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Title: Occupational physical activity and risk of mortality in women and men. The Tromsø Study 1986-2021

Edvard H Sagelv[1]*, Knut Erik Dalene[2], Anne Elise Eggen[3], Ulf Ekelund[2,4], Marius Steiro Fimland[5,6], Kim Arne Heitmann[1], Andreas Holtermann[7,8], Kristoffer R Johansen[1], Maja-Lisa Løchen[9], Bente Morseth[1], Tom Wilsgaard[3]

Affiliations:

[1]School of Sport Sciences, Faculty of Health Sciences, UiT The Arctic University of Norway, Tromsø, Norway

[2]Department of Chronic Diseases, Norwegian Institute of Public Health, Oslo, Norway

[3]Department of Community Medicine, Faculty of Health Sciences, UiT The Arctic University of Norway, Tromsø, Norway

[4]Department of Sports Medicine, Norwegian School of Sport Sciences, Oslo, Norway

[5]Department of Neuromedicine and Movement Science, Faculty of Medicine and Health Sciences, Norwegian University of Science and Technology, Trondheim, Norway

[6]Unicare Helsefort Rehabilitation Centre, Rissa, Norway

[7]National Research Centre for the Working Environment, Copenhagen, Denmark

[8]Department of Sport Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark

[9]Department of Clinical Medicine, Faculty of Health Sciences, UiT The Arctic University of Norway, Tromsø, Norway

***Correspondence:**

Edvard H Sagelv

E-mail: edvard.h.sagelv@uit.no

Phone: +47 77660236

Twitter: @edvardhsagelv

Address: UiT The Arctic University of Norway, Postboks 6050 Langnes, 9037 Tromsø, Troms, Norway

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What is already known about this topic?

- Studies of associations between occupational physical activity (OPA) and mortality are conflicting, which may be related to misclassification or confounding.
- There are few studies examining joint associations between OPA and leisure time physical activity (LTPA) on mortality.

What this study adds

- In this prospective cohort study of 29 605 participants with repeated assessment of exposure and covariates every 6-8th year over four decades, high OPA (walking and lifting) but not moderate (walking) or very high OPA (heavy manual labour) was associated with lower risk of all-cause and cardiovascular disease mortality in men.
- There were no associations between mortality and OPA in women.
- We observed a cohort effect, as very high OPA was associated with lower mortality risk in men born before 1940, while it was associated with higher risk in men born after 1950.
- In men, vigorous LTPA was associated with lower mortality risk in those with low, high, and very high OPA, but not moderate OPA.

How this study might affect research, practice, or policy

- High OPA involving walking and lifting appears to lower mortality risk independent of LTPA in men.
- In younger but not older generations, very high OPA involving heavy manual labour appears to increase risks of mortality.
- Engaging in vigorous LTPA may lower mortality risk for men with very high OPA.

Abstract

Objective: Associations between occupational physical activity (OPA) and mortality risks are inconclusive. We aimed to examine associations between 1) OPA separately and 2) jointly with leisure time physical activity (LTPA), and risk of all-cause, cardiovascular disease (CVD), and cancer mortality, over four decades with updated exposure and covariates every 6-8 years.

Methods: Adults aged 20-65 years from the Tromsø Study surveys Tromsø3-Tromsø7 (1986-2016) were included. We categorized OPA as low (sedentary), moderate (walking work), high (walking + lifting work) or very high (heavy manual labour), and LTPA as inactive, moderate, and vigorous. We used Cox/Fine and Gray regressions to examine associations, adjusted for age, body mass index, smoking, education, diet, alcohol, and LTPA (aim 1 only).

Results: Of 29605 participants with 44140 total observations, 4131 (14.0%) died, 1057 (25.6%) from CVD and 1660 (40.4%) from cancer, during follow-up (median: 29.1 years, 25^{th}-75^{th}: 16.5.1-35.3). In men, compared with low OPA, high OPA was associated with lower all-cause (hazard ratio (HR): 0.83, 95% confidence interval (CI): 0.74-0.92) and CVD (subdistributed HR (SHR): 0.68, 95%CI: 0.54-0.84) but not cancer mortality (SHR: 0.99, 95%CI: 0.84-1.19), while no association was observed for moderate or very high OPA. In joint analyses using inactive LTPA and low OPA as reference, vigorous LTPA was associated with lower all-cause mortality combined with low (HR: 0.75, 95%CI: 0.64-0.89), high (HR: 0.67, 95%CI: 0.54-0.82) and very high OPA (HR: 0.74, 95%CI: 0.58-0.94), but not with moderate OPA. In women, there were no associations between OPA, or combined OPA and LTPA, with mortality.

Conclusion: High OPA, but not moderate and very high OPA, was associated with lower all-cause and CVD mortality risk in men but not in women. Vigorous LTPA was associated with lower mortality risk in men with low, high, and very high OPA, but not moderate OPA.

Introduction

Higher physical activity levels are generally associated with lower risk of non-communicable diseases (1, 2) and premature mortality (1). However, current evidence is mostly based on studies of leisure time physical activity (LTPA), whereas studies examining associations between occupational physical activity (OPA) and disease and mortality are scarce (3).

Emerging studies suggest contrasting associations across physical activity domains, reporting higher mortality with higher OPA (4-12) and lower mortality with higher LTPA (6). However, whether high OPA is detrimental for health remains debated (13-15), as contradictory studies indicate lower mortality with higher OPA (16-25) or no association (26). Inconsistent observations may be explained by residual confounding (*e.g*., smoking, alcohol, diet, and socioeconomic status), selection bias, reverse causation, or time-varying confounding as previous studies did not examine whether exposure and covariates varied over time (13-15, 27). Additionally, considering that demanding work tasks have changed over time due to aiding technology for efficient work production (27, 28), health benefits from high OPA as consistently reported in seminal literature (16-21) may have changed over time (27, 28).

Fewer studies have examined whether LTPA lowers mortality risk also for those with different OPA levels (*i.e.*, joint associations) (29). Some reported that higher LTPA was only associated with lower mortality risk in low OPA workers (7, 8), whereas others reported that higher LTPA was associated with lower mortality risk irrespective of OPA level (6, 30, 31). As current physical activity guidelines do not differentiate between physical activity domains (32) and mostly derive from studies of LTPA (3), examining joint associations of LTPA and OPA is warranted (29).

To address these knowledge gaps, we used data from a large population-based cohort study spanning more than four decades, with updated exposure and covariate information during follow-up. We aimed to examine: 1) the association between OPA and risk of all-cause, CVD and cancer mortality, and 2) the joint association of OPA and LTPA with the same mortality outcomes.

Methods

Study population and design

The Tromsø Study is an ongoing population-based cohort study of adults in Tromsø, Northern Norway (33, 34). We used data from the third (Tromsø3, 1986-87, attendance of those invited: 81%), fourth (Tromsø4, 1994-95, attendance of those invited: 77%), fifth (Tromsø5, 2001, attendance of those invited: 79%), sixth (Tromsø6, 2007-08, attendance of those invited: 66%), and seventh survey (Tromsø7, 2015-16, attendance of those invited: 65%) in a prospective cohort design. We included participants with at least one participation, and with information on OPA, LTPA, sex, age at study entry, educational level, weight, height, diet quality, alcohol intake, and smoking status. We excluded participants over 65 years at study entry. The first attendance was set as baseline and updated data were included if available during follow-up surveys and the participant still was eligible for inclusion (*e.g.*, if aged over 65 years at a follow-up survey, only their baseline data were included where they were followed to death, censoring or study end only using their baseline data).

Patient and public involvement

The Tromsø Study advisory board includes patient and public representatives. Some participants acted as ambassadors in the Tromsø Study during data collection, and actively contributed to recruitment of participants. There was no patient or public involvement in this current study.

Mortality

Information on all-cause, CVD, and cancer mortality was retrieved from the Norwegian Cause of Death Registry (35), through 31st of December 2021. Cause-specific mortality was identified using international classification of diseases (ICD)-codes; for CVD: ICD-8 codes 390–444.1, 444.3–458, 782.4), ICD-9 codes (390–459), and ICD-10 codes (I00–I99); for cancer: ICD-8 codes (140–209), ICD-9 codes (140–208), and ICD-10 codes (C00–C97). The Norwegian Cause of Death Registry is shown to provide high completeness (100%) compared to Global Vital Statistics (36), and high completeness for causes of death (85%) (35).

Physical activity

Physical activity was self-reported with the Saltin-Grimby Physical Activity Level Scale (SGPALS) (37, 38), which was slightly modified in the Tromsø Study compared with the original (37) (described elsewhere (39)). Participants ranked their physical activity level according to four mutually exclusive levels of OPA and LTPA (Table 1). The SGPALS is found to be positively associated with device-measured physical activity for both occupation (Spearman rho, ρ-range=0.17-0.45) ((40) and leisure time (Pearson correlation, r-range=0.20-0.25) (41), and have acceptable test-retest repeatability (kappa: 0.19-0.66) (42). In Tromsø4 (1994-95), the leisure time SGPALS was replaced by the Cohort of Norway physical activity questionnaire (43) (Supplementary Table S1), which we harmonized to the SGPALS (25) (Supplementary Table S2).

Table 1. The Saltin-Grimby Physical Activity Level Scale.*

	Occupational time	Leisure time
Question	*If you have paid or unpaid work, which statement describes your work best?*	*Describe your exercise and physical exertion in leisure time over the last year*
Rank 1	Mostly sedentary work? (e.g. office work, mounting)	Reading, watching TV/screen or other sedentary activity?
Rank 2	Work that requires a lot of walking? (e.g. shop assistant, light industrial work, teaching)	Walking, cycling, or other forms of exercise at least 4 hours a week? Include walking or cycling to workplace, Sunday stroll/walk etc.
Rank 3	Work that requires a lot of walking and lifting? (e.g. postman, nursing, construction)	Participation in recreational sports, heavy gardening, etc.? (note: duration of activity at least 4 hours a week)
Rank 4	Heavy manual labour? (e.g. forestry, heavy farm work, heavy construction)	Participation in hard training or sports competitions, regularly several times a week?

*Modified from the Original (37), as described by Sagelv et al. (39).

Covariates

We selected the following covariates *a priori* based on previous literature: Sex, age, education, body mass index (BMI), smoking, diet quality, alcohol intake, and leisure time physical activity (aim 1). Age and sex were retrieved from the Norwegian Population Registry. BMI was calculated from measured weight and height (kg/m^2). Education (primary school, high school, university <4 years, and university ≥4 years, Supplementary File S1), smoking (current, previous, never), alcohol intake (harmonized as units per week, Supplementary File S2, Supplementary Tables S3-6), and diet quality (harmonized as national nutritional guidelines met (44), Supplementary File S3, Supplementary Tables S7-11) were retrieved from questionnaires.

For descriptive purposes, we additionally retrieved information on diseases and hypertension from questionnaires, medicine use, recordings of blood pressure, the Tromsø Study CVD register, and working information (full time, part time, unpaid work, shift work) (Supplementary File S4).

Statistical Analyses

We performed all analyses separately by sex as previous studies indicate effect modification by sex (4, 25). We used Cox regressions to estimate hazard ratio (HR) and 95% confidence interval (CI) for the association between OPA and all-cause mortality, adjusted for BMI, education, smoking, diet quality, alcohol intake, LTPA, and age (years) as timescale (45). To account for competing risks of other causes of death, we used Fine and Gray regressions (46) to estimate the subdistributed HR (SHR) and 95%CI for the associations between OPA and CVD and cancer mortality. We set low OPA (sedentary work) as reference category. We tested two-way interactions between OPA and birth year to examine a possible cohort effect in the association between OPA and mortality.

We used the same adjustments except for LTPA when modelling joint OPA and LTPA associations (all-cause: Cox; cause-specific: Fine and Gray). Low OPA and inactive LTPA was set as reference category.

In all models, participants´ study entry was set two years after study attendance, and participants were followed to death, emigration (censoring), death by other causes in cause-specific analyses, or study end. If participants attended a new survey, their exposure and covariates were updated before re-entering the risk analysis as a new observation two years following their new attendance; however, if a participant died or were censored within two years after their new study attendance, their exposure and covariate data were not updated to minimize reverse causation bias. Additionally, if being over 65 years at the new attendance, their data was not updated but still followed to death, censoring or study end using their previous data when meeting the inclusion criteria. To assure statistical power in sub-group analyses, we collapsed OPA and LTPA groups with a lower intensity group if deaths per covariate in models were less than five in each exposure group (*i.e.*, <35 deaths) (47).

To evaluate reverse causation bias, we performed sensitivity analyses with similar Cox/Fine and Gray regressions of OPA and mortality but set study entry to five years after study attendance (and 5-year time lag on exposure and covariate update except if participants died within 5 years following the new study attendance). As BMI may act as a mediator in the association between OPA and mortality, we performed a sensitivity analysis by excluding BMI as a covariate to determine whether this would change the results. Further, as circadian rhythms may influence health and mortality risks, we also performed sensitivity analyses split by shift and non-shift workers. Finally, as socioeconomic status may to a large degree determine individuals´ working tasks, OPA level and lifestyle choices, we performed sensitivity analyses split by educational level.

Schoenfeld's residual tests were used to examine the proportional hazard assumption; diet quality (both p<0001), and LTPA (both p<0.02) in both women and men, and BMI in men (p=0.04) were significant at alpha 0.05. Following examination of log-log survival plots for these variables, we stratified the baseline hazard for diet quality for both women and men and additionally for LTPA in men as they did not display parallel lines. The remaining covariate hazards were proportional as per residuals tests (all p>0.08). Statistical analyses were performed using Stata version 17.0 (StataCorp LLC, Texas, United States) with alpha set to 0.05. Descriptive data are presented as frequencies (%) or means ± standard deviation (SD).

Equity, diversity, and inclusion statement

Our study has high participation rates (65-81% of those invited). The Tromsø Study is situated above the Arctic Circle (*i.e.*, the Far North), and recruited participants from all socioeconomic levels (Table 2). The author team includes both women and men, and junior and senior researchers within physical activity, epidemiology, statistics, and medicine. Some authors have indigenous backgrounds, and many are affiliated with the northernmost university globally, UiT The Arctic University of Norway. We did not consider equity, socioeconomic disadvantage, inequities in marginalized communities, or geographical differences in the analysis or interpretation of results, as these factors were beyond the scope of this study´s aims.

Results

Among 29605 participants, 4131 (14.0%) died during follow-up (median: 29.1 years; 25th-75th: 16.5.1-35.3.0), of which 1057 (25.6%) died from CVD and 1660 (40.2%) from cancer, respectively (Table 2). Of those attending at baseline, 11398 (38.5%) attended a second, 1946 (6.6%) a third, 786 (2.7%) a fourth, and 405 (1.4%) all five surveys, resulting in 44140 total observations (Table 2). Of the total 29605 participants attending at baseline, 4303 (14.5%) reported different OPA level at one or more follow-up surveys, and 6830 (27.1%) reported different LTPA level. Participant selection (flow chart) is found in Supplementary Figure S1. Survey-specific descriptive characteristics are found in Supplementary Table S12.

Table 2. Descriptive characteristics of the participants at baseline. The Tromsø Study 1986-2021.

	Women	Men	Total
Total (N)	14656	14949	29605
Observations (n)^{o}	22005	22135	44140
Dead			
All-cause, n (%)	1414 (6.4)	2717 (12.3)	4131 (14.0)
Cardiovascular disease, n (%)	286 (1.3)	771 (3.5)	1057 (3.6)
Cancer, n (%)	689 (3.1)	971 (4.4)	1660 (5.6)
Follow-up time (years)			
Median (25-75th percentile)	33.6 (20.1-35.0)	27.2 (14.0-35.0)	29.1 (16.5-34.9)
Min-max	2.0-35.3	2.0-35.3	2.0-35.3
Age (mean ± SD)	37.6 ± 9.7	39.5 ± 10.4	38.6 ± 10.1
≤30 years, n (%)	4195 (28.6)	3444 (23.0)	7639 (25.8)
30-39 years, n (%)	4628 (31.6)	4508 (30.2)	9136 (30.9)
40-49 years, n (%)	4237 (28.9)	4552 (30.5)	8789 (29.7)
50-99 years, n (%)	1438 (9.8)	2139 (14.3)	3577 (12.1)
≥60 years, n (%)	158 (1.1)	306 (2.1)	464 (1.6)
Birth year			
<1940, n (%)	1463 (10.0)	2228 (14.9)	3691 (12.5)
1940-49, n (%)	2780 (19.0)	2973 (19.9)	5753 (19.4)
1950-59, n (%)	4032 (27.5)	3852 (25.8)	7884 (26.6)
1960-69, n (%)	4360 (29.8)	4084 (27.3)	8444 (28.5)
≥1970, n (%)	2021 (13.8)	1812 (12.1)	3833 (12.8)
Body mass index (mean ± SD)	23.9 ± 4.1	25.4 ± 3.6	24.7 ± 3.9
<25 kg/m^2, n (%)	10344 (70.6)	7785 (52.1)	18129 (61.2)
25-29 kg/m^2, n (%)	3137 (21.4)	5749 (38.5)	8886 (30.0)
≥30 kg/m^2, n (%)	1175 (8.0)	1415 (9.5)	2590 (8.8)
Diet quality (mean ± SD)	1.0 ± 0.7	0.8 ± 0.7	0.9 ± 0.7
<1 nutritional guideline, n (%)	3956 (27.0)	5034 (33.7)	8990 (30.4)
1.0-1.9 nutritional guidelines, n (%)	6873 (46.9)	7218 (48.3)	14091 (47.6)
≥2.0 nutritional guidelines, n (%)	3827 (26.1)	2697 (18.0)	6524 (22.0)
Alcohol intake (mean ± SD)	1.6 ± 2.1	2.9 ± 3.6	2.3 ± 3.0
Teetotaller, n (%)	1805 (12.3)	1099 (7.4)	2904 (9.8)
0.1-1.9 units·week^{-1}, n (%)	9536 (65.1)	7395 (49.5)	16931 (57.2)
2-3.9 units·week^{-1}, n (%)	2451 (16.7)	3826 (25.6)	6277 (21.2)
≥4.0 units·week^{-1}, n (%)	864 (5.9)	2629 (17.6)	3493 (11.8)
Smoking			
Current smoker, n (%)	5406 (36.9)	5585 (37.4)	10991 (37.1)
Previous smoker, n (%)	3498 (23.9)	3951 (26.4)	7449 (25.2)
Never smoker, n (%)	5752 (39.3)	5413 (36.2)	11165 (37.7)
Education			
Primary school, n (%)	3379 (23.1)	3761 (25.2)	7140 (24.1)
High school, n (%)	4646 (31.7)	4754 (31.8)	9400 (31.8)
University <4 years, n (%)	2942 (20.1)	2969 (19.9)	5911 (20.0)
University ≥4 years, n (%)	3689 (25.2)	3465 (23.2)	7154 (24.2)
Disease, n (%)	444 (3.0)	653 (4.4)	1097 (3.7)
Cardiovascular disease, n (%)	116 (0.8)	398 (2.7)	514 (1.7)
Cancer, n (%)	213 (1.8)	101 (0.8)	314 (1.1)
Diabetes, n (%)	129 (0.9)	189 (1.3)	318 (1.1)
Hypertension, n (%)	3517 (24.0)	7886 (52.9)	11403 (38.5)
Physical activity			
Occupation			
Low, n (%)	6199 (42.3)	7254 (48.5)	13453 (45.4)
Moderate, n (%)	5521 (37.7)	3485 (23.39	9003 (30.4)
High, n (%)	2775 (18.9)	3037 (20.3)	5812 (19.6)
Very High, n (%)	161 (1.1)	1173 (7.9)	1334 (4.5)
Leisure time			

Inactive	2973 (20.3)	3195 (21.4)	6168 (20.8)
Active	8722 (59.5)	6613 (44.2)	15335 (51.8)
Vigorously Active	2469 (16.9)	4016 (26.9)	6485 (21.9)
Very Vigorously Active	492 (3.4)	1125 (7.5)	1617 (5.5)
Occupation status (n)*			28247
Full time, n (%)	9347 (67.3)	12750 (88.8)	22097 (78.2)
Part time, n (%)	2905 (20.9)	557 (3.9)	3462 (12.3)
Unpaid, n (%)	1630 (11.7)	1058 (7.4)	2688 (9.5)
Shift work (n)*	11572	11775	23347
Works shift, n (%)	2206 (19.1)	2358 (20.0)	4564 (19.5)
Pain (n)*	13842	14094	27936
Any pain, n (%)	5657 (40.9)	4436 (31.5)	10093 (36.1)

Data are shown as mean ± SD, or as frequency (percentage). CVD=cardiovascular disease, SD=standard deviation. ºTotal observations at one survey include follow up of previous surveys. ¤Disease include cardiovascular disease, cancer, and diabetes; as one can have more than one disease, these do not add up to participants with any disease. *Fewer participants had information on this variable compared with the total sample.

Independent associations of OPA and mortality

In men, compared with low OPA, high OPA was associated with lower risk of all-cause (HR: 0.83, 95%CI: 0.74-0.92) and CVD (SHR: 0.68, 95%CI: 0.54-0.84) but not cancer mortality (SHR: 0.99, 95%CI: 0.84-1.19) (Figure 1-2). Moderate OPA (all-cause HR: 0.98, 95%CI: 0.89-1.08; CVD SHR: 0.95, 95%CI: 0.80-1.14; cancer SHR: 0.94, 95%CI: 0.80-1.11) and very high OPA (all-cause HR: 1.07, 95%CI: 0.94-1.22; CVD SHR: 1.02, 95%CI: 0.80-1.28; cancer SHR: 0.91, 95%CI: 0.72-1.15) versus low OPA was not associated with mortality in men (Figure 1-2). There was no association between OPA and mortality in women (Figure 1-2).

We observed a possible cohort effect by birth year for all-cause mortality in men (interaction p=0.06), where high OPA was associated with lower mortality risk in those born before 1940 (HR: 0.82, 95%CI: 0.71-0.96), whereas very high OPA was associated with higher mortality risk in those born after 1950 (HR: 1.38, 95CI: 1.00-1.89) (Supplementary Table 13). For women, although we observed no interaction (p=0.46), moderate OPA was associated with higher all-cause mortality risk in those born before 1940 (HR: 1.23, 95%CI: 1.02-1.47), which was not observed in those born after 1950 (Supplementary Table 13).

Joint OPA, LTPA, and mortality risk

In joint analyses using low OPA and inactive LTPA as reference, in men, vigorous LTPA was associated with lower all-cause mortality risk combined with low (HR: 0.75, 95%CI: 0.64-0.89), high (HR: 0.67, 95%CI: 0.54-0.82) and very high OPA (HR: 0.74, 95%CI: 0.58-0.94), but not with moderate OPA (Figure 3B). In men, moderate LTPA was only associated with lower all-cause mortality risk in those having high OPA (HR: 0.79, 95%CI: 0.67-0.94) (Figure 3B). In women, although CIs crossed unity, vigorous LTPA was associated with lower all-cause mortality risk in those having low (HR: 0.82, 95%CI: 0.62-1.08) and high OPA (HR: 0.78, 95%CI: 0.58-1.07) (Figure 3A).

Although CIs crossed unity, only high OPA appeared to lower the risk of CVD mortality in men in the joint analysis (inactive LTPA: SHR: 0.69, 95%CI: 0.45-1.06; moderate LTPA: SHR: 0.73, 95%CI: 0.52-1.02; vigorous LTPA: SHR: 0.71, 0.48-1.06) (Figure 4B). Only vigorous LTPA combined with very high OPA was associated with lower cancer mortality risk in men (SHR: 0.62, 95%CI: 0.39-0.97) (Figure 4D). There was no association between joint OPA and LTPA, and mortality in women (Figure 3-4).

Sensitivity analyses

When restricting the analyses to those with more than five years follow-up time, high compared with low OPA was associated with lower risk for CVD mortality in men (SHR: 0.76, 95%CI: 0.61-0.95), while the CIs for all-cause and cancer mortality indicated no association across OPA levels (Supplementary Table S14). Analyses without adjustment for

BMI did not change the results (Supplementary Table S15). In non-shift workers, men with high OPA had lower risk of CVD mortality (SHR: 0.69, 95%CI: 0.54-0.88), while men with very high OPA had higher risk of all-cause mortality (HR: 1.46, 95%CI: 1.12-1.90), compared with low OPA (Supplementary Table S16). In analyses split by educational level, high OPA was associated with lower all-cause and CVD mortality risk in those having primary (all-cause HR: 0.83, 95%CI: 0.72-0.97; CVD SHR: 0.75, 95%CI: 0.56-0.99) and high school (all-cause HR: 0.68, 95%CI: 0.56-0.83; CVD SHR: 0.63, 95%CI: 0.44-0.89) as their highest education (Supplementary Table S17). Men with moderate OPA and University education had higher risk of all-cause mortality (HR: 1.22, 95%CI: 1.01-1.48) (Supplementary Table S17). There were no associations between OPA and mortality across OPA levels in women split by non-shift and shift workers or by educational level (Supplementary Table S16-17).

Discussion

In this prospective cohort study over four decades from 1986 to 2021, which included updated information on covariates every ~6-8th year, high OPA, but not moderate or very high OPA, was associated with lower all-cause and CVD mortality in men. There was no clear association between OPA and cancer mortality. Higher LTPA was associated with lower mortality risk among those having low, high, and very high OPA levels, but not moderate OPA level. We observed no association between OPA, or joint LTPA and OPA, and risk of mortality in women.

Previous studies have reported conflicting results regarding the association between OPA and mortality, with some showing higher mortality (4-12), and others showing lower mortality with higher OPA (16-25), or no association (26). In our study, men with high OPA had a lower mortality risk, but this was not observed with very high OPA. We observed a cohort effect by birth year, where high OPA was only associated with lower morality risk in the older generations, and very high OPA was associated with higher mortality risk in men born after 1950. As many jobs in the 1960s-1980s were more diverse compared to today's more automated and monotonous work tasks (27, 28), this may indicate inherent cohort effects explaining recent observations in the literature where OPA is not associated with lower mortality (4-12), contrary to earlier studies (16-21).

We observed no associations between OPA and mortality in women. This aligns with a recent systematic review (4) and a recent prospective cohort study of over 400 000 Norwegian women and men (25). One possible explanation is different effect of equal amounts of physical activity in men versus women (48). Another explanation may be that work involving higher OPA is typically different in women than men (4). Thus, although women and men report similar OPA level, their perception of the effort may be different (4, 25). However, differences in perception and reporting of OPA are unlikely to fully explain the different associations observed between sexes. Future research is warranted to explore how OPA differently affects women and men.

Moreover, high OPA was only associated with lower mortality risks in men reporting daytime work. As those working shifts are at higher mortality risk compared with daytime workers (49-51), high OPA levels may be insufficient to attenuate this risk. Similarly, we only observed lower mortality risk with high OPA in men having primary and high school as highest education. Thus, high OPA, but not very high OPA, appears to lower mortality risk particularly in men with low socio-economic status. In contrast, moderate OPA was associated with higher mortality risk in men with university education. Considering that high

OPA workers with higher educations may predominantly be health care workers, this may be explained by high work demands and low work control leading to burn-out, depression, anxiety, suicide or other health problems (52).

Our study reveals nuances in how OPA levels and their combination with LTPA, associates with mortality risk. A recent systematic review of studies examining joint associations of OPA and LTPA reported that higher LTPA was associated with lower all-cause mortality risk in those with low and moderate OPA levels, but not among workers with high OPA (29). In our study, vigorous LTPA was also associated with lower mortality risk among those with high and very high OPA. In contrast, moderate LTPA, which is in the SGPALS defined to exceed current lower limit guidelines of physical activity (32), was not associated with lower mortality risk across OPA levels. This suggests that if having very high OPA that may not be associated with lower mortality, participation in moderate LTPA may be insufficient to lower mortality risks, while vigorous LTPA will likely lower their mortality risk at similar levels as for those having low OPA.

Although very high OPA (*i.e.*, heavy manual labour) may be perceived exhaustive, it may be of insufficient intensity to influence cardiorespiratory fitness (28). In fact, it is more likely that the high volume with low intensity and low worker control throughout a working day results in insufficient recovery time between every physical activity bout, which may ultimately be associated with stress, anxiety, inflammation, hypertension, and pain (28). For example, higher OPA is associated with pain-related disability pension (53). These characteristics contrast with LTPA, which is usually performed in bouts of limited duration and higher intensity, and with sufficient recovery time between bouts that usually results in higher cardiorespiratory fitness (28).

Higher OPA may also lead to lower LTPA (54), possibly due to a need for recovery from exhaustive work tasks (55). We observed no association between OPA and mortality in the younger generations and not in shift workers, and LTPA was associated with lower mortality across OPA levels. Therefore, there is a need to identify measures that can encourage and support high OPA workers to engage in LTPA and exercise (29), both to improve overall health and to increase fitness in order to lower the relative load of exhaustive working tasks (56). Indeed, a recent systematic review generally found beneficial health effects for those engaging in LTPA across OPA levels (29). Measures to increase LTPA within different OPA levels can include workplace interventions (57) or provide opportunities for physical activity as means for transport (58). However, future research is warranted to identify specific interventions for various working groups, especially at the population level.

Strengths

We used a cohort with high participation, which may limit selection bias and strengthen generalizability, at least towards Western populations. We updated exposure and covariates every ~6-8th year across four decades, which lowers risk of misclassification. We also included diet as a covariate, which is often missing in studies examining associations between OPA and mortality (15). Furthermore, the linkage with the Norwegian Cause of Death Registry minimized misclassification of mortality and causes for mortality (35, 36). Finally, the comparable findings when restricting the analyses to those with ≥5 years follow-up time suggest findings are robust for reverse causation bias.

Limitations

The western origin of this study (59) may limit generalizability to other world regions, as working environments may differ. However, lower mortality risk from OPA is also observed in low and middle-income countries (1), indicating that physical activity derives similar biological effects across populations. Although we used updated covariates and exposures, only 40% of the baseline sample attended two surveys with a complete set of new information on inclusion criteria, and 7% attended three surveys, and we cannot rule out residual confounding and misclassification bias.

Although the domain-specific SGPALS questions are both shown to indicate higher device-measured physical activity with higher ranks, the differences in physical activity, and thus also physical activity energy expenditure, is modest in the OPA question (40) compared with the LTPA question (41). This could be related to actual different energy expenditure in OPA versus LTPA although OPA may be perceived exhaustive (28), as mentioned above. However, as questions in self-reported tools can be interpreted differently by participants today compared with the 1980s, the beneficial effects of very high OPA as observed in the older generations in this study may also be caused by a cohort effect due to different interpretations of what constitutes very high OPA today versus previous decades.

Further, as the SGPALS questionnaire is crude, quantification of exact intensity and duration of the activities was unavailable (60). Moreover, as participants were asked about average physical activity over the past year, this also put a high cognitive demand on correctly memorizing all relevant activities for the participants (60). Nevertheless, as misclassification form self-reported physical activity is inevitable due to imprecise recall of intensity and duration, especially over longer time periods (60), crude groups of self-reported physical activity may be the preferred option to derive relevant associations with health outcomes (61), although at the expense of information quality (62). Future studies using devices that differentiate between physical activity domains and types are warranted to further validate our results.

Conclusion

In men, high OPA (but not moderate or very high) was associated with a lower all-cause and CVD mortality. Vigorous LTPA was associated with lower mortality risk in all OPA levels except moderate OPA. We observed no association between OPA, or OPA and LTPA, and mortality in women. These findings indicate that vigorous LTPA appears to lower mortality risks at similar levels in individuals with low and high OPA in men. The lack of an observed association between OPA and mortality in women warrants future research to explore different effects of OPA between women and men.

Figure legends

Figure 1. The association between OPA and all-cause mortality in women and men, with sedentary work as reference category. The Tromsø Study 1986-2021. Hazard ratios are adjusted for BMI, smoking, diet, alcohol intake, education, LTPA, and age (timescale). CVD=cardiovascular disease, BMI=body mass index, OPA=occupational physical activity, LTPA=leisure time physical activity.

Figure 2. The association between OPA and cause-specific mortality in women and men for A) CVD mortality, and B) cancer mortality, with sedentary work as reference category. The Tromsø Study 1986-2021. For women, very high OPA is collapsed with high OPA due to few deaths. Hazard ratios are adjusted for BMI, smoking, diet, alcohol intake, education, LTPA,

and age (timescale). CVD=cardiovascular disease, BMI=body mass index, OPA=occupational physical activity, LTPA=leisure time physical activity.

Figure 3. The joint association of OPA and LTPA with all-cause mortality in A) women B) men, with low OPA and inactive LTPA as reference category. The Tromsø Study 1986-2021. For women, very high OPA and very vigorous LTPA are collapsed with high OPA and vigorous LTPA, respectively, due to few deaths in these combinations. For men, very vigorous LTPA is collapsed with vigorous LTPA due to few deaths in these combinations. Hazard ratios are adjusted for BMI, smoking, diet, alcohol intake, and education, and age (timescale). CVD=cardiovascular disease, BMI=body mass index, OPA=occupational physical activity, LTPA=leisure time physical activity.

Figure 4. The joint association of OPA and LTPA with cause-specific mortality in A) CVD mortality in women, B) CVD mortality in men, C) cancer mortality in women, and D) cancer mortality in men, with low OPA and inactive LTPA as reference category. The Tromsø Study 1986-2021. For women, very high OPA and very vigorous LTPA are collapsed with high OPA and vigorous LTPA, respectively, due to few deaths in these combinations. For men, very vigorous LTPA is collapsed with vigorous LTPA due to few deaths in these combinations. Hazard ratios are adjusted for BMI, smoking, diet, alcohol intake, and education, and age (timescale). CVD=cardiovascular disease, BMI=body mass index, OPA=occupational physical activity, LTPA=leisure time physical activity.

Supplementary Materials

Supplementary File S1. Harmonization of education.

Supplementary File S2. Harmonization of alcohol intake.

Supplementary Table S1. The Cohort of Norway physical activity questionnaire.

Supplementary Table S2. The harmonization of the Saltin-Grimby Physical Activity Level Scale and Cohort of Norway physical activity questionnaire.

Supplementary Tables 3-6. Alcohol intake questionnaires in The Tromsø Study.

Supplementary File S3. Harmonization of diet quality.

Supplementary Tables S7-11. Diet quality questionnaires in The Tromsø Study.

Supplementary File S4. Description and harmonization of chronic pain, disease, hypertension, and work-related variables.

Supplementary Table S12. Cohort-specific descriptive characteristics of the participants at baseline. The Tromsø Study 1986-2021.

Supplementary Table S13. Occupational physical activity and risk of all-cause, CVD and cancer mortality split by birth year.

Supplementary Table S14. Occupational physical activity and risk of all-cause, CVD, and cancer mortality with excluding <5 years of follow-up time.

Supplementary Table S15. Occupational physical activity and risk of all-cause, CVD, and cancer mortality by not adjusting for body mass index as a covariate.

Supplementary Table S16. Occupational physical activity and risk of all-cause, CVD, and cancer mortality split by shift and non-shift workers.

Supplementary Table S17. Occupational physical activity and risk of all-cause, CVD, and cancer mortality split by educational level.

Supplementary Figure S1. Flow chart of included participants.

References for supplementary materials.

Declarations

Ethical considerations

The Tromsø Study surveys were conducted according to the Declaration of Helsinki. All participants provided written informed consent, except in Tromsø3 (1986-87), who provided oral consent at participation, as written informed consent was not required at the time; use of these data are in the public interest, in accordance with the Personal Data Act in Norway (LOV-2000-04-14-31, link: https://lovdata.no/dokument/NL/lov/2018-06-15-38). The Regional Ethics Committee for Medical and Health Research Region North approved this current study (Ref.: 360922). The Norwegian Centre for Research Data approved the storage of study data (Ref.: 464608).

Author contributions

EHS designed the study and act as guarantor for the study. AEE, MLL and TW contributed to acquisition and processing of raw Tromsø Study data. EHS performed statistical analyses. TW provided statistical expertise. EHS wrote the initial draft of the manuscript. All authors critically reviewed the study´s results, contributed to revisions and approved the final version of the manuscript.

Data availability

The data underlying this article were provided by The Tromsø Study under license, and so are not publicly available. Data can be shared upon application to The Tromsø Study Data and Publication Committee: https://uit.no/research/tromsostudy.

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Competing interests

MLL has received lecture fees from Bayer, Sanofi and BMS/Pfizer not related to this study. The remaining authors declare no conflict of interest.

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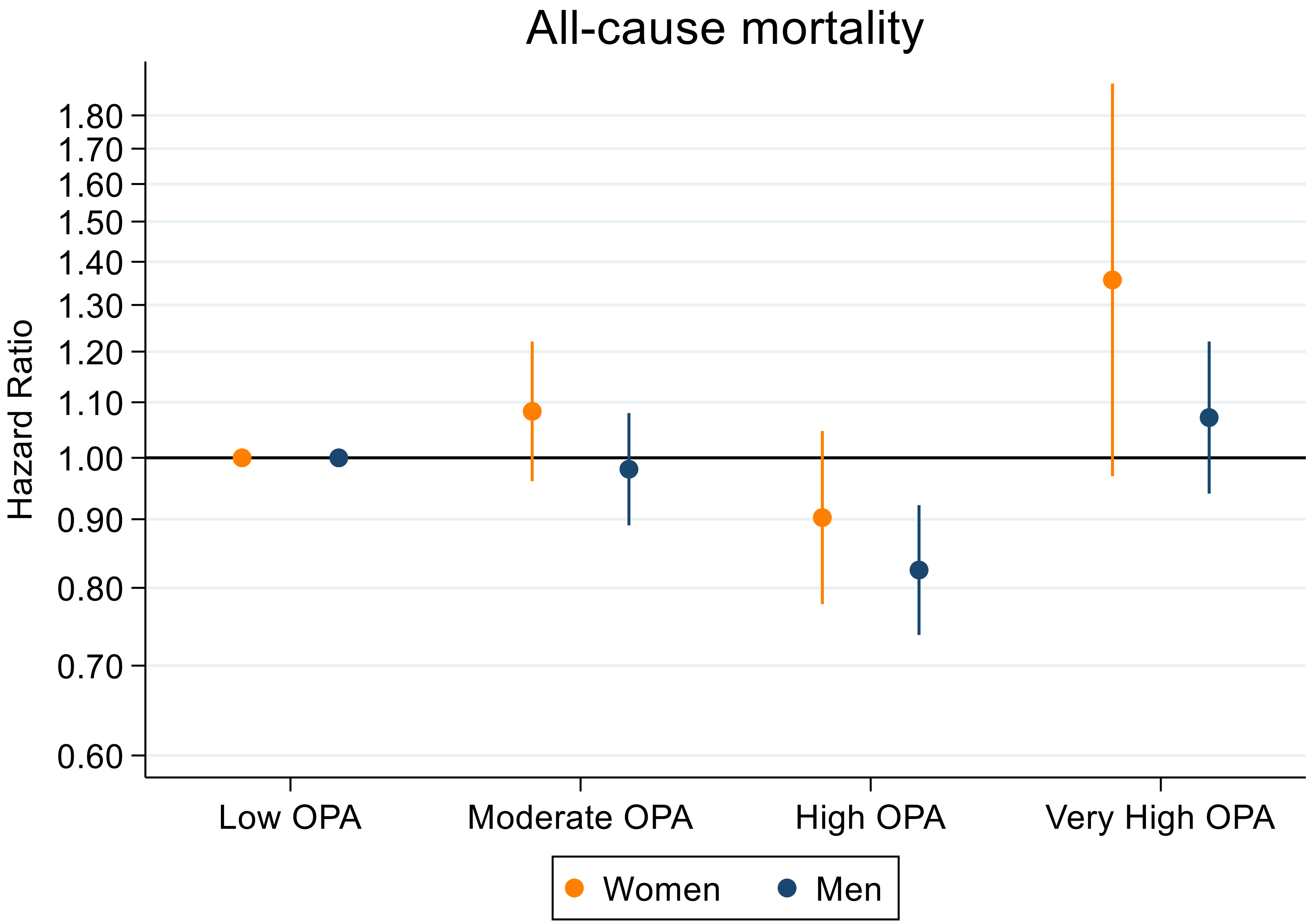
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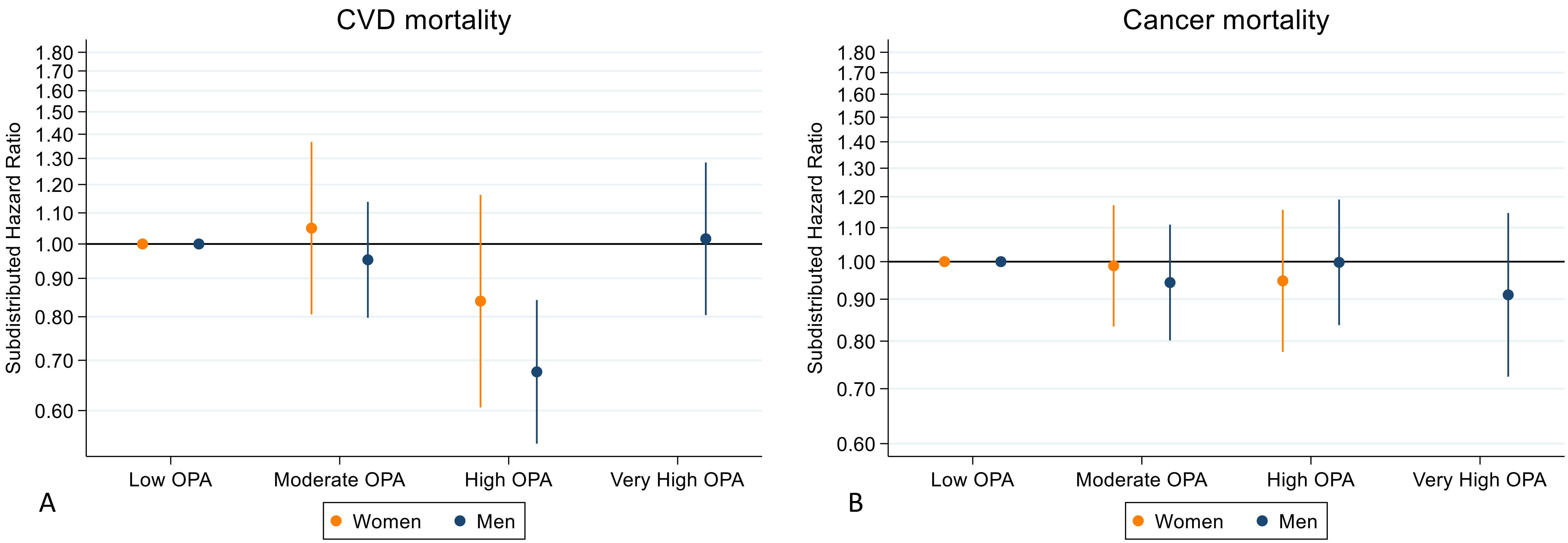
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Cancer mortality
Subdistributed Hazard Ratio
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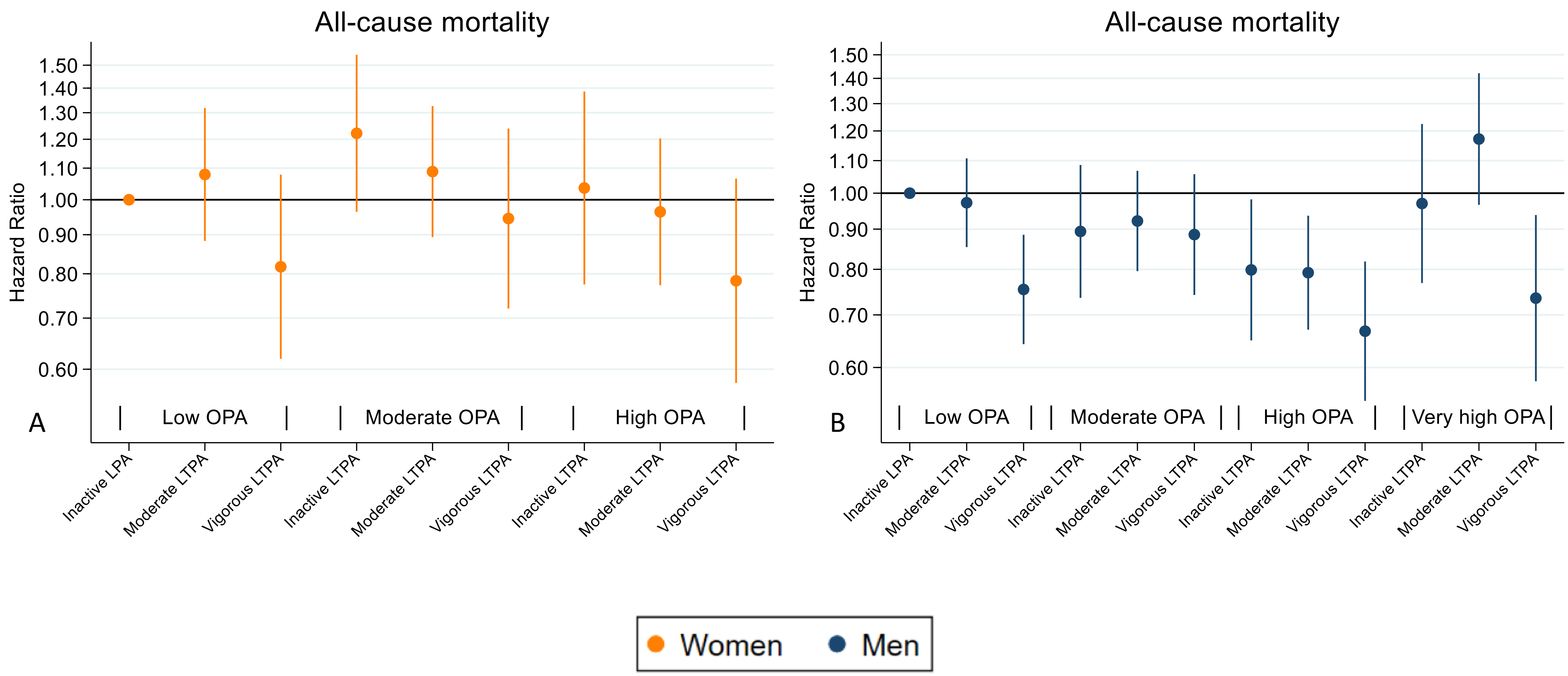

All-cause mortality
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High OPA
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Moderate LTPA
Vigorous LTPA
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All-cause mortality
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Vigorous LTPA
Women
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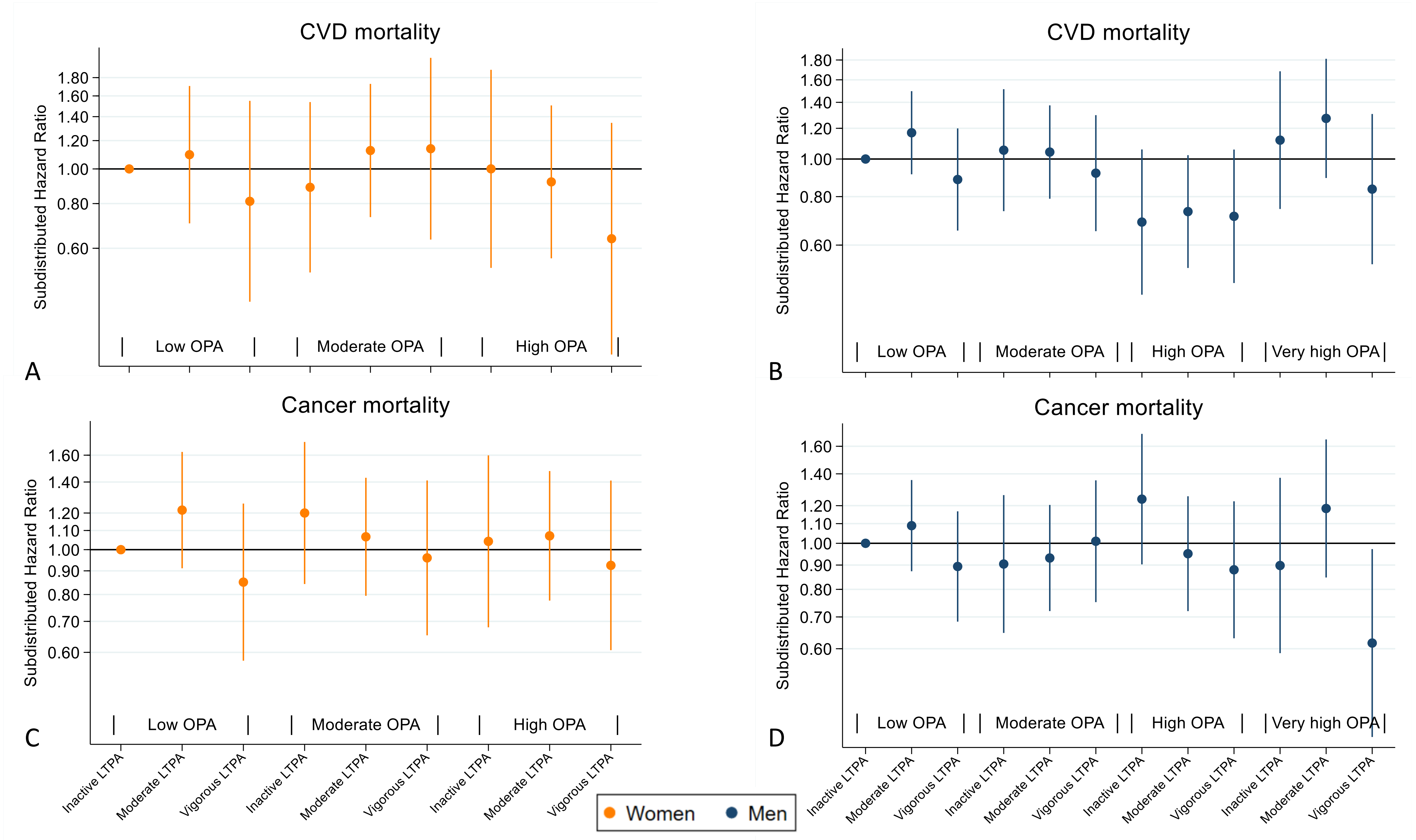

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Very high OPA
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Cancer mortality
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D
Cancer mortality
Inactive LTPA
Moderate LTPA
Vigorous LTPA
Women
Men

Supplementary materials

Contents

Supplementary File S1. Harmonization of education

Information on education was retrieved from questionnaires. In Tromsø6 (2007-08) and Tromsø7 (2015-16), participants were asked for education in four groups 1) Primary school, 2) High School, 3) University <4 years and 4) University ≥4 years. In Tromsø3 (1986-87) and Tromsø5 (2001), participants were asked about years of education, which we categorized as the four abovementioned groups according to the Norwegian educational system, as: 1) Primary School, <10 years education; 2) High School, 10-12 years; 3) University <4 years, 13-15 years; 4) University ≥4 years, ≥16 years. In Tromsø4 (1994-95), participants answered education as five groups, the four abovementioned groups and a fifth group, Technical/vocational school, which we categorized as 2) High School. Self-reported education in Tromsø7 (2015-16) is found to be adequately complete when compared against registry-based educational level from Statistics Norway (1).

Supplementary Table S1. The Cohort of Norway physical activity questionnaire.

Question	**Answer alternatives**
How has your physical activity in leisure time been during this last year? Think of your weekly average for the year (hours per week)	
Light activity (not sweating or out of breath)	1: None 2: less than 1 hour 3: 1-2 hours 4: 3 or more hours
Hard physical activity (sweating/out of breath)	1: None 2: less than 1 hour 3: 1-2 hours 4: 3 or more hours

Reference: Graff-Iversen et al, 2008, *Eur J Epidemiol* (2).

Supplementary Table S2. The harmonization of the Saltin-Grimby Physical Activity Level Scale and Cohort of Norway physical activity questionnaire.

Saltin-Grimby Physical Activity Scale	**The Cohort of Norway physical activity questionnaire**
Rank 1	Light = 1, 2 or 3 & Hard = not answered
Rank 1	Hard = 1 or 2 & Light = not answered
Rank 1	Light = 1 or 2 & Hard = 1 or 2
Rank 1	Light = 3 & Hard = 1
Rank 2	Light = 4 & Hard = not answered
Rank 2	Hard = 3 & Light = not answered
Rank 2	Light = 1 or 2 & Hard = 3
Rank 2	Light = 3 or 4 & Hard = 1 or 2
Rank 3	Light = 4 & Hard = 2 or 3
Rank 3	Light = 3 & Hard = 3
Rank 4	Hard = 4 & Light = not answered
Rank 4	Light = 1, 2, 3 or 4 & Hard = 4

According to Dalene *et al.*, 2021, *Lancet Public Health* (3).

Supplementary File S2. Description of alcohol intake.

Alcohol intake was retrieved from questionnaires. Questions on alcohol have been changing across surveys, except similar questions in Tromsø6 (2007-08 and Tromsø7 (2015-16). In Tromsø3 (1986-87) and Tromsø4 (1994-95), participants answered questions on frequency of beer, wine and spirits intake, a question on frequency of binge drinking, and if being a teetotaler. Questions in Tromsø 5-7 also included questions on volume of alcohol intake. To harmonize alcohol intake across surveys, we considered the frequency in Tromsø3-4 to include one units of alcohol, equivalent to Norwegian standards of alcohol units: 1 bottle of 0.33 L beer, 1.5 dl glass of wine and 4 cl of spirits. Answers on all questions were summed as units per week. The calculation of all questions in each survey to represent units per week are described in Supplementary Table S3-6.

Supplementary Table S3. Questions and answering alternatives for alcohol intake in Tromsø3 (1986-87).

Question	**Answer alternatives***
Are you a teetotaller?	1: Yes (0) 2: No (N/A)
If not a teetotaller, how often do you usually drink beer?	1: Never, or just a few times a year (0.125) 2: Once or twice a month (0.33) 3: About once a week (1) 4: 2-3 times a week (2.5) 5: More or less daily (6)
If not a teetotaller, how often do you usually drink wine?	1: Never, or just a few times a year (0.125) 2: Once or twice a month (0.33) 3: About once a week (1) 4: 2-3 times a week (2.5) 5: More or less daily (6)
If not a teetotaller, how often do you usually drink spirits?	1: Never, or just a few times a year (0.125) 2: Once or twice a month (0.33) 3: About once a week (1) 4: 2-3 times a week (2.5) 5: More or less daily (6)
Approximately how often during the past 12 months have you drunk alcohol corresponding to at least 5 small bottles of beer, a bottle of wine or a quarter bottle of spirits?	1: Not at all the past year (0) 2: A few times (0.3) 3: Once or twice a month (0.6) 4: Three or more times a week (15)

*Numbers in parentheses indicate units of alcohol per week, which was summed to total units per week.

Supplementary Table S4. Questions and answering alternatives for alcohol intake in Tromsø4 (1994-95).

Question	**Answer alternatives ***
Are you a teetotaller?	1: Yes (0) 2: No (N/A)
How many glasses of beer do you normally drink in a fortnight. Do not count low-alcohol beer. Put 0 if less than once a month.	Continuous scale
How many glasses of wine do you normally drink in a fortnight. Put 0 if less than once a month.	Continuous scale
How many glasses of spirits do you normally drink in a fortnight. Put 0 if less than once a month.	Continuous scale

*Frequency was regarded as one unit, which was summed to total units per week.

Supplementary Table S5. Questions and answering alternatives for alcohol intake in Tromsø5 (2001).

Question	**Answer alternatives***
Are you a teetotaller?	1: Yes (0) 2: No (N/A)
Approximately, how often have you during the last year consumed alcohol (do not count low-alcohol beer)?	1: Never consumed alcohol (0) 2: Not during the last year (0) 3: A few times (0.125) 4: 1 time per month (0.25) 5: 2-3 times per month (0.65) 6: 1 time per week (1) 7: 2-3 times per week (2.5) 8: 4-7 times per week (5.5)
When you drink alcohol, how many glasses or drinks do you normally drink?	Continuous scale multiplied by number in parentheses of question on frequency.
Approximately how many times during the last year have you consumed alcohol equivalent to 5 glasses or drinks within 24 hours.	Continuous scale divided by 52 weeks

*Numbers in parentheses indicate times per week, which was multiplied with numbers of drink when they usually drank (continuous scale). This was summed with the question of binge drinking.

Supplementary Table S6. Questions and answering alternatives for alcohol intake in Tromsø6 (2007-08) and in Tromsø7 (2015-16).

Question	**Answer alternatives***
Are you a teetotaller?	1: Yes (0) 2: No (N/A)
How often do you usually drink alcohol?	1: Never (0) 2: Monthly or less frequently (0.25) 3: 2-4 times a month (1) 4: 2-3 times a week (2.5) 4: 4 or more times a week (5.5)
How many units of alcohol (a beer, a glass of wine or a drink) do you usually drink when you drink alcohol?	1: 1-2 (1.5) 2: 3-4 (3.5) 3: 5-6 (5.5) 4: 7-9 (8) 5: 10 or more (10)
How often do you drink 6 units alcohol or more in one occasion?	1: Never (0) 2: Less frequently than monthly (1.5) 3: Monthly (1.5) 4: Weekly (6) 5: Daily or almost daily (30)

*Numbers in parentheses indicate times per week for the frequency question and units for the volume question, which was multiplied to units per week. Number in parentheses for the binge drinking question indicate units per week, which was summed with units per week from combined frequency and volume question.

Supplementary File S3. Harmonization of Diet quality

Diet quality was retrieved from questionnaires, where questions were harmonized to display number of national nutrition guidelines for fruit/vegetables/berries-, fish-, processed meat- and saturated fat intake (4) that participants met. The number of questions and possible nutrition guidelines to meet differed across surveys due to number of included questions. In Tromsø7 (2015-16), an included food frequency questionnaire (5) (validated previously (6, 7)) allowed for calculation of grams of fish and fruit/vegetables that participants consumed, which was amalgamated with the remaining food intake questions. The harmonization is shown in Supplementary Tables S7-11.

Supplementary Table S7. Questions, answer alternatives and calculation of diet quality in Tromsø3 (1986-87).

Nutritional guideline	**Question**	**Answer alternatives***
Fish intake		
"Eat fish 2-3 times per week"	*How often do you eat cod/pollock or other lean fish for dinner or in a sandwich?*	1: Less than once a week (0) sandwich? 2: Once a week (0.5) 3: Twice a week (1) 4: 3 or more times a week (1)
"Eat fish 2-3 times per week"	*How often do you eat herring, halibut, mackerel, salmon, trout or other fatty fish for dinner or in a sandwich?*	1: Less than once a week (0) 2: Once a week (0.5) 3: Twice a week (1) 4: 4 or more times a week (1)
"Eat fish 2-3 times per week"	*Do you take cod liver oil regularly?*	1: No (0) 2: Polar night (0.5) 3: All year (1)
Saturated fat intake		
"Choose oils, liquid margarine or soft margarine."	*How often do you use fat like butter, margarine, mayonnaise etc. with your dinner?*	1: Less than once a week (0.5) 2: Once or twice a week (0.25) 3: 3-4 times a week (0) 4: 5 or more times a week (0)
Fruit/vegetables intake		
"Eat five portions of fruit, vegetables and/or berries each day."	*Do you usually eat vegetables with your dinner?*	1: Yes (0.1) 0: No (0)
"Eat five portions of fruit, vegetables and/or berries each day."	*How often do you usually eat fruit?*	1: Less than once a week (0) 2: About once a week (0.05) 3: 2-3 times a week (0.2) 4: 4-5 times a week (0.5) 5: More or less daily (1)

*Each nutritional guideline was summed to represent whether it was met. If obtaining higher than 1 for one guideline, the number was replaced with 1 (*e.g.*, if obtaining 2 from the fish intake questions, it was replaced with 1 as one cannot meet a guideline twice per week). Each guideline was thereafter summed. In Tromsø3 (1986-87), number of guidelines met ranged from 0.0-3.0.

Supplementary Table S8. Questions, answer alternatives and calculation of diet quality in Tromsø4 (1994-95).

Nutritional guideline	**Question**	**Answer alternatives***
Fish intake		
"Eat fish 2-3 times per week"	*How many times per week do you normally eat fat fish (e.g. salmon/redfish) for dinner?*	1: Never (0) 2: <1 (0.2) 3: 1 (0.3) 4: 2-3 (1) 5: 4-5 (1) 6: Approximately every day (1)
"Eat fish 2-3 times per week"	*How many times per week do you normally eat lean fish (e.g. cod) for dinner?*	1: Never (0) 2: <1 (0.2) 3: 1 (0.3) 4: 2-3 (1) 5: 4-5 (1) 6: Approximately every day (1)
"Eat fish 2-3 times per week"	*How many slices of bread with fish (e.g. mackerel in tomato sauce) do you usually eat daily (number)?*	1: 0 (0) 2: <1 (0.05) 3: 1-2 (0.1) 4: 3-4 (0.15) 5: 5-6 (0.2) 6: >6 (0.3)
Saturated fat intake		
"Choose oils, liquid or soft margarine."	*What type of margarine or butter do you usually use on your bread?*	1: Do not use margarine or butter on bread (1) 2: Butter (0) 3: Hard margarine (0) 4: Soft margarine (1) 5: Butter/margarine mixtures (0.5) 6: Light margarine (1)
"Choose oils, liquid or soft margarine."	*Do you normally use butter in cooking (not on the bread) in your home?*	1: Yes (0)
"Choose oils, liquid or soft margarine."	*Do you normally use hard margarine in cooking (not on the bread) in your home?*	1: Yes (0)
"Choose oils, liquid or soft margarine."	*Do you normally use hard margarine in cooking (not on the bread) in your home?*	1: Yes (0)
"Choose oils, liquid or soft margarine."	*Do you normally use soft margarine in cooking (not on the bread) in your home?*	1: Yes (1)
"Choose oils, liquid or soft margarine."	*Do you normally use butter/margarine blend in cooking (not on the bread) in your home?*	1: Yes (0)
"Choose oils, liquid or soft margarine."	*Do you normally use oils in cooking in your home?*	1: Yes (1)

		If answering yes on more than one of use of butter/margarine/oil in cooking, the value 0.5 is given (*e.g.*, if using both oils (1) and hard margarine (0) = 0.5)
Fruit/vegetables intake		
"Eat five portions of fruit, vegetables and/or berries each day."	*How many times per week do you normally eat vegetables for dinner?*	1: Never (0) 2: <1 (0.03) 3: 1 (0.1) 4: 2-3 (0.1) 5: 4-5 (0.15) 6: Approximately every day (0.2)
"Eat five portions of fruit, vegetables and/or berries each day."	*How many times per week do you normally eat apples/pears?*	1: Never (0) 2: <1 (0.03) 3: 1 (0.1) 4: 2-3 (0.1) 5: 4-5 (0.15) 6: Approximately every day (0.2)
"Eat five portions of fruit, vegetables and/or berries each day."	*How many times per week do you normally eat oranges, mandarines?*	1: Never (0) 2: <1 (0.03) 3: 1 (0.1) 4: 2-3 (0.1) 5: 4-5 (0.15) 6: Approximately every day (0.2)
"Eat five portions of fruit, vegetables and/or berries each day."	*How much orange juice do you usually drink daily (glasses) ?*	1: 0 (0) 2: <1 (0) 3: 1-2 (0.25) 4: 3-4 (0.6) 5: 5-6 (1) 6: >6 (1)
Processed meat intake		
"Choose non-processed meat and limit intake of red meat."	*How many slices of bread with fat meat (e.g. salami) do you usually eat daily (number)?*	1: 0 (1) 2: <1 (1) 3: 1-2 (0.5) 4: 3-4 (0.25) 5: 5-6 (0) 6: >6 (0)
"Choose non-processed meat and limit intake of red meat."	*How many times per week do you normally eat unprocessed meat for dinner?*	1: Never (1) 2: <1 (1) 3: 1 (0.25) 4: 2-3 (0) 5: 4-5 (0) 6: Approximately every day (0)
"Choose non-processed meat and limit intake of red meat."	*How many times per week do you normally eat sausage/meatloaf/meatballs for dinner?*	1: Never (1) 2: <1 (1) 3: 1 (0.25) 4: 2-3 (0) 5: 4-5 (0) 6: Approximately every day (0)

*Each nutritional guideline was summed to represent whether it was met. If obtaining higher than 1 for one guideline, the number was replaced with 1 (*e.g.*, if obtaining 2 from the fish intake questions, it was replaced with 1 as one cannot met a guideline twice per week). Each guideline was thereafter summed. In Tromsø4 (1994-95), number of guidelines met ranged from 0.0-4.0.

Supplementary Table S9. Questions, answer alternatives and calculation of diet quality in Tromsø5 (2001).

Nutritional guideline	**Question**	**Answer alternatives***
Fish intake		
"Eat fish 2-3 times per week"	*How often do you usually eat fat fish (e.g. salmon, trout, mackerel, herring)?*	1: Rarely/never (0) 2: 1-3 times per month (0.15) 3: 1-3 times per week (1) 4: 4-6 times per week (1) 5: 1-2 times per day (1) 6: 3 or more times per day (1)
"Eat fish 2-3 times per week"	*Do you use cod liver oil or fish oil capsules?*	1: Yes, daily (1) 2: Sometimes (0.5) 3: No (0)
Saturated fat intake		
"Choose oils, liquid or soft margarine."	*What type of fat do you usually use for cooking?*	1: Do not use margarine or butter (1) 2: Butter (0) 3: Hard margarine (0) 4: Soft/light margarine (1) 5: Oils (1) 6: Other (0)
"Choose oils, liquid or soft margarine."	*What type of fat do you usually use on your bread?*	1: Do not use margarine or butter (1) 2: Butter (0) 3: Hard margarine (0) 4: Soft/light margarine (1) 5: Oils (1) 6: Other (0)
		If answering an alternative with value 1 for cooking and 0 for bread, the value 0.5 is given (*e.g.*, if using both oils (1) for cooking but hard margarine (0) margarine for bread = 0.5)
Fruit/vegetables intake		
"Eat five portions of fruit, vegetables and/or berries each day."	*How often do you usually eat fruit and berries?*	1: Rarely/never (0) 2: 1-3 times per month (0) 3: 1-3 times per week (0.075) 4: 4-6 times per week (0.15) 5: 1-2 times per day (0.3) 6: 3 or more times per day (0.6)
"Eat five portions of fruit, vegetables and/or berries each day."	*How often do you usually eat fresh vegetables/salad?*	1: Rarely/never (0) 2: 1-3 times per month (0) 3: 1-3 times per week (0.075) 4: 4-6 times per week (0.15) 5: 1-2 times per day (0.3) 6: 3 or more times per day (0.6)
"Eat five portions of fruit, vegetables and/or berries each day."	*Do you use vitamins and/or mineral supplement?*	1: Yes, daily (1) 2: Sometimes (0.5) 3: No (0)
"Eat five portions of fruit, vegetables and/or berries each day."	*How much juice do you normally drink?*	1: Rarely/never (0) 2: 1-6 glasses per week (0.15) 3: 1 glass per day (0.2) 4: 2-3 glasses per day (0.5) 5: 4 or more glasses per day (0.8)

*Each nutritional guideline was summed to represent whether it was met. If obtaining higher than 1 for one guideline, the number was replaced with 1 (*e.g.*, if obtaining 2 from the fish intake questions, it was replaced with 1 as one cannot met a guideline twice per week). Each guideline was thereafter summed. In Tromsø5 (2001), number of guidelines met ranged from 0.0-3.0.

Supplementary Table S10. Questions, answer alternatives and calculation of diet quality in Tromsø6 (2007-08).

Nutritional guideline	Question	Answer alternatives*
Fish intake		
"Eat fish 2-3 times per week"	*How often do you usually eat fat fish (e.g. salmon, trout, mackerel, herring, halibut, redfish) for dinner?*	1: 0-1 times per month (0) 2: 2-3 times per month (0.2) 3: 1-3 times per week (1) 4: 4-6 times per week (1) 5: 1-2 times per day (1)
"Eat fish 2-3 times per week"	*Do you use cod liver oil or fish oil capsules?*	1: Yes, daily (1) 2: Sometimes (0.5) 3: No (0)
"Eat fish 2-3 times per week"	*Do you use Omega 3 capsules (fish oil, seal oil)?*	1: Yes, daily (1) 2: Sometimes (0.5) 3: No (0)
Fruit/vegetables intake		
"Eat five portions of fruit, vegetables and/or berries each day."	*How often do you usually eat fruits, vegetables and berries?*	Continuous scale, 0 (0), 1 (0.2), 2 (0.4), 3 (0.6), 4 (0.8), ≥5 (1).
"Eat five portions of fruit, vegetables and/or berries each day."	*How many units of fruit or vegetables do you eat per day (average).* *(E.g. a fruit, a cup of juice, potatoes, vegetables)*	1: 0-1 times per month (0) 2: 2-3 times per month (0) 3: 1-3 times per week (0.075) 4: 4-6 times per week (0.15) 5: 1-2 times per day (0.3)
"Eat five portions of fruit, vegetables and/or berries each day."	*How much juice do you normally drink?*	1: Rarely/never (0) 2: 1-6 glasses per week (0.15) 3: 1 glass per day (0.2) 4: 2-3 glasses per day (0.5) 5: 4 or more glasses per day (0.8)
"Eat five portions of fruit, vegetables and/or berries each day."	*Do you use vitamins and/or mineral supplement?*	1: Yes, daily (1) 2: Sometimes (0.5) 3: No (0)

*Each nutritional guideline was summed to represent whether it was met. If obtaining higher than 1 for one guideline, the number was replaced with 1 (*e.g.*, if obtaining 2 from the fish intake questions, it was replaced with 1 as one cannot met a guideline twice per week). Each guideline was thereafter summed. In Tromsø6 (2007-08), number of guidelines met ranged from 0.0-2.0.

Supplementary Table S11. Questions, answer alternatives and calculation of diet quality in Tromsø7 (2015-16).

Nutritional guideline	Question	Answer alternatives*
Fish intake		
"Eat fish 2-3 times per week"	*How often do you usually eat fat fish (salmon, trout, redfish, mackerel, herring, halibut)?*	1: Rarely/never (0) 2: 1-3 times per month (0.15) 3: 1-3 times per week (1) 4: 4-6 times per week (1) 5: 1-2 times per day (1) 6: 3 or more times per day (1)
"the recommendation equates to 300-450 grams of fish"	*Grams of fish calculated from a food frequency questionnaire#*	<100 grams=0 100-199 grams=0.3 200-299 grams=0.6 ≥300 grams=1
Saturated fat intake		

"Choose oils, liquid or soft margarine."	*Which type of butter/margarine/oil do you mostly use for cooking? (Choose one or two types)*	1: Hard margarine, Melange (0) 2: Hard margarine, other (0) 3: Soft/light margarine, Vita Hjertego (1) 4: liquid margarine (1)
		If answering an alternative with value 1 for cooking and 0 for bread, the value 0.5 is given (*e.g.*, if using both oils (1) for cooking but hard margarine (0) margarine for bread = 0.5)
Fruit/vegetables intake		
"Eat five portions of fruit, vegetables and/or berries each day."	*How many units of fruit or vegetables do you eat per day (average). (E.g. an apple, bowl of salad)*	Continuous scale, 0 (0), 1 (0.2), 2 (0.4), 3 (0.6), 4 (0.8), ≥5 (1).
"Eat five portions of fruit, vegetables and/or berries each day."	*How often do you usually eat fruits, vegetables and berries?*	1: 0-1 times per month (0) 2: 2-3 times per month (0) 3: 1-3 times per week (0.05) 4: 4-6 times per week (0.15) 5: Once a day or more (0.2)
"Eat five portions of fruit, vegetables and/or berries each day."	*How many glasses of fruit juice do you normally drink?*	1: Rarely/never (0) 2: 1-6 glasses per week (0.15) 3: 1 glass per day (0.2) 4: 2-3 glasses per day (0.5) 5: 4 or more glasses per day (0.8)
"One portion equates to 100 grams"	*Grams of fruits calculated from a food frequency questionnaire#*	<100 grams=0.1 100-199 grams=0.2 200-299 grams=0.4 300-399 grams=0.6 400-499 grams=0.6 ≥500 grams=1
"One portion equates to 100 grams"	*Grams of vegetables calculated from a food frequency questionnaire#*	<100 grams=0.1 100-199 grams=0.2 200-299 grams=0.4 300-399 grams=0.6 400-499 grams=0.6 ≥500 grams=1

*Each nutritional guideline was summed to represent whether it was met. If obtaining higher than 1 for one guideline, the number was replaced with 1 (*e.g.*, if obtaining 2 from the fish intake questions, it was replaced with 1 as one cannot met a guideline twice per week). Each guideline was thereafter summed. In Tromsø7 (2015-16), number of guidelines met ranged from 0.0-3.0. #Derives from Lundblad et al., (5), *Food Nutr Res*.

Supplementary File S4. Description and harmonization of chronic pain, disease, hypertension, and work-related variables

Disease

Diseases was dichotomized as yes/no. Information on diseases were derived from questionnaires on cardiovascular disease (myocardial infarction, angina pectoris, stroke), diabetes and cancer, with the following question: *"Do you have, or have you had"disease X"?"* or similar phrasing. To avoid misclassification of diseases, we also used ATC-codes from reported names of medicine used by the participants, for cardiovascular disease (ATC=C07, C08, C09A, C09B, C10, C10AA) and diabetes (ATC=A10A, A10B), and of questions on using heart medicine or diabetes medicine during the last 14 days. Additionally, we also retrieved information on myocardial infarction from the Tromsø Study endpoint registry, which uses hospital records from The University Hospital North-Norway (8), if suffering a myocardial infarction prior to participation in the respective surveys.

Hypertension

Hypertension was dichotomized as yes/no. Information on hypertension was retrieved from questionnaires: Tromsø3 (1986-87): *"Are you being treated for high blood pressure?"*; Tromsø4 (1994-95): *"Do you use blood pressure lowering drugs?"*, Tromsø6 (2008-07) and Tromsø7 (2015-16): *"Have you ever had, or do you have high blood pressure?"*. To avoid misclassification of hypertension, we also used ATC-codes (C02,03, C07, C08, C09) from reported names of medicine used by the participants and used measured systolic (>130 mmHg) and diastolic (>85 mmHg) blood pressure at study attendance, which was measured three times in a seated position, where we used the mean of the last two recordings.

Chronic Pain

Pain was dichotomized as yes/no. Information on pain was retrieved from questionnaires and ATC-codes (M01, N02) from reported names of medicine used by the participants.
In Tromsø3 (1986-87), three questions on pain were included in this study: 1) "*During this last year have you suffered from back pain that has lasted longer"*, with answer alternatives *"yes/no"*; 2) *"How often do you suffer from headache?"* with answer alternatives *"Rarely or never"*, *"Once or more a month"*, *"Once or more a week"* and *"Daily"*, of which the two latter was given pain=yes, 3; *"How often do you suffer from pain in the neck or shoulder?"*

with answer alternatives "*Rarely or never*", "*Once or more a month*", "*Once or more a week*" and "*Daily*", of which the two latter was given pain=yes

In Tromsø4 (1994-95), one question was included in this study: *"Have you during the last year suffered from pain and/or stiffness in muscles and joints that have lasted continuously for at least 3 months"*; 2) *"Have you used painkillers during the past 14 days?",* and: 3) *"Have you for any length of time in the past year used sleeping pills every day or almost daily?",* all with answer alternatives *"yes/no"*.

In Tromsø5 (2001), two questions on pain were included in this study: 1) *"Have you ever had, or do you have fibromyalgia/chronic pain syndrome?"* with answer alternatives *"yes/no",* and; 2) *"Have you during the last 4 weeks suffered from pain and/or stiffness in muscles or joints in your neck/shoulders?"* with answer alternatives " No complaint", "Little complaint» and "Severe complaint", of which the latter was given pain=yes.
In Tromsø7 (2015-16), one question was included in this study: *"Have you during the last year suffered from pain and/or stiffness in muscles or joints in your neck/shoulders lasting for at least 3 consecutive months?"* with answer alternatives *"yes/no"*.

Finally, for all surveys, participants also answered the two following questions on painkillers: 1) *"How often have you used painkillers with prescription during the last 4 weeks?"*; 2) *"How often have you used painkillers without prescription during the last 4 weeks?"*, where participants were given pain=yes of answering more than 0.

Work-related variables

All work-related variables derived from self-reported questionnaires. Shift work derived from the following questions; Tromsø3 (1986-87): *"Do you usually work shifts or at night?"*; Tromsø4 (1994-95) and Tromsø5 (2001) from the following question *"Are you on call; do you work shifts or nights?"* with answers yes or no. Information on shift work was not available in Tromsø6 (2007-08) or Tromsø7 (2015-16). Full/part time or unpaid work was available in all cohorts, except in Tromsø4 (1994-95), where only information on full time or unpaid work were available.

Supplementary Table S12. Cohort-specific descriptive characteristics of the participants at baseline. The Tromsø Study 1986-2021.

	Tromsø3 (1986-87)	**Tromsø4 (1994-95)**	**Tromsø5 (2001)**	**Tromsø6 (2007-08)**	**Tromsø7 (2015-16)**
Total (N)	17656	5386	476	1469	4618
Observations (n)°	17656	15592	2610	2326	5956
Dead					
All-cause, n (%)	3713 (21.0)	371 (6.9)	4 (0.8)	32 (2.2)	11 (0.2)
Cardiovascular disease, n (%)	975 (5.5)	77 (1.4)	0 (0.0)	4 (0.3)	1 (0.02)
Cancer, n (%)	1449 (8.2)	182 (3.4)	3 (0.6)	20 (1.4)	6 (0.1)
Follow-up time (years)					
Median (25-75th percentile)	34.8 (34.7-35.1)	26.8 (26.6-26.9)	20.2 (20.1-20.5)	13.3 (13.1-13.7)	5.8 (5.5-6.2)
Min-max	2.0-35.3	2.0-27.3	2.5-20.8	2.1-14.2	2.0-6.8
Sex					
Women, n (%)	8664 (49.1)	2723 (50.6)	266 (55.9)	726 (49.4)	2277 (49.3)
Men, n (%)	8992 (50.9)	2663 (49.4)	210 (44.1)	743 (50.6)	2341 (50.7)
Age (mean ± SD)	37.4 ± 10.4	34.9 ± 8.6	33.7 ± 6.2	43.8 ± 8.1	46.3 ± 5.9
≤30 years, n (%)	5161 (29.2)	2104 (39.1)	339 (71.2)	35 (2.4)	N/A
30-39 years, n (%)	6021 (34.1)	2084 (38.7)	77 (16.2)	471 (32.1)	N/A
40-49 years, n (%)	4089 (23.2)	841 (15.6)	55 (11.6)	681 (46.4)	3606 (78.1)
50-99 years, n (%)	2240 (12.7)	275 (5.1)	5 (1.0)	213 (14.5)	844 (18.3)
≥60 years, n (%)	145 (0.8)	82 (1.5)	N/A	69 (4.7)	168 (3.6)
Birth year					
<1940, n (%)	3520 (19.9)	171 (3.2)	N/A	N/A	N/A
1940-49, n (%)	5076 (28.8)	558 (10.4)	5 (1.1)	114 (7.8)	N/A
1950-59, n (%)	5819 (33.0)	1346 (25.0)	55 (11.6)	230 (15.7)	434 (9.4)
1960-69, n (%)	3241 (18.4)	3051 (56.7)	77 (16.2)	837 (57.0)	1238 (26.8)
≥1970, n (%)	N/A	260 (4.8)	339 (71.2)	288 (19.6)	2946 (63.8)
Body mass index (mean ± SD)	23.9 ± 3.3	24.5 ± 3.7	25.4 ± 4.0	26.5 ± 4.3	27.2 ± 4.7
<25 kg/m^2, n (%)	12286 (69.6)	3338 (62.0)	262 (55.0)	596 (40.6)	1647 (35.7)
25-29 kg/m^2, n (%)	4571 (25.9)	1630 (30.3)	151 (31.7)	625 (42.6)	1909 (41.3)
≥30 kg/m^2, n (%)	799 (4.5)	418 (7.8)	63 (13.3)	248 (16.9)	1062 (23.0)
Diet quality (mean ± SD)	0.9 ± 0.6	1.6 ± 0.6	1.0 ± 0.7	0.8 ± 0.4	0.3 ± 0.6
<1 nutritional guideline, n (%)	4704 (26.6)	241 (4.5)	131 (27.5)	297 (20.2)	3617 (78.3)
1.0-1.9 nutritional guidelines, n (%)	10228 (57.9)	1788 (33.2)	238 (50.0)	1172 (79.8)	665 (14.4)
≥2.0 nutritional guidelines, n (%)	2724 (15.4)	3357 (62.3)	107 (22.5)	N/A	336 (7.3)
Alcohol intake (mean ± SD)	1.8 ± 2.7	2.5 ± 3.1	2.6 ± 3.2	3.5 ± 3.2	3.6 ± 3.4
Teetotaller, n (%)	1515 (8.6)	1365 (25.3)	17 (3.6)	4 (0.3)	3 (0.1)
0.1-1.9 units·week^{-1}, n (%)	11782 (66.7)	1868 (34.7)	265 (55.7)	711 (48.4)	2305 (49.9)
2-3.9 units·week^{-1}, n (%)	3183 (18.0)	1150 (21.4)	103 (21.6)	447 (30.4)	1394 (30.2)
≥4.0 units·week^{-1}, n (%)	1176 (6.7)	1003 (18.6)	91 (19.1)	307 (20.9)	916 (19.8)
Smoking					
Current smoker, n (%)	8015 (45.4)	1930 (35.8)	149 (31.3)	305 (20.8)	592 (12.8)
Previous smoker, n (%)	3966 (22.5)	1139 (21.2)	155 (32.6)	492 (33.5)	1697 (36.8)
Never smoker, n (%)	5675 (32.1)	2317 (43.0)	172 (36.1)	672 (45.8)	2329 (50.4)
Education					
Primary school, n (%)	5749 (32.6)	773 (14.4)	41 (8.8)	138 (9.4)	438 (9.5)
High school, n (%)	5907 (33.5)	1910 (35.5)	91 (19.1)	399 (27.2)	1093 (23.7)
University <4 years, n (%)	3259 (18.5)	1190 (22.1)	110 (23.1)	331 (22.5)	1021 (22.1)
University ≥4 years, n (%)	2741 (15.5)	1513 (28.1)	233 (49.0)	601 (40.9)	2066 (44.7)
Disease, n (%)	589 (3.3)	189 (3.5)	6 (1.3)	66 (4.5)	247 (5.4)
Cardiovascular disease, n (%)	298 (1.7)	73 (1.4)	2 (0.4)	36 (4.5)	105 (2.3)
Cancer, n (%)	211 (1.1)	79 (1.5)	0 (0.0)	0 (0.0)	24 (0.5)
Diabetes, n (%)	97 (0.5)	45 (0.8)	4 (0.8)	38 (2.6)	134 (2.9)
Hypertension, n (%)	7065 (40.0)	2105 (39.2)	112 (23.6)	576 (39.4)	1545 (33.6)
Physical activity					
Occupation					
Low, n (%)	7187 (40.7)	2483 (46.1)	226 (47.5)	807 (54.9)	2750 (59.6)

Moderate, n (%)	6108 (34.6)	1363 (25.3)	132 (27.7)	360 (24.5)	1043 (22.6)
High, n (%)	3448 (19.5)	1287 (23.9)	100 (21.0)	263 (17.9)	714 (15.5)
Very High, n (%)	913 (5.1)	253 (4.7)	18 (3.8)	39 (2.7)	111 (2.4)
Leisure time					
Inactive	4053 (23.0)	1011 (18.8)	117 (24.6)	316 (21.5)	671 (14.5)
Active	10173 (57.6)	1764 (32.8)	268 (56.3)	760 (51.7)	2370 (51.3)
Vigorously Active	2926 (16.6)	1810 (33.6)	65 (13.7)	344 (23.4)	1340 (29.0)
Very Vigorously Active	504 (2.9)	801 (14.9)	26 (5.5)	49 (3.3)	237 (5.1)
Occupation status (n)*	17301	4708	475	1425	4338
Full time, n (%)	11935 (69.0)	4520 (96.0)	386 (81.3)	1285 (90.2)	3971 (91.5)
Part time, n (%)	2936 (17.0)	0 (0.0)	55 (11.6)	129 (9.1)	342 (7.9)
Unpaid, n (%)	2430 (14.0)	188 (4.0)	34 (7.2)	11 (0.8)	25 (0.6)
Shift work (n)*	17650	5224	473	N/A	N/A
Works shift, n (%)	2983 (16.9)	1446 (27.7)	135 (28.5)	N/A	N/A
Pain (n)*	17606	5382	475	N/A	4473
Any pain, n (%)	6096 (34.6)	1712 (31.8)	251 (52.8)	N/A	2034 (45.5)

Data are shown as mean ± SD, or as frequency (percentage). CVD=cardiovascular disease, SD=standard deviation. ºTotal observations at one survey include follow up of previous surveys. ¤Disease include cardiovascular disease, cancer, and diabetes; as one can have more than one disease, these do not add up to participants with any disease. *Fewer participants had information on this variable compared with the total sample.

Supplementary Table S13. Occupational physical activity and risk of all-cause, CVD and cancer mortality split by birth year.

Women	**Low OPA**	**Moderate OPA**	**High OPA**	**Very high OPA**
<1940				
Observations (n)	861	1008	505	N/A
All-cause (n)	*217*	*303*	*145*	N/A
HR (95%CI)	*Ref.*	**1.23 (1.02-1.47)**	1.06 (0.85-1.32)	N/A
CVD (n)	*57*	*84*	*35*	N/A
SHR (95%CI)	*Ref.*	1.21 (0.86-1.70)	0.94 (0.60-1.46)	N/A
Cancer (n)	*77*	*107*	*49*	N/A
SHR (95%CI)	*Ref.*	1.15 (0.86-1.55)	0.99 (0.70-1.43)	N/A
<1940-49				
Observations (n)	2200	*2033*	*929*	N/A
All-cause (n)	*190*	*155*	*89*	N/A
HR (95%CI)	*Ref.*	0.91 (0.73-1.13)	0.88 (0.68-1.14)	N/A
CVD (n)	*26*	*38*	N/A	N/A
HR (95%CI)	*Ref.*	N/A	N/A	N/A
Cancer (n)	*128*	*87*	*56*	N/A
SHR (95%CI)	*Ref.*	0.77 (0.59-1.01)	0.89 (0.64-1.24)	N/A
≥1950				
Observations (n)	6478	4841	3150	N/A
All-cause (n)	*129*	110	76	N/A
HR (95%CI)	*Ref.*	0.99 (0.77-1.29)	0.99 (0.75-1.33)	N/A
CVD (n)	*24*	22	N/A	N/A
SHR (95%CI)	*Ref.*	N/A	N/A	N/A
Cancer (n)	*70*	66	49	N/A
SHR (95%CI)	*Ref.*	1.07 (0.76-1.49)	1.15 (0.80-1.66)	N/A
Men				
<1940				
Observations (n)	1736	944	633	402
All-cause (n)	*717*	*393*	*260*	*188*
HR (95%CI)	*Ref.*	0.99 (0.87-1.12)	**0.82 (0.71-0.96)**	0.97 (0.82-1.15)
CVD (n)	*224*	*129*	*78*	*70*
SHR (95%CI)	*Ref.*	1.06 (0.85-1.32)	0.88 (0.67-1.16)	1.15 (0.87-1.53)

Cancer (n)	*234*	*118*	*90*	*61*
SHR (95%CI)	*Ref.*	0.86 (0.68-1.07)	0.90 (0.69-1.16)	0.88 (0.65-1.19)
<1940-49				
Observations (n)	2678	1341	855	390
All-cause (n)	*324*	*178*	*114*	*77*
HR (95%CI)	*Ref.*	1.05 (0.87-1.26)	0.95 (0.76.-1.19)	1.24 (0.95-1.61)
CVD (n)	*87*	*47*	*47*	N/A
HR (95%CI)	*Ref.*	1.04 (0.72-1.50)	0.97 (0.65-1.44)	N/A
Cancer (n)	*138*	*77*	*85*	N/A
SHR (95%CI)	*Ref.*	1.09 (0.83-1.45)	1.18 (0.88-1.58)	N/A
≥1950				
Observations (n)	6534	2893	2791	938
All-cause (n)	*200*	*106*	*103*	*57*
HR (95%CI)	*Ref.*	1.04 (0.82-1.32)	0.97 (0.75-1.25)	**1.38 (1.00-1.89)**
CVD (n)	*49*	*40*	N/A	N/A
SHR (95%CI)	*Ref.*	**0.56 (0.36-0.86)**	N/A	N/A
Cancer (n)	*72*	*37*	*59*	N/A
SHR (95%CI)	*Ref.*	1.05 (0.71-1.57)	1.22 (0.85-1.77)	N/A

Data are adjusted for education, body mass index, diet quality, smoking, alcohol intake, leisure time physical activity, and age (timescale). Bold numbers indicate significant association (p<0.05). N/A=not applicable due to less than five deaths per covariate (*i.e.*, 35 deaths), rank 4 and/or 3 are collapsed to a lower intensity group (*i.e.*, rank 2 and/or 3), number of observations are obtained by addition of the applicable rank(s). CVD=cardiovascular disease, HR=hazard ratio, SHR=subdistributed hazard ratio, CI=confidence interval, OPA=occupational physical activity.

Supplementary Table S14. Occupational physical activity and risk of all-cause, CVD, and cancer mortality with excluding 5 years of follow-up time.

	Total	Low OPA	Moderate OPA	High OPA	Very high OPA
Women (N)	14578				
Observations (n)	21884	9476	*7848*	4297	263
All-cause (n)	*1378*	*513*	561	*267*	*37*
HR (95%CI)		*Ref.*	0.99 (0.88-1.13)	1.02 (0.87-1.18)	0.98 (0.70-1.37)
CVD (n)	*282*	*105*	*117*	*60*	N/A
SHR (95%CI)		*Ref.*	0.98 (0.75-1.27)	0.90 (0.65-124)	N/A
Cancer (n)	*665*	*260*	*257*	*148*	N/A
SHR (95%CI)		*Ref.*	0.98 (0.83-1.17)	0.99 (0.81-1.23)	N/A
Men (N)	*14762*				
Observations (n)	*21852*	*10800*	5117	4232	1703
All-cause (n)	*2588*	*1167*	653	457	311
HR (95%CI)		*Ref.*	1.10 (0.99-1.21)	0.92 (0.82-1.03)	1.03 (0.90-1.17)
CVD (n)	*723*	*335*	*177*	*111*	*100*
SHR (95%CI)		*Ref.*	0.96 (0.80-1.15)	**0.76 (0.61-0.95)**	1.10 (0.87-1.39)
Cancer (n)	*925*	*417*	*228*	*184*	*96*
SHR (95%CI)		*Ref.*	1.01 (0.86-1.19)	1.09 (0.91-1.31)	0.90 (0.72-1.14)

Data are adjusted for education, body mass index, diet quality, smoking, alcohol intake, leisure time physical activity, and age (timescale). Bold numbers indicate significant association (p<0.05). CVD=cardiovascular disease, HR=hazard ratio, SHR=subdistributed hazard ratio, CI=confidence interval, OPA=occupational physical activity. N/A=not applicable due to less than five deaths per covariate (*i.e.*, 35 deaths), rank 4 and/or 3 are collapsed to a lower intensity group (*i.e.*, rank 2 and/or 3), number of observations are obtained by addition of the applicable rank(s).

Supplementary Table S15. Occupational physical activity and risk of all-cause, CVD, and cancer mortality by not adjusting for body mass index as a covariate.

	Total	**Low OPA**	**Moderate OPA**	**High OPA**	**Very high OPA**
Women (N)	14656				
Observations (n)	22005	9476	*7848*	4297	263
All-cause (n)	*1378*	*513*	561	*267*	*37*
HR (95%CI)		*Ref.*	1.08 (0.96-1.22)	0.90 (0.78-1.05)	1.36 (0.97-1.90)
CVD (n)	*286*	*105*	*117*	*60*	N/A
SHR (95%CI)		*Ref.*	1.04 (0.80-1.36)	0.84 (0.61-1.16)	N/A
Cancer (n)	*689*	*260*	*257*	*148*	N/A
SHR (95%CI)		*Ref.*	0.99 (0.83-1.17)	0.95 (0.78-1.16)	N/A
Men (N)	14949				
Observations (n)	22135	10800	5117	4232	1703
All-cause (n)	*2588*	*1167*	*653*	*457*	*311*
HR (95%CI)		*Ref.*	0.98 (0.89-1.08)	**0.83 (0.74-0.92)**	1.07 (0.94-1.22)
CVD (n)	*771*	*335*	*177*	*111*	*100*
SHR (95%CI)		*Ref.*	0.94 (0.79-1.13)	**0.67 (0.54-0.83)**	1.01 (0.80-1.28)
Cancer (n)	*925*	*417*	*228*	*184*	*96*
SHR (95%CI)		*Ref.*	0.94 (0.80-1.11)	1.00 (0.84-1.19)	0.91 (0.72-1.15)

Data are adjusted for education, diet quality, smoking, alcohol intake, leisure time physical activity, and age (timescale). Bold numbers indicate significant association ($p<0.05$). CVD=cardiovascular disease, HR=hazard ratio, SHR=subdistributed hazard ratio, CI=confidence interval, OPA=occupational physical activity. N/A=not applicable due to less than five deaths per covariate (*i.e.*, 35 deaths), rank 4 and/or 3 are collapsed to a lower intensity group (*i.e.*, rank 2 and/or 3), number of observations are obtained by addition of the applicable rank(s).

Supplementary Table S16. Occupational physical activity and risk of all-cause, CVD, and cancer mortality split by shift and non-shift workers.*

	Total	Low OPA	Moderate OPA	High OPA	Very high OPA
Women (N)	12431				
No shift work (n)	9638				
Observations (n)	14143	6726	5545	1726	N/A
All-cause (n)	*1102*	*476*	*480*	*146*	N/A
HR (95%CI)		*Ref.*	1.12 (0.99-1.28)	0.94 (0.77-1.13)	N/A
CVD (n)	*586*	*99*	*376*	*111*	N/A
SHR (95%CI)		*Ref.*	1.12 (0.85-1.48)	1.00 (0.67-1.50)	N/A
Cancer (n)	*516*	*239*	*213*	*64*	N/A
SHR (95%CI)		*Ref.*	1.03 (0.85-1.24)	0.87 (0.66-1.15)	N/A
Works shift (n)	2793				
Observations (n)	3512	422	1156	1934	N/A
All-cause (n)	*237*	*28*	*63*	*146*	N/A
HR (95%CI)		*Ref.*	*0.70 (0.45-1.10)*	*0.89 (0.59-1.34)*	N/A
CVD (n)	*33*	*3*	*7*	*23*	N/A
SHR (95%CI)		*Ref.*	N/A	N/A	N/A
Cancer (n)	*131*	*17*	*32*	*82*	N/A
SHR (95%CI)		*Ref.*	N/A	N/A	N/A
Men (N)	12524				
No shift work (n)	9714				
Observations (n)	14060	6965	3285	2780	1030
All-cause (n)	*2072*	*1007*	*492*	*369*	*204*
HR (95%CI)		*Ref.*	0.94 (0.84-1.06)	0.82 (0.73-0.94)	1.01 (0.86-1.18)
CVD (n)	*601*	*299*	*147*	*92*	*63*
SHR (95%CI)		*Ref.*	0.94 (0.76-1.15)	**0.69 (0.54-0.88)**	0.95 (0.72-1.27)
Cancer (n)	*725*	*354*	160	151	60
SHR (95%CI)		*Ref.*	0.87 (0.72-1.06)	1.02 (0.83-1.25)	0.82 (0.61-1.10)
Works shift (n)	2810				
Observations (n)	3596	1327	985	808	476
All-cause (n)	*504*	*169*	*156*	*88*	*91*
HR (95%CI)		*Ref.*	1.25 (1.00-1.55)	0.98 (0.75-1.28)	**1.46 (1.12-1.90)**
CVD (n)	*132*	*47*	*41*	*44*	N/A
SHR (95%CI)		*Ref.*	1.17 (0.77-1.79)	0.86 (0.57-1.30)	N/A
Cancer (n)	*185*	*61*	*61*	*63*	N/A
SHR (95%CI)		*Ref.*	1.31 (0.93-1.87)	1.06 (0.73-1.52)	N/A

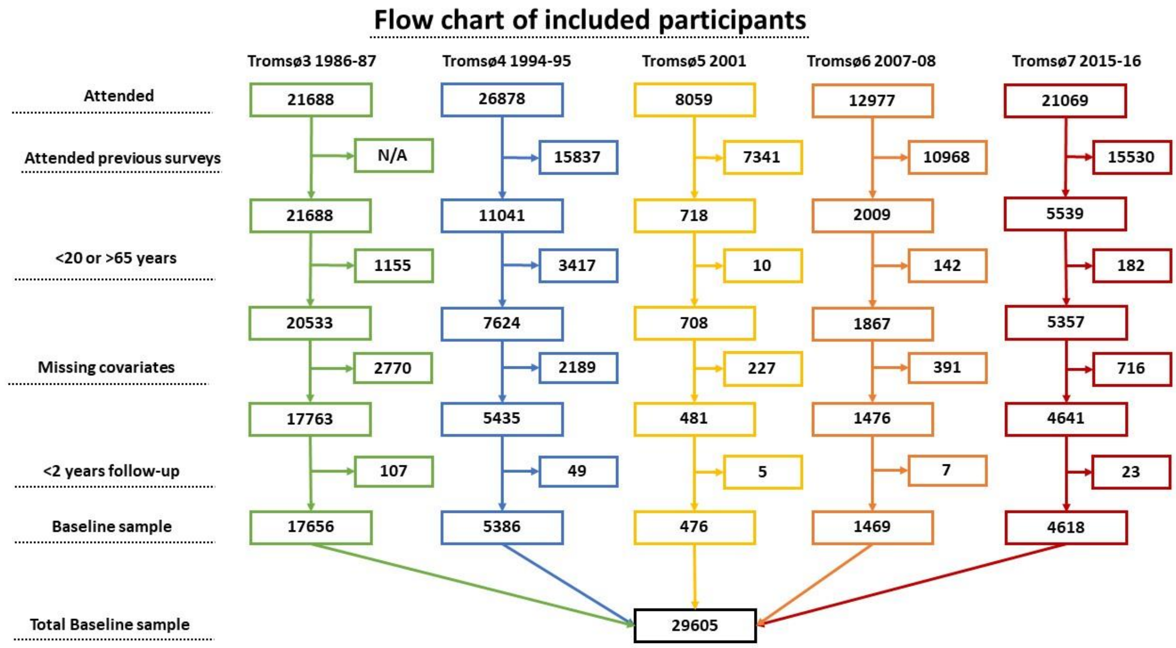
Data are adjusted for education, body mass index, diet quality, smoking, alcohol intake, leisure time physical activity, and age (timescale). Bold numbers indicate significant association ($p<0.05$). CVD=cardiovascular disease, HR=hazard ratio, SHR=subdistributed hazard ratio, CI=confidence interval, OPA=occupational physical activity. N/A=not applicable due to less than five deaths per covariate (*i.e.*, 35 deaths), rank 4 and/or 3 are collapsed to a lower intensity group (*i.e.*, rank 2 and/or 3), number of observations are obtained by addition of the applicable rank(s). *participants split by non-shift and shift work are fewer than the total cohort due to missing information in some participants.

Supplementary Table S17. Occupational physical activity and risk of all-cause, CVD, and cancer mortality split by educational level.

Education	**Total**	**Low OPA**	**Moderate OPA**	**High OPA**	**Very high OPA**
Women (N)					
Primary School (n)					
Observations (n)		1429	2454	1478	N/A
All-cause (n)		*181*	*341*	*173*	N/A
HR (95%CI)		*Ref.*	1.18 (0.99-1.42)	0.95 (0.77-1.17)	N/A
CVD (n)		*42*	*82*	*36*	N/A
SHR (95%CI)		*Ref.*	1.17 (0.80-1.70)	0.83 (0.53-1.30)	N/A
Cancer (n)		*83*	*142*	*75*	N/A
SHR (95%CI)		*Ref.*	1.04 (0.80-1.36)	0.90 (0.66-1.22)	N/A
High School (n)					
Observations (n)		3406	2247	*1698*	N/A
All-cause (n)		*210*	*133*	*88*	N/A
HR (95%CI)		*Ref.*	1.04 (0.83-1.29)	0.89 (0.69-1.14)	N/A
CVD (n)		*42*	*20*	*17*	N/A
SHR (95%CI)		*Ref.*	N/A	N/A	N/A
Cancer (n)		*108*	*63*	*52*	N/A
SHR (95%CI)		*Ref.*	0.96 (0.70-1.31)	1.00 (0.72-1.40)	N/A
*University (n)**					
Observations (n)		4704	3181	1408	N/A
All-cause (n)		*145*	*94*	*49*	N/A
HR (95%CI)		*Ref.*	0.86 (0.66-1.11)	1.12 (0.80-1.56)	N/A
CVD (n)		*23*	*17*	*7*	N/A
SHR (95%CI)		*Ref.*	N/A	N/A	N/A
Cancer (n)		*84*	*55*	*27*	N/A
SHR (95%CI)		*Ref.*	N/A	N/A	N/A
Men (N)					
Primary School (n)					
Observations (n)		*1631*	1312	1641	1053
All-cause (n)		*423*	*312*	*309*	*245*
HR (95%CI)		*Ref.*	0.88 (0.77-1.02)	**0.83 (0.72-0.97)**	0.99 (0.85-1.17)
CVD (n)		*122*	*100*	*77*	*80*
SHR (95%CI)		*Ref.*	1.02 (0.78-1.33)	**0.75 (0.56-0.99)**	1.06 (0.79-1.41)
Cancer (n)		*154*	99	131	75
SHR (95%CI)		*Ref.*	0.78 (0.60-1.01)	1.03 (0.81-1.30)	0.79 (0.60-1.05)
High School (n)					
Observations (n)		*2962*	1965	1994	543
All-cause (n)		*411*	*220*	*132*	*64*
HR (95%CI)		*Ref.*	0.96 (0.82-1.14)	**0.68 (0.56-0.83)**	1.00 (0.77-1.31)
CVD (n)		*123*	*65*	*46*	N/A
SHR (95%CI)		*Ref.*	0.93 (0.69-1.26)	**0.63 (0.44-0.89)**	N/A
Cancer (n)		*130*	*80*	*74*	N/A
SHR (95%CI)		*Ref.*	1.09 (0.82-1.44)	0.95 (0.71-1.26)	N/A
*University (n)**					
Observations (n)		*6355*	1901	778	N/A
All-cause (n)		*407*	*145*	*49*	N/A
HR (95%CI)		*Ref.*	**1.22 (1.01-1.48)**	1.22 (0.90-1.66)	N/A
CVD (n)		*115*	*30*	*13*	N/A
SHR (95%CI)		*Ref.*	N/A	N/A	N/A
Cancer (n)		*160*	*53*	*15*	N/A
SHR (95%CI)		*Ref.*	N/A	N/A	N/A

Data are adjusted for education, body mass index, diet quality, smoking, alcohol intake, leisure time physical activity, and age (timescale). Bold numbers indicate significant association ($p<0.05$). CVD=cardiovascular disease, HR=hazard ratio, SHR=subdistributed hazard ratio, CI=confidence interval, OPA=occupational physical activity. N/A=not applicable due to less than five deaths per covariate (*i.e.*, 35 deaths), rank 4 and/or 3 are collapsed to a lower intensity group (*i.e.*, rank 2 and/or 3), number of observations are obtained by addition of the applicable rank(s). *University <4 years and ≥4 years are collapsed due to few deaths in separate groups.

Supplementary Figure S1. Flow chart of included participants.



N/A=not applicable.

References for supplementary materials

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