ischemic Heart Disease Study (IIHDS) 1.09 (1.01, 1.17) 16.33
MONICA/KORA Augsburg 0.87 (0.58, 1.30) 0.99
National Health and Nutrition Examination Survey (NHANES) 1.27 (0.79, 2.03) 0.74
Nord-Trøndelag Health Study study (HUNT) 0.89 (0.77, 1.03) 6.60
Uppsala Longitudinal Study of Adult Men (ULSAM) 1.02 (0.88, 1.18) 6.63
Work, Lipids and Fibrinogen (WOLF) study 1.39 (0.92, 2.09) 0.98
Study of Health in Pomerania (SHIP) 1.61 (0.26, 9.94) 0.05
CARdio-vascular Disease, Living and Ageing in Halle (CARLA) study 1.77 (0.32, 9.75) 0.06
The Swiss WHO MONitoring of trends and determinants in CArdiovscular disease (MONICA) study 1.09 (0.88, 1.33) 3.59
National Research Program (NRP) 1A 1.09 (0.95, 1.25) 7.20
Danish National Health Interview Surveys 1.04 (0.76, 1.43) 1.61
Norwegian study 1.01 (0.98, 1.04) 30.69
Copenhagen City Heart Study 1.05 (0.96, 1.15) 13.46
Copenhagen General Population Study 1.20 (1.02, 1.42) 5.23
Overall (I-squared = 19.7%) 1.05 (1.01, 1.10) 100.00
.125
1
8
NOTE: Weights are from random-effects model

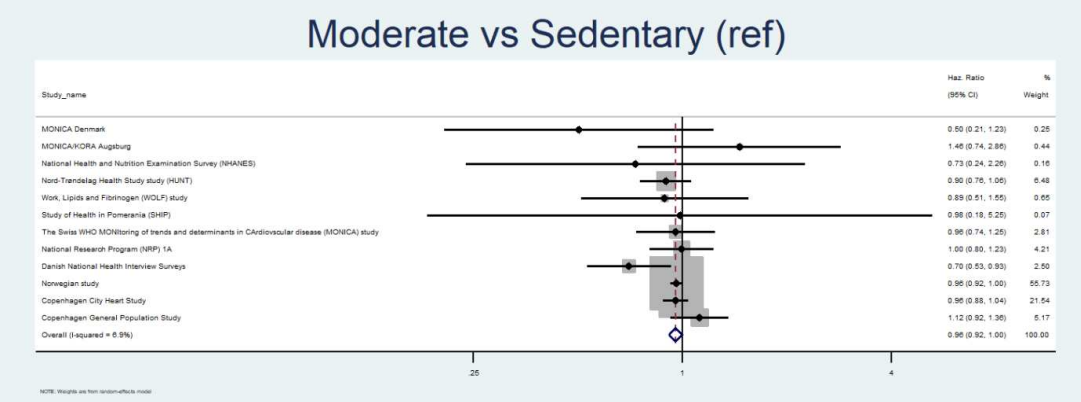
Forest plot showing the association of high versus sedentary occupational physical activity with all-cause mortality among males from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level) .



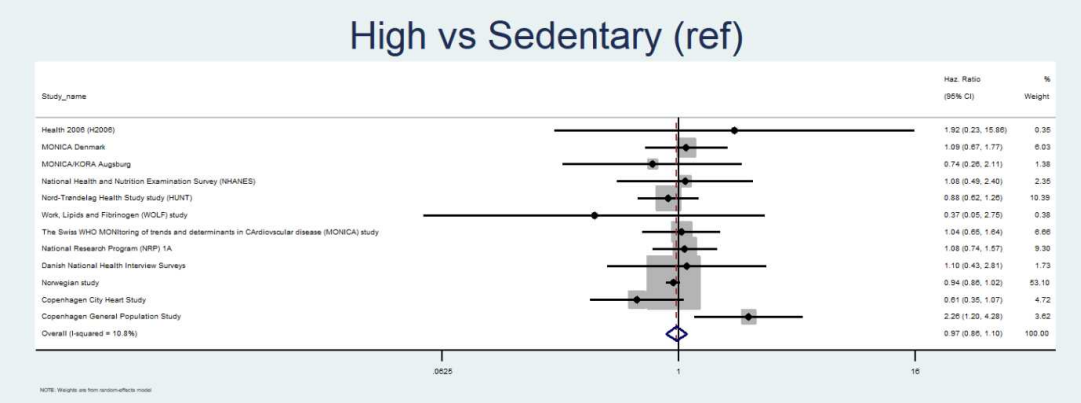
Forest plot showing the association of low versus sedentary occupational physical activity with all-cause mortality among females from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).



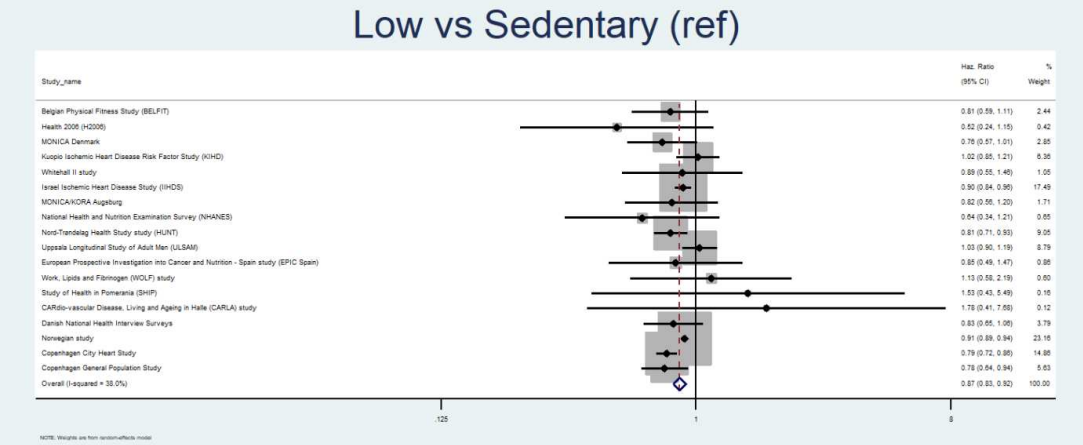
Forest plot showing the association of moderate versus sedentary occupational physical activity with all-cause mortality among females from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).



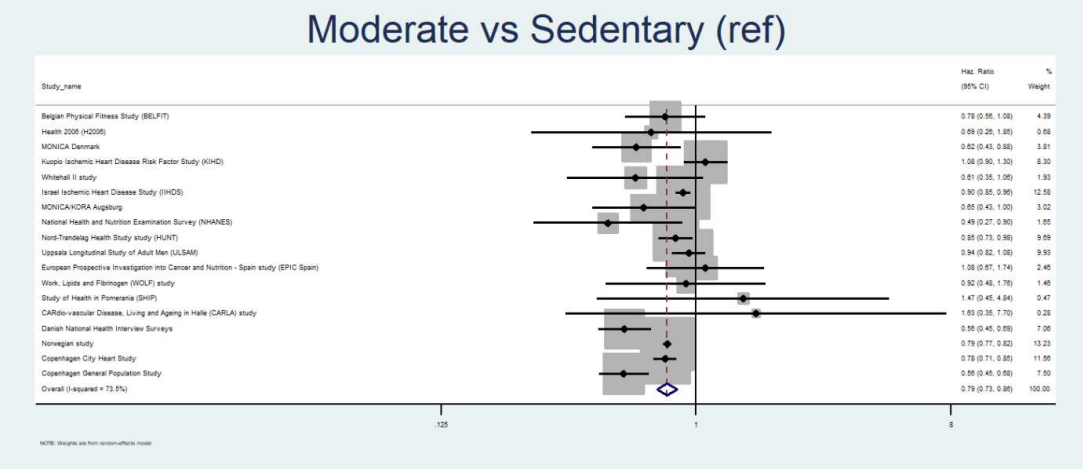
Forest plot showing the association of high versus sedentary occupational physical activity with all-cause mortality among females from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).



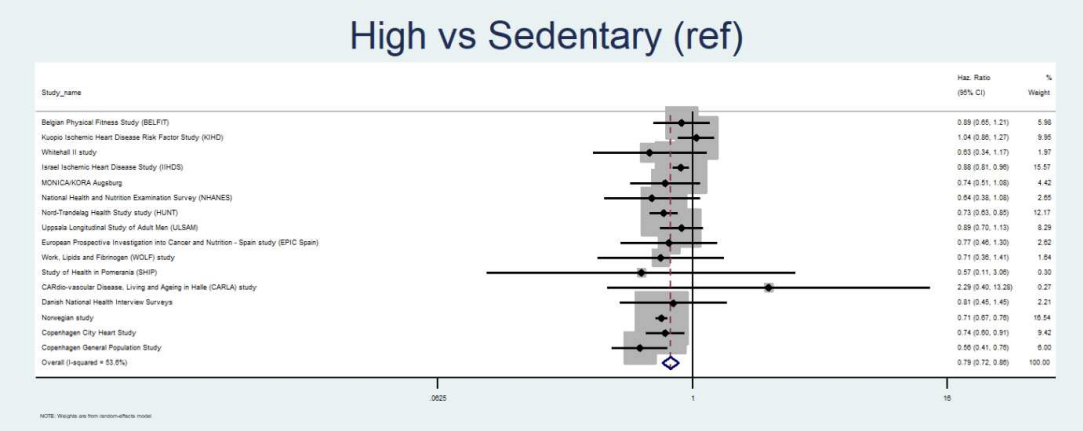
Forest plot showing the association of low versus sedentary leisure-time physical activity with all-cause mortality among males from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



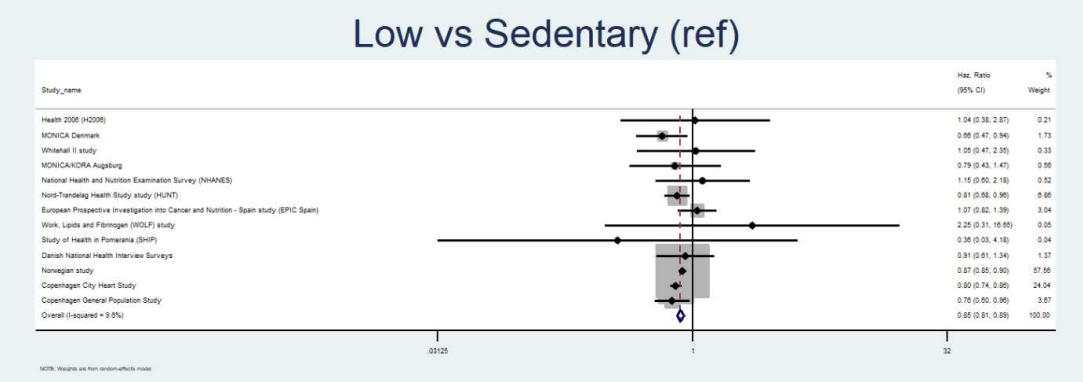
Forest plot showing the association of moderate versus sedentary leisure-time physical activity with all-cause mortality among males from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



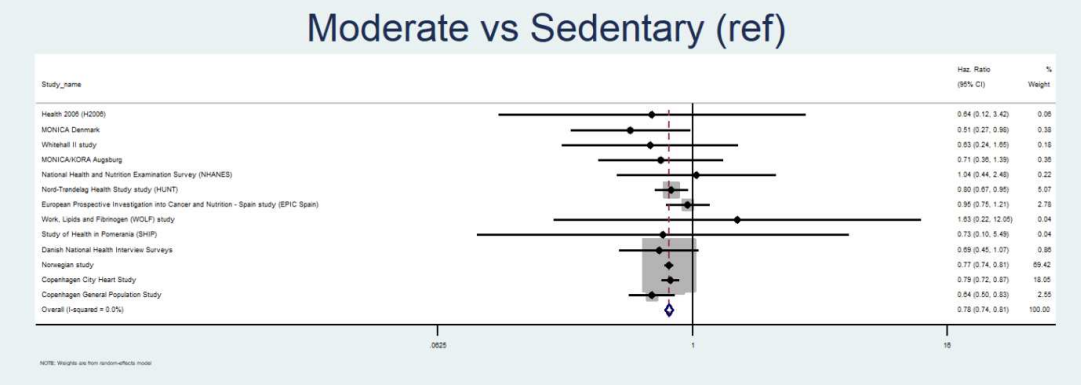
Forest plot showing the association of high versus sedentary leisure-time physical activity with all-cause mortality among males from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



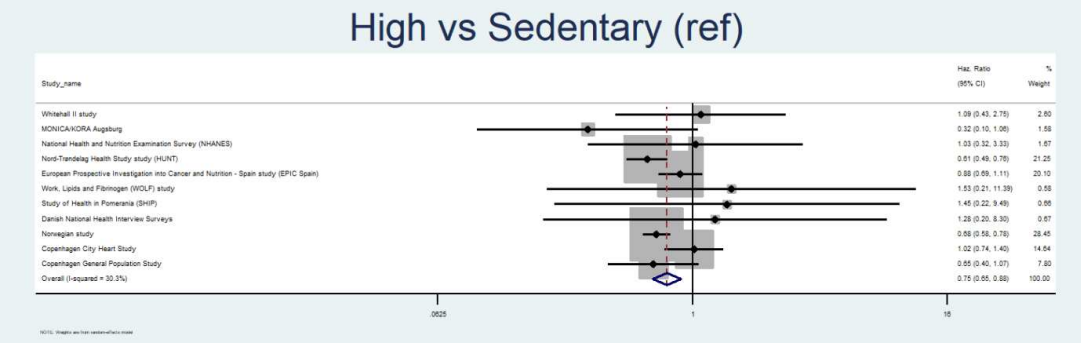
Forest plot showing the association of low versus sedentary leisure-time physical activity with all-cause mortality among females from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



Forest plot showing the association of moderate versus sedentary leisure-time physical activity with all-cause mortality among females from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



Forest plot showing the association of high versus sedentary leisure-time physical activity with all-cause mortality among females from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



Appendix 10. Sensitivity analysis showing the association of occupational physical activity (OPA) with all-cause mortality in males (left panel) and females (right panel), additionally adjusted for income (in addition to model 3 with adjustment for the other domain of physical activity, age, BMI and smoking and education level).

		Males		Females		
	n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Sedentary OPA	94,726	9	1.00 (reference)	76,396	6	1.00 (reference)
Low OPA	64,771	8	0.98 [0.95-1.01]	117,423	5	0.98 [0.92-1.04]
Moderate OPA	50,851	9	1.01 [0.96-1.06]	55,837	6	0.97 [0.94-1.01]
High OPA	29,558	8	1.02 [0.90-1.15]	19,488	5	1.02 [0.74-1.39]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; OPA = occupational physical activity.
Note that the number of studies (N) differs across comparisons, as not all occupational physical activity categories were available from all studies (see Appendix 2 for an overview).
Occupational physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high).

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Appendix 11. Sensitivity analysis showing the association of occupational physical activity (OPA) and leisure-time physical activity (LTPA) with all-cause mortality, stratified by education level.

The association of occupational physical activity (OPA) with all-cause mortality among males. Models with either the sedentary (left columns) and low OPA category (right column) as reference are shown.

		n	N	HR [95% CI]	n	N	HR [95% CI]
Low education level	Sedentary OPA	28,868	15	1.00 (reference)	28,774	14	1.01 [0.97-1.05]
	Low OPA	24,255	14	0.99 [0.95-1.03]	24,255	15	1.00 (reference)
	Moderate OPA	24,735	15	0.99 [0.94-1.04]	24,446	15	0.99 [0.95-1.02]
	High OPA	15,952	14	1.02 [0.93-1.13]	15,800	14	1.00 [0.96-1.04]
Moderate education level	Sedentary OPA	63,824	16	1.00 (reference)	63,455	15	0.99 [0.96-1.03]
	Low OPA	47,536	15	1.01 [0.97-1.04]	48,802	17	1.00 (reference)
	Moderate OPA	41,502	16	1.11 [1.02-1.20]	41,687	17	1.04 [1.01-1.08]
	High OPA	22,947	14	1.19 [1.02-1.37]	23,293	16	1.08 [0.95-1.22]
High education level	Sedentary OPA	54,543	8	1.00 (reference)	55,033	7	0.95 [0.90-1.00]
	Low OPA	26,333	7	1.06 [1.00-1.12]	27,164	9	1.00 (reference)
	Moderate OPA	10,560	8	1.10 [0.92-1.31]	10,289	8	1.07 [0.90-1.28]
	High OPA	4,793	7	1.12 [0.96-1.32]	5,399	8	1.08 [0.91-1.27]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; OPA = occupational physical activity
Note that the number of studies (N) differs across comparisons, as not all occupational physical activity categories were available from all studies (see Appendix 2 for an overview).
Estimates are from model 2: Adjusted for leisure-time physical activity, age, body mass index and smoking.
Occupational physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high).
Education levels reflect low (pre-primary/primary/lower secondary), moderate (upper secondary), and high (post-secondary) education, using the International Standard Classification of Education (ISCED-97).

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The association of occupational physical activity (OPA) with all-cause mortality among females. Models with either the sedentary (left columns) and low OPA category (right column) as reference are shown.

		n	N	HR [95% CI]	n	N	HR [95% CI]
Low education level	Sedentary OPA	25,563	10	1.00 (reference)	25,117	9	1.08 [1.00-1.16]
	Low OPA	48,980	9	0.93 [0.87-1.00]	48,964	10	1.00 (reference)
	Moderate OPA	22,547	10	0.87 [0.79-0.97]	22,264	9	0.94 [0.90-0.98]
	High OPA	7,011	9	0.93 [0.77-1.14]	6,928	9	1.08 [0.88-1.32]
Moderate education level	Sedentary OPA	61,277	13	1.00 (reference)	60,188	12	1.00 [0.89-1.12]
	Low OPA	75,131	12	1.00 [0.89-1.12]	74,887	13	1.00 (reference)
	Moderate OPA	38,337	12	0.92 [0.79-1.07]	37,941	11	0.95 [0.91-0.99]
	High OPA	4,928	8	1.15 [0.85-1.56]	4,617	8	1.02 [0.85-1.23]
High education level	Sedentary OPA	39,214	10	1.00 (reference)	38,363	8	1.06 [0.98-1.14]
	Low OPA	47,942	8	0.95 [0.88-1.02]	47,798	9	1.00 (reference)
	Moderate OPA	20,344	8	1.04 [0.94-1.15]	20,111	7	1.11 [1.01-1.22]
	High OPA	1,099	6	1.18 [0.85-1.64]	1,070	6	1.16 [0.87-1.54]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; OPA = occupational physical activity
Note that the number of studies (N) differs across comparisons, as not all occupational physical activity categories were available from all studies (see Appendix 2 for an overview).
Estimates are from model 2: Adjusted for leisure-time physical activity, age, body mass index and smoking.
Occupational physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high).

The association of leisure-time physical activity (LTPA) with all-cause mortality among males. Models with either the sedentary (left columns) and low LTPA category (right column) as reference are shown.

		n	N	HR [95% CI]	n	N	HR [95% CI]
Low education level	Sedentary LTPA	18,231	16	1.00 (reference)	18,231	16	1.11 [1.03-1.2]
	Low LTPA	37,868	16	0.90 [0.84-0.97]	38,948	19	1.00 (reference)
	Moderate LTPA	28,476	16	0.84 [0.77-0.92]	31,266	19	0.89 [0.84-0.95]
	High LTPA	7,823	13	0.83 [0.72-0.94]	8,179	16	0.88 [0.78-0.99]
		n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Moderate education level	Sedentary LTPA	34,650	18	1.00 (reference)	34,206	18	1.16 [1.09-1.24]
	Low LTPA	72,791	18	0.86 [0.81-0.92]	73,824	21	1.00 (reference)
	Moderate LTPA	51,799	18	0.78 [0.71-0.87]	54,551	21	0.90 [0.84-0.96]
	High LTPA	14,890	15	0.76 [0.65-0.89]	15,126	18	0.84 [0.77-0.92]
		n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
High education level	Sedentary LTPA	14,604	15	1.00 (reference)	14,604	14	1.21 [1.09-1.34]
	Low LTPA	39,747	14	0.83 [0.75-0.91]	40,655	19	1.00 (reference)
	Moderate LTPA	34,296	14	0.76 [0.66-0.87]	36,506	19	0.94 [0.88-1.01]
	High LTPA	10,229	12	0.80 [0.72-0.90]	11,375	17	0.94 [0.86-1.04]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; LTPA = leisure-time physical activity
Note that the number of studies (N) differs across comparisons, as not all leisure-time physical activity categories were available from all studies (see Appendix 2 for an overview).
Estimates are from model 2: Adjusted for occupational physical activity, age, body mass index and smoking.
Leisure-time physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure time activities such as slow walking or household activities (low), engaging in activities such as intense household activities or brisk walking (moderate), regular engagement in activities such as jogging or cycling (high).

The association of leisure-time physical activity (LTPA) with all-cause mortality among females. Models with either the sedentary (left columns) and low LTPA category (right column) as reference are shown.

		n	N	HR [95% CI]	n	N	HR [95% CI]
Low education level	Sedentary LTPA	17,488	10	1.00 (reference)	17,488	10	1.13 [1.09-1.18]
	Low LTPA	53,584	10	0.88 [0.85-0.92]	54,678	13	1.00 (reference)
	Moderate LTPA	25,570	10	0.80 [0.75-0.86]	26,806	13	0.92 [0.87-0.98]
	High LTPA	4,790	8	0.82 [0.63-1.07]	5,027	10	0.90 [0.70-1.16]
		n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Moderate education level	Sedentary LTPA	33,051	13	1.00 (reference)	33,051	13	1.21 [1.16-1.25]
	Low LTPA	99,501	13	0.83 [0.80-0.86]	100,279	15	1.00 (reference)
	Moderate LTPA	37,649	13	0.68 [0.58-0.79]	39,065	15	0.89 [0.83-0.94]
	High LTPA	6,907	9	0.69 [0.57-0.83]	7,143	11	0.77 [0.74-0.80]
		n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
High education level	Sedentary LTPA	14,084	9	1.00 (reference)	14,084	9	1.12 [1.03-1.22]
	Low LTPA	55,511	9	0.89 [0.82-0.97]	55,955	12	1.00 (reference)
	Moderate LTPA	31,026	8	0.81 [0.72-0.91]	32,059	11	0.95 [0.83-1.08]
	High LTPA	6,087	7	0.77 [0.61-0.96]	6,746	9	0.85 [0.70-1.03]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; LTPA = leisure-time physical activity

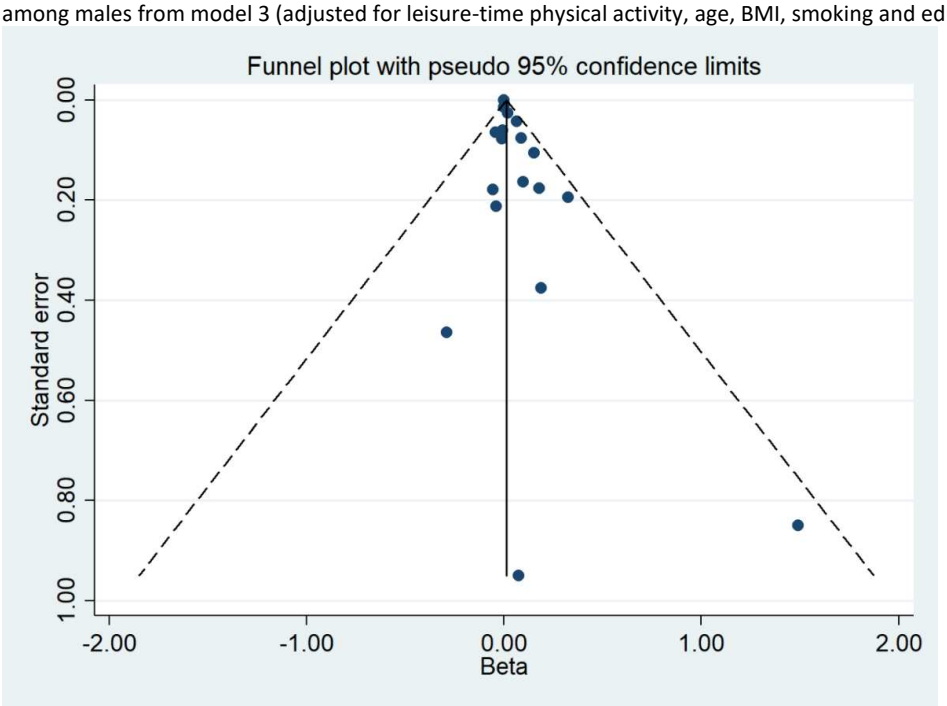
Note that the number of studies (N) differs across comparisons, as not all leisure-time physical activity categories were available from all studies (see Appendix 2 for an overview).

Estimates are from model 2: Adjusted for occupational physical activity, age, body mass index and smoking.

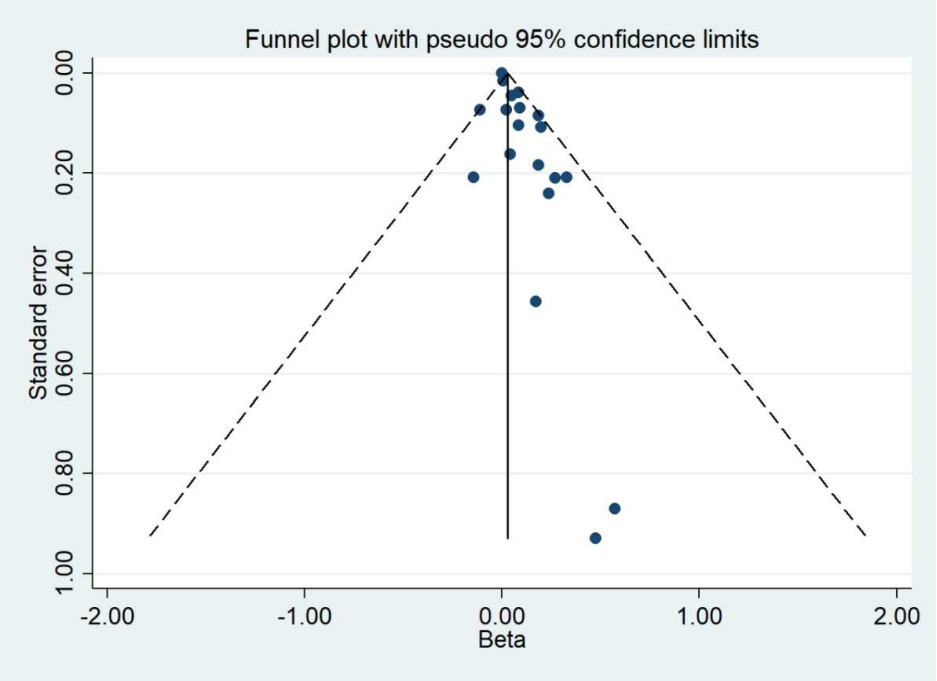
Leisure-time physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure time activities such as slow walking or household activities (low), engaging in activities such as intense household activities or brisk walking (moderate), regular engagement in activities such as jogging or cycling (high).

Appendix 12. Funnel plot showing the standard error of individual studies plotted against the beta, in order to indicate publication bias.

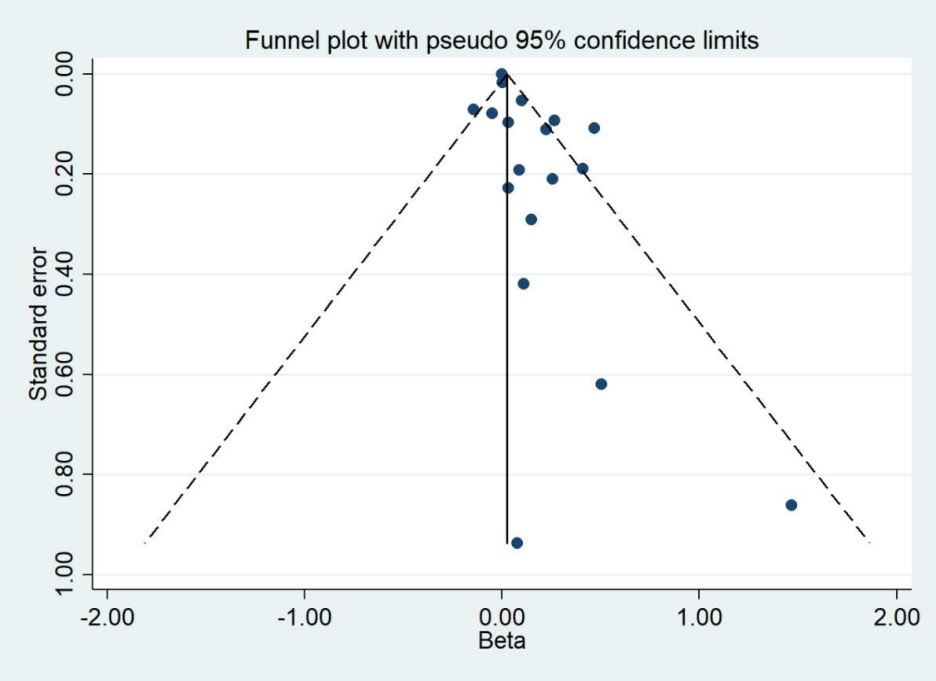
Funnel plot for the association of low versus sedentary occupational physical activity with all-cause mortality among males from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).



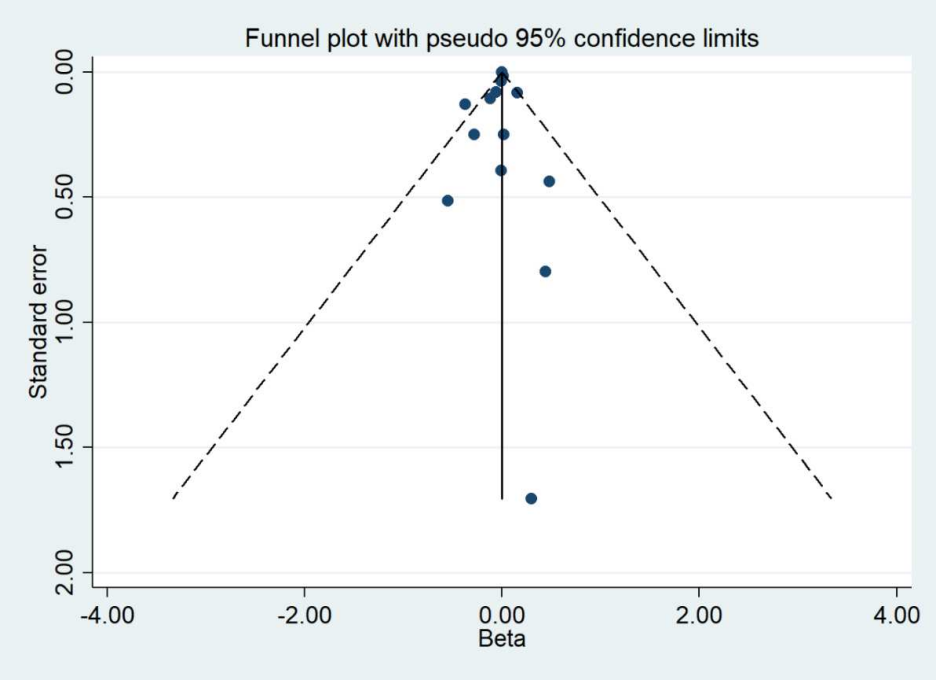
Funnel plot for the association of moderate versus sedentary occupational physical activity with all-cause mortality among males from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).



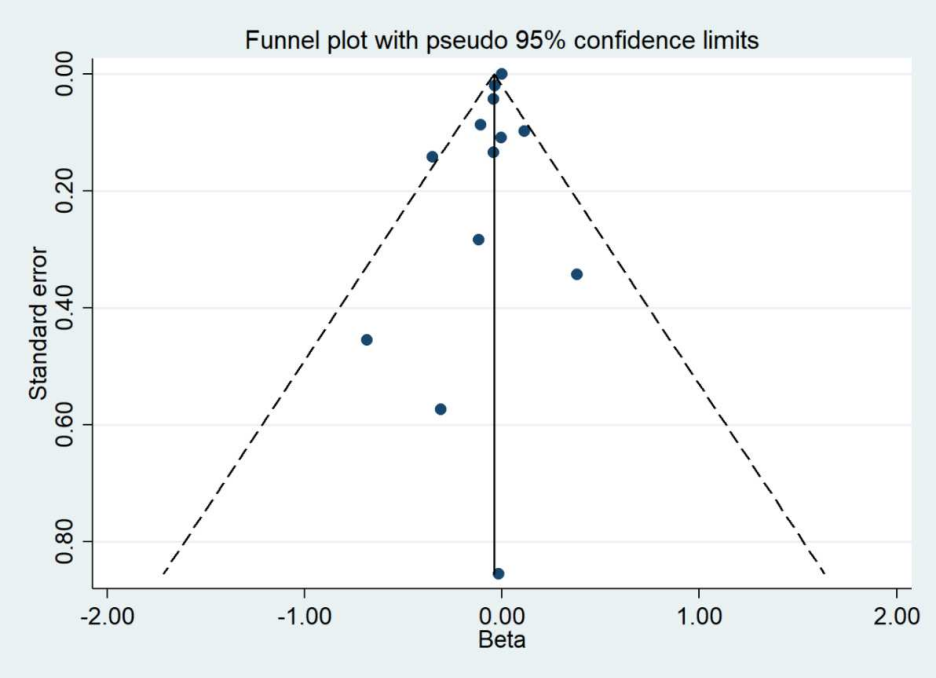
Funnel plot for the association of high versus sedentary occupational physical activity with all-cause mortality among males from model 3 (adjusted for leisure-time physical activity, age, BMI, smoking and education level).



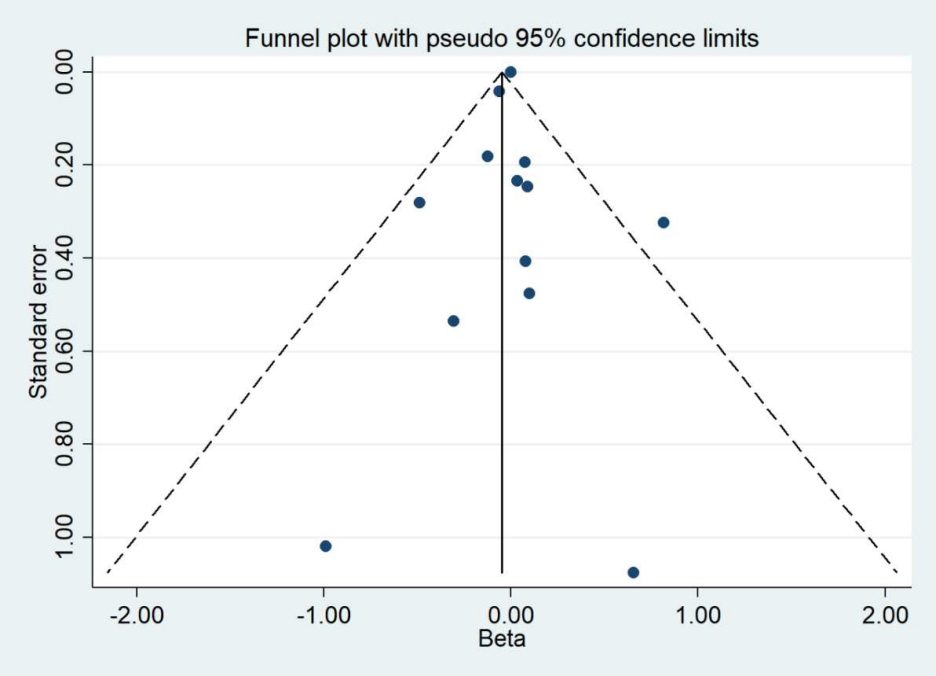
Funnel plot for the association of low versus sedentary leisure-time physical activity with all-cause mortality among females from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



Funnel plot for the association of moderate versus sedentary leisure-time physical activity with all-cause mortality among females from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



Funnel plot for the association of high versus sedentary leisure-time physical activity with all-cause mortality among females from model 3 (adjusted for occupational physical activity, age, BMI, smoking and education level).



Appendix 13. Sensitivity analyses showing the association of occupational and leisure-time physical activity with all-cause mortality for studies with low compared to moderate/high risk of bias regarding study participation, attrition and predictive variable (i.e., physical activity) assessment. Models are shown for males and females from model 3; i.e., adjusted for leisure-time physical activity, age, BMI, smoking and education level.

			Males			**Females**		
			n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Risk of bias regarding study participation	Low risk	Sedentary OPA	13,130	8	1.00 (reference)	6,537	5	1.00 (reference)
		Low OPA	11,070	8	1.00 [0.98 1.03]	5,862	5	1.01 [0.98 1.04]
		Moderate OPA	7,371	8	1.03 [0.98 1.09]	3,257	4	0.96 [0.93 1.00]
		High OPA	3,526	7	1.10 [0.99 1.22]	720	4	0.99 [0.82 1.19]
	Moderate/high risk	Sedentary OPA	103,186	10	1.00 (reference)	85,678	9	1.00 (reference)
		Low OPA	68,887	9	1.03 [0.99 1.08]	129,292	8	0.81 [0.70 0.95]
		Moderate OPA	55,193	10	1.09 [1.03 1.16]	57,225	8	0.83 [0.70 0.99]
		High OPA	33,771	10	1.17 [0.95 1.43]	5,792	8	1.02 [0.71 1.46]
			n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Risk of bias regarding attrition	Low risk	Sedentary OPA	113,431	13	1.00 (reference)	90,597	10	1.00 (reference)
		Low OPA	77,772	12	1.07 [0.83 1.38]	133,060	9	0.95 [0.63 1.43]
		Moderate OPA	61,126	13	1.26 [0.98 1.63]	59,949	10	0.58 [0.27 1.28]
		High OPA	36,127	12	1.33 [1.03 1.71]	5,703	10	1.12 [0.70 1.80]
	Moderate/high risk	Sedentary OPA	2,885	5	1.00 (reference)	1,618	4	1.00 (reference)
		Low OPA	2,185	5	1.01 [0.99 1.03]	2,094	4	0.98 [0.91 1.05]
		Moderate OPA	1,438	5	1.05 [1.00 1.10]	533	2	0.96 [0.92 1.00]
		High OPA	1,170	5	1.10 [1.00 1.21]	809	2	0.97 [0.83 1.14]
			n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Risk of bias regarding predictive variable (i.e., physical activity) assessment	Low risk	Sedentary OPA	77,269	5	1.00 (reference)	62,321	4	1.00 (reference)
		Low OPA	53,865	5	1.03 [0.99 1.06]	103,990	4	0.94 [0.84 1.05]
		Moderate OPA	42,785	5	1.07 [1.02 1.12]	39,844	2	0.95 [0.87 1.03]
		High OPA	26,039	5	1.09 [0.99 1.21]	4,069	2	1.01 [0.82 1.24]
	Moderate/high risk	Sedentary OPA	39,047	13	1.00 (reference)	29,894	10	1.00 (reference)
		Low OPA	26,092	12	1.05 [0.91 1.21]	31,164	9	1.01 [0.98 1.04]
		Moderate OPA	19,779	13	1.01 [0.98 1.04]	20,638	10	0.96 [0.92 1.00]
		High OPA	11,258	12	1.36 [0.90 2.04]	2,443	10	0.94 [0.87 1.02]

N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; OPA = Occupational physical activity
Occupational physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high).

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Appendix 14. Leave one study out analyses, showing the minimum and maximum hazard ratios found when leaving either of the 22 individual studies out of the model. Models are shown for both the association of occupational physical activity (OPA) and leisure-time physical activity (LTPA) and all-cause mortality for males and females and are from model 3; i.e., adjusted for leisure-time physical activity, age, BMI, smoking and education level.

			Males	**Females**
			HR [95% CI]	**HR [95% CI]**
Occupational physical activity	Minimum effect sizes	Sedentary OPA	1.00 (reference)	1.00 (reference)
		Low OPA	1.01 [0.99 1.03]	0.95 [0.86 1.05]
		Moderate OPA	1.04 [1.00 1.08]	0.95 [0.87 1.03]
		High OPA	1.07 [1.00 1.16]	0.94 [0.87 1.02]
	Maximum effect sizes	Sedentary OPA	1.00 (reference)	1.00 (reference)
		Low OPA	1.03 [0.99 1.07]	1.01 [0.98 1.03]
		Moderate OPA	1.07 [1.07 1.12]	0.96 [0.93 1.00]
		High OPA	1.16 [1.05 1.27]	1.02 [0.83 1.24]
Leisure-time physical activity	Minimum effect sizes	Sedentary LTPA	1.00 (reference)	1.00 (reference)
		Low LTPA	0.86 [0.82 0.91]	0.81 [0.76 0.87]
		Moderate LTPA	0.77 [0.71 0.84]	0.77 [0.74 0.80]
		High LTPA	0.77 [0.70 0.83]	0.71 [0.63 0.80]
	Maximum effect sizes	Sedentary LTPA	1.00 (reference)	1.00 (reference)
		Low LTPA	0.90 [0.87 0.93]	0.87 [0.84 0.89]
		Moderate LTPA	0.82 [0.75 0.88]	0.78 [0.73 0.84]
		High LTPA	0.81 [0.73 0.88]	0.80 [0.67 0.94]

HR = hazard ratio; 95% CI = 95% confidence interval; OPA = Occupational physical activity; LTPA = Leisure-time physical activity

Occupational physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high).

Leisure-time physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: almost no regular physical activity, spending most leisure time sitting (sedentary), occasionally engaging in leisure time activities such as slow walking or household activities (low), engaging in activities such as intense household activities or brisk walking (moderate), regular engagement in activities such as jogging or cycling (high).

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Appendix 15. Sensitivity analysis showing the association of occupational and leisure-time physical activity with all-cause mortality for studies with baseline assessment of physical activity in 1989 or earlier versus in 1990 or later. Models are shown for males and females and are from model 3; i.e., adjusted for leisure-time physical activity, age, BMI, smoking and education level.

			Males			Females		
			n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Year of baseline assessment	1989 or earlier	Sedentary OPA	90,317	11	1.00 (reference)	67,273	7	1.00 (reference)
		Low OPA	64,011	10	1.01 [0.90-1.14]	111,549	6	1.05 [0.94-1.17]
		Moderate OPA	50,249	11	1.12 [0.93-1.35]	44,957	7	0.98 [0.87-1.11]
		High OPA	29,513	10	1.14 [0.88-1.47]	5,305	7	1.19 [0.71-1.99]
	1990 or later	Sedentary OPA	25,999	7	1.00 (reference)	24,942	7	1.00 (reference)
		Low OPA	15,946	7	1.01 [0.99-1.04]	23,605	7	0.95 [0.87-1.03]
		Moderate OPA	12,315	7	1.04 [1.00-1.07]	15,525	5	0.95 [0.89-1.01]
		High OPA	7,784	7	1.14 [1.02-1.26]	1,207	5	0.94 [0.87-1.02]

N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; OPA = Occupational physical activity
Note that the number of studies (N) differs across comparisons, as not all occupational physical activity categories were available from all studies (see Appendix 4 for an overview).
Occupational physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high).

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Appendix 16. Sensitivity analyses showing the association of occupational physical activity (OPA) with all-cause mortality in males (left panel) and females (right panel) after exclusion of participants who died during the first three years after baseline from the analytic sample.

	Males			Females		
	n	**N**	**HR [95% CI]**	**n**	**N**	**HR [95% CI]**
Sedentary OPA	115,965	18	1.00 (reference)	92,232	14	1.00 (reference)
Low OPA	81,127	17	1.02 [1.00-1.04]	135,184	13	1.01 [0.98-1.04]
Moderate OPA	62,417	18	1.04 [1.00-1.08]	60,582	12	0.97 [0.94-1.00]
High OPA	37,142	17	1.10 [1.01-1.20]	6,566	12	0.93 [0.74-1.18]

n = number of participants; N = number of studies; HR = hazard ratio; 95% CI = 95% confidence interval; OPA = occupational physical activity.
Note that the number of studies (N) differs across comparisons, as not all occupational physical activity categories were available from all studies (see Appendix 4 for an overview).
Model 3: adjusted for leisure-time physical activity, age, body mass index, smoking and education level.
Occupational physical activity levels reflect the physical activity continuum, i.e., sedentary, low, moderate, and high. Categories roughly indicate: mainly sitting work (sedentary), work that mainly involves standing or walking, but without lifting or carrying loads (low), work that involves carrying light objects or walking stairs (moderate), physically demanding work involving frequent carrying or lifting heavy loads (high).

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