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ORIGINAL ARTICLE

Combined association of occupational and leisure-time physical activity with all-cause and coronary heart disease mortality among a cohort of men followed-up for 22 years

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ABSTRACT

Objectives Leisure-time physical activity (LTPA) is a well-established protective factor for all-cause mortality and cardiovascular mortality while occupational physical activity (OPA) has shown contradictory results. We examined the association between OPA and all-cause and coronary heart disease (CHD) mortality, and tested its combined effect with LTPA.

Methods The CORDIS Study (Cardiovascular Occupational Risk Factor Determination in Israel Study) is a prospective cohort study of industrial workers examined during 1985–1989 and followed-up for 22 years. Data on self-reported OPA and LTPA among 4819 males (20–70 years old) were merged with data on all-cause and CHD mortality obtained from the National Death Registry.

Results A higher incidence rate of all-cause mortality and CHD mortality was observed among men who performed moderate–hard OPA compared with those who performed none–mild OPA. Multiple regression analysis based on the Cox proportional hazards model showed that moderate–hard OPA was associated with increased risk of all-cause mortality (HR=1.42, 95% CI 1.16 to 1.74, p<0.001), while LTPA (30 min at least twice a week vs less or none) was associated with reduced risk for all-cause mortality (HR=0.61, 95% CI 0.48 to 0.79, p<0.001), after adjusting for potential confounders, including sociodemographic variables, body mass index, comorbidity and lifestyle habits. Employees who performed moderate–hard OPA and no LTPA had the greatest risk for all-cause mortality and employees who performed none–light OPA and LTPA had the lowest risk. Similar but non-significant trends were observed for the association with CHD mortality.

Conclusions Moderate–hard OPA among industrial male workers may be deleterious to health and should not be a substitute to LTPA.

What this paper adds

- The health benefits of leisure-time physical activity (LTPA) are well known, but there have been contradictory findings regarding the effect of occupational physical activity (OPA) on health.
- Moderate–hard OPA was associated with increased risk of all-cause mortality while LTPA (30 min at least twice a week vs less or none) was associated with reduced risk for all-cause mortality.
- Employees who performed moderate–hard OPA and no LTPA had the greatest risk for all-cause mortality and employees who performed none–light OPA and LTPA had the lowest risk. Similar but non-significant trends were observed for the association with CHD mortality.
- The results of this study emphasise the need to establish recommendations regarding physical activity and occupational safety and health, and to educate workers, management and societal institutions on the potential hazards of moderate–hard OPA as well as the benefits of LTPA.

INTRODUCTION

Leisure-time physical activity (LTPA) is a well-established protective factor for all-cause mortality and cardiovascular mortality,[1–7] and a recommendation to perform regular LTPA has become an integral component of most accepted guidelines for healthy lifestyle in healthy[8] and morbid populations, such as diabetic[9] and obese patients.[10]

However, occupational physical activity (OPA) has shown contradictory results. Several studies have reported that OPA is a protective factor for cardiovascular disease (CVD) and all-cause mortality,[11–14] whereas some studies identified OPA as a risk factor;[7 15 16] some others did not demonstrate an association between OPA and CVD,[17] or OPA and all-cause mortality.[18] Recent studies have shown that in order to assess the risk of all-cause or cardiovascular mortality, it is important to evaluate both LTPA and OPA in one model rather than to consider each type of physical activity (PA) separately.[19–24]

The Cardiovascular Occupational Risk Factor Determination in Israel Study (CORDIS) was a prospective cohort examined during 1985–1989 in order to identify occupational risk factors for CVD and cancer in industrial workers in Israel. A study conducted on data from this cohort, after 8 years of follow-up, showed that a high physical workload was associated with increased all-cause mortality rates (HR=1.82, 95% CI 1.18 to 2.81) compared with workers who had a low workload; a similar trend was noted for CVD and cancer mortality.[25] However, in that study, the follow-up was relatively short, and the combined effect of LTPA and OPA on all-cause and coronary heart disease (CHD) mortality was not investigated. The objective of the current study was to further elaborate on this association with a longer follow-up of 22 years, which has the advantage of reaching a higher number of cases and hence, more power to make it possible to analyse the combined effect of OPA and LTPA that was not addressed in the previous study.

METHODS

Study population

The CORDIS cohort included industrial male and female workers recruited from 21 industrial plants (metal work, textiles, light industry, electronics, food manufacturing, plywood production) throughout Israel for on-site screening of cardiovascular risk factors. The current analysis was restricted to Jewish men 20–70 years of age at baseline. Arab men (N=357) were excluded from the current analysis because they comprised a small proportion of the study population and no follow-up data were available. Females (N=2282) were excluded from the current analysis due to the small proportion of female workers who performed moderate–hard OPA and died from all-causes (N=117) and from CHD (N=21). The study questionnaire contained several questions about heart disease and individuals who reported myocardial infarction at baseline were excluded. Participants with missing information on OPA and LTPA were excluded from the analyses.

Data collection

Data on background, demographics, blood tests and risk factors were collected from 4819 male employees in two phases: 1985–1987 and 1988–1990. Trained technicians visited the various plants, and performed computerised interviews and physical examinations. The face-to-face interviews and the examinations were carried out between 7:00 and 16:00 on the same day. Fasting blood samples for complete blood count and blood chemistry were taken on a different day, within several weeks of the interviews.[26]

The study questionnaires included information on demographics (sex, age, type of housing: flat or house, number of rooms, country of birth, the birth countries of each participant's parents and grandparents, year of immigration to Israel, education status, marital status), description of occupation conditions at the plant (seniority, job description/responsibility, work schedule: shift work/hourly work and extent of physical effort during work), current and past engagement in PA, type and frequency of PA, current frequency of smoking, and a nutrition questionnaire that included consumption of alcoholic beverages, consumption of coffee, tea and soft drinks. The participants were also asked if they maintain a special diet (vegetarian/vegan, diabetic, low-sodium, low-fat or low-calorie). The medical questionnaire included family and personal medical history, including self-reported diabetes, cardiovascular history and medications.

Evaluation of physical activity

For both types of PA, standard structured questionnaires were used. These questionnaires were tested in a large pilot study in 1984 and were used in other studies.

OPA was assessed by workers' subjective ratings, considered to be an accurate measure on the basis of physiological indices.[27] OPA was self-reported with the question "Does your work generally entail physical work (not at all/light/moderate/hard)?" Other associated variables, such as blue/white collar, posture during work and work type (job description), were used for validation of the self-reported OPA and were highly correlated. A 'blue-collar' worker was defined as belonging to one of the following job categories: (1) direct production, (2) indirect production, (3) maintenance, (4) housekeeping or transportation, (5) first-line supervisor or foreman, (6) shift foreman, and (7) unclassified manual worker. All other employees were considered 'white collar'. A higher rate of employees who performed moderate–hard OPA were blue collar workers compared to those who performed none–mild OPA (96.2% vs 50.4%, $p<0.0001$). Most employees (72.7%) who reported moderate–hard OPA did their work while standing compared to only 28.1% of those who reported none–mild OPA.

LTPA was self-reported by the participants (number of times/week, duration and type). Walking, exercising/aerobic exercises, swimming, horse riding, bike riding, hiking, rowing/weight lifting, ball games, surfing or dancing were considered LTPA. Participants were classified as engaging in current LTPA if they performed it at least twice a week for at least 30 min each time. Less than that was considered as not performing current LTPA.

Mortality data collection

Data of the CORDIS cohort participants were merged in 2007 with data on mortality obtained from the National Death Registry of the Israel Ministry of the Interior and the Central Bureau of Statistics, using the participants' identification number and using other details such as the date of birth. CHD mortality was defined by the ICD-9 codes (410–414). The mean follow-up time was 22.1±3.2 years (median, 22 years). The data for 696 participants (14.4%) could not be merged as they had left the country. These participants were considered alive and included in the analyses.

Statistical analyses

The data were analysed using the SAS V.9.1 (SAS Institute, Cary, North Carolina, USA). Continuous variables are presented as means±SD and categorical data are presented as rates. To test differences in continuous variables between two groups, the independent samples t test and, if necessary, the non-parametric Mann-Whitney U test was performed. The paired comparisons between baseline and follow-up data were performed with paired t test. Associations between nominal variables were performed with the Pearson χ^2 test. p for trend was calculated by the Mantel-Haenszel test.

CHD mortality and all-cause mortality were compared for OPA and LTPA categories. χ^2 Test was applied for comparing mortality rates among the categorical variables of the study groups. The Kaplan Meier method was used to compare survival curves among study groups using the log-rank test. Multivariate regression analysis based on COX proportional hazard model for predicting mortality was performed. Interactions between OPA and LTPA and critical variables (such as age, gender, body mass index (BMI), smoking) were tested, each interaction separately. If the interaction was found statistically significant (≤0.15), it was included in the final model. Otherwise (>0.15), the interaction was not included.

The COX model was based on the incidence of the analysed event (death due to any cause or death due to CHD) and the time that passed until the event occurred. The survival model relates the time to the event to one or more confounders that may be associated with that quantity of time. Confounders were selected based on the univariate analysis. If they differed between the exposed and unexposed, and are known to be associated with the outcome, they were considered as potential confounders and entered into the multivariate model. Most of the confounders were entered into the multivariate models as they were in the data base, without recoding or transformation. All tests were two-tailed, and a p value of 5% or less was considered statistically significant.

Ethics

This study was performed under approval of the National Institute of Occupational and Environmental Medicine's Ethics Committee. The current analysis was approved by the Ethics Committee of the Chaim Sheba Medical Centre, Ramat Gan, Israel.

RESULTS

Characteristics of the study population, baseline work conditions and LTPA

Overall, 4819 males were included in the current study. The study population baseline characteristics are depicted in table 1.

Moderate–hard OPA was reported by 61.1% of the men. Compared to those performing none–mild OPA, a higher proportion of men performing moderate–hard OPA had low education level (below 12 years; p<0.001), were smokers (p<0.001), drank alcohol 3 or more times a week (p=0.006), and a lower proportion of them drank 3 or more cups of coffee per day (p<0.001), maintained a special diet, had hypertension (p=0.003), and worked only during the day (p<0.001). A higher rate of employees who reported none–mild OPA also performed LTPA compared to those who reported moderate–hard OPA (29.9% vs 21.3%, p<0.001).

All cause and CHD mortality rates by performance of OPA and LTPA

Over 22 years of follow-up, 573 employees died of all-cause mortality and 170 died of CHD. A significantly higher rate of employees who performed moderate–high OPA died of all-causes and of CHD compared with those who performed none–mild OPA (13.67% vs 9.09%, p<0.0001 for all-cause mortality; 4.04% vs 2.73%, p=0.017 for CHD mortality). Kaplan-Meier analysis demonstrated a statistically significant lower all-cause and CHD survival of moderate–hard OPA employees compared with none–mild OPA employees (figures 1A, B).

Both all-cause and CHD mortality rates were significantly lower in the employees who reported performing LTPA at least twice a week for at least 30 min each time (6.31% vs 13.67% for all-cause mortality, p<0.0001; 1.85% vs 4.08% for CHD mortality, p=0.003). Kaplan-Meier analysis demonstrated a statistically significant higher all-cause and CHD survival of employees who performed LTPA compared with those who did not engage in LTPA (figures 1C, D).

Evaluation of the association between the types of PA and risk of all-cause and CHD mortality

Table 2 shows the evaluation of the association between the types of PA and the risk of all-cause and CHD mortality.

In the univariate analysis, OPA was significantly associated with a higher risk of all-cause mortality (HR=1.56, 95% CI 1.30 to 1.87, p<0.0001). This association remained significant after adjusting for potential confounders: age at screening, socioeconomic status (number of people/room), educational status, father's country of origin, BMI, cholesterol, high-density lipoprotein cholesterol, hypertension, diabetes, smoking, coffee and alcohol consumption, maintaining a special diet and shift work (HR=1.44, 95% CI 1.18 to 1.75, p<0.001). On the other hand, LTPA was significantly associated with a lower risk of all-cause mortality (HR=0.60, 95% CI 0.47 to 0.78, p<0.0001).

When each type of PA was adjusted for the variables listed above, as well as for the other type of PA (adjusted model 2), OPA remained significantly associated with a higher risk of all-cause mortality (HR=1.42, 95%CI 1.16 to 1.74, p<0.001) while LTPA remained significantly associated with a lower risk of all-cause mortality (HR=0.61, 95% CI 0.48 to 0.79, p<0.001).

OPA was significantly associated with a higher risk of CHD mortality in the univariate analysis (HR=1.49, 95% CI 1.07 to 2.07, p=0.017). However, adjustment for all the variables listed above and for LTPA attenuated the significance of the association (adjusted models 1 and 2). LTPA was significantly associated with a lower risk of CHD mortality in the univariate analysis, but adjustment for the variables listed above and for OPA attenuated the association, which then became only borderline significant (HR=0.65, 95% CI 0.41 to 1.04, p=0.072) (adjusted models 1 and 2).

Evaluation of the association between the combination of OPA and LTPA and risk of all- cause and CHD mortality

To further characterise the contribution of each PA domain to the risk of all-cause mortality, new variables that combined LTPA and OPA were formed to describe different profiles of PA performance. All-cause mortality rate was highest in men who performed moderate–hard OPA and did not engage in LTPA (15.21%), and lowest in individuals who performed none–mild OPA and engaged in LTPA (4.84%, figure 2). Similarly, the highest CHD mortality was observed among men who performed moderate–hard OPA and did not engage in LTPA (4.41%); CHD mortality was lowest in individuals who performed none–mild OPA and engaged in LTPA (1.08%, figure 2).

Table 3 shows the association between the different PA profiles and all-cause and CHD mortality (moderate–hard OPA without LTPA as the reference category). The lowest risk of all-cause mortality was in men who performed none–mild OPA and engaged in current LTPA (HR=0.54, 95% CI 0.36 to 0.82, p=0.004). Employees performing none-mild OPA and no LTPA had a reduced risk of all-cause mortality but to a lesser degree (HR=0.70, 95% CI 0.57 to 0.87, p=0.001). In the unadjusted model, men who performed moderate–hard OPA and engaged in LTPA had a reduced risk for all-cause mortality; however, after adjustment for potential confounders the protective effect of LTPA was attenuated (p=0.34). The interaction between OPA and LTPA was not statistically significant in all of the models (p≥0.15). The different combined PA profiles were not significantly associated with the adjusted risk of CHD mortality.

DISCUSSION

The current study is one of a few studies evaluating the contribution of the combined effect of OPA and LTPA to all cause and cardiovascular mortality, and one of its strengths lies in an exceptionally long follow-up of more than 20 years. The findings of this study indicate that moderate–hard OPA confers an increased risk of all-cause mortality in male workers while LTPA is, as expected, associated with a reduced risk for all-cause mortality in this cohort. These findings corroborate the results of a previous study on the same cohort, albeit with a shorter follow-up of 8 years, which demonstrated that a high physical workload was associated with increased mortality rates from all causes and with a trend for increased CVD mortality compared with workers with a low workload.[25] Evaluation of the risk of mortality by combination of PA types revealed that workers

Table 1 Baseline demographics of the study population

Parameter	All N=4819	None-to-mild OPA N=1870	Moderate-to-hard-OPA N=2949	p Value*
Age, years	42.1±12.1	41.7±11.7	42.3±12.3	0.088
Persons/room	1.4±0.7	1.2±0.6	1.5±0.8	<0.001
Father's origin				<0.001
Africa	1328 (27.0)	384 (20.6)	927 (31.5)	
Asia	747 (15.2)	283 (15.2)	449 (15.3)	
Europe	2171 (44.1)	1056 (56.7)	1030 (35.0)	
Yemen	43 (0.9)	18 (1.0)	23 (1.0)	
Israel	638 (13.0)	122 (6.6)	514 (17.5)	
Education (years)				<0.001
<12	2962 (60.0)	708 (37.9)	2178 (73.9)	
12	1101 (22.31)	476 (25.5)	603 (20.5)	
>12	873 (17.69)	686 (36.7)	166 (5.6)	
BMI (kg/m^2)	25.7±3.7	25.6±3.5	25.7±3.8	0.449
Cholesterol (mg/dL)	201.3±42.0	202.3±42.0	199.7±41.9	0.044
HDL cholesterol (mg/dL)	42.6±10.8	42.7±10.7	42.5±10.8	0.632
Hypertension	523 (10.7)	217 (11.7)	264 (9.0)	0.003
Diabetes	177 (3.6)	55 (3.0)	105 (3.6)	0.245
Current smoking	1940 (39.3)	663 (35.5)	1243 (42.2)	<0.001
Alcohol ≥3 times/week	474 (9.8)	142 (8.0)	321 (11.0)	0.006
Coffee cups ≥3/day	1658 (33.5)	749 (40.1)	873 (29.6)	<0.001
Maintain special diet†	473 (9.6)	197 (10.6)	232 (7.9)	0.002
Blue collar	3858 (78.3)	941 (50.4)	2837 (96.2)	<0.001
Body position at work				<0.001
Sitting	1163 (23.6)	936 (50.1)	189 (6.4)	
Standing	2720 (55.2)	526 (28.1)	2145 (72.7)	
Walking/climbing	1048 (21.3)	407 (21.8)	615 (20.9)	
Job scope				0.020
Full-time job	4761 (98.8)	1844 (98.6)	2927 (99.3)	
Other	57 (1.2)	26 (1.4)	21 (0.7)	
Years in job	9.2±8.2	7.9±7.7	9.9±8.4	<0.001
Shift Work				<0.001
Day only	2964 (60.1)	1192 (63.7)	1681 (57.0)	
Day+extra hours	913 (18.5)	489 (26.2)	406 (13.8)	
Other	1056 (21.4)	189 (10.1)	862 (29.2)	
Current LTPA	1213 (24.6)	558 (29.9)	625 (21.3)	<0.001

Categorical values are displayed as N (%) and continuous variables are displayed as mean±SD.
*p Value by t test for continuous variables and by χ^2 test for categorical values.
†Vegetarian/vegan, diabetic, low-sodium, low-fat or low-calorie.
BMI, body mass index; HDL, high-density lipoproteins; LTPA, leisure time physical activity; OPA, occupational physical activity.

who performed moderate–hard OPA and did not engage in LTPA had the highest risk for all-cause mortality, while workers who performed none–mild OPA and engaged in LTPA had the lowest risk. However, the two middle categories, in which men performed both moderate–hard OPA and LTPA or none–mild OPA without LTPA, had an overlap and thus, the interpretation of the differences between them should be performed with caution. A similar trend was observed for CHD mortality, but it did not reach statistical significance in the adjusted model, perhaps because of the small number of deaths. This indicates that moderate–hard OPA is deleterious to the health of workers. However, we cannot determine from the results of this study whether LTPA ameliorates the harmful effect of OPA since men who performed moderate–hard OPA and engaged in LTPA did not have a significantly reduced risk for all-cause mortality in the adjusted model in contrast to the unadjusted analysis. This may stem from a significant confounding effect but may also be a result of an insufficient statistical power and should be further tested in larger studies.

A recently-published study conducted on 1456 male workers who participated in the Prospective Belgian Physical Fitness Study, with a follow-up period of 16.9 years, reported similar findings with increased all-cause mortality rates in workers who combined high OPA levels with low LTPA levels, especially in workers with a low physical fitness level.[20] A similar trend was also found for the association between risk of CHD mortality and OPA or LTPA but this association was only border-line statistically significant. Other studies, however, have shown an association between OPA, LTPA and CHD or CVD. In a cohort of 1706 ethnic Chinese adults from the Chin-Shan Community Cardiovascular Cohort study in Taiwan, higher levels of OPA were significantly associated with increased risk of cardiovascular mortality among men but not among women, while LTPA was associated with a lower risk of cardiovascular mortality in both genders.[24] A meta-analysis based on data from 21 prospective cohort studies showed that high-level of LTPA and moderate levels of OPA were associated with 20–30% reduced risk of incident CHD and stroke among men.[14] Similar findings were

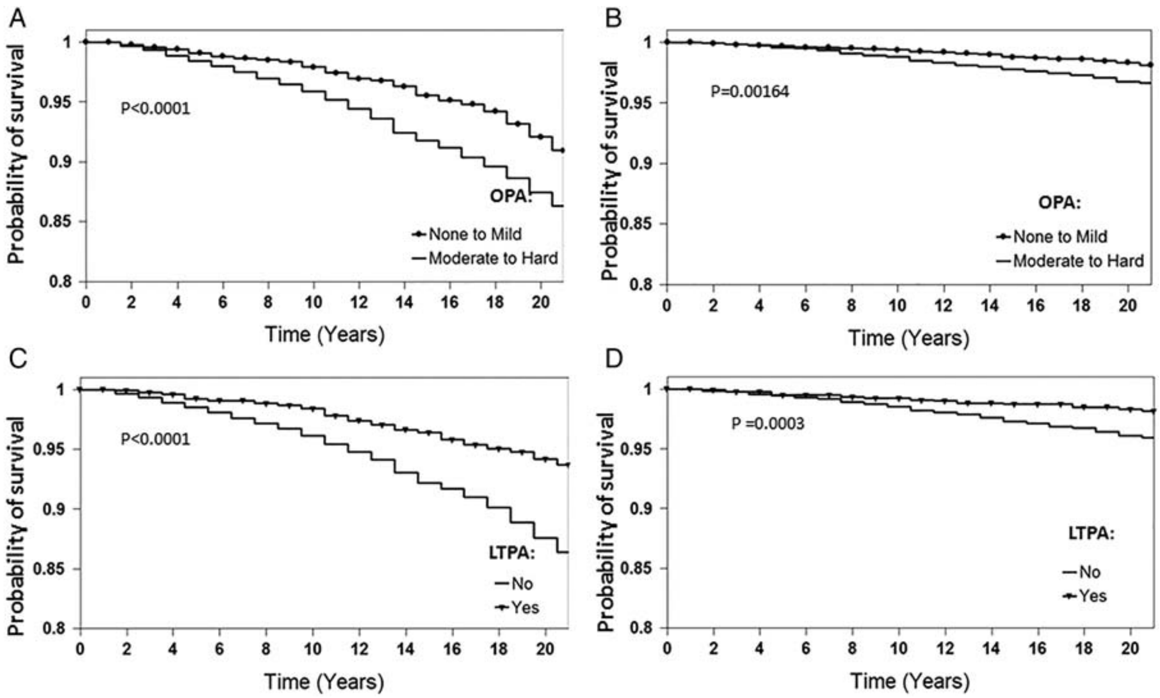

Figure 1 Kaplan-Meier survival analysis of all-cause mortality (A) and CHD mortality (B), by type of OPA. Kaplan-Meier survival analysis of all-cause mortality (C) and CHD mortality (D) by type of LTPA. p Value indicates difference between PA types by log-rank test. OPA, occupational physical activity, LTPA, leisure time physical activity CHD, coronary heart disease; PA, physical activity.

reported for the Copenhagen City Heart Study which included a 30-year follow-up of 5249 employed men, aged 40–59 years, and showed an association between high physical work demands and an increased risk of CHD mortality in the least fit and moderately fit, but not among the most fit men.[23] Another analysis on the same cohort showed that moderate and high levels of activity during leisure time were protective against CHD mortality among people with medium and high physical activity at work.[4 22] Holtermann *et al*. also reported a consistently lower risk of all-cause and CVD mortality with increasing LTPA, which was irrespective of the level of OPA among men and women.[21]

The varying contribution of OPA to the risk of mortality observed in different studies may be attributed to discrepancies in the assessment of OPA, such as different measurements of dose-response (ie, the amount and intensity of PA), or to comparisons of different occupations that may represent different socioeconomic strata and different durations of follow-up.

In the current study, the majority of moderate–hard workers were blue collar workers. They were older than those who reported none–light OPA and were from a lower socioeconomic background, that is, a significantly higher number of moderate–hard workers had less than 12 years of education. A lower socioeconomic background has been associated with increased mortality risk.[28 29] However, in our study, adjustment for age and socioeconomic background did not attenuate the association between the types of PA and risk of all-cause mortality.

Although both are considered types of PA, the opposite effects of LTPA and OPA may be attributed to their different

Table 2 Association between types of physical activity and all-cause mortality or coronary heart disease mortality

		All-cause mortality N=573				CHD mortality N=170		
Variable	Deaths (N)	HR	(95% CI)	p Value	Deaths (N)	HR	(95% CI)	p Value
Univariate								
OPA (Moderate–hard)	403	1.56	(1.30 to 1.87)	<0.0001	119	1.49	(1.07 to 2.07)	0.017
LTPA (≥30 min twice/week)	75	0.45	(0.35 to 0.57)	<0.0001	22	0.45	(0.29 to 0.70)	<0.001
Adjusted model 1*								
OPA (Moderate–hard)	403	1.44	(1.18 to 1.75)	<0.001	119	1.35	(0.94 to 1.95)	0.108
LTPA (≥30 min twice/week)	75	0.60	(0.47 to 0.78)	<0.0001	22	0.64	(0.40 to 1.02)	0.060
Adjusted Model 2*								
OPA† (Moderate–hard)	403	1.42	(1.16 to 1.74)	<0.001	119	1.36	(0.94 to 1.97)	0.102
LTPA‡ (≥30 min twice/week)	75	0.61	(0.48 to 0.79)	<0.001	22	0.65	(0.41 to 1.04)	0.072

*Cox proportional hazards regression model adjusted for age at screening, socioeconomic status (number of people/room), educational status, father's country of origin, body mass index, cholesterol, high-density lipoprotein cholesterol hypertension, diabetes, smoking, coffee consumption, alcohol consumption, maintaining a special diet, and shift work.
†Adjusted for LTPA.
‡Adjusted for OPA.
CHD, coronary heart disease; LTPA, leisure time physical activity; OPA, occupational physical activity.

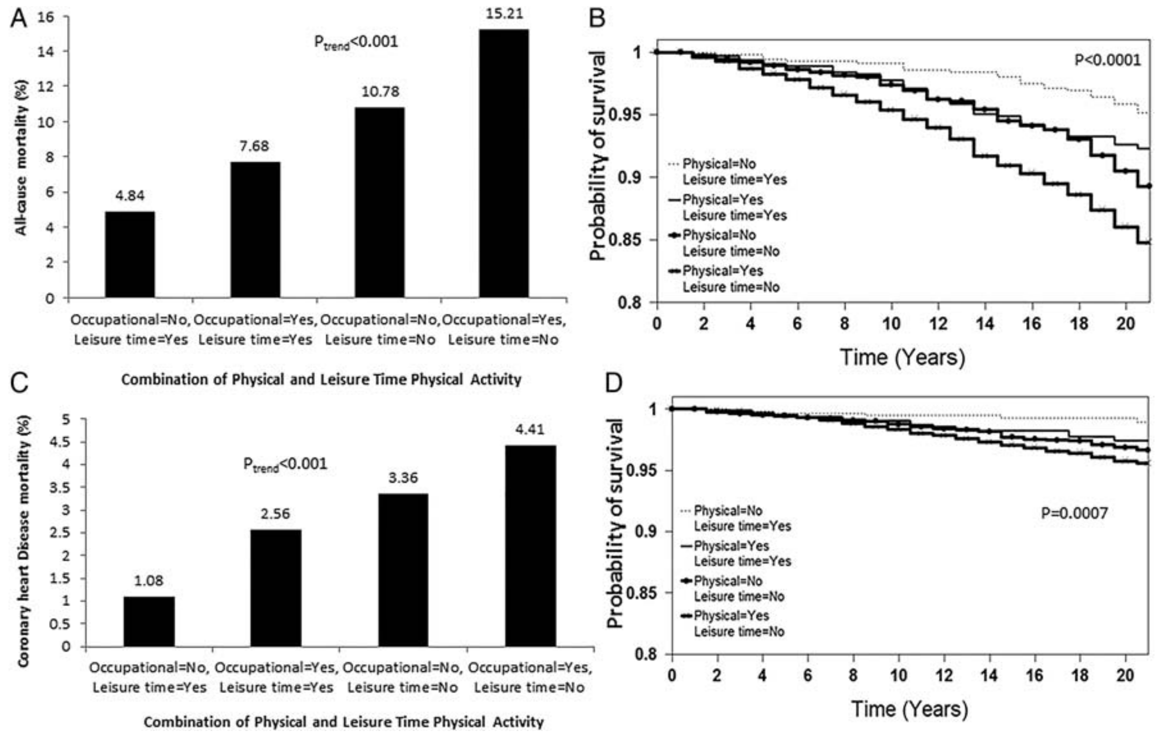

Figure 2 (A) Incidence rates of all-cause mortality by PA combination variables. (B) Kaplan-Meier survival analysis of all-cause mortality by PA combination variables. p Value indicates difference between PA combination variables by log-rank test. (C) Incidence rates of CHD mortality by PA combination variables; (D) Kaplan-Meier survival analysis of CHD mortality by PA combination variables. p Value indicates difference between PA combination variables by log-rank test. PA, physical activity; CHD, coronary heart disease.

characteristics; LTPA improves aerobic capacity, while high physical work demands do not necessarily lead to improvements in physical fitness.[23] In addition, OPA may have a different physiological effect on the body as it is usually carried out for longer periods of time (ie, hours) and is mainly characterised by monotonous, small and rapid-motor movements. Several hours per day of OPA may cause prolonged elevated heart rate, eliciting a higher fraction of the cardiac circle in the systolic phase with unfavourable intravascular turbulence and wall shear stress, leading to inflammatory processes in the arterial walls which may result in atherosclerosis, CVD and death.[30]

Furthermore, OPA often involves heavy lifting for relatively short intervals with much sedentary activity in- between, a greater proportion of static to dynamic effort, and the use of fewer muscles than in LTPA. This kind of effort can cause a rise in heart rate, systolic blood pressure, and tiredness representing increased physical strain.[31] High energy expenditure during work may have a deleterious effect on the heart.[32] In addition, LTPA was shown to decrease the viscosity of the blood while

Table 3 HR for all-cause mortality or coronary heart disease mortality according to the combined profiles of occupational physical activity and leisure time physical activity

	All-cause mortality				CHD mortality			
Variable	No. of deaths	HR	(95% CI)	p Value	No. of deaths	HR	(95% CI)	p Value
Combined PA variables model (unadjusted)*,†								
Moderate–hard OPA+no LTPA‡	352	1			102	1		
None–mild OPA+no LTPA	141	0.68	(0.56 to 0.82)	<0.0001	44	0.74	(0.52 to 1.05)	0.092
Moderate–hard OPA+LTPA	48	0.48	(0.36 to 0.65)	<0.0001	16	0.56	(0.33 to 0.95)	0.031
None–mild OPA+LTPA	27	0.30	(0.20 to 0.44)	<0.0001	6	0.23	(0.10 to 0.53)	<0.001
Combined PA variables model (adjusted)*,§								
Moderate–hard OPA+no LTPA‡	352	1			102	1		
None–mild OPA+no LTPA	141	0.70	(0.57 to 0.87)	0.001	44	0.78	(0.53 to 1.15)	0.213
Moderate–hard OPA+LTPA	48	0.86	(0.63 to 1.17)	0.341	16	1.00	(0.58 to 1.73)	0.1
None–mild OPA+LTPA	27	0.54	(0.36 to 0.82)	0.004	6	0.44	(0.18 to 1.11)	0.083

*The interaction between OPA and LTPA was not statistically significant in these models ($P \geq 0.15$).
†$p_{trend}<0.001$.
‡Reference category.
§Adjusted for age at screening, socioeconomic status (number of people/room), educational status, father's country of origin, body mass index, cholesterol, high-density lipoprotein cholesterol, hypertension, diabetes, smoking, coffee consumption, alcohol consumption, diet, and shift work.
CHD, coronary heart disease; LTPA, leisure time physical activity; OPA, occupational physical activity.

OPA did not have such an effect.[33] OPA may also have a different psychological effect compared with LTPA, leading to stress which in turn is a risk factor for CVD.[32 34]

The strength of this study lies in its relatively large sample size and long duration of follow-up (22 years). However, this study also has several limitations. From previous studies performed on this cohort it is known that men who participated in this cohort were 5 years older than those who did not take part in the study.[35] Furthermore, study participants were healthier and tended to work in smaller industrial plants compared with those who did not take part in the study.[35]

This study was conducted on a population of Jewish male industrial workers and it expends the generalisation of the findings from previous studies as well as reduces the probability for socioeconomic confounding in a relatively homogeneous population. However, it is difficult to deduce if the results observed in this study would also be valid for non-industrial workers. Therefore, additional studies in non-industrial workers would be needed to confirm the external validity of this study's findings. Some genetic characteristics may have contributed to the outcome observed. Furthermore, although the results of the study may not apply to women, a recent study among Danish nurses suggested similar results with respect to OPA and LTPA.[19]

OPA and LTPA levels were based on self-report; this invariably entails some degree of exposure misclassification. Furthermore, there was no information that allowed control for changes over time in the participants' occupational characteristics. However, these misclassification biases are non-differential due to the prospective nature of the study and thus, can only lead to underestimation of the true strength of the associations demonstrated in the study. Furthermore, for verification, the reported OPA levels were tested versus related occupational data, that is, being a blue or white collar worker, body position at work and job description, and these were found to be reliable.

Outcome misclassification may have resulted from the fact that mortality data were obtained from the National Death Registry and the major cause of death may be different from what was actually registered in some cases. However, verification of coding was previously checked and was found to be 91% accurate.[35] This misclassification is non-differential as it does not depend on PA performance that is unknown to the person completing the reasons of death. Therefore, it may have led only to underestimation of the observed associations.

Lastly, despite the adjustments made in this study, measurement error with respect to confounding factors, especially in reported parameters as dietary habits, can lead to residual confounding.[36] There may also be some hidden confounding since PA performed at home or during commuting was not accounted for. Previous studies have shown that light household activity was related to lower all-cause and CVD mortality.[11 18] Therefore, not accounting for this domain of PA may have confounded the results and needs to be considered in future studies.

In summary, this long follow-up study performed on industrial workers in Israel corroborates and strengthens the results of other studies performed in the USA and in Europe that suggested that OPA and LTPA have opposite effects on health. Employees who perform moderate–hard OPA and no LTPA had the greatest risk of all-cause mortality while employees who performed none–light OPA and LTPA had the lowest risk. These associations were temporal and remained significant after adjusting for confounding factors. The results of this study emphasises the need to establish health recommendations regarding OPA and occupational safety, and to educate workers, management and societal institutions on the potential hazards of moderate–hard OPA as well as about the benefits of LTPA. Industrial workers should be made aware that moderate–hard OPA is not a substitute for LTPA; rather, workers who perform moderate–hard OPA should be encouraged to engage in LTPA. Further studies on the general population, as well as on females, are warranted.

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