

Physical fitness and risk of myocardial infarction in Copenhagen males aged 40-59

A five- and seven-year follow-up study

by Finn Gyntelberg, MD,^{1,2} Lone Lauridsen, MD,³ Ken Schubell, CS¹

GYNTEMBERG F, LAURIDSEN L, SCHUBELL K. Physical fitness and risk of myocardial infarction in Copenhagen males aged 40-59: A five- and seven-year follow-up study. *Scand j work environ health* 6 (1980) 170-178. A 5-a follow-up study on 5,249 Copenhagen males showed that the incidence of myocardial infarction was related to the level of physical fitness at the time of entry into the study, as determined by the indirect measurement of maximal oxygen uptake. Men having a physical fitness level within the lowest fifth of the total sample had a three times higher incidence of myocardial infarction than men in the upper two-fifths. This increased risk was independent of smoking habits and serum cholesterol level but may be partly or entirely dependent on blood pressure levels, as shown by use of a multiple logistic regression analysis. The men with the heaviest occupational physical activity had a somewhat higher risk of myocardial infarction than men with sedentary jobs. The data on leisure-time physical activity and risk of coronary heart disease indicated that only physical activity inducing a physical training effect is related to decreased risk.

Key terms: bicycling, coronary heart disease, leisure-time physical activity, occupational physical activity, physical activity.

A relationship between lack of physical activity and cardiovascular disease has been demonstrated in several epidemiologic studies, as reviewed by Fox et al (4).

In 1953 Morris et al (15) first formulated a hypothesis on the protective role of low occupational physical activity against coronary heart disease. Later in 1973 a new hypothesis concerning vigorous exercise in leisure time and low risk of coronary heart disease was advanced (13).

Physical fitness, defined by an individual's maximal oxygen uptake, reflects both habitual exercise and constitutional

factors. A low level of physical fitness, however, cannot be entirely due to constitutional factors. More likely, a sedentary life-style contributes, since a low level of physical fitness can always be increased by physical training (3), even to high levels in healthy subjects (10).

In a mainly sedentary population the physical fitness value is then a reasonably good measure of habitual vigorous exercise. Accordingly, it is interesting to relate physical fitness in epidemiologic studies to the risk of coronary heart disease and thus to test the aforementioned hypothesis further. Thus far such an attempt has been made in only one study, and no statistically significant correlation was found (17).

In 1970, a prospective cardiovascular survey study was initiated with the main objective of investigating the possible relationship between low physical fitness levels and cardiovascular disease. Five- and seven-year follow-up data are now available, and results on the incidence of myocardial infarction, physical activity, and

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physical fitness are presented in this report.

Subjects and methods

From autumn 1970 to autumn 1971 a cross-sectional prevalence study was carried out on 5,249 males aged 40–59 a and employed in public and private Copenhagen companies. The initial response rate was 87.3 %. The examination of each subject comprised the following: (i) a short interview on the basis of a previously completed questionnaire, (ii) blood-pressure measurement, (iii) measurement of height and weight, and (iv) indirect measurement of maximal aerobic power ($\dot{V}O_2\text{max}_p$) with the bicycle ergometer test introduced by Åstrand (1).

The questionnaire used yielded information on the familiar occurrence of coronary heart disease, hypertension, and diabetes mellitus. A reasonably good anamnesis, including information on earlier myocardial infarction, was obtained. Standard questions recommended by the World Health Organization were used to detect angina pectoris, intermittent claudication, and history of cough. Questions on smoking habits, use of drugs, coffee, and alcohol were also included.

As no standardized questionnaire concerning physical activity was available, questions on habitual physical activity on the job, during transportation to the job, and during leisure time were developed by one of us (FG) (5).

Blood pressure was measured with the cuff method and the same mercury manometer. After at least 5 min of rest with the subject sitting in a chair, a 12-cm broad and 26-cm long cuff was firmly and evenly applied to the subject's right arm, the lower edge of the cuff being 2 cm above the antecubital space. Diastolic pressure was recorded from the disappearance of the Korotkow sounds.

Height and weight were measured with the subject wearing light clothing and shoes; 2 cm were subtracted from the height and 2 kg from the weight. Relative weight was calculated as the percentage of normal weight for a given weight according to the insurance company Hafnia's tables, as previously described (5). Indirect measurement of $\dot{V}O_2\text{max}_p$ was performed

with a Monarch bicycle ergometer. Heart rate was measured during work in a steady state with the aid of a stop-watch and stethoscope. The loads used were 100, 150, and 200 W. One, two, or, in a few cases, three different leads were used.

The load chosen in each case was determined from the weight and age of the person or heart rate during the first minute of the test. The determination of $\dot{V}O_2\text{max}_p$ was accomplished with the aid of Åstrand's nomogram. Thirty-five men did not perform the exercise test because of orthopedic problems. All measurements of height, weight, and the Åstrand test were performed by two specially trained nurses.

The examination took place in rooms in the different work settings. The temperature in the rooms was maintained between 17 and 22°C. The participants were examined between 0800 and 1200 and between 1300 and 1600 at least 1 h after eating. No smoking was allowed for at least 30 min before the examination. The examination took place between October 1970 and August 1971. All of the men were interviewed by one of us (FG), who also measured the men's blood pressure. The serum cholesterol level of 400 men was determined.

Follow-up studies were carried out 1 and 2 a after the initial prevalence study, as previously reported (6). After 5 a in the autumn of 1975 and spring of 1976, a postal questionnaire was distributed, and survival rates were studied with the aid of the public Central Person Register (CPR), the Copenhagen Heart Register, and individual death certificates supplied by the Danish health authorities. The CPR covers all Danes, and apart from 40 participants who did not give their CPR number initially, the men could be checked as to whether they were "alive" or "dead" 5 a after entry. Fatal myocardial infarction occurring during the 7-a period of follow-up was registered from the death certificates. Nonfatal myocardial infarction was registered from the 5-a follow-up questionnaire and hospital records. Nonfatal myocardial infarction among nonresponders to the 5-a questionnaire study and nonfatal myocardial infarction during the sixth and seventh year of follow-up were included when recorded in the Copenhagen Heart

Register, which registers all hospitalized myocardial infarction cases in the Copenhagen area. The postal 5-a follow-up questionnaire was returned by 4,022 men, a response rate of 78.8 %.

Diagnostic criteria and methods for comparing myocardial infarction cases and referents

The diagnosis of myocardial infarction during the first 5 a of observation was based on information in hospital records and notifications to the heart register. The following symptoms were required for a positive diagnosis of myocardial infarction: retrosternal pain for longer than 20 min, typical serial changes in the electrocardiogram, and elevation in serum enzymes (alanine aminotransferase, lactate dehydrogenase, creatine-phosphokinase-MB). For the (145) men who died during the 5-a period a diagnosis of myocardial infarction on the death certificate was accepted. Four

cases of sudden unexpected death were also included. The autopsy rate on those who died was 66 %.

For every case of myocardial infarction, and of course excluding in all cases men who had a myocardial infarction prior to the initial examination, three age-matched referents were selected at random from the total sample. Persons experiencing first attacks of myocardial infarction were compared to the referents with respect to characteristics found in the initial study.

Cases with angina pectoris or intermittent claudication at the initial examination were also excluded from the present analysis. The data were processed in the Northern European University Computing Center.

Chi-square was used as the test of statistical significance, at a probability level of 5 %, and Kendall's tau was used as the measure of statistical dependence. After these statistical methods were used, a multiple logistic regression analysis was performed.

Table 1. Relationship between physical fitness measured by indirectly determined maximal oxygen uptake ($\text{ml O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), and incidence of myocardial infarction among 5,249 Copenhagen males aged 40–59 a in 1970–1971. Lethal and nonlethal myocardial infarction cases (MI) are compared to noninfarction cases in the total sample (T) and to age-matched referents (R). The distribution within quintiles of physical fitness at entry into the study and at 1-a follow-up is presented.

Physical fitness score ($\text{ml O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	MI (%)	T (%)	R (%)
<i>At entry</i>			
≤ 27	37.3	22.5	27.3
28–30	20.1	17.4	20.3
31–34	18.3	22.3	20.5
35–38	11.2	17.6	14.5
≥ 39	13.0	20.3	17.3
		$p < 0.00001$	$p < 0.005$
		$\chi^2_{[4]} = 26.71$	Kendall's tau 13 0.08
<i>At 1-a follow-up</i>			
≤ 27	31.5	21.7	28.5
28–30	26.1	18.3	20.0
31–34	24.3	24.6	22.9
35–38	10.8	18.4	15.5
≥ 39	7.2	17.0	13.0
		$p < 0.01$	$p < 0.03$
		$\chi^2_{[4]} = 17.82$	Kendall's tau 13 0.07

Table 2. Occupational physical activity of 5,249 Copenhagen males aged 40–59 a in 1970–1971. Lethal and nonlethal myocardial infarction cases (MI) are compared to noninfarction cases in the total sample (T) and to age-matched referents (R). Questions asked at entry into the study, at the 1-a follow-up, and at the 5-a follow-up are presented. (NS = not significant).

Question	MI (%)	T (%)	R (%)
<i>At entry</i>			
Heavy work on the job?			
Often	5.9	4.8	5.5
Now and then	35.5	26.9	26.4
Rarely	58.6	68.2	68.0
		$p < 0.003$	$p < 0.02$
		$\chi^2_{[2]} = 6.73$	Kendall's tau 13 0.07
Work on the job makes you sweat			
Often	9.7	7.1	6.4
Now and then	42.4	32.9	33.9
Rarely	47.9	60.0	59.7
		$p < 0.05$	$p < 0.003$
		$\chi^2_{[2]} = 5.01$	Kendall's tau 0.10
<i>At 1-a follow-up</i>			
Type of job			
Mostly sedentary	25.5	30.6	30.9
Walking and lifting of light burdens	55.2	52.0	49.3
Stairclimbing, lifting heavy burdens now and then	14.5	15.7	18.3
Regular hard physical work (digging, lift- ing heavy burdens daily)	4.8	1.7	1.5
		$p < 0.01$	$p < 0.05$
		$\chi^2_{[3]} = 12.04$	$\chi^2_{[3]} = 7.91$
<i>At 5-a follow-up</i>			
Type of job			
Sedentary	38.9	42.9	41.2
Light	53.7	50.3	51.2
Heavy	7.4	6.8	7.5
		NS	NS
		$\chi^2_{[2]} = 0.60$	$\chi^2_{[2]} = 1.07$
Do you sweat on the job because of physical effort?			
Yes	35.8	34.3	34.4
		NS	NS
		$\chi^2_{[1]} = 0.03$	$\chi^2_{[1]} = 0.00$
How often do you sweat?			
Daily	23.5	23.4	21.6
Weekly	50.0	37.1	42.5
More rarely	26.5	39.5	35.8
		NS	NS
		$\chi^2_{[2]} = 2.91$	$\chi^2_{[2]} = 3.74$

Table 3. Leisure-time physical activity of 5,249 Copenhagen males aged 40—59 a in 1970—1971. Lethal and nonlethal myocardial infarction cases (MI) are compared to noninfarction cases in the total sample (T) and to age-matched referents (R). Questions asked at entry into the study, at the 1-a follow-up, and at the 5-a follow-up are presented. (NS = not significant).

Question	MI (%)	T (%)	R (%)
<i>At entry</i>			
How many minutes do you ride a bicycle per day?			
10	74.4	64.0	62.1
11—20	14.9	14.2	16.9
20	10.7	21.8	21.0
		p < 0.001	p < 0.001
		$\chi^2_{[2]} = 14.28$	$\chi^2_{[2]} = 11.19$
Do you regularly take part in sports activities?			
Yes	16.7	20.9	18.5
		NS	NS
		$\chi^2_{[1]} = 1.60$	$\chi^2_{[1]} = 0.35$
Do you often sweat from leisure-time physical activity?			
Yes	28.7	31.6	29.8
		NS	NS
		$\chi^2_{[1]} = 0.54$	$\chi^2_{[1]} = 0.00$
Do you take part in handball, soccer, tennis, badminton, ping-pong, track and field, swimming, etc?		No differences	
Do you do heavy gardening regularly?			
Yes	19.9	21.0	22.2
		NS	NS
		$\chi^2_{[1]} = 0.07$	$\chi^2_{[1]} = 0.00$
Do you go for a walk regularly?			
Yes	69.9	61.6	63.5
		p < 0.005	p < 0.03
		$\chi^2_{[1]} = 3.99$	$\chi^2_{[1]} = 4.66$
Have you taken part in sports activities?			
Yes	19.4	24.0	23.3
		NS	NS
		$\chi^2_{[1]} = 1.46$	$\chi^2_{[1]} = 1.74$
How do you get to your job?			
Walk	6.4	5.6	6.0
Other means (bus, train)	44.7	35.0	31.4
		0.05	NS
		$\chi^2_{[1]} = 5.46$	$\chi^2_{[1]} = 3.19$

Table 3. (continued)

Question	MI (%)	T (%)	R (%)
<i>At 1-a follow-up</i>			
Hours of sports activities per week			
1	40.0	39.8	41.5
2	30.0	38.8	40.6
3	30.0	21.4	17.9
		NS	NS
		$\chi^2_{[2]} = 1.57$	$\chi^2_{[2]} = 3.06$
<i>At 5-a follow-up</i>			
Does physical activity make you sweat?			
Yes	69.5	72.5	70.0
		NS	NS
		$\chi^2_{[1]} = 0.29$	$\chi^2_{[1]} = 0.03$
Do you jog?			
Yes	3.4	6.1	5.6
		NS	NS
		$\chi^2_{[1]} = 1.40$	$\chi^2_{[1]} = 1.29$

Results

During the 5 and 7 a of observation 41 men initially free of angina pectoris or previous myocardial infarction died from a first myocardial infarction; in addition, 129 men had a nonfatal first myocardial infarction according to the preceding criteria, the total of first myocardial infarctions therefore being 170.

Physical fitness

Table 1 presents the distribution, in quintiles, of the indirectly measured $\dot{V}O_2\max_p$, "fitness score" for the cases, referents, and the total population. Thirty-seven percent of the men who subsequently had a fatal or nonfatal myocardial infarction had a $\dot{V}O_2\max_p$ ($\text{ml O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) within the lowest quintile in the initial study. This percentage is significantly different from that of the age-matched referents, of whom only 27 % fell into this category.

Physical activity at work

Table 2 shows the distribution of cases and referents according to physical activity at work in the initial study and at the 1- and 5-a follow-ups. Somewhat more men with jobs requiring the heaviest activity had a lethal or nonlethal myocardial infarction; however, only a few men in this study had jobs requiring heavy physical activity.

Physical activity in leisure time

In table 3 the distribution of cases and referents with respect to various leisure-time activities at the time of entry into the study and at the 1- and 5-a follow-ups is seen. There is only a tendency for greater leisure-time physical activity among the referents than the cases, but regular bicycle riding was highly significantly less frequent among the men who subsequently developed infarction.

Table 4. Risk of myocardial infarction among 5,249 Copenhagen men estimated in a multiple logistic regression analysis including smoking, year of birth, relative weight, systolic blood pressure, and indirectly determined maximal oxygen uptake.

	Coefficient	Range
Smoking versus never smoked	0.8224	0.3689
Age	— 0.0629	0.0164
Relative weight	0.0031	0.0066
Systolic blood pressure	0.0167	0.0039
Maximal oxygen uptake (ml O ₂ · kg ⁻¹ · min ⁻¹)	— 0.0125	0.0121

Multiple logistic regression analysis

Factors which were statistically related to the 5- and 7-a incidence of myocardial infarction by the chi-square test were included in a multiple logistic regression analysis as shown in table 4. Age, systolic blood pressure, and smoking explained the variation in the risk of myocardial infarction, there being only a small contribution from physical fitness and relative weight.

Discussion

The data presented indicate that a low level of physical fitness and a low level of vigorous activity in leisure time are coronary risk factors. In the present study physical fitness correlates with vigorous leisure-time physical activity like bicycling, but not with occupational physical activity (8). This finding is in agreement with that of Wilhelmsen et al (17). When a low level of physical fitness is related to an increased risk of myocardial infarction, the problem arises of whether this relationship is only a reflection of an association with other coronary risk factors such as high serum cholesterol, high blood pressure, or cigarette smoking. These risk factors have previously been analyzed with a multiple regression analysis in relation to physical fitness. Serum cholesterol was found to be slightly inversely related to $\dot{V}O_{2\max_p}$ (9). Blood pressure and $\dot{V}O_{2\max_p}$ correlated more strongly. With an increase in blood pressure with time, a fall in $\dot{V}O_{2\max_p}$ was found during 1 a of observation and vice versa, independent of weight changes (7).

The heavy cigarette smokers in our study had slightly lower $\dot{V}O_{2\max_p}$ values than the smokers and exsmokers (8), but only a few percent of the total population were heavy cigarette smokers. Pipe smokers and the total group of smokers had a higher $\dot{V}O_{2\max_p}$ than the nonsmokers.

Serum cholesterol differences and differences in smoking habits between men with high and low physical fitness are unlikely explanations for the relationship found between physical fitness and coronary risk in this study. Blood pressure, however, correlated strongly with physical fitness in this study, and, when blood pressure and physical fitness were analyzed together in a multiple logistic regression analysis, physical fitness no longer contributed as a predictor of myocardial infarction. This result may mean that low physical fitness is not an independent risk factor, but only appears to be a risk factor because of its correlation with blood pressure. This interpretation may however be too simple. It should be considered that the measurement of blood pressure is much more accurate than an indirect determination of physical fitness, and therefore the significance of blood pressure is favored in a multiple logistic regression analysis.

Also one may ask the following question: Did the men have a low level of physical fitness because of high blood pressure or vice versa? In some studies it has been shown that physical training may lead to a reduction of blood pressure (2, 11). Accordingly another hypothesis may be that a low level of physical fitness, caused mainly by a sedentary life-style, is a risk factor for both hypertension and myocardial infarction. The possibility exists that the men who suffered a myocardial infarction

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Silicosis: Observations on a case register

Page	Column	Line	Instead of	Read
1		Top of page		From the Department of Hygiene, Umeå University, Umeå, Sweden, and the National Swedish Board of Occupational Safety and Health, Solna, Sweden
17	2	32	number	number of
18	Fig 1, legend	1	Fig. 1.	Fig 1. Mining —
22	Fig 6	Heading	1951—1974	1951—1969
23	Table 51	1	silicosis	silicosis
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27	2	56	size	sex
28	Fig 11, legend	12	= 120	= 720
28	2	8	fig 19	fig 20
28	2	10	fig 20	fig 19
31	1	19	fig 21	fig 22
37	1	21	lung cancer risks	the lung cancer risks
38	1	10	lung cancer	cancer
38	1	12	"other cancer"	"lung cancer"
38	1	13	"other causes"	"all cancer"
38	Table 61	4	Lung cancer	All cancer
38	Table 61	6	35.4	23.0
38	Table 62	4	Lung cancer	All cancer
38	Table 62	6	55.8	54.4
38	Table 62	6	22	21.8
38	Table 62	8	40.2	41.3
38	Table 62	8	35	35.9
40	2	4	advanced	advanced stages
41	2	21	by lung	by
41	Table 63	2	quarrying	quarrying
42	2	34	lung cancer	cancer
42	2	36	of lung can-	of can-
42	2	46	for	for use in epidemiologic studies regarding
52	Table 70	1	1960 and 1970	1963 and 1968
52	Table 71	1	1960 and 1970	1963 and 1968
64	2	4	$Z = \frac{O/E - 1}{1/\sqrt{E}}$,	$Z = \frac{O/E - 1}{1/\sqrt{E}}$,
66	1	5	$[x + 1, x + 2]$.	$[x + 1, x + 2]$.
66	1	20 & 21	$p_x = \frac{(1/2d_x + \sqrt{1/4d_x'^2 + 4(N_x - 1/2n_x)(s_x + 1/2w_x)})^2}{2(N_x - 1/2n_x)}$	$p_x = \left[\frac{1/2d_x + \sqrt{1/4d_x'^2 + 4(N_x - 1/2n_x)(s_x + 1/2w_x)}}{2(N_x - 1/2n_x)} \right]^2$
66	2	8	$S(p_{0x}) =$	$s(p_{0x}) =$
67	2	11	$q_{x,r} = 1 - p_x (D_x - D_{xr})/D_x$.	$q_{x,r} = 1 - p_x (D_x - D_{xr}/D_x)$.
80	Fig 7, 8 & 9	Heading	1951—70	1951—1969
81	Fig 10	Heading	1951—70	1951—1969
86	Table 69	1	10 a	less than 10 a

tion during the period of observation were already marked by atherosclerotic disease and therefore had a low physical fitness at the time of the initial study.

However, after the first 2 a of follow-up, physical fitness could not be detected as a coronary risk factor (6), and the men with intermittent claudication or angina pectoris in the initial study were excluded from the present analysis. Since a correlation between vigorous leisure-time activity and VO_2max , was previously found, it is quite reasonable that vigorous leisure-time physical activity (bicycling) tended to be negatively correlated with a risk of coronary heart disease. This finding is consistent with what has been reported in previous studies by others (12, 13).

It seems interesting that myocardial infarction cases were less active bicycle riders than the referents. This finding indicates that bicycle riding, which involves vigorous exercise, may be a prophylactic measure against myocardial infarction.

It is somewhat surprising that taking part in sports activities and other kinds of leisure-time physical activity was not related to a low risk of coronary heart disease. Probably such participation between the ages of 40 and 59 a does not involve much vigorous exercise. If so, it would support the hypothesis (14) that vigorous exercise leading to a high fitness level is the kind of exercise that may be a preventive measure in coronary heart disease. All other kinds of physical activity may not be as efficient. Even if a man has a positive attitude towards exercise, there would be no preventive value if he is not exercising enough to provide a physical training effect.

In contrast to the findings of several studies, occupational physical activity did not seem to provide protection against coronary heart disease in our study; instead a tendency for an association between heavy physical activity on the job and myocardial infarction risk was observed.

There may be several reasons for the finding that men in the heaviest jobs had a higher risk of myocardial infarction. A possible explanation could be that occupational physical activity with the lifting of heavy burdens, which was the most

common activity among these men, may be risky because of the increase in blood pressure induced by the lifting and the subsequent high load on the myocardium (static isometric exercise).

Thus Morris & Crawford (14) also found a higher number of myocardial scars among stonemasons and boilermakers than among other men with physical activity in their jobs. Theorell et al (16) found that concrete workers had a high risk of myocardial infarction and suggested that it could be due to heavy isometric work. Heavy occupational work carried out by untrained men is perhaps a risk factor of myocardial infarction.

In conclusion the data presented in this study support the hypothesis that vigorous leisure-time physical activity is a protective measure against myocardial infarction and that increased physical fitness obtained by regular exercise may be of significance in the protective mechanism. However, other factors, like smoking and high blood pressure, are much better predictors of myocardial infarction risk than low physical fitness.

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