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# Change in Submaximal Cardiorespiratory Fitness and All-Cause Mortality

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## Abstract

**Objective:** To evaluate the relationship between change in submaximal cardiorespiratory fitness (sCRF) and all-cause mortality risk in adult men and women.

**Patients and Methods:** A prospective study with at least 2 clinical visits (mean follow-up time, 4.2±3.0 years) between April 1974 and January 2002 was conducted to assess the relationship between change in sCRF and mortality risk during follow-up. Participants were 6106 men and women. Submaximal CRF was determined using the heart rate obtained at the 5-minute mark of a graded maximal treadmill test used to determine maximal CRF (mCRF). Change in sCRF from baseline to follow-up was categorized into 3 groups: increased fitness (decreased heart rate, <−4.0 beats/min), stable fitness (heart rate, −4.0 to 3.0 beats/min), and decreased fitness (increased heart rate, >3.0 beats/min).

**Results:** The mean change in sCRF at follow-up for all 6106 study participants was −0.5±10.0 beats/min, and the mean change in mCRF was −0.3±1.4 metabolic equivalents. Change in sCRF was related to change in mCRF, though the variance explained was small ($R^2$=0.21; $P$<.001). The hazard ratios (95% CIs) for all-cause mortality were 0.60 (0.38-0.96) for stable and 0.59 (0.35-1.00) for increased sCRF compared with decreased sCRF after adjusting for age, change in weight, and other common risk factors for premature mortality. The hazard ratios for changes in sCRF and mCRF were not significant after adjusting for changes in mCRF ($P$=.29) and sCRF ($P$=.60), respectively.

**Conclusion:** A simple 5-minute submaximal test of CRF identified that adults who maintained or improved sCRF were less likely to die from all causes during follow-up than were adults whose sCRF decreased.

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Overwhelming evidence has established that maximal cardiorespiratory fitness (mCRF) predicts cardiovascular disease (CVD) and all-cause mortality beyond risk factors commonly obtained in clinical examinations.[1] Despite this evidence, measurement of mCRF has not been widely adopted in clinical practice with barriers including the need for expensive testing systems, specialized personnel, and time.[2,3]

A potential alternative to measures of mCRF include tests of submaximal CRF (sCRF). Relatively short (3-5 minutes) tests of sCRF overcome the barriers associated with the measurement of mCRF and may offer a pragmatic alternative to obtain objective measures of CRF in clinical settings.

Although objective assessment of sCRF is straightforward, routine measurement in clinical practice competes for the limited time available in a busy office practice. Therefore, sCRF should be measured only if it can provide additional information that influences patient management. We posited that measures of sCRF, in particular the change in heart rate during submaximal exercise, would uniquely reflect cardiovascular adaptations in response to physical activity and thus predict mortality risk above and beyond traditional risk factors. Furthermore, because changes in sCRF are only modestly related to corresponding changes in mCRF,[4] we hypothesized that change in sCRF would predict mortality risk independent of change in mCRF.

To test our hypotheses we used data from the Aerobics Center Longitudinal Study, which provides the opportunity for the first time to evaluate the relationship between changes in sCRF and mortality in a cohort of

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men and women with at least 2 clinical examinations and subsequent follow-up for mortality.

## PATIENTS AND METHODS

The Aerobics Center Longitudinal Study is a prospective observational study of individuals in the United States who received an extensive medical evaluation. Study participants were referred by their employers or physicians or were self-referred to the Cooper Clinic in Dallas, Texas. They are primarily non-Hispanic whites and college graduates from middle to upper socioeconomic strata.[5] To assess changes in CRF, we included men and women who received at least 2 medical examinations between April 1974 and January 2002 and had complete data on treadmill grade and speed as well as on heart rate at the 5-minute mark of the exercise test. Baseline characteristics of participants without follow-up data or heart rate at 5 minutes can be found in Supplemental Table 1, available online at http://www.mayoclinicproceedings.org. For individuals attending more than 2 examinations, we used the first (baseline) and last examinations and followed individuals for subsequent mortality after the last examination. From the 29,221 eligible individuals 20 years and older at baseline, we excluded 17,682 individuals who did not have follow-up clinical data; 2186 individuals having myocardial infarction, stroke, cancer, or high blood pressure; and 1264 individuals with body mass index (calculated as the weight in kilograms divided by the height in meters squared) less than 18.5 kg/m$^2$. The reason(s) for patients not returning for a follow-up visit is unknown. In addition, 2 individuals whose baseline and last maximal treadmill tests were less than 5 minutes in duration, 1865 individuals with less than 1 year of mortality follow-up, 1 individual with an extreme value of body mass index change (>10 kg/m$^2$ change per year), 106 individuals with extreme values of change in sCRF heart rate (<−30.0 beats/min and >30.0 beats/min), and 9 individuals with less than 5 months between their first and last medical examinations were excluded. The final sample included 6106 individuals for the analysis of all-cause mortality. The extensive exclusion criteria were used to minimize potential bias due to preexisting diseases or subclinical conditions on changes in sCRF and mCRF in relation to mortality risk. Baseline chronic illnesses of included participants can be found in Supplemental Table 2, available online at http://www.mayoclinicproceedings.org. The study was reviewed and approved annually by the Cooper Institute's institutional review board, and all participants gave written informed consent for the examinations and follow-up study.

### Clinical Examination

Participants underwent comprehensive clinical examinations by a physician.[6] Blood samples were taken after an overnight fast. Resting blood pressure was measured by standard auscultation techniques after at least 5 minutes of seated rest.[6] Electrocardiograms (ECGs) were recorded at rest and with exercise, where abnormal ECG responses included rhythm and conduction disturbances and ischemic ST-T wave abnormalities. Information on smoking status, alcohol intake, physical activity, parental CVD, and physician-diagnosed myocardial infarction, stroke, cancer, hypertension, diabetes mellitus, and hypercholesterolemia was obtained from the medical questionnaire.[6] *Parental CVD* was defined as the occurrence of heart attacks, coronary disease, angioplasty, or stroke before the age of 50 years in either biological parent.[6]

### Cardiorespiratory Fitness Test

Maximal CRF was determined by a maximal treadmill test using the modified Balke protocol. Standardization of the test included using the same protocol for every patient, calibrating the speed and grade at standard intervals, and not allowing handrail support during the test. Patients also performed the treadmill test after an overnight fast. Treadmill speed was initially set at 88 m/min. Treadmill grade was initially set at 0% for the first minute and 2% for the second minute and was increased by 1% each minute thereafter. After 25 minutes the speed was increased to 5.4 m/min without grade change. The treadmill test continued until the patient reached volitional fatigue or the physician terminated the test for medical reasons.[7]