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Original Article

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Associations of psychosocial and physical work demands with all-cause mortality: a pooled analysis of prospective cohort studies

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Abstract

Background: The findings regarding mortality risk attributable to psychosocial and physical work demands are inconsistent. Pooled estimates using participant-level data from multiple cohort studies may provide more conclusive evidence.

Methods: Four prospective cohort studies conducted in England, Finland, France, and the USA were used (age 36–62 years; $n = 41\ 760$). We studied 34 903 and 36 076 individuals who had baseline (1981–2005) information on self-reported psychosocial and physical work demands, respectively. All-cause mortality until the year 2018 was ascertained through linkage to national registers, National Death Index, and company databases. We investigated the associations of psychosocial and physical demands with all-cause mortality separately for females and males using Cox regression models that were adjusted for socio-demographic and lifestyle factors. Using random-effects meta-analysis, we calculated pooled estimates of all-cause mortality for moderate and high exposure levels.

Results: During the mean follow-up of 25 years, 2105 deaths occurred among females and 5048 deaths occurred among males with information on psychosocial demands. The corresponding numbers for those with information on physical demands were 2176 and 5101. Fully adjusted models indicated that psychosocial demands were associated with both lower and higher all-cause mortality risks in both sexes. Physical demands increased the risk of all-cause mortality in both sexes and the association was strongest among males with moderate exposure levels (pooled hazard ratio 1.10, 95% confidence interval 1.02–1.19).

Conclusion: The relationship between psychosocial work demands and all-cause mortality remains inconclusive, whereas moderate physical work demands increase the mortality risk among males.

Keywords: work exposure; psychological demands; physical demands; occupational physical activity; mortality; meta-analysis; individual participant data.

Key Messages

- This study examined the associations of psychosocial and physical work demands with all-cause mortality among 41 760 participants from Europe and the USA using pooled analysis of participant-level data.
- After adjusting for baseline socio-demographic and lifestyle factors, we found both weak positive and negative associations between moderate to high psychosocial demands and all-cause mortality, yet there was a rigorous positive association for moderate to high physical demands in females and males.
- The data suggest inconclusive evidence of any association between higher levels of psychosocial demands and all-cause mortality, whereas exposure to higher levels of physical demands may increase the risk of all-cause mortality, particularly among males.

Introduction

Work, depending on its characteristics, can either promote or diminish one's chances of living into old age. Psychosocial work stressors, when defined as low job control or high job strain, have been generally shown to increase the risk of mortality [1–8]. However, when assessed as high psychosocial demands, they have been associated with lower [8] and higher [7] risks of mortality or no association [1–3].

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The relationship between physical work demands and mortality is likewise unclear [9–17]. The recent scientific literature has recognized the contradictory outcomes that result from leisure-time and work-related physical activities, known as the physical activity (PA) health paradox [11]. Although PA is generally a protective factor against many diseases, extended hours of physically heavy work have been suggested to negatively affect cardiovascular and musculoskeletal health [12, 18] and may eventually contribute to overall mortality [13].

To date, studies that have addressed the associations of psychosocial and physical work demands with all-cause mortality have mostly used either a single cohort [1, 7, 9, 13–15], which may have lacked sufficient power from which to draw conclusions, or meta-analyses of published results [2, 16, 17], which are prone to selective reporting and publication bias [19], whereas pooled estimates with participant-level data from several cohort studies enables analysis with large sample sizes, standardized analyses across studies, and further evaluation of the replicability of the findings [20–22]. Therefore, this method potentially increases the precision as well as the generalizability of the estimates that could not otherwise be achieved through single-cohort studies [22].

This study aimed to investigate the relationships of psychosocial and physical work demands with all-cause mortality using individual participant data from multiple cohort studies across Europe and the USA. Additionally, as previous studies have indicated that the impacts of work exposures might be more detrimental among males than females [4–6, 13, 16, 23, 24], we studied the associations separately by sex.

Methods

Study population

We used data from four prospective cohort studies that were conducted in England [English Longitudinal Study of Ageing (ELSA)], Finland [Finnish Longitudinal Study of Aging Municipal Employees (FLAME)], France [*GAZ* and *Electricité* (GAZEL)], and the USA [The Health and Retirement Study (HRS)] (Table 1) [25–30]. The participants in ELSA are a national representative sample of the general population aged ≥50 years who live in private households in England. FLAME was conducted among public-sector workers aged 44–58 years at baseline across different municipalities in Finland. The GAZEL cohort comprised employees of the French national gas and electricity companies (*Électricité de France-Gaz de France*/EDF-GDF) with a baseline age ranging from 35 years for females and 40 years for males to 50 years old. HRS was based on representative sample of a ≥50-year-old population in the USA. In all cohorts, participation was voluntary and participants gave their informed consent. The relevant ethical committees granted the ethical approval for each of the studies.

All-cause mortality

All-cause mortality was ascertained through linkage to national registers, the National Death Index, and the EDF-GDF database (GAZEL). We extracted the register linked year of death from each cohort. Mortality data were available until 2012 for ELSA, 2010 for FLAME, 2018 for GAZEL, and 2017 for HRS.

Measurement of the work exposures

Psychosocial demands

Assessment of psychosocial work demand in ELSA was based on participant's agreement with the statement: "I am under constant time pressure due to a heavy workload." In FLAME, it was assessed through three questions concerning accuracy at information processing, complex decision-making, and decision-making under pressure. GAZEL had a single question: "Do you find your work mentally tiring?" In HRS, it was a question that asked whether much stress was involved in the participant's current job.

Physical demands

In ELSA, physical work demand was assessed using a single-item question regarding the degree of physical effort required in the job. FLAME had four questions on physical demands at work, including standing in one place, continuous walking or movement, carrying objects by hand, and sudden strainful effort. In GAZEL, physical demand was based on a single item: "Do you find your work physically tiring?" In HRS, it was measured using two questions, asking whether the participant's current job required a lot of physical effort and the lifting of heavy loads.

The questions that were used to measure psychosocial and physical work demands in the present study have been used and some have been validated in existing studies [31–35]. Details of the measurement reliability are provided in the Supplementary material. While psychosocial demands were mostly measured using a single item and therefore may lack information about the specificity of the work stress, the single questions have been reported to correlate with a GHQ-12, which is a scale for assessing mental ill-health with strong psychometric properties [36]. Similarly, although some measures of physical demands were not validated, the questions were narrowly defined, making them less likely to be misinterpreted and deviate from the physical demands construct.

We harmonized the psychosocial and physical demands variables across the cohorts to express them as three exposure levels (low, moderate, and high). Throughout the cohorts, the least intense responses were classified as low whereas the most intense responses were high. Anything between the least and most intense responses were considered to be moderate. We used three categories to discriminate the risk of mortality between different levels of exposures. The exact question wordings and response categories are given in Supplementary Table S1.

Covariates

Socio-demographic (baseline age, sex, and level of education) and lifestyle factors [smoking, alcohol consumption, and leisure-time PA (LTPA)] were used as covariates (Supplementary Table S1). People in manual compared with those in professional occupations are more likely to be males, come from a lower socioeconomic position, and adopt health-deteriorating behaviors, which are known to be independently associated with higher mortality risk [16, 37, 38]. Therefore, we accounted for them in the analysis to achieve unbiased results. Psychosocial and physical demands were mutually adjusted in the models.

Statistical analysis

We stratified the analyses by sex and type of work demands. We determined the characteristics of the participants as

Table 1. Description of the study population by cohort

Cohort	Baseline	Follow-up [years, mean (SD)]	Age at baseline [years, median (IQR), range]	No. of eligible participants at baseline	No. of participants with information on psychosocial work demands (%)	Person-years[a]	No. of deaths (per 10 000 person-years)[a]	No. of participants with information on physical work demands (%)	Person-years[b]	No. of deaths (per 10 000 person-years)[b]
ELSA[c]	2002–5[c]	10.2 (1.1)[c]	56 (6), 50–62	5174[d]	2144 (41.4)	22 025	69 (31.3)	3423 (66.2)	34 920	129 (36.9)
FLAME	1981	25.5 (6.4)	50 (6), 44–58	6234	5864 (94.0)	149 749	1992 (133.0)	6085 (97.6)	155 035	2095 (135.1)
GAZEL	1989	27.6 (4.5)	44 (5), 36–50	20 591	20 295 (98.6)	560 193	2879 (51.4)	19 932 (96.8)	550 083	2827 (51.4)
HRS	1992	21.9 (6.0)	55 (5), 50–62	9761	6600 (67.6)	144 826	2213 (152.8)	6636 (68.0)	145 628	2226 (152.9)

ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité*; HRS, Health and Retirement Study; SD, standard deviation; IQR, interquartile range.

[a] Based on the number of participants exposed to psychosocial work demands.

[b] Based on the number of participants exposed to physical work demands.

[c] Work exposures in ELSA were measured in different study waves: physical demands in Wave 1, 2002–3 and psychosocial demands in Wave 2, 2004–5. The mean (SD) follow-up time presented in the table is based on the physical work demands. The mean (SD) follow-up time of the psychosocial work demands is 10.3 (0.8).

[d] All the participants who entered the study at Wave 1 between the ages of 50 and 62 years.

frequencies and percentages for categorical variables, and as median and interquartile range (IQR) for continuous variables. Participants from each cohort were followed up for the incidence of all-cause mortality from baseline measurement of the respective work demands until the time of death or end of follow-up, whichever occurred first. We used the follow-up years as a timescale variable in the analysis.

The associations of psychosocial and physical demands with all-cause mortality were examined in two steps. First, we investigated the associations for both work demands separately in each cohort using Cox proportional-hazards regression models. Crude associations were calculated in Model 1, followed by hazard ratios (HRs) and their 95% confidence intervals (CIs) adjusted for socio-demographic variables (Model 2), additionally adjusted for lifestyle factors (Model 3), and further adjusted for work factors, physical or psychosocial demands accordingly (Model 4, fully adjusted), by referencing the low-exposure group. We then tested the proportional-hazards assumption for Model 4. Because the assumption was violated, we used Weibull distribution to model the hazard function. Second, we calculated the pooled estimates of all-cause mortality for both work demands based on the cohort-specific HRs from Model 4 by using a random-effects meta-analysis. Heterogeneity between studies was calculated by using the Higgins' I^2 test statistic and the Paule–Mandel estimator for τ^2 [2]. Nelson–Aalen cumulative hazard curves for all-cause mortality are also presented. The analyses were performed in Strata version 17 and R version 4.2.2.

Results

The participants were followed up for an average of 25 years [standard deviation (SD) 7], with the shortest mean follow-up year in ELSA (10.2 years, SD 1.1) and longest in GAZEL (27.6 years, SD 4.5) (Table 1). Among participants with psychosocial work demands, we recorded 5048 deaths from all causes among males (out of 7153 deaths) over 554 718 person-years (py) at risk (out of 876 793 py), resulting in an incidence rate of 91.0 per 10 000 py. Among participants with physical work demands, 5101 out of 7277 deaths were contributed by males during 558 137 py (out of 885 666 py) with an incidence rate of 91.4 per 10 000 py. Detailed description of the distribution of socio-demographic and lifestyle factors by cohort and by psychosocial and physical demands for females (Tables 2a and 2b) and males (Tables 3a and 3b) is provided in the Supplementary material.

All-cause mortality among females

The pooled estimates (Fig. 1a) based on the fully adjusted models showed lower risk of all-cause mortality for females with moderate (HR 0.96, 95% CI 0.85–1.07) and high (HR 0.98, 95% CI 0.82–1.17) compared with those with low psychosocial work demands. No heterogeneity between the cohorts was observed for the estimates for moderate exposure ($I^2 = 0\%$) but there was modest heterogeneity for the estimates for high exposure ($I^2 = 39\%$). The cohort-specific results (Table 4a) showed inconsistent associations throughout Models 1–4, suggesting that the risk would increase or decrease, depending on the model and cohort. Regarding the physical work demands, the pooled estimates indicated that the risk of mortality increased for moderate (HR 1.02, 95% CI 0.86–1.21) and high (HR 1.06, 95% CI 0.91–1.23) exposure levels. Between-study heterogeneity (I^2) was low, at 22% and 25%, individually. In both work demands, based on the cohort-specific results, a few strong associations with mortality were found in Models 1 and 2, which were not sustained after adjustment for lifestyle factors (Model 3).

All-cause mortality among males

The pooled estimates for psychosocial work demands among males (Fig. 1b) based on the fully adjusted models showed lower risk of all-cause mortality at moderate (HR 0.98, 95% CI 0.90–1.06) and high (HR 0.96, 95% CI 0.88–1.05) exposures versus low with no heterogeneity between the cohorts ($I^2 = 0\%$). Conflicting indications of positive and negative associations were seen throughout the cohort-specific results from Models 1 to 4 (Table 4b). In terms of the physical work demands, the pooled estimates suggested that the mortality risk increased by a 10%-point (HR 1.10, 95% CI 1.02–1.19) and 7%-point (HR 1.07, 95% CI 0.98–1.17) among males with moderate and high exposure levels compared with low, correspondingly. In both work demands across the cohort-specific results, a few strong associations were recorded in Models 1 and 2, which were attenuated after adjustment for lifestyle factors (Model 3).

Cumulative hazard for all-cause mortality

Figure 2 presents the unadjusted cohort-specific Nelson–Aalen cumulative hazard estimates for all-cause mortality due to psychosocial and physical work demands by sex. The cumulative hazard increased linearly during the follow-up and the curves for each exposure level began to diverge in the fifth year of follow-up. The rates were higher for males than females and, in the case of physical demands, for those with moderate and high exposure levels than low.

Discussion

Our findings can be summarized as follows. (i) In both sexes, it was unclear whether psychosocial work demands increased or decreased all-cause mortality risk. (ii) Most of the findings demonstrated a positive association between physical work demands and all-cause mortality in both sexes, which was even more robust for moderate exposure among males. (iii) All-cause mortality risks attributable to physical demands were noticeably higher among males than females, whereas the same could not be said for psychosocial demands.

Our findings were inconclusive in terms of the effects of psychosocial demands on the risk of death. Our results among females partly resonate with those of studies that document both positive [6, 7] and negative [4, 8] associations with all-cause mortality. Similarly, in males, existing investigations showed that psychosocial demands were either not associated [3, 4] or, if any, associated with lower mortality risk [6, 8], and our results somewhat support the latter conclusion. However, exposure to psychosocial work stressors has been suggested to affect survival negatively, especially among males [4–6]. In the studies that show the association, psychosocial stressors were measured as high job strain, i.e. the combination of high job demands and low job control. Yet, our study included only job demands, which is narrower than the broad concept of psychosocial stressors, which therefore might explain the discrepancy with earlier findings.

Our study revealed that physical demands increased the risk of all-cause mortality in both sexes. The findings in our

Table 2a. Characteristics of the female participants based on the psychosocial work demands by cohort

Characteristics	Cohort											
	ELSA ($N = 1062$)			FLAME ($N = 3242$)			GAZEL ($N = 5494$)			HRS ($N = 3060$)		
	Low ($n = 606$)	Moderate ($n = 330$)	High ($n = 126$)	Low ($n = 539$)	Moderate ($n = 1268$)	High ($n = 1435$)	Low ($n = 1560$)	Moderate ($n = 1701$)	High ($n = 2233$)	Low ($n = 1157$)	Moderate ($n = 1271$)	High ($n = 632$)
Age (years) [median (IQR)]	55 (5)	54 (4)	53 (3)	51 (7)	50 (6)	50 (6)	41 (7)	42 (6)	42 (7)	56 (5)	55 (5)	54 (5)
Education [*n* (%)]												
High	331 (62.34)	242 (79.61)	100 (84.75)	15 (2.82)	118 (9.37)	264 (18.46)	1111 (73.33)	1213 (73.29)	1556 (71.61)	880 (76.06)	1031 (81.12)	526 (83.23)
Low	200 (37.66)	62 (20.39)	18 (15.25)	517 (97.18)	1142 (90.63)	1166 (81.54)	404 (26.67)	442 (26.71)	617 (28.39)	277 (23.94)	240 (18.88)	106 (16.77)
Physical work demands [*n* (%)]												
Low	225 (39.47)	152 (47.35)	42 (34.15)	22 (4.08)	193 (15.24)	322 (22.66)	1389 (92.29)	1107 (67.29)	1168 (54.25)	400 (34.57)	362 (28.48)	167 (26.42)
Moderate	226 (39.65)	114 (35.51)	55 (44.72)	228 (42.30)	537 (42.42)	461 (32.44)	94 (6.25)	505 (30.70)	645 (29.96)	331 (28.61)	364 (28.64)	187 (29.59)
High	119 (20.88)	55 (17.13)	26 (21.14)	289 (53.62)	536 (42.34)	638 (44.90)	22 (1.46)	33 (2.01)	340 (15.79)	426 (36.82)	545 (42.88)	278 (43.99)
Smoking [*n* (%)]												
Non-smoker	275 (45.38)	137 (41.52)	58 (46.03)	427 (79.22)	1009 (79.57)	1051 (73.24)	1012 (66.23)	1126 (67.10)	1453 (65.75)	539 (46.59)	602 (47.36)	284 (44.94)
Past smoker	212 (34.98)	132 (40.00)	44 (34.92)	57 (10.58)	138 (10.88)	220 (15.33)	196 (12.83)	180 (10.73)	270 (12.22)	333 (28.78)	387 (30.45)	178 (28.16)
Current smoker	119 (19.64)	61 (18.48)	24 (19.05)	55 (10.20)	121 (9.54)	164 (11.43)	320 (20.94)	372 (22.17)	487 (22.04)	285 (24.63)	282 (22.19)	170 (26.90)
Alcohol consumption [*n* (%)]												
Never drinker	212 (36.36)	103 (32.09)	36 (30.51)	266 (49.63)	587 (46.44)	558 (39.08)	289 (23.65)	338 (24.55)	433 (24.31)	517 (44.68)	516 (40.60)	238 (37.66)
Moderate drinker	298 (51.11)	182 (56.70)	68 (57.63)	255 (47.57)	648 (51.27)	817 (57.21)	887 (72.59)	983 (71.39)	1287 (72.26)	540 (46.67)	649 (51.06)	339 (53.64)
Heavy drinker	73 (12.52)	36 (11.21)	14 (11.86)	15 (2.80)	29 (2.29)	53 (3.71)	46 (3.76)	56 (4.07)	61 (3.43)	100 (8.64)	106 (8.34)	55 (8.70)
LTPA [*n* (%)]												
Vigorous	146 (24.13)	78 (23.64)	35 (27.78)	236 (44.78)	606 (48.95)	773 (55.02)	449 (36.59)	451 (32.78)	560 (31.39)	222 (19.19)	252 (19.83)	116 (18.35)
Moderate	145 (23.97)	80 (24.24)	35 (27.78)	218 (41.37)	544 (43.94)	544 (38.72)	287 (23.39)	364 (26.45)	503 (28.20)	656 (56.70)	689 (54.21)	360 (56.96)
Inactive	314 (51.90)	172 (52.12)	56 (44.44)	73 (13.85)	88 (7.11)	88 (6.26)	491 (40.02)	561 (40.77)	721 (40.41)	279 (24.11)	330 (25.96)	156 (24.68)

ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité*; HRS, Health and Retirement Study; IQR, interquartile range.
Variables with missing values that are >5% in ELSA: Education $n = 109$; in GAZEL: Alcohol consumption $n = 1114$, LTPA $n = 1107$.
Variables with missing values that are <5% in ELSA: Physical demands $n = 48$, Alcohol consumption $n = 40$, LTPA $n = 1$; in FLAME: Education $n = 20$, Physical demands $n = 16$, Alcohol consumption $n = 14$, LTPA $n = 72$; in GAZEL: Education $n = 151$, Physical demands $n = 191$, Smoking $n = 78$.

Table 2b. Characteristics of the female participants based on the physical work demands by cohort

Characteristics	Cohort											
	ELSA ($N = 1700$)			FLAME ($N = 3390$)			GAZEL ($N = 5316$)			HRS ($N = 3074$)		
	Low ($n = 643$)	Moderate ($n = 679$)	High ($n = 378$)	Low ($n = 547$)	Moderate ($n = 1312$)	High ($n = 1531$)	Low ($n = 3671$)	Moderate ($n = 1246$)	High ($n = 399$)	Low ($n = 935$)	Moderate ($n = 886$)	High ($n = 1253$)
Age (years) [median (IQR)]	55 (5)	55 (5)	55 (4)	50 (7)	50 (6)	50 (6)	41 (7)	42 (6)	43 (8)	55 (6)	55 (6)	55 (5)
Education [*n* (%)]												
High	441 (80.04)	365 (59.06)	183 (53.35)	163 (29.96)	144 (11.06)	92 (6.06)	2671 (74.65)	831 (68.68)	250 (65.27)	854 (91.34)	752 (84.88)	842 (67.20)
Low	110 (19.96)	253 (40.94)	160 (46.65)	381 (70.04)	1158 (88.94)	1426 (93.94)	907 (25.35)	379 (31.32)	133 (34.73)	81 (8.66)	134 (15.12)	411 (32.80)
Psychosocial work demands [*n* (%)]												
Low	225 (53.70)	226 (57.22)	119 (59.50)	22 (4.10)	228 (18.60)	289 (19.75)	1389 (37.91)	94 (7.56)	22 (5.57)	400 (43.06)	331 (37.53)	426 (34.11)
Moderate	152 (36.28)	114 (28.86)	55 (27.50)	193 (35.94)	537 (43.80)	536 (36.64)	1107 (30.21)	505 (40.59)	33 (8.35)	362 (38.97)	364 (41.27)	545 (43.63)
High	42 (10.02)	55 (13.92)	26 (13.00)	322 (59.96)	461 (37.60)	638 (43.61)	1168 (31.88)	645 (51.85)	340 (86.08)	167 (17.98)	187 (21.20)	278 (22.26)
Smoking [*n* (%)]												
Non-smoker	280 (43.55)	306 (45.07)	139 (36.77)	386 (70.57)	1032 (78.66)	1192 (77.86)	2403 (66.47)	817 (66.21)	262 (66.84)	439 (46.95)	414 (46.73)	580 (46.29)
Past smoker	253 (39.35)	225 (33.14)	128 (33.86)	96 (17.55)	162 (12.35)	172 (11.23)	439 (12.14)	143 (11.59)	45 (11.48)	300 (32.09)	273 (30.81)	327 (26.10)
Current smoker	110 (17.11)	148 (21.80)	111 (29.37)	65 (11.88)	118 (8.99)	167 (10.91)	773 (21.38)	274 (22.20)	85 (21.68)	196 (20.96)	199 (22.46)	346 (27.61)
Alcohol consumption [*n* (%)]												
Never drinker	158 (31.04)	185 (36.27)	120 (46.15)	184 (33.70)	594 (45.52)	707 (46.67)	695 (23.47)	254 (25.50)	81 (27.74)	329 (35.19)	324 (36.57)	623 (49.72)
Moderate drinker	287 (56.39)	264 (51.76)	113 (43.46)	332 (60.81)	680 (52.11)	771 (50.89)	2162 (73.02)	704 (70.68)	197 (67.47)	504 (53.90)	490 (55.30)	541 (43.18)
Heavy drinker	64 (12.57)	61 (11.96)	27 (10.38)	30 (5.49)	31 (2.38)	37 (2.44)	104 (3.51)	38 (3.82)	14 (4.79)	102 (10.91)	72 (8.13)	89 (7.10)
LTPA [*n* (%)]												
Vigorous	158 (24.61)	135 (19.91)	113 (29.89)	268 (50.00)	634 (49.76)	755 (50.74)	1025 (34.42)	308 (31.59)	86 (28.20)	129 (13.80)	137 (15.46)	327 (26.10)
Moderate	159 (24.77)	163 (24.04)	79 (20.90)	236 (44.03)	538 (42.23)	599 (40.26)	772 (25.92)	264 (27.08)	78 (25.57)	532 (56.90)	527 (59.48)	655 (52.27)
Inactive	325 (50.62)	380 (56.05)	186 (49.21)	32 (5.97)	102 (8.01)	134 (9.01)	1181 (39.66)	403 (41.33)	141 (46.23)	274 (29.30)	222 (25.06)	271 (21.63)

ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité*; HRS, Health and Retirement Study; IQR, interquartile range; LTPA, leisure-time physical activity.
Variables with missing values that are >5% in ELSA: Education $n = 188$, Psychosocial demands $n = 686$, Alcohol consumption $n = 421$; in GAZEL: Alcohol consumption $n = 1067$, LTPA $n = 1058$.
Variables with missing values that are <5% in ELSA: LTPA $n = 2$; in FLAME: Education $n = 26$, Psychosocial demands $n = 164$, Alcohol consumption $n = 24$, LTPA $n = 92$; in GAZEL: Education $n = 145$, Psychosocial demands $n = 13$, Smoking $n = 75$; in HRS: Psychosocial demands $n = 14$.

Table 3a. Characteristics of the male participants based on the psychosocial work demands by cohort

Characteristics	Cohort											
	ELSA ($N=1082$)			FLAME ($N=2622$)			GAZEL ($N=14\,801$)			HRS ($N=3540$)		
	Low ($n=617$)	Moderate ($n=310$)	High ($n=155$)	Low ($n=335$)	Moderate ($n=1167$)	High ($n=1120$)	Low ($n=2643$)	Moderate ($n=4396$)	High ($n=7762$)	Low ($n=1350$)	Moderate ($n=1539$)	High ($n=651$)
Age (years) [median (IQR)]	55 (5)	55 (6)	54 (4)	50 (6)	50 (6)	50 (6)	45 (5)	45 (5)	45 (4)	55 (5)	55 (5)	55 (5)
Education [*n* (%)]												
High	404 (68.59)	239 (79.40)	122 (80.26)	3 (0.91)	58 (5.00)	134 (12.05)	2002 (77.24)	3453 (80.32)	6203 (81.46)	982 (72.74)	1229 (79.86)	541 (83.10)
Low	185 (31.41)	62 (20.60)	30 (19.74)	327 (99.09)	1103 (95.00)	978 (87.95)	590 (22.76)	846 (19.68)	1412 (18.54)	368 (27.26)	310 (20.14)	110 (16.90)
Physical work demands [*n* (%)]												
Low	222 (37.63)	125 (41.67)	67 (44.08)	49 (14.67)	191 (16.49)	395 (35.71)	1774 (68.44)	2126 (49.28)	3775 (49.18)	338 (25.04)	423 (27.49)	211 (32.41)
Moderate	142 (24.07)	69 (23.00)	40 (26.32)	211 (63.17)	730 (63.04)	402 (36.35)	615 (23.73)	1714 (39.73)	2448 (31.89)	402 (29.78)	453 (29.43)	181 (27.80)
High	226 (38.31)	106 (35.33)	45 (29.61)	74 (22.16)	237 (20.47)	309 (27.94)	203 (7.83)	474 (10.99)	1453 (18.93)	610 (45.19)	663 (43.08)	259 (39.78)
Smoking [*n* (%)]												
Non-smoker	185 (30.18)	93 (30.29)	56 (36.13)	86 (25.67)	347 (29.73)	341 (30.45)	965 (36.72)	1558 (35.64)	2494 (32.30)	359 (26.59)	433 (28.14)	170 (26.11)
Past smoker	311 (50.73)	153 (49.84)	72 (46.45)	127 (37.91)	480 (41.13)	493 (44.02)	893 (33.98)	1481 (33.88)	2768 (35.85)	609 (45.11)	715 (46.46)	289 (44.39)
Current smoker	117 (19.09)	61 (19.87)	27 (17.42)	122 (36.42)	340 (29.13)	286 (25.54)	770 (29.30)	1332 (30.47)	2459 (31.85)	382 (28.30)	391 (25.41)	192 (29.49)
Alcohol consumption [*n* (%)]												
Never drinker	122 (20.57)	68 (23.21)	31 (20.53)	52 (15.66)	139 (11.99)	118 (10.59)	187 (8.77)	329 (9.24)	528 (8.35)	434 (32.15)	442 (28.72)	180 (27.65)
Moderate drinker	277 (46.71)	153 (52.22)	77 (50.99)	214 (64.46)	785 (67.73)	763 (68.49)	1602 (75.14)	2623 (73.70)	4775 (75.48)	601 (44.52)	730 (47.43)	305 (46.85)
Heavy drinker	194 (32.72)	72 (24.57)	43 (28.48)	66 (19.88)	235 (20.28)	233 (20.92)	343 (16.09)	607 (17.06)	1023 (16.17)	315 (23.33)	367 (23.85)	166 (25.50)
LTPA [*n* (%)]												
Vigorous	193 (31.48)	89 (28.99)	38 (24.52)	129 (39.09)	531 (46.25)	543 (49.23)	821 (37.37)	1320 (35.51)	2352 (35.71)	274 (20.30)	322 (20.92)	151 (23.20)
Moderate	144 (23.49)	88 (28.66)	53 (34.19)	152 (46.06)	512 (44.60)	486 (44.06)	688 (31.32)	1226 (32.98)	2243 (34.05)	496 (36.74)	525 (34.11)	223 (34.25)
Inactive	276 (45.02)	130 (42.35)	64 (41.29)	49 (14.85)	105 (9.15)	74 (6.71)	688 (31.32)	1171 (31.50)	1992 (30.24)	580 (42.96)	692 (44.96)	277 (42.55)

ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité*; HRS, Health and Retirement Study; IQR, interquartile range; LTPA, leisure-time physical activity.
Variables with missing values that are >5% in GAZEL: Alcohol consumption $n=2784$, LTPA $n=2300$.
Variables with missing values that are <5% in ELSA: Education $n=40$, Physical demands $n=40$, Smoking $n=7$, Alcohol consumption $n=45$, LTPA $n=7$; in FLAME: Education $n=19$, Physical demands $n=24$, Alcohol consumption $n=17$, LTPA $n=41$; in GAZEL: Education $n=295$, Physical demands $n=219$, Smoking $n=81$.

Table 3b. Characteristics of the male participants based on the physical work demands by cohort

Characteristics	Cohort											
	ELSA ($N=1723$)			FLAME ($N=2695$)			GAZEL ($N=14\,616$)			HRS ($N=3562$)		
	Low ($n=668$)	Moderate ($n=406$)	High ($n=649$)	Low ($n=647$)	Moderate ($n=1400$)	High ($n=648$)	Low ($n=7687$)	Moderate ($n=4788$)	High ($n=2141$)	Low ($n=978$)	Moderate ($n=1043$)	High ($n=1541$)
Age (years) [median (IQR)]	55 (6)	56 (5)	55 (5)	50 (6)	50 (6.5)	50 (7)	45 (5)	45 (5)	45 (5)	55 (5)	55 (5)	55 (5)
Education [n (%)]												
High	545 (83.98)	281 (71.50)	331 (54.89)	119 (18.48)	56 (4.05)	20 (3.10)	6207 (82.02)	3701 (79.13)	1616 (77.73)	897 (91.72)	888 (85.14)	982 (63.72)
Low	104 (16.02)	112 (28.50)	272 (45.11)	525 (81.52)	1326 (95.95)	626 (96.90)	1361 (17.98)	976 (20.87)	463 (22.27)	81 (8.28)	155 (14.86)	559 (36.28)
Psychosocial work demands [n (%)]												
Low	222 (53.62)	142 (56.57)	226 (59.95)	49 (7.72)	211 (15.71)	74 (11.94)	1774 (23.11)	615 (12.87)	203 (9.53)	338 (34.77)	402 (38.80)	610 (39.82)
Moderate	125 (30.19)	69 (27.49)	106 (28.12)	191 (30.08)	730 (54.36)	237 (38.23)	2126 (27.70)	1714 (35.88)	474 (22.25)	423 (43.52)	453 (43.73)	663 (43.28)
High	67 (16.18)	40 (15.94)	45 (11.94)	395 (62.20)	402 (29.93)	309 (49.84)	3775 (49.19)	2448 (51.25)	1453 (68.22)	211 (21.71)	181 (17.47)	259 (16.91)
Smoking [n (%)]												
Non-smoker	223 (33.38)	136 (33.50)	183 (28.20)	200 (30.91)	408 (29.14)	187 (28.86)	2685 (35.08)	1587 (33.35)	672 (31.64)	286 (29.24)	271 (25.98)	413 (26.80)
Past smoker	347 (51.95)	194 (47.78)	301 (46.38)	279 (43.12)	586 (41.86)	262 (40.43)	2683 (35.06)	1688 (35.47)	723 (34.04)	479 (48.98)	493 (47.27)	649 (42.12)
Current smoker	98 (14.67)	76 (18.72)	165 (25.42)	168 (25.97)	406 (29.00)	199 (30.71)	2285 (29.86)	1484 (31.18)	729 (34.32)	213 (21.78)	279 (26.75)	479 (31.08)
Alcohol consumption [n (%)]												
Never drinker	80 (16.16)	70 (24.05)	140 (30.70)	70 (10.89)	167 (12.01)	85 (13.18)	515 (8.03)	352 (9.21)	155 (9.54)	234 (23.93)	298 (28.57)	533 (34.59)
Moderate drinker	260 (52.53)	142 (48.80)	198 (43.42)	442 (68.74)	949 (68.27)	415 (64.34)	4898 (76.36)	2832 (74.10)	1162 (71.51)	487 (49.80)	494 (47.36)	663 (43.02)
Heavy drinker	155 (31.31)	79 (27.15)	118 (25.88)	131 (20.37)	274 (19.71)	145 (22.48)	1001 (15.61)	638 (16.69)	308 (18.95)	257 (26.28)	251 (24.07)	345 (22.39)
LTPA [n (%)]												
Vigorous	167 (25.00)	99 (24.38)	225 (34.67)	316 (49.61)	638 (46.30)	272 (43.31)	2528 (38.13)	1342 (33.70)	553 (32.06)	225 (23.01)	196 (18.79)	332 (21.54)
Moderate	178 (26.65)	108 (26.60)	146 (22.50)	284 (44.58)	625 (45.36)	266 (42.36)	2186 (32.97)	1330 (33.40)	587 (34.03)	360 (36.81)	385 (36.91)	505 (32.77)
Inactive	323 (48.35)	199 (49.01)	278 (42.84)	37 (5.81)	115 (8.35)	90 (14.33)	1916 (28.90)	1310 (32.90)	585 (33.91)	393 (40.18)	462 (44.30)	704 (45.68)

ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité*; HRS, Health and Retirement Study; IQR, interquartile range; LTPA, leisure-time physical activity.
Variables with missing values that are >5% in ELSA: Psychosocial demands $n=681$, Alcohol consumption $n=481$; in GAZEL: Alcohol consumption $n=2755$, LTPA $n=2279$.
Variables with missing values that are <5% in ELSA: Education $n=78$; in FLAME: Education $n=23$, Psychosocial demands $n=97$, Alcohol consumption $n=17$, LTPA $n=52$; in GAZEL: Education $n=292$, Psychosocial demands $n=34$, Smoking $n=80$; in HRS: Psychosocial demands $n=22$.

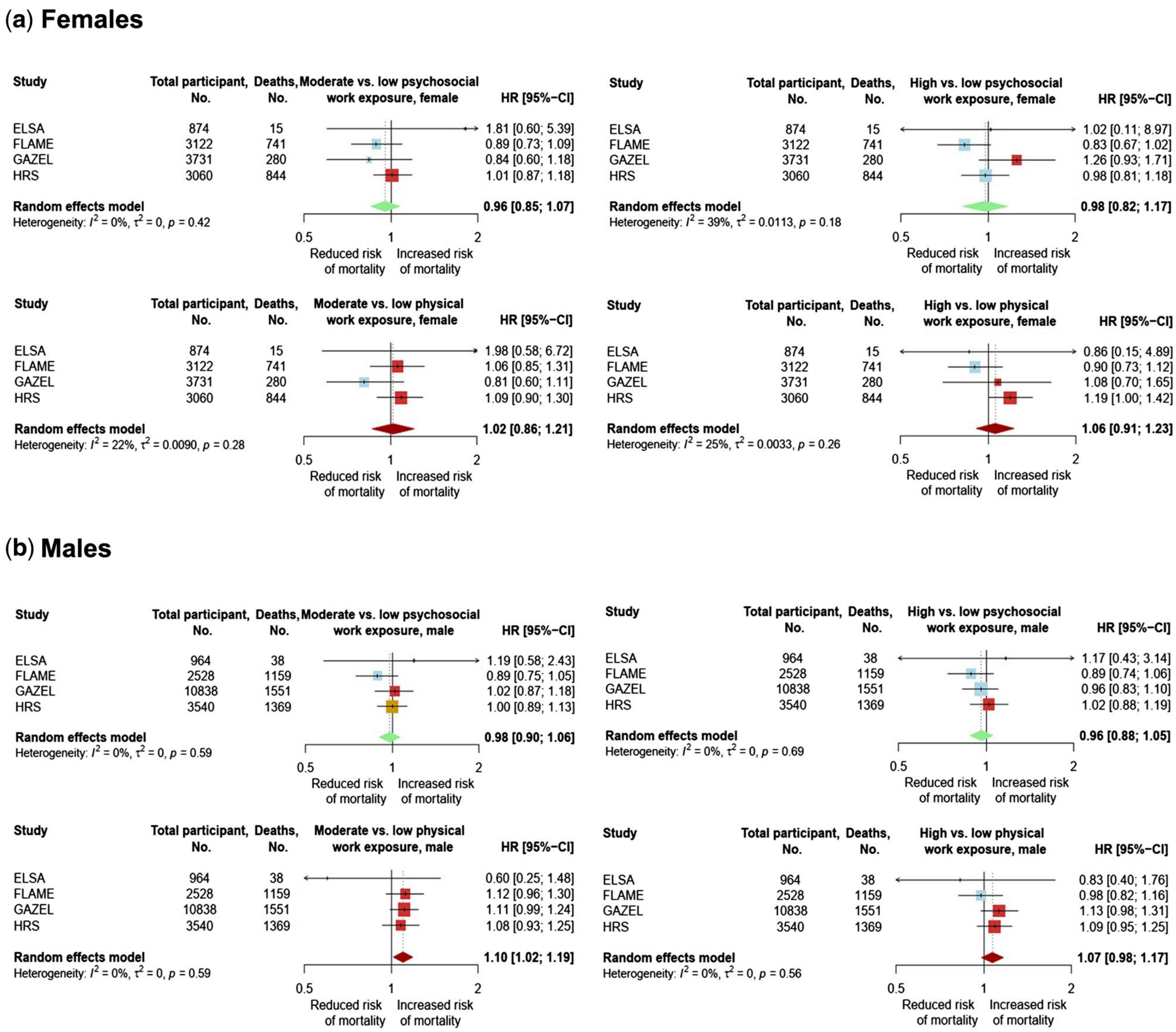

Figure 1. Pooled and cohort-specific estimates of the associations of psychosocial (top) and physical (bottom) work demands with all-cause mortality among (a) female and (b) male participants in two comparison groups: moderate versus low exposure (left) and high versus low exposure (right). The pooled estimates of all-cause mortality for both work demands were calculated using random-effects meta-analysis. Heterogeneity between the cohort studies was calculated using the Higgins' I^2 test statistic and the Paule–Mandel estimator for τ^2. The estimates are based on Models 4 in Table 4a and 4b, which included adjustment for socio-demographic information, lifestyle factors, and physical or psychosocial work demands, accordingly. ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité*; HRS, Health and Retirement Study; VS, versus.

investigation are at odds with earlier works that described no clear associations for either sex [14, 39, 40]. Particularly noticeable were the results for females in GAZEL and HRS, which were indicative of strong, positive associations with all-cause mortality. These associations were sustained in the pooled analysis and in the cohort-specific results in the supplementary analysis, and exceptionally held true in the case of HRS, with 19%-point increased risk after full adjustment. This is possibly due to the fact that the questions in HRS and GAZEL measured the perceived physical heaviness of work more directly than those in the other two cohorts, hence the weaker and inconsistent associations in ELSA and FLAME.

Regarding males, our results are in line with those of a recent study [41] in which the same method as ours was used and other studies that report a higher mortality risk due to heavy physical work [13, 16, 23, 24, 42]. In our findings, although a high level of physical demands was positively associated with mortality, the magnitude of the estimate was slightly lower than that of the moderate level. This could imply the presence of healthy worker bias in which jobs with the utmost physical demands are often performed by the fittest workers, as those with the poorest health are more likely to have died, quit, or been relocated to jobs with lower demands.

Sex differences in the risk of all-cause mortality

Our findings documented the sex differences in mortality risk attributable to physical demands in which males were at higher risk of death than females. Previous studies also found a higher risk of death among males in relation to psychosocially and physically strenuous work, although the extent varied between studies [4–6, 13, 16, 23, 41]. Males are more likely to perform jobs that are characterized by heavy mental and physical workloads, low decision latitude, long hours,

Table 4a. Crude and adjusted associations of psychosocial and physical work demands with all-cause mortality among female participants by cohort

Cohort	Psychosocial demands				Physical demands			
	Participants (n)	Deaths (n)	HR (95% CI)		Participants (n)	Deaths (n)	HR (95% CI)	
			Moderate	High			Moderate	High
Model 1								
ELSA	1062	23	1.26 (0.54–2.95)	0.37 (0.05–2.83)	1700	49	0.80 (0.43–1.51)	0.80 (0.38–1.71)
FLAME	3242	776	0.86 (0.71–1.05)	0.79 (0.65–0.96)	3390	833	1.05 (0.86–1.28)	0.94 (0.77–1.15)
GAZEL	5494	462	1.01 (0.78–1.30)	1.37 (1.10–1.72)	5316	444	1.06 (0.85–1.32)	1.32 (0.96–1.83)
HRS	3060	844	0.97 (0.83–1.12)	0.94 (0.78–1.13)	3074	850	1.10 (0.92–1.32)	1.33 (1.13–1.57)
Model 2								
ELSA	953	21	1.93 (0.77–4.86)	0.65 (0.08–5.18)	1512	44	0.70 (0.35–1.40)	0.71 (0.32–1.58)
FLAME	3222	771	0.89 (0.73–1.08)	0.84 (0.69–1.03)	3364	824	1.07 (0.87–1.31)	0.93 (0.75–1.14)
GAZEL	5343	448	0.99 (0.76–1.28)	1.34 (1.07–1.69)	5171	430	1.02 (0.82–1.28)	1.28 (0.92–1.77)
HRS	3060	844	1.02 (0.87–1.18)	1.03 (0.85–1.24)	3074	850	1.06 (0.89–1.28)	1.21 (1.02–1.43)
Model 3								
ELSA	914	19	1.95 (0.74–5.12)	0.84 (0.10–6.97)	1141	24	1.17 (0.46–2.97)	0.79 (0.23–2.71)
FLAME	3136	745	0.90 (0.73–1.10)	0.83 (0.68–1.02)	3252	787	1.11 (0.90–1.37)	0.93 (0.75–1.15)
GAZEL	3850	291	0.80 (0.58–1.10)	1.21 (0.91–1.60)	3738	281	0.84 (0.62–1.13)	1.29 (0.87–1.92)
HRS	3060	844	1.03 (0.88–1.20)	0.99 (0.83–1.20)	3074	850	1.08 (0.90–1.30)	1.18 (0.99–1.40)
Model 4								
ELSA	874	15	1.81 (0.60–5.39)	1.02 (0.11–8.97)	874	15	1.98 (0.58–6.72)	0.86 (0.15–4.89)
FLAME	3122	741	0.89 (0.73–1.09)	0.83 (0.67–1.02)	3122	741	1.06 (0.85–1.31)	0.90 (0.73–1.12)
GAZEL	3731	280	0.84 (0.60–1.18)	1.26 (0.93–1.71)	3731	280	0.81 (0.60–1.11)	1.08 (0.70–1.65)
HRS	3060	844	1.01 (0.87–1.18)	0.98 (0.81–1.18)	3060	844	1.09 (0.90–1.30)	1.19 (1.00–1.42)

ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité;* HRS, Health and Retirement Study; HR, hazard ratios. Low exposure as the reference group.
Model 1: Crude association. Model 2: Adjusted for socio-demographic information (age and education). Model 3: Adjusted for socio-demographic information and lifestyle factors [smoking, alcohol consumption, and leisure-time physical activity (LTPA)]. Model 4: Adjusted for socio-demographic information, lifestyle factors, and physical or psychosocial demands, accordingly.
Decreasing number of participants from Model 1 to Model 2 due to missing data on education: ELSA $n = 109$ (psychosocial) and $n = 188$ (physical); FLAME $n = 12$ and $n = 26$; GAZEL $n = 151$ and $n = 145$.
Decreasing number of participants from Model 2 to Model 3 due to missing data on education and lifestyle factors: ELSA $n = 39$ (psychosocial) and $n = 371$ (physical); FLAME $n = 86$ and $n = 112$; GAZEL $n = 1493$ and $n = 1433$.
Decreasing number of participants from Model 3 to Model 4 due to missing data on education, lifestyle factors, and work demands: ELSA $n = 40$ (psychosocial) and $n = 267$ (physical); FLAME $n = 14$ and $n = 130$; GAZEL $n = 119$ and $n = 7$; HRS $n = 14$ (physical).

Table 4b. Crude and adjusted associations of psychosocial and physical work demands with all-cause mortality among male participants by cohort

Cohort	Psychosocial demands				Physical demands			
	Participants (*n*)	Deaths (*n*)	HR (95% CI)		Participants (*n*)	Deaths (*n*)	HR (95% CI)	
			Moderate	High			Moderate	High
Model 1								
ELSA	1082	46	1.07 (0.56–2.04)	0.92 (0.38–2.24)	1723	80	1.24 (0.67–2.29)	1.64 (0.98–2.73)
FLAME	2622	1216	0.78 (0.66–0.92)	0.71 (0.60–0.84)	2695	1262	1.24 (1.08–1.43)	1.17 (0.99–1.38)
GAZEL	14 801	2417	1.03 (0.91–1.16)	1.02 (0.91–1.31)	14 616	2383	1.14 (1.04–1.25)	1.24 (1.10–1.39)
HRS	3540	1369	0.93 (0.83–1.05)	0.95 (0.82–1.11)	3562	1376	1.14 (0.99–1.32)	1.28 (1.12–1.46)
Model 2								
ELSA	1042	45	1.14 (0.59–2.20)	1.19 (0.48–2.93)	1645	76	1.03 (0.54–1.94)	1.43 (0.84–2.46)
FLAME	2603	1203	0.82 (0.69–0.97)	0.79 (0.66–0.94)	2672	1248	1.14 (0.99–1.32)	1.07 (0.91–1.27)
GAZEL	14 506	2363	1.03 (0.91–1.16)	1.02 (0.91–1.14)	14 324	2331	1.13 (1.03–1.23)	1.23 (1.10–1.38)
HRS	3540	1369	0.98 (0.87–1.11)	1.05 (0.90–1.22)	3562	1376	1.11 (0.96–1.29)	1.16 (1.01–1.33)
Model 3								
ELSA	997	42	1.16 (0.58–2.31)	1.30 (0.52–3.24)	1192	55	0.64 (0.29–1.40)	1.03 (0.55–1.92)
FLAME	2551	1173	0.89 (0.75–1.05)	0.87 (0.73–1.04)	2609	1211	1.13 (0.98–1.31)	1.01 (0.85–1.20)
GAZEL	11 000	1578	1.04 (0.90–1.21)	0.98 (0.86–1.13)	10 852	1554	1.11 (0.99–1.24)	1.12 (0.96–1.29)
HRS	3540	1369	1.00 (0.89–1.13)	1.02 (0.88–1.19)	3562	1376	1.07 (0.92–1.23)	1.09 (0.95–1.25)
Model 4								
ELSA	964	38	1.19 (0.58–2.43)	1.17 (0.43–3.14)	964	38	0.60 (0.25–1.48)	0.83 (0.40–1.76)
FLAME	2528	1159	0.89 (0.75–1.05)	0.89 (0.74–1.06)	2528	1159	1.12 (0.96–1.30)	0.98 (0.82–1.16)
GAZEL	10 838	1551	1.02 (0.87–1.18)	0.96 (0.83–1.10)	10 838	1551	1.11 (0.99–1.24)	1.13 (0.98–1.31)
HRS	3540	1369	1.00 (0.89–1.13)	1.02 (0.88–1.19)	3540	1369	1.08 (0.93–1.25)	1.09 (0.95–1.25)

ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité;* HRS, Health and Retirement Study; HR, hazard ratios. Low exposure as the reference group.
Model 1: Crude association. Model 2: Adjusted for socio-demographic information (age and education). Model 3: Adjusted for socio-demographic information and lifestyle factors [smoking, alcohol consumption, and leisure-time physical activity (LTPA)]. Model 4: Adjusted for socio-demographic information, lifestyle factors, and physical or psychosocial demands, accordingly.
Decreasing number of participants from Model 1 to Model 2 due to missing data on education: ELSA $n = 40$ (psychosocial) and $n = 78$ (physical); FLAME $n = 19$ and $n = 23$; GAZEL $n = 295$ and $n = 292$.
Decreasing number of participants from Model 2 to Model 3 due to missing data on education and lifestyle factors: ELSA $n = 45$ (psychosocial) and $n = 453$ (physical); FLAME $n = 52$ and $n = 63$; GAZEL $n = 3506$ and $n = 3472$.
Decreasing number of participants from Model 3 to Model 4 due to missing data on education, lifestyle factors, and work demands: ELSA $n = 33$ (psychosocial) and $n = 228$ (physical); FLAME $n = 23$ and $n = 81$; GAZEL $n = 162$ and $n = 14$; HRS $n = 22$ (physical).

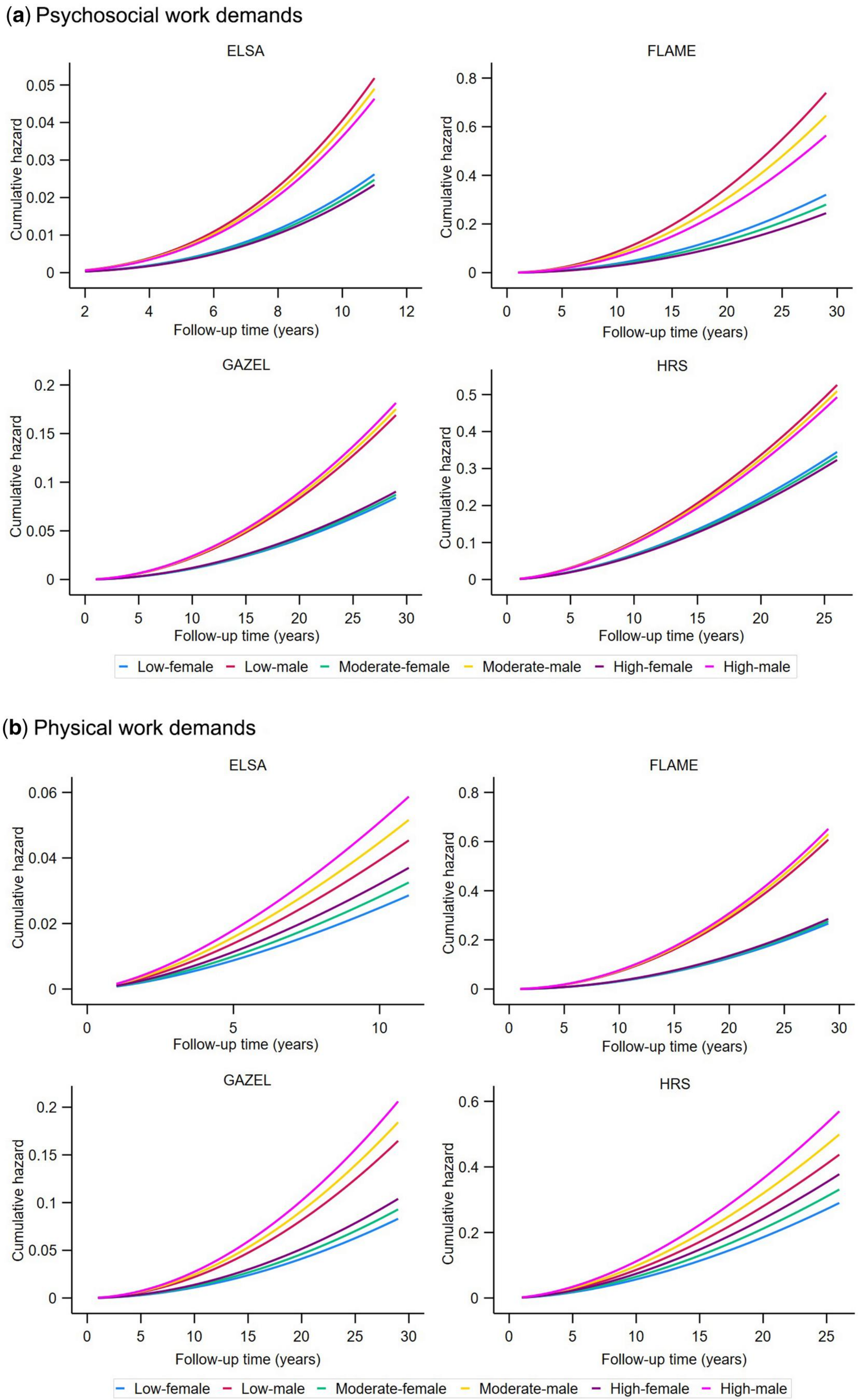

Figure 2. Unadjusted cumulative hazard estimates of the association between (a) psychosocial and (b) physical work demands and all-cause mortality, stratified by sex and cohort. The hazard functions were visualized using the Nelson–Aalen analysis. In each cohort and in both sexes, the cumulative hazards of death increased during the follow-up period, measured in years. ELSA, English Longitudinal Study of Ageing; FLAME, Finnish Longitudinal Study of Aging Municipal Employees; GAZEL, *GAZ* and *Electricité*.

and poor working conditions. Work stress is a known risk factor for coronary heart disease and mental disorders [43, 44] whereas heavy physical work has been linked to musculoskeletal disorders [18, 24]. The health problems that occur from such work demands are not only debilitating, but also among the leading causes of death. Males in these types of occupations are likely to be of lower socioeconomic backgrounds, which are known to have lower life expectancy than females in general and males in higher socioeconomic positions [45]. Subsequently, behavioral factors may also play a role, as males with a lower socioeconomic status are more likely to adopt health-deteriorating lifestyles [16, 38]. Alternatively, the discrepancy in mortality risk could be explained by the difference in physiological responses to work stressors [46].

The observed sex differences in the current study could also be interpreted in a few ways. First, males and females may have a distinguished approach in performing the same physical tasks [47]. Second, the same work demands might be experienced and perceived differently by males and females, which applies to both psychosocial and physical demands [2, 16]. It has been suggested that males' assessment of their work is more parallel to experts' rating than females' [48] and, in our case, this might have been true given that heterogeneity was only detected among females. However, it could also mean that the content and intensity of the same work are more diverse among females across these cohorts, which are also influenced by cultural and individual factors, whereas the nature of work for males might have been constant over the different time periods.

Strength and weakness

This study stands among the first to have examined the relationships between psychosocial and physical work demands with all-cause mortality by utilizing individual participant data from multiple cohort studies and pooled the cohort-specific estimates following the original investigation [41]. As the cause of death was not specified and the data were obtained from national registers and company databases, there was no room for outcome misclassification bias.

The present study has several limitations. The number of participants declined due to incomplete information on the covariates. However, when the analysis was repeated only among those with the complete covariates, the results were similar to the main results (Supplementary Tables S2a and b). Adjustment of the associations for lifestyle factors may have undermined the effects of the work exposures. Nevertheless, adjustments were necessary to estimate the independent effects of the work exposures. Re-categorization of the work exposures from multiple to three categories may have introduced misclassification bias that consequently could have attenuated the estimated effects. We compared the results across three different techniques of categorization: original scales of each cohort, two categories, and the current categories with three exposure levels (Supplementary Tables S3 and S4). These sensitivity analyses indeed showed that, overall, re-categorizations underestimated the associations with mortality in both sexes. Nonetheless, our results with three categories summarized the nuances in the results with the original scales fairly well and should therefore remain representative.

The use of subjective measures of work exposures may have led to reporting bias. However, when investigating work demands, self-reports may be more favorable than objective measures, as one's perceptions of work could reflect the reality of the work burden and further influence the health status. Additionally, self-reports likely capture the heterogeneity of the work exposures among employees whereas objective instruments provide an assumed averaged exposure [49]. It is crucial to note that, in some of our cohorts, the exposure measurement had limited validity, which makes the accurate separation of psychosocial from physical demands and vice versa difficult. Thus, it might have pulled the association towards the null. We also acknowledge that the measures of work demands were heterogeneous across the cohorts. Nevertheless, the selected measures have been used in previous studies to represent psychosocially and physically demanding work within the corresponding cohorts [31–35]. This study lacks adjustment for exposure to other occupational hazards (e.g. airborne particles and hazardous chemicals), factors that characterized the context of each cohort (e.g. labor and social policies), and the survey period, which may have attenuated the association between work demands and mortality. Extrapolation of the current findings to the general working population in their mid- or late careers should be done with caution, as the participants in half of our cohorts came from a specific sector of work. Our results are drawn from the most developed countries in the northern hemisphere, likely underestimating the actual health consequences of heavy psychosocial and physical work in other regions.

Conclusion

Our study demonstrates an inconsistency in the association of psychosocial demands with all-cause mortality but a positive association for higher levels of physical demands, particularly among males with moderate exposure. Further research using multiple cohorts with detailed work exposure measurement is warranted.

Ethics approval

All of the included studies have been conducted in accordance with the Declaration of Helsinki ethical principles for medical research involving human patients. FLAME was approved by the ethics committee of the Finnish Institute of Occupational Health and GAZEL received the approval of France's national ethics committee (*Commission Nationale Informatique et Libertè*/CNIL). Ethical approval for ELSA was obtained from the London Multicentre Research Ethics Committee. HRS ethical approval was obtained from the University of Michigan Institutional Review Board.

Author contributions

S.N. had full access to all the data in the study. K.T. takes responsibility for the integrity of the data and the accuracy of the data analysis. S.N. obtained the funding. S.N. and P.K.C. supervised the research. K.T., P.K.C., and S.N. conceptualized and designed the study, and drafted the manuscript. K.T. and P.K.C. performed statistical analyses. S.K., C.H.N., and M.G. made substantial contributions to the interpretation of data and the critical revision and editing of the manuscript. All authors revised the manuscript for important intellectual content and read and approved the final manuscript.

Supplementary data

Supplementary data are available at *IJE* online.

Use of artificial intelligence (AI) tools

No AI tools were used in the process of conducting the study or preparing the manuscript.

Conflict of interest: None declared.

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Data availability

The analyses in this study used data from the Harmonized ELSA dataset, Version E as of April 2017 and the RAND HRS Longitudinal File 2016 (V1) developed by the Gateway to Global Aging Data, which are available at https://g2aging.org/app/hrd/overview. The data for FLAME (S.N.) and GAZEL (M.G.) are available from the authors upon reasonable request.

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