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Cardiorespiratory Fitness and Adiposity as Mortality Predictors in Older Adults

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Abstract

Context—Associations among cardiorespiratory fitness (thus referred to as “fitness”), adiposity, and mortality in older adults have not been adequately examined.

Objectives—To examine these associations, we report on a 12-year follow-up of adults ages 60 years and older, in whom fitness was assessed by a maximal exercise test and adiposity was assessed by body mass index (BMI), waist circumference (WC), and percent body fat.

Design, Setting, and Patients—2603 adults (age 64.4±4.8 yr; 19.8% women) completed a baseline health examination at the Cooper Clinic during 1979-2001. Low fitness was defined as the lowest fifth of the gender-specific distribution of maximal treadmill exercise test duration. The distributions of BMI, WC, and percent body fat were grouped for analysis according to clinical guidelines.

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Main Outcome Measures—All-cause mortality.

Results—There were 450 deaths during an average follow-up of 12 years and 31 236 person-years of exposure. Death rates per 1000 person-years, adjusted for age, gender, and examination year were: 13.9, 13.3, 18.3, and 31.8 across BMI groups of 18.5-24.9, 25.0-29.9, 30.0-34.9, and ≥35 kg/m^2, respectively (trend *P*=.01); 13.3 and 18.2 for normal and high WC (≥102 cm in men; ≥88 cm in women), respectively (*P*=.004); 13.7 and 14.6 for normal and high percent body fat (≥25% in men; ≥30% in women), respectively (*P*=.51); and 32.6, 16.6, 12.8, 12.3 and 8.1 across incremental fifths of fitness, respectively (*P*<.001). The association between WC and mortality persisted after further adjustment for smoking, baseline health status, and BMI (*P*=.02), but not after additional adjustment for fitness (*P*=.86). Fitness predicted mortality risk after further adjustment for smoking, baseline health, and either WC, BMI or percent body fat (*P*<.001).

Conclusions—Fitness is a significant mortality predictor in older adults independent of overall or abdominal adiposity. Practitioners should consider the importance of preserving functional capacity, by recommending regular physical activity for older individuals, normal weight and overweight alike.

Population aging, obesity, and physical inactivity are notable public health challenges. By the year 2030, 22% of the U.S. population, 70 million individuals, will be older than 65.[1] About 32% of Americans are obese[2] and the vast majority of U.S. adults do not engage in regular physical activity.[3] A high proportion of adults have levels of functional capacity that are low enough to increase mortality risk.[4] Levels of physical activity and functional aerobic capacity each decline steadily with age,[5,6] while the prevalence of obesity tends to increase with age. Total medical expenditures associated with inactivity and obesity are greatest in the older population, a fact that underscores the significant economic burden to society posed by an aging population of inactive obese individuals.[7]

Prospective studies provide convincing evidence that obesity and physical inactivity each produce excess mortality risk in middle-aged adults.[8-15] However, data regarding associations among obesity, physical activity, and survival in older adults are sparse and largely equivocal.[16-25] Some studies have found that obesity-related mortality risk is reduced at older ages,[17,18,20-24] while others have not.[19,25] Most of these studies have used body mass index (BMI) as a crude measure of adiposity.[17,19-21,25] Few studies have examined simultaneously physical activity levels and clinical measures of adiposity, such as waist circumference (WC)[22-24] or percent body fat,[26,27] in relation to mortality specifically in older adults.[17] Cardiorespiratory fitness (thus referred to as "fitness") is an objective reproducible measure that reflects the functional consequences of recent physical activity habits, disease status, and genetics.[28] To our knowledge, no study has been conducted on the independent and joint associations among fitness, various clinical measures of adiposity, and mortality in older women and men. We, therefore, examined this issue in a cohort of older adults who are enrolled in the Aerobics Center Longitudinal Study (ACLS).

METHODS

Study Population

The present study consisted 2087 men and 516 women aged 60 years and older (64.4±4.8, range 60-100). All participants completed a baseline clinical examination during 1979-2001 at the Cooper Clinic (Dallas, TX). Study participants came to the clinic for periodic preventive health examinations and for counseling regarding diet, exercise, and other lifestyle factors associated with increased risk of chronic disease. Many participants were sent by their employers for the examination. Some were referred by their personal physicians. Others were self-referred. Inclusion criteria for the current analysis required participants to have a maximal treadmill exercise test at baseline, during which they must have achieved at least 85% of their age-predicted maximal heart rate (220 minus age in years). We excluded those with a BMI less than 18.5 kg/m^2 at the baseline examination and those younger than age 60 at baseline. We classified participants by race/ethnicity based on their self-report when checking specific categories on the medical history. These categories are a standard part of the medical history, and we did not collect this information for the present report. The majority of the study participants were white, well-educated and from middle to upper socioeconomic strata. All participants provided written consent to participate in the follow-up study, and the Cooper Institute Institutional Review Board approved the study annually.

Clinical Data

Participants completed a comprehensive health evaluation that included self-reported personal and family health histories, a standardized medical examination by a physician, fasting blood chemistries, and a maximal treadmill exercise test. BMI (kg/m^2) was computed from measured weight and height. Percent body fat was assessed with hydrostatic weighing, with the sum of 7 skinfold measures, or with both assessments, following standardized protocols.[29] Detailed description of our hydrodensitometry procedures has been published elsewhere.[13] Fat mass (kg) was computed as weight (kg) × (percent body fat ÷ 100). Fat free mass (FFM) (kg) was computed as weight (kg) - fat mass (kg).[13] WC was measured level with the umbilicus. Adiposity exposure groups were based on standard clinical definitions for: BMI (normal weight 18.5-24.9, overweight 25.0-29.9, obese class I 30.0-34.9, and obese class II ≥ 35.0); WC (normal <88.0 cm for women, < 102.0 cm for men; abdominal obesity ≥88.0 cm for women, ≥ 102.0 cm for men); and percent body fat (normal <30% for women, <25% for men; obese ≥30% for women, ≥25% for men).[30] As there is not a consensus clinical categorization for FFM, groups were based on quintiles of the FFM distribution.

Blood pressure was measured with standard auscultatory methods after the participant had been seated for five minutes. Systolic and diastolic blood pressure was recorded as the first and fifth Korotkof sounds, respectively. Abnormal exercise electrocardiogram (ECG) responses included rhythm and conduction disturbances and ischemic ST-T wave abnormalities, as described in detail elsewhere.[31] Previously, we found 90% agreement between the ECG interpretation recorded in our database and a group of three physicians who read a random sample of 357 patient records.[31] Total cholesterol levels were determined in the Cooper Clinic clinical chemistry laboratory, which participates in and meets the quality control standards of the CDC Lipid Standardization Program. Baseline medical conditions, such as previous myocardial infarction, stroke, hypertension, diabetes, and hypercholesterolemia were defined as a history of physician diagnosis, measured phenotypes that met clinical thresholds for a specific condition, or when appropriate the combination of both methods. Smoking habits (current smoker or not) and physical activity habits (physically active or not) were obtained from a standardized questionnaire.

We determined fitness using a maximal treadmill exercise test and a modified-Balke protocol [32] as previously described.[12,13,33,34] Total test time correlates highly ($r \geq 0.92$) with directly measured maximal oxygen uptake in men[35] and women.[36] Participants were encouraged not to hold on to the handrails. The test endpoint was volitional exhaustion or termination by the physician for medical reasons. Fitness was grouped for our primary analysis using quintiles of the sex-specific distribution of maximal exercise duration. In secondary analyses we grouped fitness into a binary variable, low fitness (the lowest 20%) compared with higher fitness (the remaining 80%).[33] Individuals in the lowest 20% within each gender group were classified as physically unfit, and all others as physically fit.[33] We recognize that there currently is not a consensus clinical definition of low fitness. The approach for defining low fitness used here is a standardized methodology in the ACLS. Previous ACLS reports have shown that low fitness by this definition is an independent predictor of morbidity and mortality,[12,13,33,34] including an earlier report in elderly participants.[37] To standardize interpretation of exercise test performance, maximal metabolic equivalents (METs, 1 MET = 3.5 ml O_2 uptake/kg/min) were estimated based on the final treadmill speed and grade.[38] Fitness exercise durations (minutes) for the incremental fifth of fitness categories for men were: < 7.8, 7.8-10.5, 10.5-13.1, 13.1-16.4, and >16.4. The corresponding durations for women were: < 5.5, 5.5-7.0, 7.0-9.0, 9.0-11.3, and > 11.3. In equivalent METs values, the thresholds that defined these categories were 7.2, 8.5, 9.5, and 10.8 METs for men, 5.8, 6.7, 7.6, and 8.6 METs for women.

Mortality Surveillance

Vital status was ascertained using the National Death Index and using death certificates from states in which participant deaths occurred. Over 95% of mortality follow-up is complete by these methods. Causes of death were identified using International Classification of Diseases, Ninth Revision (ICD-9) codes before 1999, and Ten Revision (ICD-10) codes (in parentheses) during 1999-2003: Cardiovascular disease (CVD), 390-449.9 (I00-I78); Coronary heart disease (CHD),410-414, 429.2 (I20-I25); Cancer, 140-208 (C00-C97).

Statistical Analyses

The follow-up interval was computed from the date of a participant's baseline examination until the date of death for decedents, or until December 31, 2003 for survivors. Descriptive statistics summarized baseline characteristics by survival status and by fitness levels. Groups were compared using *t*- tests, χ^2 tests, and *F* tests. We used fisher's Z transformation to examine the correlations among adiposity measures and exercise duration by assessing Pearson coefficients (Table 3). Cox proportional hazard models estimated hazard ratios (HRs) and 95% confidence intervals (CIs) of mortality according to fitness, adiposity, age, smoking status, abnormal exercise ECG and baseline medical condition exposure categories. Multivariable analyses included the following 6 baseline covariables: age (years), sex, examination year, current smoker, abnormal exercise ECG responses, and chronic medical conditions (CVD (myocardial infarction or stroke), hypertension, diabetes, or hypercholesterolemia). The proportional hazards assumption was examined by comparing the cumulative hazard plots grouped on exposure; no appreciable violations were noted. Tests of linear trends in mortality rates and risk estimates across exposure categories were computed using ordinal scoring for fitness and age groups. Models including BMI also were fitted with BMI squared to assess non-linearity. We also examined associations between specific causes of death and fitness, BMI, WC, percent body fat, and FFM. Finally, we tested joint associations of adiposity and fitness with all-cause mortality. There were no significant interactions among exposure groups. Due to the small sample size (516) and number of deaths (52) in women, we were unable to perform a meaningful analysis in women alone. The pattern of the association between fitness, adiposity measurements and all-cause mortality in men was similar as that seen in analyses of men and women combined. We also examined the potential interaction between sex and other covariates in the Cox regression model, and no significant interactions were observed. We therefore believe that combining women and men is an acceptable alternative. Statistical tests were 2-sided; $P < .05$ was accepted to indicate statistical significance.

RESULTS

Overall, the mean age (± SD) of participants was 64.4 (± 4.8) years and 20% of the study sample were female. There were 450 deaths during an average follow-up of 12 years and 31 236 person-years of exposure. Participants' baseline characteristics by vital status and by fitness categories are summarized in Tables 1 and 2. Decedents were older, had lower fitness levels, and had more cardiovascular risk factors than survivors. However, there were no significant differences in adiposity measures across vital status. Participants in the higher fitness groups were for the most part less likely to have CVD risk factors, such as hypertension, diabetes, or high cholesterol. Table 3 shows that all measures of adiposity and treadmill exercise duration were significantly correlated, except for percent body fat and FFM (r=0.02, P=.26). BMI and fat mass were highly correlated, but BMI and WC or percent body fat were only moderately correlated.

Table 4 presents all-cause death rates per 1000 person-years for each exposure category, adjusted for age, sex, and examination year. Death rates were 32.6, 16.6, 12.8, 12.3, and 8.1 across incremental fifths of fitness (linear P_{trend}<.001); 20.4, and 12.1 for individuals with abnormal exercise ECG responses or without (P<.001); 16.2, and 11.3 for those with chronic medical conditions or without (P<.001); and 18.2, and 13.3 for those with abdominal obesity or without (P=.004). There was a J-shaped relationship between BMI and mortality (quadratic term, P=.01). Excluding individuals who died within 2 years of follow-up did not notably alter the association between the exposures and mortality. No relationship was found between mortality risk and percent body fat or FFM.

Table 5 and 6 show the estimated HRs and 95% CIs for adiposity and fitness exposure categories and all-cause mortality. After adjusting for age, sex, examination year, smoking, abnormal exercise ECG, and baseline health conditions (Table 5), HRs of mortality across incremental quintiles of fitness were 1.00, 0.53, 0.44, 0.43 and 0.30 (linear P_{trend} < .001). Additional adjustment for BMI, WC, percent body fat, or FFM (Table 5) did not meaningfully change the results. Turning to the adiposity categories shown in Table 6, when adjusted for the same set of covariables, those with abdominal obesity had a higher mortality risk (HR, 1.25; 95% CI, 1.00-1.56; P=.05), although this relationship did not persist after further adjustment for fitness (HR, 0.99; 95% CI, 0.79-1.25; P=.95). The J-shaped relationship between BMI and mortality remained significant after adjusting for covariables and fitness (P = .005), although it should be noted that most of the interval estimates for the BMI strata are not individually significantly different from the reference category. There were no significant associations between mortality and percent body fat or FFM.

Finally, we examined joint associations of all-cause mortality, adiposity, and fitness where fitness was dichotomized to unfit and fit in order to preserve sample size and numbers of deaths within each adiposity stratum and to provide greater clinical meaning for physicians and other health professionals working with older populations (Table 7). There were no significant interactions noted in analyses that included cross-product interaction terms for each fitness-adiposity exposure combination. Fit participants had lower death rates than the unfit within each stratum of adiposity, except for the Class I and II obesity groups. In most instances among overweight individuals, death rates for those with higher fitness were less than half of those who were unfit.

COMMENT

The study objective was to evaluate relationships between mortality risk and well-defined measures of adiposity, fat distribution, and fitness in older adults. In age, gender, and examination year adjusted analyses both BMI and WC were associated with mortality risk; but percent body fat and FFM were not related to mortality. The association between total mortality with WC persisted after adjusting for baseline differences in age, gender, smoking, abnormal exercise ECG responses, and health status. Further adjustment for fitness eliminated the significant mortality risk associated with abdominal obesity. A J-shaped relationship between BMI and mortality remained significant after considering the influences of several covariables, including fitness. Fitness had a strong inverse association with mortality, and this pattern of results was changed little by adjustments for adiposity or fat distribution. Thus our primary finding is that both fitness and BMI were strong and independent predictors of all-cause mortality in adults ages 60 years or older. Other adiposity measures either did not predict mortality (percent body fat, FFM), or did not do so in models adjusted for competing risk predictors (WC).

We previously demonstrated that lower levels of fitness are strongly associated with higher risk of all-cause and CVD mortality in younger and middle-aged men with various levels of health status.[12,13,39,40] The analogous relationship is clear within adiposity subgroups.[12,13] Our findings from the current study are consistent with these earlier ACLS results, and expand them to the older segment of the cohort. Especially notable is our finding (Table 7) that higher levels of fitness are inversely related to all-cause mortality in both normal weight and overweight BMI subgroups, in those with a normal WC and in those with abdominal obesity, and in those who have normal percent body fat and those who have excessive percent body fat. However, obese (BMI ≥30 kg/m^2) unfit individuals were at no higher risk for mortality when compared with obese fit individuals. The obese I and II group had relatively small sample sizes and fewer deaths; therefore, these results must be confirmed in larger studies. In addition, we observed that fit individuals who were obese (such as BMI, 30.0-34.9, or abdominal obesity, or excessive percent body fat) had a lower risk of all-cause mortality than did unfit, normal weight or lean individuals. Our data therefore suggest that fitness levels in older people influence the association of obesity to mortality.

There have been controversial results concerning the relationship between mortality and obesity in older adults. Some studies,[18,23,25] but not all,[19,21] have suggested lower mortality risk in heavier individuals. We found a J-shaped association between mortality and BMI computed from measured height and weight. The age, sex, and examination year adjusted mortality rate per 1000 person-years was the lowest in the overweight group, and the highest in the class II obesity group (Table 4). However, the multivariate (without fitness) adjusted model showed a non significant association (HR, 0.87; 95% CI, 0.70-1.07) with overweight compared with normal weight persons (Table 6, column 1). The fully adjusted model (including fitness) attenuated the quadratic trend (Table 6, column 2). Our findings are consistent with the report from Gale et al,[26] who also found no evidence of increased mortality risk in mildly to moderately overweight women and men aged 65 and over after adjusting for self-reported physical activity. Further joint analysis (Table 7) showed that in fit individuals the mortality risk was not significantly different across the 4 BMI categories, while in unfit individuals the mortality risk was J-shaped, with lower risk in those with BMI 25.0-34.9 and higher risk in those with BMI 18.5-24.9 and 35.0 or greater. These results support the hypothesis that moderate and higher fitness levels favorably influence mortality risk across categories of body composition. Normal weight individuals in our study had greater longevity only if they were physically fit; furthermore, obese individuals who were fit did not have elevated mortality. The quadratic trend across BMI in the unfit individuals deserves further comment. In general, unfit individuals were inactive and had low aerobic power at baseline, whereas fit individuals were highly active and had high aerobic power. In the elderly, BMI is also a marker of other factors such as fitness and muscle mass; therefore, maintaining BMI at older age is an overall marker of health.[17] This may be attributable to competing causes of mortality that become important factors with increasing age. It may also reflect selection factors that have allowed survival to older age.

In older populations, abdominal obesity, assessed by WC,[22-24] has been a better mortality predictor than BMI. Other indicators of adiposity, such as body fat, also have been examined for mortality associations.[26,27] However, the independent association between body fat and mortality in the older population has not been adequately demonstrated.[14,27]Researchers speculate that the controversial association between adiposity and mortality in older people may be attributable to selective survival, cohort effects, or unadjusted confounding.[41] We found that BMI or WC, but not percent body fat, predicted overall mortality in adults at least 60 years old. From a practical perspective, these findings suggest that more complicated and expensive body fat measurement does not provide an advantage in assessing mortality risk over more readily available and less expensive obesity measures such as BMI or WC. These findings also suggest that total adiposity per se may not be the factor that increases mortality risk among the elder. Rather, fat distribution and some other factor intrinsic to BMI (e.g., frame size) may underlay mortality risk in older adults. Further investigation of effects of various measures of adiposity on mortality in other elderly populations, and on the potential role of confounding and modifying variables, would contribute usefully to this research area.

Our results also support the hypothesis that higher levels of fitness can reduce the risk of premature death,[12,33,42,43] and expand the evidence supporting this relationship in obese older persons. In a prospective cohort of 18 750 male and 37 417 female Chinese ages 65 or older, Schooling et al.[17] recently reported that both physical activity and higher BMI were strongly associated with lower mortality in a dose-response manner. Our earlier ACLS report in older persons also demonstrated that lower fitness, an objective measure of functional capacity that is related to recent physical activity habits, is associated with higher risk of all-cause mortality.[37] However, neither our earlier report nor that by Schooling et al. assessed the joint associations of physical activity, BMI, and outcomes. In the current study, we found that fitness is a strong predictor of overall death among older adults, independent of body composition and other mortality risk factors. Additional studies are needed that concurrently evaluate the joint association among objective measures of fitness or activity, body size and fatness, and longevity in the rapidly growing older population.

Growing evidence suggests that skeletal muscle function (e.g., strength, power, endurance) may contribute to improved physical functioning and longevity through biological pathways that are related to but independent of aerobic fitness.[44,45] FFM was not a significant predictor of mortality risk in the present study. However, it is possible that the quality of FFM (e.g., functional phenotype) rather than the absolute amount of FFM is the key factor in determining health risk. We were unable to include in the present study an objective measure of muscle function in order to examine its independent and joint relationship with adiposity, fitness, and mortality risk. More data are needed to further explore the role of muscle function in successful aging and enhanced longevity among older adults.

Our study had several strengths. We used standardized and objective measurements of fitness and adiposity and examined their associations with mortality, providing quantitative risk estimates and a lower likelihood of misclassification on the exposure variables. We are unaware of any other report in which these data are available. The extensive baseline physical examination permitted systematic evaluation of the presence or absence of baseline medical conditions. The relatively long follow-up (average 12 years) was sufficient to accrue enough fatal endpoints to allow for assessing the joint association among risk factors and mortality within adiposity strata.

Limitations of the current study include a focus on participants who were primarily white and well-educated, with middle to upper socioeconomic status. The results may not apply to other groups of older adults. However, the homogeneity of our sample strengthens the internal validity of our findings by reducing potential confounding by unmeasured factors related to socioeconomic status, such as income, education, or prestige. Residual confounding from undetected subclinical disease at baseline may exist, although it seems unlikely that it would explain all of the observed association between fitness, adiposity, and mortality, especially given the extensive medical examination performed at baseline. The primary results were not changed meaningfully when deaths in the first 2 years of follow-up were excluded. We did not have adequate information about diet or medication use to study these factors. Physical activity was assessed by self-report on the standardized medical history/health habits questionnaire, and is likely to be a crude approximation of actual physical activity habits. We focused primarily on all-cause mortality because of the relatively small number of cause-specific deaths, which prevented us from stratifying cause-specific analyses by adiposity measures. However, we did some exploratory analyses on associations between fitness, BMI, WC, percent body fat, or FFM, and cause-specific mortality (data not shown). In the current study, CVD and cancer accounted for 74% of total deaths. After adjusting for age, sex, examination year, and current smoking, fitness was significantly associated with CVD, CHD, and cancer mortality (Linear P_{trend} <.05, for each). All adiposity exposures were associated with cancer mortality (P<.05, for each). Future studies should include these important exposures, and extend the analysis to these and other specific causes of death with particular interest to public health, such as CVD, CHD, stroke, diabetes mellitus, and cancer. Due to a limited sample of women, who contributed relatively few deaths to the analysis, we combined women and men for analyses, and adjusted the analyses for sex. In our previous reports on fitness in which we have been able to perform parallel analyses in men and women, results have generally been similar for women and men.[34,46] We only have a single baseline assessment on fitness, adiposity measurements, and other exposures, thus we can not examine whether changes in any of these variables occurred during follow-up, and whether this may have influenced the study results.

In conclusion, our prospective findings in adults ages 60 and over show that low fitness predicted higher all-cause mortality risk after adjustment for potential confounding factors including adiposity. Fit individuals had greater longevity than unfit individuals regardless of their body composition or fat distribution. Our data provide further evidence regarding the complex long-term relationship among fitness, body size, and survival. We may be able to reduce all-cause death rates among older adults, including those who are obese, by promoting regular physical activity, such as brisk walking for 30 minutes or more on most days of the week (about 8-kcal/kg per week), which will keep most individuals out of the low fitness category.[43] Enhancing functional capacity also should allow older adults to achieve a healthy lifestyle and to enjoy longer life in better health.

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Table 1

Baseline Characteristics by Vital Status in 2603 Older Adults- Aerobics Center Longitudinal Study, 1979-2003.

	All (n=2603)	Survivors (n=2153)	Decedents (n=450)
Female, No. (%)	516 (19.8)	464 (21.6)	52 (11.6)*
Age, mean (SD), y	64.4 (4.8)	64.2 (4.7)	65.7 (5.0)*
BMI, mean (SD), kg/m^2	26.3 (3.7)	26.4 (3.7)	26.2 (3.9)
Waist circumference, mean (SD), cm	90.3 (19.9)	90.4 (19.3)	90.3 (22.6)
Percent body fa†, mean (SD)	26.5 (5.4)	26.5 (5.4)	26.6 (5.6)
Fat free mass†, mean (SD), kg	58.4 (9.4)	58.4 (9.5)	58.5 (8.7)
Fat mass†, mean (SD), kg	21.6 (7.2)	21.5 (7.1)	21.8 (7.8)
Treadmill time, mean (SD), min	12.6 (4.8)	12.9 (4.7)	11.0 (4.8)*
Maximal METs, mean (SD)	9.1 (2.2)	9.3 (2.2)	8.4 (2.2)*
BMI-defined weight groups, No. (%)			
18.5-24.9	1020 (39.2)	828 (38.5)	192 (42.7)
25.0-29.9	1206 (46.3)	1010 (46.9)	196 (43.6)
30.0-34.9	316 (12.1)	266 (12.4)	50 (11.1)
≥35	61 (2.3)	49 (2.3)	12 (2.7)
Waist circumference ≥ 88 cm for women; ≥102 cm for men, No. (%)	643 (24.7)	528 (24.5)	115 (25.6)
Lipids, mean (SD), mmol/L			
Total cholesterol	5.6 (1.1)	5.6 (1.1)	5.7 (1.2)
HDL-C	1.3 (0.4)	1.3 (0.4)	1.2 (0.4)*
Triglycerides	1.5 (1.0)	1.5 (1.0)	1.6 (0.9)
Fasting blood glucose, mean (SD), mmol/L	5.9 (1.4)	5.9 (1.3)	6.0 (1.6)
Physically inactive, No. (%)	657 (25.2)	546 (25.4)	111 (24.7)
Current smoker, No. (%)	235 (9.0)	175 (8.1)	60 (13.3)*
Abnormal exercise ECG responses, No. (%)	532 (20.4)	405 (18.8)	127 (28.2)*
Metabolic syndrome‡, No. (%)	644 (24.7)	505 (23.5)	139 (30.9)*
Chronic medical condition§, No. (%)			
CVD	139 (5.3)	93 (4.3)	46 (10.2)*
Diabetes	266 (10.2)	212 (9.9)	54 (12.0)
Hypertension	1241 (47.7)	993 (46.1)	248 (55.1)*
Hypercholesterolemia	1034 (39.7)	881 (40.9)	153 (34.0)*

Abbreviations: BMI, body mass index; METs, maximal metabolic equivalents achieved during the treadmill test; ECG, electrocardiogram; SBP, systolic blood ressure; DBP, diastolic blood pressure; HDL-C, high density lipoprotein

*Difference between survivors and decedents was statistically significant (*P*<.05).

†Percent body fat, fat mass and fat free mass: n = 2584 (442 deaths)

‡Defined as the presence of ≥3 of the 5 metabolic risk factors based on NCEP ATP-III criteria

§Chronic medical condition was defined as the presence of hypercholesterolemia (history of physician diagnosed high cholesterol or measured fasting total cholesterol ≥ 240 mg/dL [6.20 mmol/L]) or diabetes (history of physician diagnosis, or use of insulin or measured fasting glucose ≥126 mg/dL [7.0 mmol/L]); or hypertension (history of physician diagnosis or resting SBP ≥140 mmHg or DBP ≥90 mmHg); or personal history of physician diagnosed CVD (MI or stroke).

Table 2

Baseline Characteristics According to Cardiorespiratory Fitness Categories in 2603 Older Adults- Aerobics Center Longitudinal Study, 1979-2003*.

	Cardiorespiratory Fitness Quintile (min)				
	Q1 (<8.7)	**Q2 (8.7-11.3)**	**Q3 (11.3-13.7)**	**Q4 (13.7-18.4)**	**Q5 (≥18.4)**
Female, No. (%)	57 (11.1)	93 (18.0)	83 (16.1)	134 (26.0)	149 (28.9)
Age, mean (SD), y	66.1 (5.0)	65.3 (5.0)	64.4 (4.8)	63.8 (3.9)	63.7 (5.0)
BMI, mean (SD), kg/m2	29.0 (4.9)	27.3 (3.9)	27.0 (3.4)	26.0 (3.2)	24.3 (2.6)
Waist circumference, mean (SD), cm	97.8 (23.5)	94.4 (18.0)	92.9 (19.8)	89.4 (18.9)	83.1 (18.1)
Percent body fat†, mean (SD)	29.9 (5.2)	28.5 (4.8)	27.6 (4.7)	26.3 (4.8)	23.1 (5.3)
Fat free mass†, mean (SD), kg	61.1 (10.5)	58.8 (9.8)	59.5 (9.0)	58.1 (8.9)	56.5 (9.0)
Fat mass†, mean (SD), kg	26.8 (9.2)	23.9 (7.0)	23.1 (6.5)	20.9 (5.9)	17.1 (5.3)
Treadmill time, mean (SD), min	5.4 (1.6)	8.7 (1.4)	11.3 (1.6)	13.7 (2.1)	18.4 (3.6)
Maximal METs, mean (SD)	5.8 (0.7)	7.4 (0.6)	8.5 (0.7)	9.7 (1.0)	11.8 (1.7)
BMI-defined weight groups, No. (%)					
18.5-24.9	64 (6.3)	123 (12.1)	153 (15.0)	259 (25.4)	421 (41.3)
25.0-29.9	121 (10.0)	225 (18.7)	293 (24.3)	348 (28.9)	219 (18.2)
30.0-34.9	73 (23.1)	85 (26.9)	89 (28.2)	58 (18.4)	11 (3.5)
≥35	33 (54.1)	15 (24.6)	9 (14.8)	3 (4.9)	1 (1.6)
Waist circumference ≥ 88 cm for women; ≥102 cm for men, No. (%)	148 (23.0)	172 (26.8)	166 (25.8)	128 (19.9)	29 (4.5)
Lipids, mean (SD), mmol/L					
Total cholesterol	5.8 (1.2)	5.6 (1.1)	5.7 (1.0)	5.6 (1.1)	5.5 (1.1)
HDL-C	1.2 (0.3)	1.2 (0.4)	1.2 (0.4)	1.3 (0.4)	1.4 (0.4)
Triglycerides	1.8 (1.1)	1.7 (1.0)	1.7 (1.1)	1.5 (0.9)	1.2 (0.6)
Fasting blood glucose, mean (SD), mmol/L	6.6 (2.4)	6.1 (1.7)	5.9 (1.2)	5.8 (1.10	5.6 (0.80
Physically inactive, No. (%)	142 (48.8)	179 (40.0)	165 (30.3)	113 (16.9)	58 (8.9)
Current smoker, No. (%)	43 (18.3)	55 (23.4)	54 (23.0)	50 (21.3)	33 (14.0)
Abnormal exercise ECG responses, No. (%)	90 (16.9)	122 (22.9)	116 (21.8)	116 (21.8)	88 (16.5)
Metabolic syndrome‡, No. (%)	130 (20.2)	159 (24.7)	166 (25.8)	142 (22.1)	47 (7.3)
Chronic medical condition§, No. (%)					
CVD	30 (21.6)	35 (25.2)	38 (27.3)	20 (14.4)	16 (11.5)

	Cardiorespiratory Fitness Quintile (min)				
	Q1 (<8.7)	**Q2 (8.7-11.3)**	**Q3 (11.3-13.7)**	**Q4 (13.7-18.4)**	**Q5 (≥18.4)**
Diabetes	66 (24.8)	54 (20.3)	57 (21.4)	58 (21.8)	31 (11.7)
Hypertension	167 (13.5)	245 (19.7)	278 (22.4)	305 (24.6)	246 (19.8)
Hypercholesterolemia	128 (12.4)	174 (16.8)	229 (22.2)	286 (27.7)	217 (21.0)

Abbreviations: BMI, body mass index; METs, maximal metabolic equivalents achieved during the treadmill test; ECG, electrocardiogram; SBP, systolic blood ressure; DBP, diastolic blood pressure; HDL-C, high density lipoprotein cholesterol; CVD, cardiovascular disease; MI, myocardial infarction.

[*] All the tests for linear trends across quintiles were significant (*P*<.05).

[†] Percent body fat, fat mass and fat free mass: n = 2584 (442 deaths)

[‡] Metabolic syndrome was defined as the presence of ≥3 of the 5 metabolic risk factors based on NCEP ATP-III criteria

[§] Chronic medical condition was defined as the presence of hypercholesterolemia (history of physician diagnosed high cholesterol or measured fasting total cholesterol ≥ 240 mg/dL [6.20 mmol/L]) or diabetes (history of physician diagnosis, or use of insulin or measured fasting glucose ≥126 mg/dL [7.0 mmol/L]); or hypertension (history of physician diagnosis or resting SBP ≥140 mmHg or DBP ≥90 mmHg); or personal history of physician diagnosed MI or stroke.

Table 3

Univariate Associations between Adiposity Measures and Treadmill Exercise Duration in 2603 Older Adults- Aerobics Center Longitudinal Study, 1979-2003

	Pearson		Correlation	Coefficients*		
	BMI	**Percent body fat**	**Fat mass**	**Fat free mass**	**WC**	**Treadmill test duration**
BMI (kg/m^2)	1.00	0.60	0.87	0.66	0.52	-0.30
Percent body fat		1.00	0.84	0.02	0.23	-0.50
Fat mass (kg)			1.00	0.54	0.48	-0.37
Fat free mass (kg)				1.00	0.55	-0.09
WC (cm)					1.00	-0.10
Treadmill test duration (min)						1.00

Abbreviations: BMI, body mass index; WC, waist circumference.

*P<.001, except coefficient comparing percent body fat and fat free mass.

Table 4

Risk of All-cause Mortality across Exposure Groups in 2603 Older Adults- Aerobics Center Longitudinal Study, 1979-2003.

	Person-years	Deaths	Rate* (per 1000)	HR (95% CI)*
BMI, kg/m^2				
Normal weight (18.5-24.9)	13 168	192	13.9	1.00 (referent)
Overweight (25.0-29.9)	14 412	196	13.3	0.95 (0.78-1.17)
Obese I (30.0-34.9)	3226	50	18.3	1.31 (0.96-1.80)
Obese II (≥35.0)	528	12	31.8	2.29 (1.27-4.12)
P-quadratic trend				.01
Percent body fat				
Normal (< 30.0 women; < 25.0 men)	13 859	180	13.7	1.00 (referent)
Abnormal (≥30.0 women; ≥ 25.0 men)	17 227	262	14.6	1.07 (0.88-1.30)
P-difference				.51
Fat free mass quintiles, kg				
< 50.6	6375	72	12.9	1.00 (referent)
50.6-57.0	6729	111	14.0	1.08 (0.73-1.60)
57.0-61.2	6612	95	12.7	0.99 (0.65-1.49)
61.2-66.0	5998	83	14.3	1.10 (0.72-1.68)
≥66.0	5366	81	17.9	1.38 (0.90-2.12)
P-Linear trend				.10
Waist circumference, cm				
Normal (<88.0 women; < 102.0 men)	24 402	335	13.3	1.00 (referent)
Abnormal (≥88.0 women; ≥ 102.0 men)	6925	115	18.2	1.37 (1.11-1.70)
P-difference				.004
Fitness quintiles† based on treadmill time, min				
<8.7	3381	106	32.6	1.00 (referent)
8.7-11.3	5690	98	16.6	0.51 (0.39-0.67)
11.3-13.7	6762	95	12.8	0.39 (0.30-0.52)
13.7-18.4	7729	90	12.3	0.38 (0.29-0.50)
≥18.4	7772	61	8.1	0.25 (0.18-0.34)
P-Linear trend				<.001
Age, y				
60-70	28 095	358	12.4	1.00 (referent)
70-80	2765	82	34.4	2.78 (2.18-3.54)
80+	464	10	15.7	1.27 (0.67-2.38)
P-Linear trend				<.001
Current smoker				
No	28 345	390	14.0	1.00 (referent)
Yes	2977	60	17.9	1.28 (0.97-1.69)
P-difference				.08
Abnormal exercise ECG responses				

	Person-years	**Deaths**	**Rate* (per 1000)**	**HR (95% CI)***
No	22 789	272	12.1	1.00 (referent)
Yes	8,550	178	20.4	1.64 (1.33-2.01)
P-difference				<.001
Chronic medical condition				
No	11689	119	12.0	1.00 (referent)
Yes	19 645	279	17.7	1.48 (1.19-1.84)
P-difference				<.001

Abbreviations: BMI, body mass index; Fitness, cardiorespiratory fitness; ECG, electrocardiogram.

*Rates per 1000 person-years and HRs are adjusted for age, sex, and examination year.

†Quintiles of fitness were based on the distribution of treadmill exercise duration standardized to the 60+ yr age group in the overall ACLS population of women and men. The tabulated values reflect the average value for the women and men included in this analysis. MET levels of fitness associated with each quintile were <7.4, 7.4-8.5, 8.5-9.7, 9.7-11.8, and ≥11.8.

Table 5

Risk of All-cause Mortality According Cardiorespiratory Fitness (Fitness) Categories - Aerobics Center Longitudinal Study, 1979-2003.

	HR (95% CI)*	**HR (95% CI)†**	**HR (95% CI)‡**	**HR (95% CI)§**	**HR (95% CI)//**
Fitness quintiles					
Q1	1.00	1.00	1.00	1.00	1.00
Q2	0.53 (0.40-0.70)	0.51 (0.39-0.68)	0.52 (0.40-0.69)	0.53 (0.40-0.71)	0.54 (0.41-0.72)
Q3	0.44 (0.33-0.58)	0.42 (0.31-0.56)	0.43 (0.32-0.57)	0.43 (0.32-0.57)	0.44 (0.33-0.59)
Q4	0.43 (0.32-0.58)	0.40 (0.30-0.55)	0.42 (0.31-0.56)	0.41 (0.31-0.56)	0.44 (0.33-0.59)
Q5	0.30 (0.22-0.42)	0.27 (0.19-0.39)	0.29 (0.21-0.40)	0.27 (0.19-0.39)	0.31 (0.22-0.43)
P for linear trend	<.001	<.001	<.001	<.001	<.001

Abbreviations: Fitness, cardiorespiratory fitness; HR, hazard ratio; CI, confidence interval; CVD, cardiovascular disease.

* adjusted for covariables: age, sex, examination year, smoking status, abnormal exercise electrocardiogram responses, and baseline health conditions (CVD, hypertension, diabetes, hypercholesterolemia, present or not for each).

† adjusted for covariables plus body mass index

‡ adjusted for covariables plus waist circumference

§ adjusted for covariables plus percent body fat

// adjusted for covariables plus fat free mass

Table 6

Risk of All-cause Mortality According Adiposity Measures- Aerobics Center Longitudinal Study, 1979-2003.

Adiposity Measures	HR (95% CI)*	HR (95% CI) †
Body Mass Index		
Normal weight	1.00	1.00
Overweight	0.87 (0.70-1.07)	0.72 (0.58-0.89)
Obese I	1.11 (0.80-1.53)	0.76 (0.54-1.07)
Obese II	1.98 (1.09-3.61)	1.11 (0.60-2.05)
P for quadratic trend	.004	.005
WC		
Normal	1.00	1.00
Abdominal obesity	1.25 (1.00-1.56)	0.99 (0.79-1.25)
P for difference	.05	.95
Percent body fat		
Normal	1.00	1.00
Obese	1.03 (0.85-1.25)	0.83 (0.67-1.01)
P for difference	.78	.07
Fat free mass quintiles		
Q1	1.00	1.00
Q2	1.04 (0.70-1.53)	1.01 (0.69-1.49)
Q3	0.92 (0.61-1.38)	0.86 (0.57-1.28)
Q4	1.01 (0.66-1.54)	0.90 (0.59-1.37)
Q5	1.21 (0.79-1.86)	1.02 (0.66-1.57)
P for linear trend	.36	.91

Abbreviations: HR, hazard ratio; CI, confidence interval; WC, waist circumference.

Body mass index, WC and percent body fat, fat free mass groupings are the same as in Table 3.

* adjusted for covariables: age, sex, examination year, smoking status, abnormal exercise electrocardiogram responses, and baseline health conditions (CVD, hypertension, diabetes, hypercholesterolemia, present or not for each).

† adjusted for covariables plus cardiorespiratory fitness

Table 7

Joint Associations of Cardiorespiratory fitness (Fitness) and Adiposity Exposures with All-cause Mortality-Aerobics Center Longitudinal Study, 1979-2003.*

	Fit			Unfit			
	No. of death	**Rates†**	**HR (95% CI)‡**	**No. of death**	**Rates†**	**HR (95% CI)‡**	***P* Value**
BMI, kg/m^2							
18.5-24.9	158	1.2	1.00 (referent)	34	4.9	3.63 (2.47-5.32)	<.001
25.0-29.9	152	1.2	0.88 (0.70-1.11)	44	2.7	1.74 (1.23-2.46)	<.001
30.0-34.9	32	1.6	1.12 (0.76-1.66)	18	2.5	1.68 (1.02-2.78)	.46
≥35.0	2	1.2	0.86 (0.21-3.50)	10	4.8	3.35 (1.74-6.44)	.05
WC, cm							
<88.0 (women); < 102.0 (men)	274	5.1	1.00 (referent)	61	14.5	2.84 (2.15-3.75)	<.001
≥88.0 (women); ≥ 102.0 (men)	70	6.2	1.21 (0.93-1.58)	45	13.5	2.65 (1.93-3.63)	<.001
Percent body fat							
<30.0 (women); < 25.0 (men)	151	9.1	1.00 (referent)	29	26.8	2.94 (1.97-4.38)	<.001
≥30.0 (women); ≥ 25.0 (men)	190	8.7	0.96 (0.78-1.19)	72	21.8	2.39 (1.81-3.16)	<.001

Abbreviations: Fitness, cardiorespiratory fitness; BMI, body mass index; WC, waist circumference; HR, hazard ratio; CI, confidence interval; CVD, cardiovascular isease.

*Cross-product tests of interaction between Fitness and adiposity exposures were not statistically significant: Fitness-BMI (df=1, X^2 = 0.05, *P* = .82); Fitness-WC (df=1, X^2 = 1.38, *P* = .24); Fitness-percent fat (df=1, X^2 = 0.04, *P* = .84).

†All-cause death rates per 1000 person-years adjusted for age, sex, and examination year.

‡Adjusted for age, sex, examination year, smoking status, abnormal exercise electrocardiogram responses, and baseline health conditions (CVD, hypertension, diabetes, hypercholesterolemia, present or not for each).