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# Risk factors for ischaemic heart disease mortality among men with different occupational physical demands. A 30-year prospective cohort study

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Original study protocol It does not exist.



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## ABSTRACT

**Objectives:** Men with high physical work demands have elevated cardiovascular strain, which may lead to enhanced atherosclerosis. Theoretically, the impact of risk factors for ischaemic heart disease (IHD) may thus depend on physical work demands. The authors investigated this hypothesis.

**Design:** Prospective 30-year follow-up.

**Setting:** The Copenhagen Male Study.

**Participants:** 5249 gainfully employed men aged 40–59 years; 311 men with cardiovascular disease/diabetes were excluded.

**Primary and secondary outcome measures:** IHD and all-cause mortality.

**Results:** 579 men (11.8%) died due to IHD and 2628 (53.7%) from all-cause mortality. Similarities and differences in risk predictors were found between men with low (n=1219), medium (n=2636) and high (n=846) physical work demands. After control for potential confounders, high physical fitness conferred a reduced risk of IHD mortality only among men with high physical work demands (HR: 0.48, 95% CI 0.24 to 0.96), a moderate/high level of leisure-time physical activity was associated with reduced risk of IHD mortality only among men with moderate and high physical work demands. High systolic blood pressure and smoking were risk factors in all groups. Similar, but less pronounced differences in risk factors for all-cause mortality between groups were found.

**Conclusions:** The risk factors for IHD and all-cause mortality, low physical fitness and low leisure-time physical activity are not identical for men with different physical work demands. Preventive initiatives for IHD should be tailored to the physical work demands.

## ARTICLE SUMMARY

### Article focus

- Men with high physical work demands have elevated cardiovascular strain and risk of ischaemic heart disease (IHD).
- Unknown if established risk factors for IHD impose divergent risk for IHD mortality among men with different levels of occupational physical activity.

### Key messages

- Risk factors for IHD and all-cause mortality are not identical for men with different physical work demands.
- Low physical fitness and leisure-time physical activity particularly increase the risk of IHD mortality among men with high physical work demands.
- Preventive initiatives for IHD ought not to be general but tailored to the physical work demands of employees.

### Strengths and limitations of this study

- Study strengths are the 30-year follow-up on objective outcomes, inclusion of several objectively measured risk factors for IHD and mortality and exclusion of workers with pre-existing cardiovascular disease at baseline.
- Study limitations are that physical work demands were based on self-assessment and lacking repeated measures of exposure during the relatively long follow-up period.

## INTRODUCTION

Cardiovascular diseases are leading causes of death worldwide and account for about 30% of all deaths.[1] Occupational factors may be responsible for up to about 20% of all ischaemic heart disease (IHD) incidents.[2] Exposure to high physical work demands is an independent risk factor for IHD mortality and carotid arterial atherosclerosis.[3–5]

Physiologically, dynamic or static occupational physical activity several hours per day may induce a prolonged intravascular turbulence and increased wall shear stress,[6] inducing inflammatory processes in the arterial walls that may potentially lead to atherosclerosis.[5] These acute adverse effects of occupational physical activity may be

modified by leisure-time physical activity known to promote cardiorespiratory physical fitness [7] and reduce heart rate and blood pressure during daily activities.[8] A higher cardiorespiratory physical fitness and lower heart rate provide a longer period in the diastolic phase of the cardiac circle, causing better myocardium perfusion and a favourable intravascular turbulence and wall shear stress, reducing risk for inflammation and atherosclerosis.[5 6] Previous results from the Copenhagen Male Study support this rationale[4] showing that high physical work demands confer an increased risk of IHD mortality among men with a low physical fitness but not among men with high physical fitness.

The theoretical implication is that those exposed to high physical demands and cardiovascular strain at work might be particularly vulnerable when exposed to other established risk factors for IHD mortality like smoking, high blood pressure and low leisure-time physical activity. Therefore, these risk factors for IHD and all-cause mortality may impose a divergent impact on people with different physical activity levels at work. The hypothesis of the study is that established hazards for IHD impose a divergent risk for IHD mortality among men with different level of occupational physical activity. This hypothesis has not previously been addressed in the scientific medical literature, although, if supported, it may have important public health implications and be relevant in an occupational health context.

## MATERIALS AND METHODS

### Study design and population

The Copenhagen Male Study was established in 1970–1971. At 14 companies in Copenhagen, covering the railway, public road construction, military, post, telephone, customs, national bank and the medical industry, all men aged 40–59 years were invited; 5249 men, 87% of potential participants, agreed to participate.[9 10]

The examination consisted of a questionnaire, a short interview and a clinical examination including measurements of height, weight and blood pressure, and measurement of cardiorespiratory (physical) fitness following a bicycle ergometer test. Indirect measurement of physical fitness ($VO_2$max) was performed with a bicycle ergometer. Thirty-five men with orthopaedic problems unable to perform the bicycle test were excluded from the study.

From the questionnaire, information about working conditions, including perceived psychosocial pressure during work, lifestyle and general health, including history of myocardial infarction, angina pectoris and intermittent claudication, was obtained. The information given in the questionnaire was clarified with each subject in the ensuing interview by one of the authors (FG). Details on the questionnaire have already been published[11] and are elaborated in more detail below.

### Weekly work hours

Participants reported their weekly number of work hours in categories: (1) <30, (2) 30–35, (3) 36–40, (4) 41–45 and (5) >45. The distributions of answers in these groups were 0.2%, 0.6%, 12.1%, 68.6% and 18.6%, respectively, among men eligible for study. Due to the small number of men working <36 h/week, the first three groups were pooled.

### Markers of psychosocial pressure at work and leisure

"Are you under psychological pressure when performing your work?" Answer options were: 'rarely' and 'regularly'.
"Do you take sedatives or sleep medicine?" Answer options were: 'rarely', 'regularly' and 'never'.
"Are you under psychological pressure in your leisure time?" Answer options were: 'rarely' and 'regularly'.

### Physical work demands

Physical activity at work was estimated using the following questions:

Which description most precisely covers your pattern of physical activity at work?

1. You are mainly sedentary and do not walk much around at your workplace. *E.g.* desk work, work including assembling of minor parts.
2. You walk around quite a bit at your workplace but do not have to carry heavy items. *E.g.* light industrial work, non-sedentary office work, inspection and the like.
3. Most of the time you walk, and you often have to walk up stairs and lift various items. Examples include mail delivery and construction work.
4. You have heavy physical work. You carry heavy burdens and carry out physically strenuous work. *E.g.* work including digging and shoveling.

In the analyses, group 1 is referred to as low and group 2 as moderate; since only 2.4% belonged to group 4, groups 3 and 4 were pooled and are referred to as high.

In addition, the following question on physical strenuous work was used:

"Do you perform strenuous work (work resulting in sweating)?" Answer options were 'often', 'occasionally' and 'seldom or never' and coded as 1=seldom or never, 2=occasionally and 3=often.

In order to discriminate between men with presence or absence of physically demanding work, we constructed an additional variable based on the two described above. With respect to physical activity at work, groups were coded: low=1, moderate=2 and high=3. With respect to physical strenuous work, groups were coded: often=3, occasionally=2 and seldom or never=1. Summing up the two gave values from 2 to 6. A low combined score of 2 was defined as low physical work demands, a score of 3 or 4 was defined as moderate physical work demands and a score of 5 or 6 was defined as high physical work demands.

### Physical fitness

Heart rate was measured during submaximal bicycle work in a steady state with the aid of a stopwatch and stethoscope. The loads used were 100, 150 and 200 W.

One, two or in a few cases three different loads were used. The maximum load chosen in each case was based on weight and age of the person or heart rate during the first minute of the test, and the estimation of $VO_2$max was accomplished with the aid of Åstrand's nomogram.[12] The correlation between directly and indirectly measured $VO_2$max is high. The method used has previously been described in detail.[9]

### Physical activity in leisure time

Which description most precisely covers your pattern of physical activity in leisure time?

1. You are mainly sedentary *e.g.* you read, watch television, go to the pictures. In general you spend most of your leisure time performing sedentary tasks.
2. You go for a walk, use your bicycle a little or perform activity for at least 4 hours/week. e.g. light gardening, leisure-time building activity, table tennis and bowling.
3. You are an active athlete, run, play tennis or badminton for at least 3 hours/week. If you frequently perform heavy gardening, you also belong to this group.
4. You take part in competitive sports, swim, play European football, handball or run long distances regularly i.e. several times/week.

In the analyses, group 1 is referred to as low and group 2 as moderate; since only 0.4% belonged to group 4, groups 3 and 4 were pooled and are referred to as high.

### Lifestyle factors

#### *Smoking*

The men reported if they smoked currently, previously or had never smoked.

#### *Alcohol*

Participants reported their daily average alcohol consumption as the number of alcoholic beverages consumed per day in categories: 0, 1–2, 3–5, 6–10 and >10.

### Clinical and health-related factors

#### *Body mass index*

Based on height and weight measurements, body mass index was calculated as kilograms per square meter.

#### *Blood pressure*

Measurements of blood pressure were carried out with the subject seated and after at least 5 min rest. A 12 cm wide 26 cm long cuff was firmly and evenly applied to the subject's right upper arm with the lower edge of the cuff placed 2 cm antecubitally. Diastolic blood pressure was recorded at the point where the Korotkoff sounds disappeared (phase 5).

#### *Hypertension treatment*

The participants were asked if they received treatment due to hypertension from their physician or elsewhere. Answer options were yes and no.

#### *Diabetes treatment*

The participants were asked if they received treatment due to diabetes mellitus from their physician or elsewhere. Whether their diabetes was type 1 or 2 was not recorded, and neither was their actual medication. Answer options were yes and no.

### Social class

The men were divided into five social classes according to a system originally elaborated by Svalastoga, later adjusted by Hansen.[13 14] This classification system is based on education level and job position in terms of number of subordinates. Typical jobs in the study cohort were in social class I: officer, civil engineer, office executive, head of department; social class II: head clerk, engineer; social class III: engine driver, train guard; social class IV: machine fitter in a telephone company; social class V: unskilled labourer, mechanic, driver.

#### *Eligibility*

In addition to the 35 men unable to carry out the bicycle test, men with a history of myocardial infarction (n=74), angina pectoris (n=165) or intermittent claudication (n=105) and 37 men receiving treatment due to diabetes were excluded from the prospective study. In total, this latter group comprised 311 men and nine men with missing answers leaving 4906 men for the incidence study. With respect to all variables included, missing values ranged from 0% to 2.7%.

#### *End points*

Information on death diagnoses within the period 1970–1971 to the end of 2001 was obtained from official national registers. The IHD mortality diagnoses used encompassed ICD-8 codes: 410–414 and (from 1994) ICD-10 codes: I20–I25.

### Statistical analyses

Basic statistical analyses, including $\chi^2$ analysis (likelihood ratio), unpaired (Student) t test and regression analyses, were performed. Relative risks were estimated by $\exp(\beta)$, where $\beta$ is the hazard coefficient for the variable of interest in a Cox's proportional hazards regression model with the maximum likelihood ratio method. Assumptions regarding the use of Cox's proportional hazards were met by inspection of the log minus log function at the covariate mean. A two-sided probability value of $p \leq 0.05$ was a priori taken as significant.

## RESULTS

In the eligible study population of male employees who had completed the ergometer test and were without a history of myocardial infarction, angina pectoris, intermittent claudication or diabetes, 579 died (11.8%) from IHD during the period 1970/1971 to 2001. During the same period, 2628 (53.7%) died in total.

Table 1 shows the association between lifestyle and other potential predictors with risk of IHD mortality including the entire population eligible for study. HRs (95% CI) are presented for each factor following

**Table 1** All men eligible for the incidence study

| | Cumulative incidence, % | HR* | HR† | HR‡ | HR§ |
|---|---|---|---|---|---|
| Age | | | | | |
| Youngest half (max 48 y), n=2436 | 7.6 | NA | 1¶ | 1¶ | 1¶ |
| Oldest half (>48 y), n=2470 | 16.0 | | **2.72 (2.27 to 3.26)** | **2.33 (1.95 to 2.79)** | **2.42 (2.01 to 2.92)** |
| Smoking | | | | | |
| Current, n=3522 | 12.7 | 1¶ | 1¶ | 1¶ | 1¶ |
| Previous, n=937 | 9.9 | **0.66 (0.53 to 0.82)** | **0.68 (0.54 to 0.86)** | **0.57 (0.45 to 0.71)** | **0.60 (0.47 to 0.75)** |
| Never, n=446 | 9.0 | **0.59 (0.43 to 0.81)** | **0.63 (0.44 to 0.86)** | **0.50 (0.36 to 0.69)** | **0.51 (0.36 to 0.71)** |
| Alcohol, beverages/d | | | | | |
| 0, n=1658 | 12.6 | 1¶ | 1¶ | 1¶ | 1¶ |
| 1–2, n=2315 | 10.6 | 0.84 (0.70 to 1.01) | **0.82 (0.68 to 0.99)** | **0.84 (0.69 to 1.00)** | 0.84 (0.69 to 1.02) |
| 3–5, n=764 | 13.1 | 1.18 (0.93 to 1.49) | 1.06 (0.83 to 1.36) | 1.07 (0.84 to 1.36) | 0.87 (0.68 to 1.13) |
| 6+, n=151 | 16.6 | 1.97 (1.30 to 2.99) | 1.73 (1.13 to 2.65) | 1.63 (1.06 to 2.50) | 1.14 (0.73 to 1.77) |
| Leisure-time physical activity | | | | | |
| Low, n=798 | 15.4 | 1¶ | 1¶ | 1¶ | 1¶ |
| Medium, n=3478 | 11.3 | **0.68 (0.56 to 0.84)** | **0.71 (0.58 to 0.87)** | **0.70 (0.57 to 0.86)** | **0.73 (0.59 to 0.89)** |
| High, n=498 | 8.1 | **0.51 (0.35 to 0.73)** | **0.54 (0.38 to 0.78)** | **0.57 (0.40 to 0.82)** | **0.62 (0.43 to 0.90)** |
| BMI | | | | | |
| −25, n=2358 | 10.1 | 1¶ | 1¶ | 1¶ | 1¶ |
| >25 to 28, n=1710 | 11.9 | 1.11 (0.92 to 1.34) | 1.14 (0.94 to 1.38) | 0.97 (0.80 to 1.18) | 0.96 (0.79 to 1.56) |
| >28, n=829 | 16.7 | **1.66 (1.34 to 2.04)** | **1.67 (1.34 to 2.08)** | **1.25 (1.0 to 1.56)** | 1.23 (0.97 to 1.56) |
| Systolic BP, mm Hg | | | | | |
| −120, n=1383 | 6.4 | 1¶ | 1¶ | 1¶ | 1¶ |
| >120 to 150, n=2869 | 12.6 | **2.01 (1.59 to 2.53)** | **2.09 (1.65 to 2.66)** | **1.65 (1.29 to 2.11)** | **1.80 (1.40 to 2.34)** |
| >150, n=650 | 20.2 | **3.32 (2.52 to 4.36)** | **3.54 (2.67 to 4.70)** | **2.02 (1.44 to 2.85)** | **2.42 (1.72 to 3.41)** |
| Diastolic BP, mm Hg | | | | | |
| −75, n=1421 | 8.3 | 1¶ | 1¶ | 1¶ | 1¶ |
| >75 to 90, n=2736 | 11.4 | **1.38 (1.11 to 1.70)** | **1.48 (1.19 to 1.84)** | 1.16 (0.93 to 1.45) | 1.12 (0.89 to 1.42) |
| >90, n=745 | 20.0 | **2.79 (2.12 to 3.44)** | **2.91 (2.26 to 3.75)** | **1.66 (1.21 to 2.27)** | **1.74 (1.27 to 2.37)** |
| Hypertension** | | | | | |
| No, n=4826 | 11.6 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=77 | 27.3 | **2.41 (1.56 to 3.73)** | **2.36 (1.52 to 3.66)** | 1.38 (0.87 to 2.17) | 1.46 (0.92 to 2.30) |
| Physical fitness ($VO_2$max) | | | | | |
| 15–26, n=882 | 16.7 | 1¶ | 1¶ | 1¶ | 1¶ |
| 27–38, n=3017 | 11.5 | **0.74 (0.61 to 0.90)** | **0.76 (0.62 to 0.93)** | 0.88 (0.71 to 1.07) | 0.88 (0.71 to 1.08) |
| 39–78, n=1007 | 8.5 | **0.56 (0.43 to 0.73)** | **0.60 (0.45 to 0.80)** | 0.77 (0.57 to 1.02) | 0.78 (0.58 to 1.05) |
| Psychological pressure at work | | | | | |
| No, n=3834 | 12.2 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=1060 | 10.5 | 0.86 (0.70 to 1.05) | 0.86 (0.70 to 1.07) | 0.84 (0.68 to 1.04) | 0.88 (0.70 to 1.10) |
| Psychological pressure at leisure | | | | | |
| No, n=4556 | 11.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=332 | 12.7 | 1.11 (0.81 to 1.53) | 1.04 (0.75 to 1.44) | 1.17 (0.85 to 1.60) | 1.14 (0.81 to 1.61) |
| Work, h/week | | | | | |
| <40, n=628 | 8.3 | 1¶ | 1¶ | 1¶ | 1¶ |
| 40–45, n=3366 | 12.9 | **1.62 (1.22 to 2.16)** | **1.57 (1.17 to 2.10)** | **1.57 (1.17 to 2.09)** | 1.25 (0.92 to 1.69) |
| >45, n=911 | 10.2 | 1.28 (0.91 to 1.79) | 1.33 (0.94 to 1.88) | 1.26 (0.89 to 1.77) | 1.12 (0.79 to 1.59) |
| Social class | | | | | |
| High (I, II, III), n=2196 | 9.1 | 1¶ | 1¶ | 1¶ | 1¶ |
| Low (IV, V), n=2688 | 14.0 | **1.72 (1.45 to 2.05)** | **1.61 (1.35 to 1.93)** | **1.72 (1.45 to 2.05)** | **1.48 (1.22 to 1.79)** |

Lifestyle and other predictors of IHD mortality (n=579, 11.8%) during the 30-year follow-up 1970/1971 to 2001. Statistically significant results are highlighted in bold.
*Adjusted for age.
†Adjusted for age + lifestyle (smoking, leisure-time physical activity, alcohol).
‡Adjusted for age + clinical factors (BMI, BP including treatment for, physical fitness).
§Age + all other confounders/risk factors (lifestyle, clinical factors, psychosocial stress at work and leisure, number of work hours and social class).
¶Reference category.
**Receives doctor's treatment due to hypertension.
BMI, body mass index; BP, blood pressure; IHD, ischaemic heart disease; NA, not applicable.

different adjustment criteria: control for age only, age plus lifestyle, age plus clinical factors and, finally, a model including all available potential risk factors/confounders. In the final model controlling for all factors, significant risk factors of IHD mortality were age, smoking, low leisure-time physical activity, high systolic and diastolic blood pressure and low social class. Despite the fact that blood pressure was measured only once, the predictive strength of systolic as well as diastolic was strong.

Table 2 presents the results of a similar analysis including only men with low physical work demands. In the final, fully adjusted model, significant associations with risk of IHD mortality were found for age, alcohol consumption—with a lower risk among those consuming 1–2 beverages—systolic and diastolic blood pressure. Never-smokers had half the risk of IHD mortality compared with current smokers, HR=0.51 (95% CI 0.25 to 1.02).

Table 3 presents the association between lifestyle and other potential predictors and risk for IHD mortality among men with moderate physical work demands. In the final model, significant positive associations with risk of IHD mortality were found for age, smoking, low leisure-time physical activity, high systolic blood pressure and low social class. Surprisingly, perceived psychological pressure at work conferred a lower risk of IHD mortality.

Table 4 shows the association between lifestyle and other potential predictors and risk for IHD mortality among men with high physical work demands. In the final model, significant positive associations with risk of IHD mortality were found for age, smoking, low leisure-time physical activity, high systolic blood pressure and low physical fitness.

Among the total eligible study population, significant multi-adjusted (ie, age, lifestyle, clinical factors, psychosocial stress at work and leisure, number of work hours and social class) positive associations with risk of all-cause mortality were found for smoking, alcohol consumption, low leisure-time physical activity, high systolic and diastolic blood pressure, low physical fitness and low social class (data on all-cause mortality not shown). An inverse multi-adjusted association was found for number of weekly work hours and all-cause mortality. Among men with low physical work demands, multi-adjusted significant positive associations with risk of all-cause mortality were found for age, smoking, low leisure-time physical activity, high systolic and diastolic blood pressure and low social class. Among men with moderate physical work demands, significant multi-adjusted positive associations with risk of all-cause mortality were found for age, smoking, alcohol consumption, low leisure-time physical activity, high systolic blood pressure and low physical fitness. Among men with high physical work demands, significant multi-adjusted positive associations with risk of all-cause mortality were found for age, smoking, alcohol consumption, high diastolic blood pressure, low physical fitness and low social class.

## COMMENTS

The findings of this study support the hypothesis that risk factors for IHD and all-cause mortality have a divergent impact on people with different physical activity levels at work. However, the well-established risk factors smoking and high blood pressure were strongly associated with IHD mortality risk whether physical work demands were low, moderate or high. With respect to alcohol consumption, we confirmed the well-known U- or J-shaped relationship with cardiovascular mortality risk,[15] with a lower risk among those with a moderate daily consumption. This relationship was consistent among those with low and moderate physical work demands but absent among the group with the highest physical work demands.

Surprisingly, among men with moderate physical work demands, but not among others, those who reported exposure to regular psychological work pressure had a lower risk of IHD mortality than those who did not. This lower risk could not be attributed to underlying risk factor characteristics of men with and without perceived psychological work pressure. A biologically plausible explanation for this observation will be speculative.

Low physical activity in leisure time was a statistically significant risk factor among those with a moderate or high level of physical work demands. Among those with low physical work demands, the association was weaker and did not reach statistical significance. Only among men with high physical work demands, those with highest level of physical fitness had a significantly lower risk of IHD mortality compared with those with a low fitness level. This finding supports previous observations that physical work demands may generally have the opposite effect on cardiovascular health, general health and physical function than that of leisure-time physical activity.[3 16 17]

Physical fitness is a well-established predictor of cardiovascular disease and mortality.[7 18–20] In our study, considerable differences were found between men with different occupational physical demands in the predictive role of physical fitness for both IHD and all-cause mortality (data not shown). High physical fitness was found to reduce the risk for IHD mortality among men with high physical work demands with as much as 52% but only modestly (22%) and non-significantly (9%) among men with low and moderate physical work demands, respectively. Among men with moderate physical work demands, a high physical fitness was though associated with reduced all-cause mortality risk (38%). These findings add further support to our previous observation that men with high physical work demands and high physical fitness do not have an increased risk of IHD mortality in contrast to men with high physical work demands and low physical fitness.[4] The results also show that those with high physical work demands do not have a higher level of physical fitness compared with those with low physical work demands, indicating that high physical work demands do not lead to improvements in physical fitness.

**Table 2** Men with low physical work demands only, n=1219

| | Cumulative incidence, % | HR* | HR† | HR‡ | HR§ |
|---|---|---|---|---|---|
| Age | | | | | |
| Youngest half (max 48 y), n=602 | 7.5 | NA | 1¶ | 1¶ | 1¶ |
| Oldest half (>48 y), n=617 | 11.9 | | **1.90 (1.31 to 2.76)** | **1.72 (1.17 to 2.52)** | **1.75 (1.19 to 2.58)** |
| Smoking | | | | | |
| Current, n=808 | 9.5 | 1¶ | 1¶ | 1¶ | 1¶ |
| Previous, n=275 | 11.7 | 1.12 (0.74 to 1.69) | 1.07 (0.71 to 1.62) | 1.03 (0.68 to 1.56) | 0.96 (0.63 to 1.47) |
| Never, n=135 | 7.4 | 0.67 (0.35 to 1.30) | 0.58 (0.30 to 1.14) | 0.56 (0.29 to 1.10) | 0.51 (0.25 to 1.02) |
| Alcohol, beverages/d | | | | | |
| 0, n=478 | 12.0 | 1¶ | 1¶ | 1¶ | 1¶ |
| 1–2, n=617 | 7.5 | **0.59 (0.40 to 0.88)** | **0.58 (0.40 to 0.86)** | **0.56 (0.38 to 0.83)** | **0.59 (0.40 to 0.88)** |
| 3–5, n=110 | 13.6 | 1.26 (0.72 to 2.23) | 1.15 (0.65 to 2.05) | 1.08 (0.60 to 1.91) | 1.04 (0.57 to 1.89) |
| 6+, n=12 | 0 | NA | NA | NA | NA |
| Leisure-time physical activity | | | | | |
| Low, n=227 | 12.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| Medium, n=859 | 8.9 | 0.66 (0.43 to 1.02) | **0.65 (0.42 to 1.0)** | 0.74 (0.48 to 1.15) | 0.74 (0.47 to 1.15) |
| High, n=130 | 10.0 | 0.74 (0.38 to 1.42) | 0.70 (0.36 to 1.35) | 0.86 (0.44 to 1.68) | 0.76 (0.38 to 1.53) |
| BMI | | | | | |
| −25, n=690 | 8.2 | 1¶ | 1¶ | 1¶ | 1¶ |
| >25 to 28, n=381 | 10.3 | 1.25 (0.83 to 1.89) | 1.30 (0.86 to 1.96) | 0.99 (0.65 to 1.52) | 1.04 (0.68 to 1.60) |
| >28, n=146 | 15.8 | **1.93 (1.19 to 3.15)** | **1.79 (1.09 to 2.92)** | 1.35 (0.81 to 2.26) | 1.17 (0.69 to 1.98) |
| Systolic BP, mm Hg | | | | | |
| −120, n=337 | 4.5 | 1¶ | 1¶ | 1¶ | 1¶ |
| >120 to 150, n=720 | 10.4 | **2.62 (1.50 to 4.56)** | **2.46 (1.41 to 4.29)** | **1.90 (1.07 to 3.39)** | 1.62 (0.89 to 2.95) |
| >150, n=160 | 17.5 | **4.50 (2.38 to 8.49)** | **4.55 (2.41 to 8.60)** | 1.80 (0.81 to 4.02) | **2.34 (1.10 to 4.99)** |
| Diastolic BP, mm Hg | | | | | |
| −75, n=338 | 4.5 | 1¶ | 1¶ | 1¶ | 1¶ |
| >75 to 90, n=680 | 9.9 | **2.42 (1.38 to 4.24)** | **2.43 (1.39 to 4.27)** | **2.04 (1.15 to 3.64)** | **1.94 (1.07 to 3.53)** |
| >90, n=199 | 18.2 | **5.03 (2.75 to 9.20)** | **4.90 (2.67 to 9.0)** | **2.93 (1.40 to 6.12)** | **3.21 (1.56 to 6.60)** |
| Hypertension** | | | | | |
| No, n=1196 | 9.5 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=23 | 21.7 | 1.85 (0.75 to 4.56) | 2.28 (0.91 to 5.66) | 0.92 (0.36 to 2.33) | 1.20 (0.46 to 3.12) |
| Physical fitness ($VO_2$max) | | | | | |
| 15–26, n=238 | 13.9 | 1¶ | 1¶ | 1¶ | 1¶ |
| 27–38, n=749 | 8.7 | **0.65 (0.42 to 0.99)** | 0.67 (0.44 to 1.03) | 0.81 (0.52 to 1.26) | 0.82 (0.53 to 1.27) |
| 39–78, n=232 | 8.7 | 0.68 (0.38 to 1.19) | 0.70 (0.39 to 1.25) | 0.98 (0.54 to 1.78) | 0.91 (0.49 to 1.66) |
| Psychological pressure at work | | | | | |
| No, n=830 | 9.6 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=386 | 10.2 | 1.15 (0.79 to 1.70) | 1.11 (0.76 to 1.64) | 1.10 (0.74 to 1.61) | 1.02 (0.68 to 1.55) |
| Psychological pressure at leisure | | | | | |
| No, n=1107 | 9.6 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=109 | 11.1 | 1.18 (0.65 to 2.15) | 1.09 (0.59 to 2.01) | 1.34 (0.73 to 2.45) | 1.35 (0.71 to 2.58) |
| Work, h/week | | | | | |
| <40, n=209 | 8.1 | 1¶ | 1¶ | 1¶ | 1¶ |
| 40–45, n=738 | 10.9 | 1.35 (0.80 to 2.29) | 1.31 (0.78 to 2.23) | 1.26 (0.74 to 2.13) | 1.11 (0.65 to 1.90) |
| >45, n=272 | 7.7 | 0.95 (0.50 to 1.80) | 0.93 (0.48 to 1.77) | 0.98 (0.51 to 1.86) | 0.84 (0.43 to 1.63) |
| Social class | | | | | |
| High (I, II, III), n=946 | 8.5 | 1¶ | 1¶ | 1¶ | 1¶ |
| Low (IV, V), n=260 | 13.8 | **1.69 (1.14 to 2.51)** | **1.61 (1.08 to 2.41)** | **1.69 (1.13 to 2.53)** | 1.45 (0.96 to 2.20) |

Lifestyle and other predictors of ischaemic heart disease mortality (n=118, 9.7%) during the 30-year follow-up 1970/1971 to 2001. Statistically significant results are highlighted in bold.
*Adjusted for age.
†Adjusted for age + lifestyle (smoking, leisure-time physical activity, alcohol).
‡Adjusted for age + clinical factors (BMI, BP including treatment for, physical fitness).
§Age + all other confounders/risk factors (lifestyle, clinical factors, psychosocial stress at work and leisure, number of work hours and social class).
¶Reference category.
**Receives doctor's treatment due to hypertension.
BMI, body mass index; BP, blood pressure; NA, not applicable.

**Table 3** Men with moderate physical work demands only, n=2636

| | Cumulative incidence, % | HR* | HR† | HR‡ | HR§ |
|---|---|---|---|---|---|
| Age | | | | | |
| Youngest half (max 48 y), n=1316 | 7.2 | NA | 1¶ | 1¶ | 1¶ |
| Oldest half (>48 y), n=1320 | 16.6 | | **2.98 (2.33 to 3.81)** | **2.69 (2.10 to 3.45)** | **2.74 (2.13 to 3.52)** |
| Smoking | | | | | |
| Current, n=1901 | 13.0 | 1¶ | 1¶ | 1¶ | 1¶ |
| Previous, n=502 | 8.8 | **0.57 (0.41 to 0.78)** | **0.59 (0.43 to 0.82)** | **0.47 (0.34 to 0.65)** | **0.52 (0.38 to 0.73)** |
| Never, n=233 | 9.0 | **0.57 (0.37 to 0.89)** | **0.60 (0.39 to 0.95)** | **0.52 (0.33 to 0.81)** | **0.53 (0.33 to 0.83)** |
| Alcohol, beverages/d | | | | | |
| 0, n=898 | 13.1 | 1¶ | 1¶ | 1¶ | 1¶ |
| 1–2, n=1250 | 10.7 | 0.82 (0.64 to 1.05) | 0.83 (0.64 to 1.06) | 0.83 (0.64 to 1.06) | 0.84 (0.65 to 1.09) |
| 3–5, n=404 | 11.7 | 1.00 (0.71 to 1.41) | 0.95 (0.68 to 1.34) | 0.93 (0.66 to 1.31) | 0.82 (0.58 to 1.17) |
| 6+, n=74 | 18.9 | 2.25 (1.29 to 3.92) | 2.06 (1.17 to 3.60) | 1.85 (1.03 to 3.32) | 1.31 (0.72 to 2.38) |
| Leisure-time physical activity | | | | | |
| Low, n=409 | 14.9 | 1¶ | 1¶ | 1¶ | 1¶ |
| Medium, n=1978 | 12.1 | **0.73 (0.55 to 0.96)** | **0.76 (0.57 to 1.01)** | **0.73 (0.55 to 0.97)** | 0.78 (0.59 to 1.04) |
| High, n=240 | 4.6 | **0.29 (0.15 to 0.55)** | **0.32 (0.17 to 0.60)** | **0.32 (0.17 to 0.60)** | **0.37 (0.19 to 0.72)** |
| BMI | | | | | |
| −25, n=1220 | 10.0 | 1¶ | 1¶ | 1¶ | 1¶ |
| >25–28, n=957 | 12.3 | 1.13 (0.87 to 1.45) | 1.12 (0.87 to 1.45) | 1.03 (0.79 to 1.34) | 1.02 (0.78 to 1.32) |
| >28, n=454 | 16.1 | **1.56 (1.16 to 2.09)** | **1.54 (1.14 to 2.08)** | 1.21 (0.88 to 1.65) | 1.19 (0.86 to 1.65) |
| Systolic BP, mm Hg | | | | | |
| −120, n=757 | 6.9 | 1¶ | 1¶ | 1¶ | 1¶ |
| >120 to 150, n=1523 | 12.5 | **1.77 (1.30 to 2.41)** | **1.93 (1.41 to 2.63)** | **1.54 (1.11 to 2.13)** | **1.82 (1.31 to 2.54)** |
| >150, n=355 | 19.5 | **2.87 (1.99 to 4.12)** | **3.27 (2.26 to 4.73)** | **2.00 (1.27 to 3.16)** | **2.56 (1.64 to 4.01)** |
| Diastolic BP, mm Hg | | | | | |
| −75, n=768 | 8.9 | 1¶ | 1¶ | 1¶ | 1¶ |
| >75 to 90, n=1491 | 11.7 | 1.26 (0.95 to 1.67) | **1.35 (1.02 to 1.80)** | 1.07 (0.80 to 1.44) | 1.01 (0.75 to 1.37) |
| >90, n=376 | 18.6 | **2.25 (1.61 to 3.14)** | **2.50 (1.78 to 3.52)** | 1.42 (0.92 to 2.20) | 1.39 (0.91 to 2.12) |
| Hypertension** | | | | | |
| No, n=2592 | 11.6 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=41 | 26.8 | **2.95 (1.61 to 5.40)** | **2.90 (1.58 to 5.32)** | 1.74 (0.92 to 3.32) | 1.51 (0.80 to 2.87) |
| Physical fitness ($VO_2$max) | | | | | |
| 15–26, n=465 | 16.4 | 1¶ | 1¶ | 1¶ | 1¶ |
| 27–38, n=1616 | 11.8 | 0.79 (0.60 to 1.03) | 0.78 (0.60 to 1.03) | 0.89 (0.67 to 1.18) | 0.92 (0.69 to 1.22) |
| 39–78, n=555 | 8.3 | **0.56 (0.39 to 0.82)** | **0.59 (0.41 to 0.86)** | 0.73 (0.49 to 1.09) | 0.78 (0.53 to 1.17) |
| Psychological pressure at work | | | | | |
| No, n=2133 | 12.6 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=496 | 8.5 | **0.65 (0.47 to 0.90)** | **0.70 (0.48 to 0.93)** | **0.64 (0.46 to 0.89)** | **0.68 (0.48 to 0.96)** |
| Psychological pressure at leisure | | | | | |
| No, n=2462 | 11.9 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=163 | 11.7 | 1.12 (0.71 to 1.79) | 1.14 (0.72 to 1.83) | 1.17 (0.73 to 1.87) | 1.26 (0.77 to 2.06) |
| Work, h/week | | | | | |
| <40, n=341 | 7.9 | 1¶ | 1¶ | 1¶ | 1¶ |
| 40–45, n=1865 | 13.1 | **1.71 (1.14 to 2.54)** | **1.61 (1.08 to 2.40)** | **1.66 (1.11 to 2.47)** | 1.31 (0.87 to 1.96) |
| >45, n=429 | 9.8 | 1.26 (0.78 to 2.04) | 1.34 (0.82 to 2.17) | 1.25 (0.77 to 2.06) | 1.16 (0.71 to 1.89) |
| Social class | | | | | |
| High (I, II, III), n=1075 | 9.2 | 1¶ | 1¶ | 1¶ | 1¶ |
| Low (IV, V), n=1554 | 13.7 | **1.64 (1.29 to 2.08)** | **1.53 (1.20 to 1.95)** | **1.62 (1.27 to 2.07)** | **1.35 (1.05 to 1.75)** |

Lifestyle and other predictors of ischaemic heart disease mortality (n=312, 11.8%) during the 30-year follow-up 1970/1971 to 2001. Statistically significant results are highlighted in bold.
*Adjusted for age.
†Adjusted for age + lifestyle (smoking, leisure-time physical activity, alcohol).
‡Adjusted for age + clinical factors (BMI, BP including treatment for, physical fitness).
§Age + all other confounders/risk factors (lifestyle, clinical factors, psychosocial stress at work and leisure, number of work hours and social class).
¶Reference category.
**Receives doctor's treatment due to hypertension.
BMI, body mass index; BP, blood pressure; NA, not applicable.

**Table 4** Men with high physical work demands only, n=846

| | Cumulative incidence, % | HR* | HR† | HR‡ | HR§ |
|---|---|---|---|---|---|
| Age | | | | | |
| Youngest half (max 48 y), n=420 | 8.6 | NA | 1¶ | 1¶ | 1¶ |
| Oldest half (>48 y), n=426 | 19.5 | | **3.16 (2.12 to 4.71)** | **2.48 (1.64 to 3.73)** | **2.52 (1.66 to 3.83)** |
| Smoking | | | | | |
| Current, n=648 | 15.3 | 1¶ | 1¶ | 1¶ | 1¶ |
| Previous, n=131 | 9.2 | **0.46 (0.25 to 0.84)** | **0.45 (0.24 to 0.82)** | **0.40 (0.22 to 0.73)** | **0.38 (0.20 to 0.71)** |
| Never, n=67 | 11.9 | 0.67 (0.32 to 1.37) | 0.71 (0.34 to 1.46) | 0.47 (0.22 to 1.03) | 0.49 (0.22 to 1.09) |
| Alcohol, beverages/d | | | | | |
| 0, n=218 | 12.4 | 1¶ | 1¶ | 1¶ | 1¶ |
| 1–2, n=355 | 15.2 | 1.23 (0.78 to 1.96) | 1.23 (0.77 to 1.95) | 1.31 (0.81 to 2.11) | 1.41 (0.87 to 2.29) |
| 3–5, n=208 | 13.0 | 1.11 (0.65 to 1.90) | 1.00 (0.58 to 1.72) | 1.14 (0.65 to 1.98) | 0.95 (0.53 to 1.67) |
| 6+, n=60 | 16.7 | **2.10 (1.01 to 4.35)** | 1.84 (0.88 to 3.84) | 2.05 (0.97 to 4.33) | 1.43 (0.67 to 3.05) |
| Leisure-time physical activity | | | | | |
| Low, n=144 | 20.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| Medium, n=586 | 12.6 | **0.62 (0.40 to 0.95)** | **0.59 (0.38 to 0.90)** | **0.62 (0.40 to 0.96)** | **0.56 (0.36 to 0.88)** |
| High, n=114 | 13.2 | 0.67 (0.36 to 1.26) | 0.64 (0.34 to 1.21) | 0.80 (0.42 to 1.52) | 0.77 (0.40 to 1.48) |
| BMI | | | | | |
| −25, n=351 | 12.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| >25 to 28, n=299 | 12.0 | 0.82 (0.53 to 1.28) | 0.87 (0.56 to 1.36) | 0.66 (0.42 to 1.05) | 0.73 (0.45 to 1.17) |
| >28, n=194 | 18.6 | 1.37 (0.88 to 2.13) | 1.34 (0.84 to 2.12) | 1.02 (0.64 to 1.62) | 1.08 (0.66 to 1.76) |
| Systolic BP, mm Hg | | | | | |
| −120, n=238 | 7.1 | 1¶ | 1¶ | 1¶ | 1¶ |
| >120 to 150, n=499 | 15.2 | **2.02 (1.19 to 3.42)** | **2.16 (1.27 to 3.68)** | 1.68 (0.96 to 2.95) | **1.93 (1.07 to 3.46)** |
| >150, n=108 | 24.1 | **3.20 (1.72 to 5.95)** | **3.41 (1.81 to 6.44)** | 2.13 (0.97 to 4.66) | 2.14 (0.98 to 4.66) |
| Diastolic BP, mm Hg | | | | | |
| −75, n=253 | 11.5 | 1¶ | 1¶ | 1¶ | 1¶ |
| >75 to 90, n=455 | 12.5 | 1.05 (0.67 to 1.64) | 1.05 (0.67 to 1.66) | 0.90 (0.55 to 1.46) | 0.79 (0.47 to 1.30) |
| >90, n=137 | 24.1 | **2.18 (1.32 to 3.60)** | **2.53 (1.51 to 4.23)** | 1.43 (0.73 to 2.78) | 1.60 (0.83 to 3.09) |
| Hypertension** | | | | | |
| No, n=834 | 13.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=12 | 33.3 | 2.32 (0.85 to 6.30) | 2.12 (0.76 to 5.90) | 1.80 (0.64 to 5.13) | 1.82 (0.62 to 5.34) |
| Physical fitness ($VO_2$max) | | | | | |
| 15–26, n=125 | 23.2 | 1¶ | 1¶ | 1¶ | 1¶ |
| 27–38, n=531 | 13.9 | **0.65 (0.42 to 1.00)** | **0.63 (0.40 to 0.99)** | 0.73 (0.46 to 1.16) | 0.70 (0.43 to 1.13) |
| 39–78, n=190 | 8.4 | 0.41 (0.22 to 0.76) | 0.39 (0.21 to 0.74) | 0.54 (0.27 to 1.06) | **0.48 (0.24 to 0.96)** |
| Psychological pressure at work | | | | | |
| No, n=708 | 13.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=136 | 14.7 | 1.01 (0.62 to 1.63) | 1.08 (0.66 to 1.76) | 0.98 (0.60 to 1.60) | 1.04 (0.61 to 1.78) |
| Psychological pressure at leisure | | | | | |
| No, n=795 | 14.0 | 1¶ | 1¶ | 1¶ | 1¶ |
| Yes, n=47 | 17.0 | 1.11 (0.54 to 2.27) | 1.15 (0.56 to 2.37) | 1.04 (0.50 to 2.14) | 1.09 (0.51 to 2.30) |
| Work, h/week | | | | | |
| <40, n=51 | 9.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| 40–45, n=618 | 14.6 | 1.50 (0.61 to 3.70) | 1.68 (0.68 to 4.19) | 1.47 (0.60 to 3.63) | 1.54 (0.62 to 3.85) |
| >45, n=177 | 13.6 | 1.49 (0.57 to 3.89) | 1.81 (0.68 to 4.86) | 1.38 (0.52 to 3.64) | 1.58 (0.70 to 3.18) |
| Social class | | | | | |
| High (I, II, III), n=74 | 10.8 | 1¶ | 1¶ | 1¶ | 1¶ |
| Low (IV, V), n=771 | 14.3 | 1.47 (0.72 to 3.01) | 1.43 (0.69 to 2.96) | 1.55 (0.75 to 3.18) | 1.49 (0.70 to 3.18) |

Lifestyle and other predictors of ischaemic heart disease mortality (n=119, 14.1%) during the 30-year follow-up 1970/1971 to 2001. Statistically significant results are highlighted in bold.
*Adjusted for age.
†Adjusted for age + lifestyle (smoking, leisure-time physical activity, alcohol).
‡Adjusted for age + clinical factors (BMI, BP including treatment for, physical fitness).
§Age + all other confounders/risk factors (lifestyle, clinical factors, psychosocial stress at work and leisure, number of work hours and social class).
¶Reference category.
**Receives doctor's treatment due to hypertension.
BMI, body mass index; BP, blood pressure; NA, not applicable.

Also the inverse association between leisure-time physical activity and risk of IHD mortality was most pronounced among men with moderate and high occupational physical activity. High or medium leisure-time physical activity reduced the risk of IHD mortality among men with moderate and high occupational physical demands, with 63% and 44%, respectively. These findings indicate that it is particularly important to be physically active during leisure time when having moderate or high occupational physical activity for preventing IHD mortality.[3] The particular importance of leisure-time physical activity and high physical fitness among men with high physical work demands may be due to a lower heart rate during daily activities and a subsequent improvement of myocardial perfusion and a lower intravascular turbulence and wall shear stress among these workers with high cardiovascular strain several hours per day.

A methodological aspect of this study is that the information regarding physical work demands was based on self-assessment, which invariably entails some degree of misclassification.[21] However, no technical equipment for measuring daily physical activity at work and in leisure was available in 1970, at least not in Denmark. In addition, the lack of continuous exposure data and repeated measures of exposure during the relatively long follow-up period may have contributed to misclassification of exposure. The study population of the Copenhagen Male Study is urban Danish male workers between 40–59 years of age in 1970–1971. It is unknown whether the findings of this study are relevant also for women, younger workers, self-employed or workers from other (eg, rural) communities and nationalities. The healthy worker effect may be particularly strong among the men with high physical work demands and therefore reduced differences in risk estimates between the groups of physical work demands. Information about lipids was not available, which may have induced some confounding effect on the results. Moreover, the workers with pre-existing cardiovascular disease were excluded from this study.

In conclusion, well-established risk factors like smoking and high blood pressure were strongly associated with IHD mortality risk among all groups of physical work demands. However, other risk factors for IHD and all-cause mortality were not identical for men with different physical work demands. Low physical fitness and low leisure-time physical activity were observed to only increase the risk for IHD mortality among men with high physical work demands. Preventive initiatives for IHD ought to be tailored to the physical work demands.

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**Competing interests** None.

**Ethics approval** When the Copenhagen Male Study (CMS) was initiated as a closed cohort study in 1970–1971, no ethics committee for medical research had been established in Denmark. However, in 1985–1986, when survivors from the first baseline were re-examined, the study was approved by the ethics committee for medical research in the county of Copenhagen, and all participants in the study gave informed consent to participate, as stated in many previous publications from the CMS based on analyses using the 1985–1986 baseline.

**Contributors** All authors contributed to the conception, design, interpretation of data and writing or critically revising the manuscript. PS made the statistical analyses. AH and PS are guarantors.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** Technical appendix and statistical code available from the corresponding author at aho@nrcwe.dk. Consent was not obtained, but the presented data are anonymised, and risk of identification is very low. No additional data available.

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STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

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