



## Original Contribution

# The Combined Relationship of Occupational and Leisure-Time Physical Activity With All-Cause Mortality Among Men, Accounting for Physical Fitness

Els Clays\*, Mark Lidegaard, Dirk De Bacquer, Koen Van Herck, Guy De Backer, France Kittel, Patrick de Smet, and Andreas Holtermann

\* Correspondence to Dr. Els Clays, Department of Public Health, Ghent University, University Hospital—(2) Block A, De Pintelaan 185, B-9000 Ghent, Belgium (e-mail: els.clays@UGent.be).

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The aim of this study was to assess the combined relationship of occupational physical activity and leisure-time physical activity with all-cause mortality among men, while accounting for physical fitness. The prospective Belgian Physical Fitness Study included 1,456 male workers aged 40–55 years who were free of coronary heart disease at baseline. Baseline data were collected through questionnaires and clinical examinations from 1976 to 1978. To estimate physical fitness, a submaximal graded exercise test was performed on a bicycle ergometer. Total mortality was registered during a mean follow-up period of 16.9 years. Main results were obtained through Cox proportional hazards regression analysis. A total of 145 deaths were registered during follow-up. After adjustment for confounders, a significantly increased mortality rate was observed in workers who had low levels of both physical activity types (hazard ratio = 2.07, 95% confidence interval: 1.03, 4.19) but also in workers combining high occupational physical activity and low leisure-time physical activity (hazard ratio = 2.04, 95% confidence interval: 1.07, 3.91); the latter finding was particularly pronounced among workers with a low physical fitness level. The present results confirm the existence of a complex interplay among different physical activity settings and fitness levels in predicting mortality.

mortality; occupation; physical activity; physical fitness

Abbreviations: BELSTRESS, Belgian Job Stress Project; LTPA, leisure-time physical activity; OPA, occupational physical activity; PA, physical activity.

Physical activity (PA) is one of the most important and most widely documented behavioral factors determining overall health, particularly cardiovascular disease risk (1). Nonetheless, although its positive influence is not disputed and detailed public health recommendations for PA exist (2, 3), recent trends in PA research have indicated the necessity to better describe and understand the many facets of PA and their complex association with disease risk.

The reduced risk of morbidity and mortality derived from leisure-time physical activity (LTPA) is widely established in the literature (4). On the other hand, the association between occupational physical activity (OPA) and cardiovascular disease has been examined to a much lesser extent, and findings are more inconsistent (5, 6). In recent years, a number of prospective cohort studies have shown that performing heavy

physical activities at work has detrimental influences on health (7–11). Even in modern service economies, an important proportion of the working population is still exposed to heavy physical demands (8, 12, 13). There is increasing evidence that OPA and LTPA have independent, contrasting health consequences, with beneficial outcomes arising from LTPA and adverse outcomes from OPA (12, 14). Hence, more research is needed to disentangle the roles of different types of PA in cardiovascular health (5, 6).

Besides PA pattern, level of cardiorespiratory fitness is known to be a strong independent predictor of all-cause mortality (15–17). While habitual LTPA is widely documented as a primary determinant of physical fitness, this is not so obvious for OPA (9, 18). Epidemiologic evidence also suggests that level of physical fitness is an important

confounder or mediator in the interplay between LTPA and OPA, although only a few large-scale prospective studies have addressed this (6). The Copenhagen Male Study showed different health relationships for physical work demands, depending on the worker's level of physical fitness (9).

In his highly influential editorial, Dr. Niklas Krause made a convincing plea to differentiate between beneficial and detrimental consequences of different types and settings of PA while controlling for fitness (6). With the availability of detailed measures of PA during both working and leisure time as well as physical fitness level in the Belgian Physical Fitness Study, we had the potential to bring more clarity to the currently available evidence about the independent and interactive associations of OPA, LTPA, and physical fitness with health. Our aim was to assess the combined relationship of OPA and LTPA with all-cause mortality among men, while taking physical fitness into account.

## MATERIALS AND METHODS

### Study design and population

The Belgian Physical Fitness Study was a prospective epidemiologic study including 2,363 male industry workers. Details on the study protocol have been published previously (19). All men aged 40–55 years and regularly employed by selected organizations were invited to participate; the response rate was 75%. The baseline examination was conducted in 1976–1978 and entailed the administration of various questionnaires, a bioclinical examination, and a submaximal graded exercise test. The baseline examinations were carried out in the occupational medicine departments of the study organizations by trained researchers following standardized protocols. We excluded 270 persons with a previous hospitalization for coronary heart disease or with electrocardiographic abnormalities suggestive of coronary heart disease, leaving a sample of 2,093 middle-aged men who were free of coronary heart disease at baseline. The results presented here are based on a restricted sample of 1,456 participants who were able to complete the exercise test and for whom data on PA were obtained. All participants gave their informed consent before inclusion in the study. The study was approved by the ethics committees of Ghent University and the Free University of Brussels.

### Questionnaire data

Participants completed several self-administered questionnaires that requested information about sociodemographic factors, medical antecedents, and smoking habits. Primary school was classified as a low educational level, secondary school as a medium educational level, and high school or university as a high educational level. Occupations were grouped into blue-collar, white-collar, and executive. Participants were classified as having diabetes if they positively answered a question on whether they had ever been or presently were diabetic. Current smokers were defined as those who regularly smoked cigarettes.

Two additional questionnaires assessing PA on the job and during leisure time were administered by the interviewer (19).

A questionnaire was designed to assess OPA, including detailed information on attitudes, movements, and postures during a regular working day. Values for caloric expenditure in various professional activities were derived. This resulted in the calculation of total occupational energy expenditure, expressed as kilocalories per working hour, which included a basal metabolism fixed at 73 kcal/hour. The Minnesota Leisure Time Physical Activity Questionnaire, which has been validated by objective measures of physical fitness, was used to determine energy expenditure during leisure hours (20). Energy expenditure was calculated in terms of the metabolic index (20) as light activity (metabolic index within the intensity code range 2.0–4.0), moderate activity (intensity code 4.5–5.5), heavy activity (intensity code  $\geq 6.0$ ), and total activity. These values were expressed as accumulated energy expenditure, in kilocalories, over the past 3 months. For the current analysis, we used PA of heavy intensity during the past 3 months as the exposure variable, in line with international guidelines regarding the health impact of PA (2, 3). For both OPA and LTPA, subjects were assigned low, medium, and high levels according to the tertile distribution of the sample.

### Clinical examination and exercise test

The clinical examination included assessment of blood pressure levels, height and weight measurements, electrocardiographic recordings, and collection of a fasting blood sample (19). Body mass index was calculated as body weight (kg) divided by the square of height (m). Total cholesterol was measured in a central laboratory.

A submaximal graded exercise test was performed on a bicycle ergometer for estimation of physical working capacity (19). The initial workload was fixed at 75 watts, with 25-watt increments every 2.5 minutes. The target heart rate was 150 beats/minute, corresponding to 80% of the predicted maximal heart rate in the study population. Physical working capacity was defined as the work load, expressed in watts, at a heart rate of 150 beats/minute and was calculated by interpolation only. The physical working capacity value was standardized for body weight and was used as the criterion for physical fitness (in watts/kg). Low, medium, and high fitness levels were defined according to the tertile values. For safety reasons, strict criteria were applied for exclusion from and discontinuation of the exercise test, based on medical history, resting blood pressure ( $\geq 170/105$  mm Hg), and resting electrocardiogram following the Minnesota Code readings (19). Of the 2,093 men who were free of coronary heart disease at entry into the study, 386 did not meet the inclusion criteria for the exercise test, and 244 persons started the test but did not reach the target heart rate of 150 beats/minute. Another 7 persons were excluded because of missing data on PA.

### Mortality follow-up

Vital status was obtained from the national registry of the Belgian population, and all mortality events were linked to the coded death certificates at the National Institute for Statistics (21). Mean follow-up time was 16.9 years (standard deviation, 3.3), with an interquartile range of 17.5–18.6. Within

the study sample of 1,456 men who were free of coronary heart disease at baseline, a total of 145 fatal events were registered. The specific causes of 119 of the 145 events were provided by the National Institute for Statistics: 36 of these events were cardiovascular deaths (of which 24 were coronary), 78 were cancer deaths, and 5 were deaths due to external causes. In this study, total mortality was used as the outcome.

### Statistical analyses

The characteristics of the participants were determined through proportions for categorical variables, mean values and standard deviations for normally distributed continuous variables, and median values and interquartile ranges for skewed continuous variables. *T* tests and  $\chi^2$  tests were used to compare the study sample with the subgroup that was excluded from performing or finishing the exercise test. Analyses of covariance adjusting for age, educational level, occupational class, smoking, body mass index, systolic blood pressure, and total cholesterol were performed to compare average fitness levels between PA groups. Combined exposure to both PA types was assessed by creating a new variable. Four separate groups were defined according to the combination of low and high levels of OPA and LTPA, with low levels corresponding to the lowest tertile groups of the original OPA and LTPA classifications and high levels including the medium and high tertile groups. Risk factor profiles were compared between PA groups by means of analysis of variance and  $\chi^2$  tests. We used Cox proportional hazards regression modeling to assess the relationship between PA exposures and all-cause mortality in a predictive model for time-to-event data. Parameter estimation was conducted via the maximum likelihood method;  $\exp(B)$  and the corresponding 95% confidence interval was obtained as the estimated hazard ratio. A visual inspection of the log-minus-log plots was performed to check whether the proportional hazards assumption was met. Adjustment for confounders was done stepwise. Age-adjusted hazard ratios were generated in the first model, while in the second model additional adjustments were made for educational level, occupational class, smoking, body mass index, systolic blood pressure, and total cholesterol. We tested additional models adding 2-way and 3-way interaction terms for interactions among OPA, LTPA, and physical fitness.

A *P* value at the 0.05 level was considered statistically significant. All analyses were conducted with IBM SPSS Statistics, version 20 (IBM, Somers, New York).

### RESULTS

The 1,456 subjects who completed the exercise test showed a significantly different profile than the group of 630 workers who were excluded: On average, they were younger (46.3 years vs. 48.5 years;  $P < 0.001$ ), smoked less (45.4% vs. 57.8%;  $P < 0.001$ ), had a lower proportion of persons with diabetes (1.0% vs. 4.0%;  $P < 0.001$ ), and had a lower average body mass index (25.5 vs. 26.1;  $P < 0.001$ ), systolic/diastolic blood pressure (131.9/82.1 mm Hg vs.

**Table 1.** Baseline Sociodemographic, Cardiovascular, and Physical Activity Characteristics of 1,456 Men from the Belgian Physical Fitness Study Who Were Free of Coronary Heart Disease at Baseline, 1976–1978

| Characteristic                           | Mean (SD)                        | No. of Participants | %    |
|------------------------------------------|----------------------------------|---------------------|------|
| Age, years                               | 46.3 (4.2)                       |                     |      |
| Educational level <sup>a</sup>           |                                  |                     |      |
| Low                                      |                                  | 372                 | 25.9 |
| Medium                                   |                                  | 894                 | 62.3 |
| High                                     |                                  | 168                 | 11.7 |
| Occupational class                       |                                  |                     |      |
| Executive                                |                                  | 225                 | 15.5 |
| White-collar                             |                                  | 701                 | 48.1 |
| Blue-collar                              |                                  | 530                 | 36.4 |
| Current smoker                           |                                  | 662                 | 45.5 |
| Diabetes                                 |                                  | 14                  | 1.0  |
| BMI <sup>b</sup>                         | 25.5 (2.9)                       |                     |      |
| BMI group                                |                                  |                     |      |
| Normal-weight (BMI <25)                  |                                  | 653                 | 44.8 |
| Overweight (BMI 25–<30)                  |                                  | 706                 | 48.5 |
| Obese (BMI ≥30)                          |                                  | 97                  | 6.7  |
| Systolic blood pressure, mm Hg           | 131.9 (13.4)                     |                     |      |
| Diastolic blood pressure, mm Hg          | 82.1 (10.5)                      |                     |      |
| Total cholesterol, mg/dL                 | 232.0 (32.8)                     |                     |      |
| HDL cholesterol, mg/dL                   | 54.1 (14.0)                      |                     |      |
| Physical fitness, watts/kg               | 1.48 (0.28)                      |                     |      |
| Physical fitness group                   |                                  |                     |      |
| Low                                      |                                  | 482                 | 33.1 |
| Medium                                   |                                  | 485                 | 33.3 |
| High                                     |                                  | 489                 | 33.6 |
| OPA, kcal/working hour                   | 1,675 (1,230–2,234) <sup>c</sup> |                     |      |
| OPA group                                |                                  |                     |      |
| Low                                      |                                  | 466                 | 32.0 |
| Medium                                   |                                  | 493                 | 33.9 |
| High                                     |                                  | 497                 | 34.1 |
| Heavy LTPA (total kcal in last 3 months) | 720 (0–4,269) <sup>c</sup>       |                     |      |
| Heavy LTPA group                         |                                  |                     |      |
| Low                                      |                                  | 697                 | 47.9 |
| Medium                                   |                                  | 368                 | 25.3 |
| High                                     |                                  | 391                 | 26.9 |

Abbreviations: BMI, body mass index; HDL, high-density lipoprotein; LTPA, leisure-time physical activity; OPA, occupational physical activity; SD, standard deviation.

<sup>a</sup> Data on educational level were missing for 22 participants.

<sup>b</sup> Weight (kg)/height (m)<sup>2</sup>.

<sup>c</sup> Median and interquartile range (25th–75th percentiles).

**Table 2.** Associations of Physical Fitness and Occupational and Leisure-Time Physical Activity With Physical Fitness Level and All-Cause Mortality in 1,456 Men from the Belgian Physical Fitness Study, 1976–1978

|                                      | Physical Fitness Level       |                      | All-Cause Mortality |      |             |                 |            |                 |            |
|--------------------------------------|------------------------------|----------------------|---------------------|------|-------------|-----------------|------------|-----------------|------------|
|                                      | Adjusted Mean, watts/kg (SE) | P Value <sup>a</sup> | No. of Deaths       | %    | P for Trend | HR <sup>b</sup> | 95% CI     | HR <sup>c</sup> | 95% CI     |
| Occupational physical activity       |                              | 0.60                 |                     |      | 0.09        |                 |            |                 |            |
| Low                                  | 1.49 (0.014)                 |                      | 37                  | 7.9  |             | 1               |            | 1               |            |
| Medium                               | 1.51 (0.013)                 |                      | 52                  | 10.5 |             | 1.32            | 0.86, 2.01 | 1.31            | 0.84, 2.04 |
| High                                 | 1.50 (0.014)                 |                      | 56                  | 11.3 |             | 1.39            | 0.91, 2.10 | 1.21            | 0.74, 1.97 |
| Heavy leisure-time physical activity |                              | <0.01                |                     |      | <0.05       |                 |            |                 |            |
| High                                 | 1.53 (0.014)                 |                      | 30                  | 7.7  |             | 1               |            | 1               |            |
| Medium                               | 1.51 (0.015)                 |                      | 32                  | 8.7  |             | 1.10            | 0.67, 1.82 | 1.10            | 0.66, 1.83 |
| Low                                  | 1.48 (0.012)                 |                      | 83                  | 11.9 |             | 1.46            | 0.96, 2.22 | 1.35            | 0.87, 2.09 |
| Physical fitness                     |                              | <0.001               |                     |      | 0.69        |                 |            |                 |            |
| High                                 | 1.78 (0.007)                 |                      | 48                  | 9.8  |             | 1               |            | 1               |            |
| Medium                               | 1.47 (0.007)                 |                      | 46                  | 9.5  |             | 0.97            | 0.65, 1.45 | 1.05            | 0.69, 1.60 |
| Low                                  | 1.20 (0.007)                 |                      | 51                  | 10.6 |             | 1.08            | 0.73, 1.60 | 1.34            | 0.88, 2.04 |

Abbreviations: CI, confidence interval; HR, hazard ratio; SE, standard error.

<sup>a</sup> Analysis of covariance; adjusted for age, educational level, occupational class, smoking, body mass index, systolic blood pressure, and total cholesterol.

<sup>b</sup> Cox proportional hazards regression analysis; adjusted for age.

<sup>c</sup> Cox proportional hazards regression analysis; adjusted for age, educational level, occupational class, smoking, body mass index, systolic blood pressure, and total cholesterol and respectively for occupational physical activity/heavy leisure-time physical activity/physical fitness.

139.5/88.0 mm Hg;  $P < 0.001$ ), and total cholesterol level (232.0 mg/dL vs. 236.2 mg/dL;  $P < 0.01$ ).

During a mean follow-up time of 16.9 years, cumulative mortality in the study population was 10% (145 deaths among 1,456 men). A significantly ( $P < 0.001$ ) higher proportion of 17% was observed in the subgroup that was excluded from the exercise test (106 deaths among 630 men). Baseline characteristics of the cohort are shown in Table 1. For both PA measures and physical fitness level, the study sample was divided into low, medium, and high groups. Almost 48% of participants scored zero on energy expenditure from heavy-intensity LTPA during the past 3 months.

Table 2 shows the associations of PA groups with average fitness levels and total mortality. A significant graded relationship was observed between LTPA of heavy intensity during the past 3 months and level of physical fitness.

No significant interaction effects were observed among LTPA, OPA, and fitness in relation to total mortality. The combined relationship of OPA and LTPA with all-cause mortality was evaluated in both the complete group and men with different fitness levels; results are shown in Table 3. Table 4 provides an overview of the risk-factor profile among the combined PA groups. After adjustment for confounders, a significantly increased mortality rate was observed in workers who had low levels of both PA types, but also in workers who had a combination of high OPA and low LTPA. Based on stratified analyses, the combination of high OPA and low LTPA was related to the highest mortality rate among men with a low physical fitness level.

## DISCUSSION

This study provides additional insight into the current controversies in PA research by disentangling the nature of the associations of different PA settings and physical fitness levels with mortality. In a sample of 1,456 men aged 40–55 years from the Belgian Physical Fitness Study, we assessed the combined relationship of OPA and LTPA with all-cause mortality, while taking physical fitness into account. The main findings were that low levels of both types of PA, as well as the combination of high OPA and low LTPA, were independently associated with higher mortality, with the combined condition being particularly harmful among men with a low fitness level.

The overall harmful impact of lack of PA on health is widely documented in the literature and was recognized in this study. However, our findings also add to the growing evidence showing contrasting health associations of PA performed in different settings such as work and leisure time. There is rising support for the view that PA performed at work is associated with increased risk of ill health. In a Finnish cohort of working men, higher levels of energy expenditure at work were associated with increased progression of carotid atherosclerosis (8). Physical work demands predicted all-cause mortality among men from the Copenhagen City Heart Study (22), as well as the Copenhagen Male Study (9), and in a study including Israeli industrial employees (7). From a public health perspective, it is essential to examine the health impact of OPA, especially in light of the

**Table 3.** Hazard Ratio for All-Cause Mortality According to Combined Occupational and Leisure-Time Physical Activity and Level of Physical Fitness Among 1,456 Men From the Belgian Physical Fitness Study, 1976–1978

| Physical Activity Combination <sup>a</sup> | No. of Deaths | %    | HR <sup>b</sup>   | 95% CI     | HR <sup>c</sup>   | 95% CI      |
|--------------------------------------------|---------------|------|-------------------|------------|-------------------|-------------|
| <i>Total (All Physical Fitness Levels)</i> |               |      |                   |            |                   |             |
| Low OPA–high LTPA                          | 13            | 5.4  | 1                 |            | 1                 |             |
| High OPA–high LTPA                         | 49            | 9.4  | 1.81              | 0.98, 3.33 | 1.83              | 0.95, 3.54  |
| Low OPA–low LTPA                           | 24            | 10.6 | 2.00 <sup>d</sup> | 1.02, 3.94 | 2.07 <sup>d</sup> | 1.03, 4.19  |
| High OPA–low LTPA                          | 59            | 12.5 | 2.20 <sup>d</sup> | 1.21, 4.02 | 2.04 <sup>d</sup> | 1.07, 3.91  |
| <i>Low Physical Fitness Level</i>          |               |      |                   |            |                   |             |
| Low OPA–high LTPA                          | 4             | 5.3  | 1                 |            | 1                 |             |
| High OPA–high LTPA                         | 9             | 6.3  | 1.39              | 0.42, 4.55 | 1.41              | 0.42, 4.70  |
| Low OPA–low LTPA                           | 10            | 10.8 | 2.30              | 0.72, 7.34 | 2.40              | 0.75, 7.68  |
| High OPA–low LTPA                          | 28            | 16.5 | 3.30 <sup>d</sup> | 1.16, 9.41 | 3.42 <sup>d</sup> | 1.17, 10.00 |
| <i>Medium Physical Fitness Level</i>       |               |      |                   |            |                   |             |
| Low OPA–high LTPA                          | 4             | 4.9  | 1                 |            | 1                 |             |
| High OPA–high LTPA                         | 18            | 9.6  | 1.74              | 0.59, 5.16 | 1.62              | 0.50, 5.28  |
| Low OPA–low LTPA                           | 9             | 13.6 | 2.53              | 0.78, 8.25 | 2.93              | 0.83, 10.28 |
| High OPA–low LTPA                          | 15            | 10.0 | 1.71              | 0.56, 5.20 | 1.51              | 0.45, 5.16  |
| <i>High Physical Fitness Level</i>         |               |      |                   |            |                   |             |
| Low OPA–high LTPA                          | 5             | 6.0  | 1                 |            | 1                 |             |
| High OPA–high LTPA                         | 22            | 11.7 | 1.97              | 0.75, 5.20 | 2.00              | 0.64, 6.25  |
| Low OPA–low LTPA                           | 5             | 7.5  | 1.28              | 0.37, 4.44 | 1.27              | 0.33, 4.87  |
| High OPA–low LTPA                          | 16            | 10.6 | 1.70              | 0.62, 4.69 | 1.48              | 0.45, 4.88  |

Abbreviations: CI, confidence interval; HR, hazard ratio; LTPA, leisure-time physical activity; OPA, occupational physical activity.

<sup>a</sup> Low = first tertile group; high = second and third tertile groups.

<sup>b</sup> Cox proportional hazards regression analysis; adjusted for age.

<sup>c</sup> Cox proportional hazards regression analysis; additionally adjusted for fitness level in the complete-group analysis and for educational level, occupational class, smoking, body mass index, systolic blood pressure, and total cholesterol in all analyses.

<sup>d</sup>  $P < 0.05$ .

observation that physical job demands are still widely prevalent in modern working life (8, 12, 13). A number of studies have also simultaneously investigated the differentiating influences of both OPA and LTPA. The Stockholm Heart Epidemiology Program (SHEEP) Study, a case-control study on myocardial infarction, showed independent preventive relationships with LTPA and adverse relationships with physical work load (23). Likewise, these opposing associations of OPA and LTPA with long-term sickness absence were observed in the Danish Work Environment Cohort Study (12) and with coronary heart disease in male workers from the Belgian Job Stress Project (BELSTRESS) cohort (11). A plausible explanation for these contrasting influences is that PA during work and PA during leisure time generate differing physiological mechanisms: While exercise during leisure time generally includes dynamic aerobic activities of shorter durations and sufficient rest, inducing a training effect, heavy physical demands on the job usually include more static physical activities of longer duration, often with limited restitution, which creates an overloading effect on the cardiovascular system (6, 8). In line with this hypothesis, a few studies

specifically addressed the impact of performing lifting activities at work and showed relationships with risk of ischemic heart disease (24) and elevated systolic blood pressure (14). Additional support for the contrasting physiological consequences of OPA and LTPA is provided by our finding of a significant relationship between heavy-intensity LTPA during the past 3 months and level of physical fitness, while OPA was not associated with fitness—the latter also being observed in earlier studies (9, 18).

Contrary to expectations, physical fitness level did not significantly predict total mortality in this cohort. This finding is probably due to a selection bias towards a healthier profile in those participants who were allowed and able to complete the exercise test. The group that was excluded was older, included more smokers and persons with diabetes, and had higher body mass index, blood pressure, and total cholesterol levels. As a result of this, our study sample, with its rather homogeneously healthier profile, might have included insufficient exposure contrast in physical fitness to show a long-term relationship with mortality. Although no significant interaction between PA and fitness in relation to

**Table 4.** Distribution of Baseline Sociodemographic and Cardiovascular Risk Factors According to Combined Physical Activity Group Among 1,456 Men From the Belgian Physical Fitness Study, 1976–1978

| Characteristic                 | Physical Activity Combination <sup>a</sup> |                  |      |                    |     |      |                  |     |      |                   |     | <i>P</i><br>Value <sup>b</sup> |        |
|--------------------------------|--------------------------------------------|------------------|------|--------------------|-----|------|------------------|-----|------|-------------------|-----|--------------------------------|--------|
|                                | Low OPA–High LTPA                          |                  |      | High OPA–High LTPA |     |      | Low OPA–Low LTPA |     |      | High OPA–Low LTPA |     |                                |        |
|                                | Mean (SD)                                  | No. <sup>c</sup> | %    | Mean (SD)          | No. | %    | Mean (SD)        | No. | %    | Mean (SD)         | No. |                                | %      |
| Age, years                     | 45.8 (4.0)                                 |                  |      | 45.7 (4.1)         |     |      | 46.7 (4.1)       |     |      | 47.0 (4.3)        |     |                                | <0.001 |
| Educational level <sup>d</sup> |                                            |                  |      |                    |     |      |                  |     |      |                   |     | <0.001                         |        |
| Low                            |                                            | 13               | 5.4  |                    | 155 | 30.2 |                  | 27  | 12.2 |                   | 177 | 38.5                           |        |
| Medium                         |                                            | 167              | 69.9 |                    | 317 | 61.8 |                  | 160 | 72.1 |                   | 250 | 54.3                           |        |
| High                           |                                            | 59               | 24.7 |                    | 41  | 8.0  |                  | 35  | 15.8 |                   | 33  | 7.2                            |        |
| Occupational class             |                                            |                  |      |                    |     |      |                  |     |      |                   |     | <0.001                         |        |
| Executive                      |                                            | 63               | 26.2 |                    | 70  | 13.5 |                  | 41  | 18.1 |                   | 51  | 10.8                           |        |
| White-collar                   |                                            | 159              | 66.2 |                    | 192 | 37.0 |                  | 154 | 68.1 |                   | 196 | 41.6                           |        |
| Blue-collar                    |                                            | 18               | 7.5  |                    | 257 | 49.5 |                  | 31  | 13.7 |                   | 224 | 47.6                           |        |
| Current smoker                 |                                            | 83               | 34.6 |                    | 237 | 45.7 |                  | 97  | 42.9 |                   | 245 | 52.0                           | <0.001 |
| Body mass index <sup>e</sup>   | 25.1 (2.7)                                 |                  |      | 25.5 (2.8)         |     |      | 25.4 (3.0)       |     |      | 25.8 (2.9)        |     |                                | <0.05  |
| Systolic blood pressure, mm Hg | 132.6 (13.0)                               |                  |      | 131.1 (13.4)       |     |      | 132.5 (13.6)     |     |      | 132.0 (13.4)      |     |                                | 0.44   |
| Total cholesterol, mg/dL       | 231.6 (32.6)                               |                  |      | 230.5 (35.0)       |     |      | 234.9 (29.7)     |     |      | 232.7 (31.8)      |     |                                | 0.38   |
| Physical fitness, watts/kg     | 1.50 (0.28)                                |                  |      | 1.52 (0.27)        |     |      | 1.44 (0.26)      |     |      | 1.46 (0.29)       |     |                                | <0.001 |

Abbreviations: LTPA, leisure-time physical activity; OPA, occupational physical activity; SD, standard deviation.

<sup>a</sup> Low = first tertile group; high = second and third tertile groups.

<sup>b</sup> Analysis-of-variance *F* test for continuous variables and  $\chi^2$  test for categorical variables.

<sup>c</sup> Number of participants.

<sup>d</sup> Data on educational level were missing for 22 participants.

<sup>e</sup> Weight (kg)/height (m)<sup>2</sup>.

mortality was observed, stratified results showed that the combined relationship of both PA types with mortality varied to some extent according to physical fitness level. Among workers with a low fitness level, high OPA in combination with a low level of heavy LTPA showed the highest mortality risk. This is in line with findings from the Copenhagen Male Study showing that high physical work demands increased the risk of mortality among persons with low physical fitness (9, 25). In people with low and medium fitness levels, a non-significantly increased mortality rate was observed for the group that had low PA levels during both leisure time and working hours. These findings suggest that a sedentary lifestyle might be more harmful for overall health if people have a lower level of physical fitness.

No statistically significant effect of interaction among different PA settings and mortality was observed in this study: OPA and LTPA showed additive contrasting influences on total mortality, particularly in men with low fitness levels. This is in contrast to what was recently observed within the BELSTRESS cohort, where a significant interaction effect between PA settings was observed, showing that men with high physical job demands who also engaged in PA during leisure time had an almost 4 times' increased incidence of coronary events (11). The limited number of studies investigating these interaction effects have shown mixed results, so whether people with high physical job demands should be advised to rest or be physically active in their leisure time

remains a topic for intense scientific debate (22, 26, 27). It is often difficult to compare results from different studies because of the notable differences in the applied methodologies, such as length of follow-up, definition of outcome events, and (especially) operationalization of PA. More research using detailed objective measures of PA is needed to unravel the influence of these complex relationships among OPA, LTPA, and fitness in affecting health.

The main strength of this study is that we were able to disentangle the nature of the associations among OPA, LTPA, and physical fitness in relation to objective outcome data within a prospective study design. Rigorous follow-up procedures were applied to obtain complete long-term mortality registration in this cohort. There are also some important study limitations that need to be taken into account. The analyses controlled for major known confounding variables, including age, educational level, occupational class, smoking, body mass index, systolic blood pressure, and total cholesterol. Our findings showed that PA patterns were associated with different risk profiles relating to age, socioeconomic status, smoking, body mass index, and fitness level. Blue-collar and less educated workers were highly represented within workers exposed to high levels of OPA. Because we included both education and occupation as confounders, we consider the observed findings to not merely be a result of socioeconomic confounding. Nonetheless, it remains possible that the findings in this observational study are due to residual confounding.

For instance, we had no available data regarding nutritional habits or alcohol consumption. Moreover, residual confounding cannot be ruled out for the factors that were included in the analyses, because some measurement error may have occurred in assessing these variables with self-report instruments or clinical measurements. Detailed interview-based questionnaires were administered to assess levels of OPA and LTPA in this study. The majority of currently available studies in this research area typically applied more generic measures of PA including only 1 item or a limited number of items (7, 9, 11, 22). The questionnaires used in the present study had the advantage that PA level was measured in a more detailed and thorough manner through consideration of different dimensions of PA, such as type, frequency, intensity, and duration of activity. Notwithstanding this benefit, subjective PA instruments based on self-report data are known to have limited reliability and validity in comparison with objective monitoring methods (28). Only a single PA assessment was linked to long-term follow-up data, although it is reasonable to assume that a proportion of the participants changed their PA levels over the course of follow-up. Within the Copenhagen City Heart Study, for instance, the general level of OPA had changed in about 40% of the adult population after 5 years, while for LTPA level this proportion was 48% (22, 29). It is thus very likely that our data were influenced by misclassification bias, which to some extent masked the true relationships in this cohort. We were limited to investigating only total mortality as the outcome because of the low number of coronary deaths in this cohort. In addition, the findings presented here have limited external validity, since no women were included in the study. Participants in the Belgian Physical Fitness Study were not recruited from a representative sample of the working population. More important in this type of analytical study, however, is that the study population contained substantial variation in terms of job type, educational level, and employment sector. A fairly high response rate of 75% was reached. On the other hand, the selection bias relating to the exercise test, as described above, together with the general healthy worker effect, may have led to underestimation of the true associations.

In conclusion, the results of the present study confirm the existence of a complex interplay among different types of PA and fitness levels in predicting mortality. In a sample of 1,456 men aged 40–55 years from the Belgian Physical Fitness Study, exposure to low levels of PA both at work and during leisure time was independently associated with higher mortality, which overall confirms the widely documented adverse health impact of lack of PA. The combination of high OPA and low LTPA was also related to a significantly higher mortality risk, and this was particularly pronounced among workers with low physical fitness levels. Hence, our findings add to the growing evidence showing contrasting health associations of PA performed in different settings such as work and leisure.

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Author affiliations: Department of Public Health, Faculty of Medicine and Health Sciences, Ghent University, Ghent,

Belgium (Els Clays, Dirk De Bacquer, Koen Van Herck, Guy De Backer); National Research Centre for the Working Environment, Copenhagen, Denmark (Mark Lidegaard, Andreas Holtermann); and Social Approaches to Health Unit, School of Public Health, Université Libre de Bruxelles, Brussels, Belgium (France Kittel, Patrick de Smet).

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