Physical activity and physical demand on the job and risk of cardiovascular disease and death: The Framingham Study

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Over the past 25 years it has become increasingly evident that much of atherosclerotic cardiovascular disease is a product of a faulty life-style that has evolved in Western society, a society that eats too much of a too rich diet, exercises too little, grows fat and smokes too much.[1] Physical indolence is considered by many to be an important ingredient of the multifactorial cardiovascular risk profile of potential coronary victims.[2] Endurance exercise is thought to play a role, both by influencing the level of the major cardiovascular risk factors and by directly affecting the efficiency of the cardiovascular system, including an improved peripheral utilization of oxygen.[3]

From epidemiologic data and information based on work physiology, there is uncertainty about the amount and kind of exercise optimal for cardiovascular health.[2] Some claim that vigorous, sustained exercise is needed, while other data suggest that moderate amounts of exercise may suffice.[2,4,5] It is also not clear whether a state of physical fitness must be attained and whether the benefits are long-lasting or transient, requiring a continuing high level of activity. This report examines the role of low levels of activity at work and during leisure in the development of cardiovascular morbidity and mortality over the short and long term. It is based on 24 years of follow-up of men participating in the Framingham Study.

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METHODOLOGY

The Framingham Study has been in continuous operation since 1948, following a cohort of 5209 persons biennially for the development of cardiovascular morbidity and mortality in relation to atherogenic personal attributes and living habits that promote them.[6] The occurrence of new events was documented based on a detailed cardiovascular examination, daily monitoring of hospitalizations, death certification, and information from attending physicians.[2,7] The sampling procedure, response rate, follow-up, and laboratory methodology have been reported elsewhere.[6] Criteria for cardiovascular events have been uniformly applied based on a review of information from all sources by a panel of investigators.[6] Cardiovascular events include all clinical manifestations of coronary heart disease, stroke, cardiac failure, and peripheral arterial disease.[6]

Evaluation of physical activity and demand on the job. Physical activity in general over 24 hours, and the physical demand of the job, were ascertained for each subject. A physical activity index was also constructed for each subject based on weighted hours spent at activities of assigned caloric equivalents over the 24 hours.[2,8] This was done at the time of the fourth biennial examination.

Each job reported by participants on each examination was assigned a Dictionary of Titles (DOT) code reflecting the degree of physical activity demanded by the job.[7] In addition, the DOT "strength" factor was used to differentiate between sedentary, light, moderate, and heavy work. This is based on the amount of lifting, carrying, pushing, pulling, and walking demanded on the job. In this report, physical demand on the job as measured on the fourth biennial examination was used for analysis.

A total of 1166 out of 2336 men participating in the Framingham Heart Study were included in this

Table I. Cardiovascular mortality by physical activity index: 24-year follow-up, Framingham Study

Physical activity index[1]	24-year cumulative rate per 1000 — Age (yr) 45-49	50-54	55-59	60-64	Age-adjusted rate 45-64*
<29	250	294	436	539	367
29-34	168	294	347	349	283
>34	174	210	286	250	226

[1]Physical Activity Index at Examination No. 4; population at risk = all persons alive.
*$p < 0.001$ for trend of mortality in relation to physical activity.

Table II. Coronary heart disease mortality by physical activity index: 24-year follow-up, Framingham Study

Physical activity index[1]	24-year cumulative rate per 1000 — Age (yr) 45-49	50-54	55-59	60-64	All ages age-adjusted 45-64†
<29	250	147	255	404	255
29-34	114	177	264	198	184
>34	147	124	200	141	152

[1]Physical activity index at Examination No. 4; population at risk = all persons alive.
†$p < 0.01$ for trend of coronary heart disease (CHD) mortality in relation to physical activity.

analysis. These 1166 consisted of those alive and aged 45 to 64 at Examination 4 whose physical activity was measured and whose work history information was available and coded. Physical demand of work at Examination 4 and the 24-hour physical activity index score were examined in relation to the occurrence of cardiovascular events and mortality over the ensuing 24 years of follow-up.

The statistical analysis employed in this investigation were chi square tests of trends on 24-year age-adjusted morbidity and mortality rates,[18] logistic regression to examine the net effect of activity taking coexistent major cardiovascular risk factors into account,[6,9] and Cox proportional hazards regression analysis to investigate event rates over time.[19]

OBSERVATIONS

Over the 24 years following the classification of the cohort of men according to their level of physical activity at leisure and work, there were 325 cardiovascular deaths of which 220 were from coronary heart disease. There were 303 noncardiovascular

Table III. Cardiovascular and noncardiovascular mortality by physical activity index: 24-year follow-up, Framingham Study—Men aged 45 to 64

Physical activity index[1]	Cumulative 24-year age-adjusted rate per 1000 — Non C-V* mortality[2]	C-V‡ mortality[2]	Overall* mortality[2]	CHD† mortality[2]
<29	229	367	596	255
30-34	261	283	544	184
>34	300	226	526	152
All	264	285	549	189

C-V = cardiovascular; CHD = coronary heart disease
[1]Examination No. 4.
[2]All persons alive.
*$p < 0.05$.
†$p < 0.01$.
‡$p < 0.001$.

Table IV. Coronary and all cardiovascular events by physical activity index: Framingham Study—Men aged 45 to 64

Physical activity index[1]	24-year cumulative age-adjusted rate per 1000 — Coronary* heart disease[2]	Cardiovascular† disease[3]
<29	414	539
29-34	353	511
>34	311	423
All	351	491

[1]Examination No. 4.
[2]Free of coronary heart disease at Examination No. 4.
[3]Free of coronary heart disease, cerebrovascular accident, congestive heart failure, and intermittent claudication at Examination No. 4.
*$p < 0.05$.
†$p < 0.01$.

deaths. Morbidity was also substantial, with 502 cardiovascular events, of which 371 were clinical manifestations of coronary heart disease.

Physical activity index

Mortality. Active persons as assessed by the 24-hour physical activity index lived longer and suffered less cardiovascular mortality. Overall, cardiovascular and coronary heart disease mortality improved with increasing level of physical activity at all ages including the elderly. Both cardiovascular and coronary heart disease mortality were increased in those least active (Tables I and II). There was no decrease in impact with age for both cardiovascular mortality in general and coronary heart disease (CHD) mortality in particular (Tables I and II). The impact for cardiovascular and CHD mortality—50% to 60% excess mortality in the most inactive com-

Table V. Cardiovascular events by physical activity index according to age: Framingham Study—Men aged 45 to 64

Physical activity	24-year cumulative rate per 1000				Age-adjusted rate 45-64
	Age (yr)				
	45-49	50-54	55-59	60-64	
<29	444	483	614	686	539
29-34	415	538	548	576	511
>35	400	430	508	346	423
All	413	498	549	529	491

Table VI. Mortality according to physical demand of work: Framingham Study—Men aged 45 to 64

Physical demand of work[1]	Age-adjusted cumulative 24-year rate per 1000			
	Non C-V[2] mortality*	C-V† mortality[2]	CHD† mortality	Overall mortality†
Sedentary	192	320	216	573
Light	249	301	209	550
Medium	297	260	169	556
Heavy[1]	300	238	170	537
All	264	281	189	546

C-V = cardiovascular; CHD = coronary heart disease.
[1]Classified at Examination No. 4.
[2]All persons alive.
*$p < 0.001$.
†not significant.

Table VII. Cardiovascular mortality by physical demands of work: 24-year follow-up, Framingham Study

Physical work demand[1]	24-year cumulative rate per 1000				Age-adjusted rate 45-64
	Age (yr)				
	45-49	50-54	55-59	60-64	
Sedentary	205	235	326	593	320
Light	211	289	416	311	301
Medium	129	247	315	392	260
Heavy	138	300	292	225	238

[1]Physical demands of work at Examination No. 4.
Population at risk = all persons alive. Trend not statistically significant.

Table VIII. Coronary and total cardiovascular events by physical demand of work: Framingham Study—Men aged 45 to 64

Physical work demand[1]	Age-adjusted 24-year cumulative rate per 1000	
	Coronary[2] Heart Disease†	Any[3] C-V Disease†
Sedentary	355	494
Light	405	527
Medium	307	451
Heavy	325	486
All	356	494

[1]At Examination No. 4.
[2]Persons free of coronary heart disease.
[3]Persons free of coronary heart disease, cerebrovascular accident, congestive heart failure, and intermittent claudication.
†not significant.

pared to those most active—exceeded that for overall mortality (Table III). This is because there was an opposite effect on noncardiovascular mortality which *increased* with the level of physical activity, although this observed trend was not statistically significant. As the mortality benefits apply both in those with and without intervening overt cardiovascular disease, it is unlikely that physical inactivity reflects already existent myocardial damage.

Morbidity. Cardiovascular events in general and CHD incidence in particular over 24 years of follow-up was significantly inversely related to physical activity index reflecting 24-hour caloric expenditure (Table IV). For CHD, the benefit persists on long-term follow-up with no indication of diminishing impact on extended follow-up (Fig. 1). As for mortality, the benefits of physical activity for lethal and nonlethal cardiovascular (C-V) events apply at least as much in the elderly as in the younger adult (Table V).

Physical demands of the job

Mortality. A moderate inverse relation of cardiovascular mortality to the physical demands of the workplace was noted (Table VI). This, however, was not statistically significant. The benefit, if any, was more apparent in the elderly than in the younger members of the cohort still in the work force (Table VII). Overall mortality, on the other hand, gave no indication of a trend (Table VI). This is attributable to non-C-V mortality, which increases significantly with physical work demand on the job (Table VI).

Morbidity. An examination of the relation of cardiovascular events in general and of coronary disease in particular in relation to antecedent physical demand at work, indicates no significant relationship (Table VIII). In neither the younger nor older subjects was there any discernible trend of sizable proportions (Table IX).

Net effects. For both cardiovascular mortality in general and coronary mortality in particular, physical activity in men remains protective, taking other risk factors into account in a multiple logistic regression ($p < 0.01$) (Table X). The other risk factors

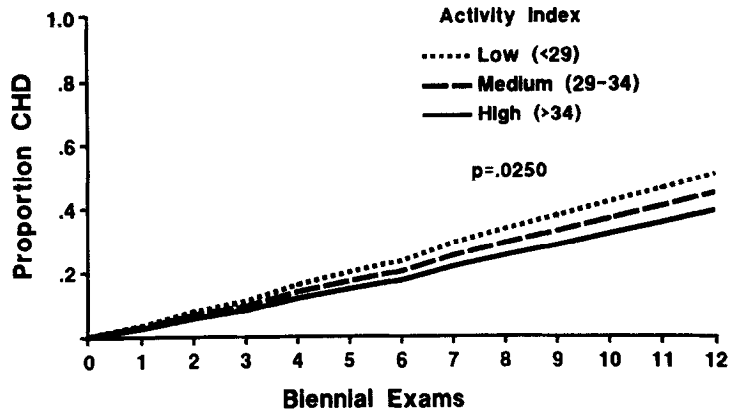

Fig. 1. Risk of coronary heart disease by physical activity level according to length of follow-up. Rates obtained from Cox Proportional Hazards Regression with age and physical activity as independent variables.

Table IX. Coronary heart disease mortality by physical demands of work: 24-year follow-up, Framingham Study

Physical work demand[1]	24-year cumulative rate per 1000 — Age (yr) 45-49	50-54	55-59	60-64	Age-adjusted rate 45-64
Sedentary	205	74	174	482	216
Light	145	204	310	189	209
Medium	129	135	217	215	169
Heavy	103	200	250	125	170

[1]Physical demands of work at Examination 4.
Population at risk = All persons alive. Trend not statistically significant.

Table X. Net effect of physical activity index taking other risk factors into account: 24-hour follow-up, Framingham Study—Men aged 45 to 64

	Multivariate regression coefficients
Fatal outcomes	
Noncardiovascular mortality	+0.207*
Cardiovascular mortality	−0.303**
Coronary mortality	−0.226+
Fatal and nonfatal outcomes	
Coronary events	0.193*
Cardiovascular events	−0.256**

Variables: Age, systolic blood pressure, cholesterol, cigarettes, ECG-LVH, relative weight, glucose intolerance, physical activity index.

considered in the logistic regression were age, systolic blood pressure, serum cholesterol, cigarettes smoked, ECG-LVH (left ventricular hypertrophy), relative weight, and glucose intolerance. For other cardiovascular disease, including stroke, no significant relationship to physical activity either at work or over 24 hours was discernible.

COMMENT

Epidemiologic studies in general, including this one, are hampered by imprecise, varied, nonobjective measures of the amount of physical activity. This leads to an underestimate of the effect. A variety of indicators of physical activity have been used over the years to test a possible exercise-CHD connection. These include social class data, occupational subgroup comparisons, geographic variations, and urban-rural comparisons among others.[1-5] These crude physical activity indicators have been replaced by a variety of questionnaire assessments of leisure time and occupational activity. Well-designed questionnaires appear to be useful in epidemiologic studies, but when population samples are sedentary middle-aged men who differ little from one another, the correlation between fitness and activity is bound to be low and assessments imprecise. Most of the variability under these circumstances is likely to be due to innate endowment.

An epidemiologic association is more likely to be causal if there are plausible pathogenetic mechanisms to support it. There is some evidence to suggest that exercise is helpful in controlling major cardiovascular risk factors, although it is not clear that the benefits claimed for physical activity derive entirely from this. Training and level of exercise have been reported to improve many of the major cardiovascular risk factors including high-density lipoprotein (HDL)-cholesterol, relative weight, blood pressure, serum cholesterol, vital capacity, heart rate, and glucose tolerance.[2,3,10-14] Physical activity also has effects on the efficiency of the cardiovascular system, demonstrated both in animals and in man.[2,3]

The physical activity–CHD relationship demonstrated for the 24-hour activity assessment is supported by a number of more objective physiologic correlates of activity and fitness. Heart rate, vital capacity, and relative weight have been found to be correlated with physical fitness assessed by treadmill work capacity.[2,14] Previous studies conducted in the Framingham cohort have shown that the greater the number of these sedentary traits, the greater the risk of CHD.[2]

There is uncertainty about the amount and kind of exercise optimal for cardiovascular health. Some epidemiologists and the work physiologists claim that vigorous exercise is needed. The data from the Framingham Study reported here suggest that moderate amounts of exercise may suffice. There is a paucity of prospective epidemiologic data that evaluates the role of physical *fitness* in cardiovascular disease. Such data are beginning to appear, suggesting benefit in subjects at high risk because of other risk factors.[15] However, such studies do not allow a judgment as to how much exercise is required. It is also difficult in such studies to dissociate the effect of innate fitness from that of physical activity.

The reason for the contrary findings for noncardiovascular mortality in relation to 24-hour physical activity and physical work demand is uncertain. Some preliminary data suggest that the increasing mortality associated with more physical work is due to cancer. One suspects that this reflects exposure to noxious agents in industries with a high level of physical work.

It is widely accepted that the benefit of physical training is short-lived and lost once the activity is discontinued. The data herein indicate a sustained effect, with an apparent increase of the effect on extended follow-up. Although activity over 24 hours was not monitored over the extended period of follow-up, it seems likely that activity decreased as the cohort aged. At any rate, the physical activity index was better at long-term than at short-term predictions (Fig. 1).

The conclusive demonstration of the benefits of physical activity requires a controlled field trial. Trial data for primary prevention are sparse and inconclusive.[2] Secondary prevention trials suggest some benefit, but the studies are flawed by high drop-out rates, crossover of treatment and control groups, use of drug treatment or surgery, and modification of other risk factors. These data fall short of proving or disproving that physical activity is beneficial. However, it would appear desirable to retain more vigorous exercise patterns, if only to improve general well-being. Also, there may well be a bonus in improved cardiovascular health.

The data on physical demands of work suggest that with machines replacing muscle power, it is no longer feasible to obtain adequate endurance exericise in the work situation unless we can engineer physical activity back into daily living. The unexpected relationship of noncardiovascular mortality rates to physical activity merits further study of possible noxious exposures in work situations where physical exertion is common.

SUMMARY

Cardiovascular events over 24 years of surveillance were examined in 1166 men participating in the Framingham Study, classified by physical demands of their work and by a 24-hour index of physical activity. Findings are based on 303 noncardiovascular, 220 coronary, and 325 cardiovascular deaths in men aged 45 to 64 years at time of physical activity assessment.

For level of physical activity over 24 hours, there is a clear trend of improved overall, cardiovascular, and coronary mortality with increased level of physical activity at all ages, including the elderly. The effect is sustained with a more pronounced effect with the passage of time, despite presumed decrease in level of activity. The mortality benefits apply both in those with and without intervening overt cardiovascular disease, making it unlikely that the physical inactivity-mortality relationships reflects already existent myocardial damage.

For physical demands of the job, there is only a suggestion (not statistically significant) of benefit for cardiovascular mortality including coronary deaths. In sharp contrast, noncardiovascular mortality was *positively* related to both physical demand of the job and 24-hour physical activity index.

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Overall and coronary heart disease mortality rates in relation to major risk factors in 325,348 men screened for the MRFIT

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The original screening of 325,384 white middle-aged men for the Multiple Risk Factor Intervention Trial (MRFIT) allows detailed examination of the relationship of risk factors to coronary heart disease (CHD) mortality rates. More precise estimates of risk than were previously available can be obtained, particularly at the low end of the risk factor distribution. Better insight into age trends in risk factor impact on mortality rates may be obtained and other interactions between the risk factors can be studied. The net and joint effects of the risk factors can be determined directly from the sample data as well as from multivariate statistical estimates. These are the objectives of this report.

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METHODOLOGY

An initial screening for candidates to assess their eligibility by established criteria for the MRFIT was carried out over a 2-year period beginning in 1973. This randomized controlled trial[1-4] involved men ages 35 to 57 years, who were free of overt evidence of CHD but at high risk of CHD because their levels of serum cholesterol, blood pressure, and cigarette