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Association between muscular strength and mortality in men: prospective cohort study

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Association between muscular strength and mortality in men: prospective cohort study

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ABSTRACT

Objective To examine prospectively the association between muscular strength and mortality from all causes, cardiovascular disease, and cancer in men.

Design Prospective cohort study.

Setting Aerobics centre longitudinal study.

Participants 8762 men aged 20-80.

Main outcome measures All cause mortality up to 31 December 2003; muscular strength, quantified by combining one repetition maximal measures for leg and bench presses and further categorised as age specific thirds of the combined strength variable; and cardiorespiratory fitness assessed by a maximal exercise test on a treadmill.

Results During an average follow-up of 18.9 years, 503 deaths occurred (145 cardiovascular disease, 199 cancer). Age adjusted death rates per 10 000 person years across incremental thirds of muscular strength were 38.9, 25.9, and 26.6 for all causes; 12.1, 7.6, and 6.6 for cardiovascular disease; and 6.1, 4.9, and 4.2 for cancer (all $P<0.01$ for linear trend). After adjusting for age, physical activity, smoking, alcohol intake, body mass index, baseline medical conditions, and family history of cardiovascular disease, hazard ratios across incremental thirds of muscular strength for all cause mortality were 1.0 (referent), 0.72 (95% confidence interval 0.58 to 0.90), and 0.77 (0.62 to 0.96); for death from cardiovascular disease were 1.0 (referent), 0.74 (0.50 to 1.10), and 0.71 (0.47 to 1.07); and for death from cancer were 1.0 (referent), 0.72 (0.51 to 1.00), and 0.68 (0.48 to 0.97). The pattern of the association between muscular strength and death from all causes and cancer persisted after further adjustment for cardiorespiratory fitness; however, the association between muscular strength and death from cardiovascular disease was attenuated after further adjustment for cardiorespiratory fitness.

Conclusion Muscular strength is inversely and independently associated with death from all causes and cancer in men, even after adjusting for cardiorespiratory fitness and other potential confounders.

INTRODUCTION

Several studies have shown an inverse association between muscular strength and all cause mortality,[1-13] but most had limitations. We examined the importance of muscular strength as a predictor of death from all causes, cardiovascular disease, and cancer in a cohort of men. We also examined the association of muscular strength and cardiorespiratory fitness with mortality risk.

METHODS

Between 1980 and 1989, 10 265 men received a medical examination and muscular strength test and were enrolled in the aerobics centre longitudinal study. They were periodically examined. The death rate for the subgroup of men in this analysis is not significantly different from the overall cohort adjusted for age, risk factor, health status, and family history.

Participants performed a maximal graded treadmill test to assess their cardiorespiratory fitness. After exclusions, 8762 predominantly white, well educated, men aged 20-82 from the middle and upper socio-economic strata were followed up from the date of the baseline examination until the date of death or 31 December 2003. Mortality surveillance was by the National Death Index.[14]

The clinical examination and measures of muscular strength and cardiorespiratory fitness are described elsewhere.[15-17] Briefly, the baseline examination included a physical examination and measurements of body mass index, systolic and diastolic blood pressure, and concentrations of total and high density lipoprotein cholesterol, triglycerides, and glucose. Participants completed a questionnaire on medical history, including myocardial infarction, stroke, hypertension, diabetes, or cancer; a family history of cardiovascular disease or cancer; smoking status; alcohol intake; and physical activity.

We assessed muscular strength in the upper and lower body using a standardised strength testing protocol of variable resistance. Upper body strength was assessed with a one repetition maximum bench press and lower body strength with a one repetition maximum leg press. We computed a score for muscular strength by combining the standardised values of bench and leg presses (see bmj.com). We calculated the score separately for each age group (20-29, 30-39, 40-49, 50-59, and ≥60). The score for muscular strength was calculated as the mean of the two standardised scores (bench and leg presses). For analysis we used thirds of the age specific composite strength score.

We assessed cardiorespiratory fitness by a maximal treadmill test using a modified Balke protocol.[15 18] Most participants achieved maximal effort. We estimated maximal metabolic equivalents from the final treadmill speed and grade.[19] We dichotomised cardiorespiratory fitness as unfit and fit corresponding to the lower 20% and upper 80% of the age specific distribution of treadmill exercise duration in the overall population of the aerobics centre longitudinal study.[20-24] We computed person years of exposure as the sum of follow-up time among decedents and survivors.

Statistical analysis

We calculated the baseline characteristics of the study population by vital status and thirds of muscular strength. Differences in covariates were tested using Student *t* tests, χ^2 tests, and F tests. We used Cox proportional hazards regression to estimate hazard ratios, 95% confidence intervals, and deaths per 10 000 person years of follow-up, according to exposure categories. We adjusted multivariable analyses for age (model 1); for age, physical activity, smoking, alcohol intake, body mass index, baseline medical conditions (hypertension, diabetes, or hypercholesterolaemia), and family history of cardiovascular disease (model 2); and after further adjustment for cardiorespiratory fitness (model 3).

To determine differences by age and body mass index, we examined muscular strength and mortality in younger men (<60) and older men (≥60) and in men of normal weight (18.5-24.9 kg/m^2) and overweight men (≥25 kg/m^2). Finally, we examined the combined effects of muscular strength and cardiorespiratory fitness on all cause mortality by creating six categories for combinations of strength and fitness on the basis of thirds of muscular strength, which we dichotomised in to fit and unfit groups. We compared the effect of each combination group (see bmj.com) with the referent group (low strength, unfit). We calculated two sided P values and we considered those <0.05 as significant.

RESULTS

During an average follow-up of 18.9 years and 165 251 person years of observation 503 (5.7%) deaths occurred: 145 (28.8%) from cardiovascular disease and 199 (39.6%) from cancer. Muscular strength, exercise duration, and maximal metabolic equivalents were significantly higher in survivors than in decedents. A direct gradient of treadmill test

Rates and hazard ratios for mortality in men from all causes, cardiovascular disease, and cancer by thirds of muscular strength

Mortality (third)	No of deaths	Age adjusted rate per 10 000 person years	Hazard ratio (95% CI) Model 1*	Model 2†	Model 3‡
All causes:					
Lower	214	38.9	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Middle	143	25.9	0.66 (0.54 to 0.82)	0.72 (0.58 to 0.90)	0.74 (0.59 to 0.91)
Upper	146	26.6	0.68 (0.55 to 0.84)	0.77 (0.62 to 0.96)	0.80 (0.64 to 0.996)
P for linear trend			<0.001	0.01	0.03
Cardiovascular disease:					
Lower	66	12.1	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Middle	42	6.6	0.63 (0.43 to 0.93)	0.74 (0.50 to 1.10)	0.78 (0.52 to 1.16)
Upper	37	7.6	0.55 (0.37 to 0.82)	0.71 (0.47 to 1.07)	0.78 (0.51 to 1.20)
P for linear trend			0.003	0.09	0.22
Cancer:					
Lower	88	6.1	1.00 (Referent)	1.00 (Referent)	1.00 (Referent)
Middle	58	4.2	0.66 (0.47 to 0.92)	0.72 (0.51 to 1.00)	0.71 (0.50 to 0.996)
Upper	53	4.9	0.60 (0.43 to 0.85)	0.68 (0.48 to 0.97)	0.67 (0.47 to 0.96)
P for linear trend			0.003	0.03	0.02

*Adjusted for age.
†Adjusted for age, physical activity, current smoking, alcohol intake, body mass index, baseline medical conditions, and family history of cardiovascular disease.
‡Adjusted for age plus physical activity, current smoking, alcohol intake, body mass index, baseline medical conditions, family history of cardiovascular disease, and cardiorespiratory fitness.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Cardiorespiratory fitness provides strong and independent prognostic information about the overall risk of illness and death

Most prospective studies examining the association between muscular strength and death have had limitations

WHAT THIS STUDY ADDS

Muscular strength in major muscle groups is independently associated with death from all causes and cancer in men aged 20-82

These findings are valid for those who are normal weight or overweight, younger or older, and even after adjusting for a number of potential confounders including cardiorespiratory fitness

Muscular strength seems to add to the protective effect of cardiorespiratory fitness against the risk of death in men

duration across thirds of muscular strength was observed. Age, body mass index, blood pressure, and levels of total cholesterol, triglycerides, and glucose were higher in decedents and in those with lower levels of muscular strength.

All cause mortality was 1.50 (38.9/25.9) and 1.46 (38.9/26.6) times greater for those in the lowest third of muscular strength than for those in the middle and upper thirds of muscular strength (table). The differences for death from cardiovascular disease were 1.83 (12.1/6.6) and 1.59 (12.1/7.6) times greater, and for death from cancer were 1.45 (6.1/4.2) and 1.24 (6.1/4.9) times greater. The age adjusted results of model 1 showed a notably declining risk of death from all causes, cardiovascular disease, and cancer across incremental thirds of muscular strength ($P<0.01$ for linear trend). After the additional adjustments (model 2), risks of death from all causes and cancer remained progressively lower with higher levels of muscular strength ($P<0.05$), whereas the association between muscular strength and death from cardiovascular disease was attenuated ($P=0.08$). After further adjustment for cardiorespiratory fitness the association between muscular strength and risks of death from all causes or cancer remained significant ($P<0.05$), whereas the association between muscular strength and risk of death from cardiovascular disease was no longer statistically significant ($P=0.23$).

Strong statistical evidence existed of an interaction between muscular strength and age in predicting death from all causes and cancer (see bmj.com) but weak evidence of an interaction between muscular strength and body mass index in predicting such deaths (see bmj.com). A significant inverse gradient was found for death from all causes and cancer across incremental thirds of muscular strength within each age group ($P<0.05$ for linear trend). Across age strata, those in the lowest third of muscular strength had a 1.4-fold to 2.2-fold and 1.5-fold to 4.3-fold higher rates of mortality from all causes and cancer than those in the upper third of muscular strength. Muscular strength also was inversely associated with all cause mortality in men of normal weight and overweight men ($P<0.05$) and with cancer mortality in overweight men ($P=0.03$; see bmj.com). Across incremental thirds of muscular strength, age adjusted total death rates per 10 000 person years were 32.9, 25.6, and 20.7 in men of normal weight ($P=0.009$) and 42.1, 26.2, and 33.8 in overweight men ($P=0.046$).

The death rate in unfit men with the lowest muscular strength was the highest among the six muscular strength and cardiorespiratory fitness categories (see bmj.com). The adjusted death rate per 10 000 person years was inversely related to muscular strength within the fit cardiorespiratory fitness group ($P=0.008$), and inversely related to cardiorespiratory fitness within the lowest third ($P=0.003$) and middle third ($P=0.03$) of muscular strength.

DISCUSSION

Muscular strength was significantly and inversely associated with risk of death from all causes and cancer after controlling for potential confounders, including cardiorespiratory fitness. The inverse association was consistent in strata of age (<60, ≥60) and body mass index (18.5-24.9 kg/m^2, ≥25 kg/m^2). Muscular strength was significantly and inversely associated with risk of cardiovascular death after controlling for age, yet the association was attenuated once other potential confounders were entered in the model and was not significant after further adjustment for cardiorespiratory fitness. The age adjusted death rate in men with high levels of both muscular strength and cardiorespiratory fitness was 60% lower ($P<0.001$) than the death rate in unfit men with the lowest levels of muscular strength.

Muscular strength and cardiorespiratory fitness were moderately correlated, suggesting that the association between muscular strength and risk of death from cancer works at least partially through different mechanisms than those associated with the protective effects of cardiorespiratory fitness. In this cohort the number of deaths from cardiovascular disease was lower than that from cancer (145 and 199). This may have reduced the statistical power to detect a significant independent association between muscular strength and risk of death from cardiovascular disease.

Muscle fibre type and configuration has a genetic component and influences strength, yet it is clear that resistance type physical activities are major determinants of muscular strength.[25 26] We have reported a strong and positive association between the frequency of self reported resistance exercise and maximal muscular strength in men.[17] Results from intervention studies indicate that resistance training enhances muscular strength and endurance, muscle mass, functional capacity, daily physical activity, risk profile for cardiovascular disease, and quality of life.[25] These factors are well known predictors of higher risk of mortality. We observed an inverse association between muscular strength and risk of death from all causes and cancer in older men (≥60) and younger men (<60).

We showed an inverse association between muscular strength and risk of death from all causes and cancer in overweight and obese men, as well as between muscular strength and risk of all cause mortality in those of normal body weight.

Strengths and limitations

Although our findings applied to well educated white men of middle to upper socioeconomic status we have no reason to believe that the benefits of muscular strength would be different in other ethnic or socioeconomic groups. Values for blood pressure and cholesterol levels, body weight, and cardiorespiratory fitness from participants in the aerobics centre longitudinal study were similar to those reported in two population based studies in North America.[15] No detailed information about drug use or diet was available, which may have biased the results through residual confounding. It seems unlikely, however, that these factors would account for all of the observed association between muscular strength and mortality.

A major strength of this study was the inclusion of objective and standardised maximal tests for muscular strength and cardiorespiratory fitness using reliable measurement protocols in a large cohort of men with extensive follow-up. Moreover, participants were healthy enough to achieve at least 85% of aged predicted maximal heart rate during the treadmill test.

Conclusions

Muscular strength seems to add to the protective effect of cardiorespiratory fitness against the risk of death in men. It might be possible to reduce all cause mortality among men by promoting regular resistance training involving the major muscle groups of the upper and lower body two or three days a week.[25]

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