Changes in physical fitness and changes in mortality

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Summary
Background Point estimates of physical fitness give important information on the risk of death in healthy people, but there is little information available on effects of sequential changes in physical fitness on mortality. We studied this latter aspect in healthy middle-aged men over a total follow-up period of 22 years.

Methods 2014 healthy men aged 40–60 years had a bicycle exercise test and clinical examination, and completed a questionnaire in 1972–75 (survey 1). This was repeated for 1756 (91%) of 1932 men still alive by Dec 31, 1982 (survey 2). The exercise scores were adjusted for age. The change in exercise scores between surveys was divided into quartiles (Q1=least fit, Q4=fittest). An adjusted Cox’s proportional hazards model was used to study the association between changes in physical fitness and mortality, with the Q1 men used as controls.

Findings By Dec 31, 1994, 238 (17%) of the 1428 men had died, 120 from cardiovascular causes. There were 37 deaths in the Q4 group (19 cardiovascular); their relative risks of death were 0·45 (95% CI 0·29–0·69) for any cause and 0·47 (0·26–0·86) for cardiovascular causes. There was a graded, inverse relation between changes in physical fitness and mortality irrespective of physical fitness status at survey 1.

Interpretation Change in physical fitness in healthy middle-aged men is a strong predictor of mortality. Even small improvements in physical fitness are associated with a significantly lowered risk of death. If confirmed, these findings should be used to influence public health policy.


Introduction
Studies based on point estimates of physical fitness show that such estimates are a good long-term predictor of cardiovascular mortality and all-cause mortality in healthy people. However, these studies generally assume a homogenous decline in physical fitness with age throughout the population. Patterns of physical fitness may in fact vary between subgroups because of, for example, changes in physical activity and smoking habits over time: the Global Burden of Disease Study puts physical inactivity and smoking among the top ten risk factors that threaten global health. Information on changes in physical fitness and lifestyle may provide more information on long-term prognosis than can be obtained from a single estimate.

To study the relations between physical fitness, changes in physical fitness, and mortality, we tested the physical fitness of a group of apparently healthy middle-aged men. The men were tested on two occasions, with an interval of 7 years. Total follow-up time was 22 years.

Participants and methods
Participants
2014 men aged 40–60 years took part in a baseline survey (survey 1) in 1972–75. Men were defined as “apparently healthy” if they had no evidence of heart disease, no diagnosed hypertension requiring drug treatment, and no diabetes mellitus, cancer, advanced pulmonary, renal, or liver disease, or other serious disorders, and were able to undertake a symptom-limited exercise test. 1756 (91%) of the men participated in a second identical survey in 1980–82 (survey 2), and our study uses these data.

258 of the participants in survey 1 did not participate in survey 2. Of these, 92 had died—45 from cardiovascular causes, 27 from cancer, and 20 from other causes. Of the remaining 166 men who did not take part in survey 2, 47 were too ill to participate, 47 had too far to travel, and 72 gave no reasons for non-participation. Among the 1756 men who took part in the second survey, 328 were excluded for one or more of the following reasons: myocardial infarction, stroke, angina pectoris, cancer, diabetes mellitus, pulmonary, renal, or liver diseases, hypertension requiring drug treatment, and inability to do the exercise test. Thus, data from 1428 men were included in our analysis. For these 1428 men, follow-up started at the date of survey 2 and ended by Dec 31, 1994.

1456 (86%) of the original cohort were surveyed for a third time in 1989–90 (survey 3), and some of these most recent data were used to check our models.

Survey methods
The methods of surveys 1 and 2 were the same. All participants had a clinical examination, with blood tests, spirometry, a chest radiograph, measurements of height and weight, and an exercise electrocardiographic (ECG) test. The exercise test used an electrically braked bicycle, which demanded a constant output of energy at each workload irrespective of pedalling rate. The test workload was set at 1·405 kcal/min (100 W) to begin with, and was increased by 0·703 kcal/min...
Risks were calculated between groups. Pearson's variables, relative risks associated with increases of 1 SD are Cox models.

Information from survey 3, gave similar results to the standard Control runs with time-dependent covariates, which used assumptions of the proportional-hazards model were acceptable. Diagnostic plots of log S(t) versus log (t) showed that the index, amounts of physical activity, exercise results, and smoking concentrations of total cholesterol and triglycerides, body-mass index, and all-cause mortality, adjusted for the quartiles of physical fitness and bodyweight as a separate variable, gave similar findings. For all these variables, the highest quartile of physical fitness had the values indicating lowest risk. Total cholesterol concentration was not significantly associated with physical fitness. Between-group variations in physical fitness were associated with only small variations in body-mass index.

By the end of 1994, 238 (16.7%) of the 1428 men who participated in survey 2 had died, from cardiovascular causes (120), cancer (75), and other causes (43). We found an inverse relation between all-cause mortality and physical fitness (table 2). With only physical fitness and age as predictors of all-cause mortality, the relative risk of death in quartiles Q2, Q3, and Q4 compared with the least fit quartile Q1 were 0.63, 0.37, and 0.31 respectively. With a larger set of risk factors included (table 3), the relations between all-cause mortality, cardiovascular mortality, and physical fitness remained similar. Of all the parameters included in the model, only smoking status, resting heart rate, systolic blood pressure, and vital capacity appeared as confounders of the predictive power of physical fitness. Another Cox model, which used total work capacity as the measure of physical fitness and bodyweight as a separate variable, gave similar results. Thus, physical fitness was a strong predictor of cardiovascular and total mortality even when other risk factors were taken into account.

Although there was a good correlation between PF1 and PF2 (r=0.74), many of the men had changed their standard of physical fitness by survey 2. Table 4 groups participants according to quartiles of PF1 and according to quartiles of changes in physical fitness from PF1 to PF2. In five of the 16 subquartiles, PF2 was higher than PF1 (ratio>100). To illustrate what this change means in terms of exercise capacity, for the least fit quartile at survey 1 (PF1 Q1) those who increased physical fitness most (PF2/PF1 Q4), the PF2/PF1 ratio was 136% and the change in exercise capacity was only 2 min at bicycle load 2 (150W).

Our results showed that there was a graded, inverse relation between changes in physical fitness and mortality irrespective of physical fitness at survey 1. Proportional-hazards analysis that included all risk factors, PF1, and findings. For all these variables, the highest quartile of physical fitness had the values indicating lowest risk. Total cholesterol concentration was not significantly associated with physical fitness. Between-group variations in physical fitness were associated with only small variations in body-mass index.

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Changes in physical fitness (log(PF2/PF1)), showed that changes in physical fitness have a highly significant effect on all-cause mortality (p<0.001, table 5). PF1 had significant predictive power in proportional-hazards models, including PF2 (p<0.01, data not shown).

Changes in physical fitness between PF1 and PF2 were associated with changes in other measured variables (details not shown). The group with the lowest PF2/PF1 ratio (Q1) became less physically active by survey 2 (14.8% physically active at survey 1, 10.9% physically active at survey 2). By contrast, men with the highest PF2/PF1 ratio (Q4) increased their physical activity over the same period (18.6% physically active at survey 1, 29.3% physically active at survey 2). We also found similar differences between groups Q1 and Q4 for sequential changes in systolic blood pressure, vital capacity, and resting heart rate. Moreover, in all PF1 quartiles, the groups with the lowest PF2/PF1 ratio were twice as likely to be smokers as those with the highest ratio.

Discussion

Our data from a group of healthy men show that not only physical fitness itself, but also the magnitude and direction of changes in physical fitness have a highly significant effect on all-cause mortality (p<0.001, table 5). PF1 had significant predictive power in proportional-hazards models, including PF2 (p<0.01, data not shown).

Our data probably give a conservative estimate of the relation between physical fitness, health, and death. M any of the 328 men who were excluded from the present material for health reasons had low physical fitness at survey 1, as had most of those who had died, or who did not participate in survey 2 (data not shown).

Table 3: Relative risks of all-cause and cardiovascular mortality among 1428 apparently healthy men of survey 2 during 13 years' follow-up

Table 4: Changes in physical fitness from survey 1 (PF1) to survey 2 (PF2) and changes in all-cause mortality

Table 5: Relative risk of all-cause mortality during 13 years' follow-up associated with variables measured at survey 2, with both age-adjusted PF1 and log (PF2/PF1) in the model
the lowest maximum heart rate (10% of the total study group) did not significantly affect our results. Adjustment for body size in our definition of physical fitness was of marginal significance, and changes in bodyweight over time did not affect our results for physical fitness or changes in fitness.

Up to 30% of the men in survey 1 maintained or even increased their fitness by survey 2. Some men may have had undetected, intercurrent disorders at survey 1, which led to poor exercise-test results, but the overall increase in fitness was more likely to be linked to increases in leisure-time activity, giving up smoking, or both.15,16 It may be relevant that all participants in survey 1 received a written report of the results, and that those who were less fit received various recommendations for improving their health. Increased public awareness of the beneficial effects of giving up smoking and increased exercise may also have played a part in the observed increase in fitness during follow-up.

Physical fitness is influenced by genetic factors (40%) and other factors (60%).17 Genetic causes of differences in physical fitness are difficult to measure. The effects of physical activity on fitness are more easily assessed. The most rapid declines in fitness between survey 1 and survey 2 were probably caused by changes in lifestyle, development of subclinical disease, or both. The beneficial effects on long-term physical fitness of giving up smoking, and the detrimental effects of continuing to smoke, are well known.18 A good standard of physical fitness has beneficial effects on serum lipid concentrations, fibrinolysis, glucose tolerance and insulin metabolism, platelet function, blood pressure, autonomic-system function, myocardial electric stability, dimensions of the coronary arteries, and the immune system.14

In our study, good physical fitness was associated with a favourable risk-factor profile, and improvements in physical fitness were associated with improvements in risk-factor profile. Follow-up studies based on single tests of physical fitness1–7 show similar results to ours, irrespective of selection procedures, methods, and follow-up, as do published data on physical activity.19–26 To our knowledge, only one other study has used data on repeated tests of physical fitness,11 and the results accord with ours. Although our study was observational, the fitness data were corrected for several important confounders and the results seem biologically plausible. A large-scale, prospective, randomised study is needed to test these theories further, but such a study may not be possible.

Many people rely on drug therapies and medical interventions to improve their health. We have shown that physical fitness is associated with a lowered risk of death, and that improvement in physical fitness over time also further reduces this risk. The men in our study who were and remained physically fit had the most favourable prognosis. However, according to these data, probably the most important suggestion is that moderate improvements in physical fitness, particularly among those who are least fit, bring substantial benefits to health.

Contributors

Gunnar Erikssen designed the study, analysed the data, and had the main responsibility for writing the paper. Knut Liestøl provided scientific guidance and contributed to data analysis. Jan Erikssen initiated the first survey in 1972. Jørgen Bjernhoit undertook data collection. Erik T Haukel collected data and was involved in planning the study. Leiv Sandvik did statistical analysis of the database. All investigators contributed to the writing of the paper.

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References