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Leisure-Time Running Reduces All-Cause and Cardiovascular Mortality Risk

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ABSTRACT

BACKGROUND Although running is a popular leisure-time physical activity, little is known about the long-term effects of running on mortality. The dose-response relations between running, as well as the change in running behaviors over time, and mortality remain uncertain.

OBJECTIVES We examined the associations of running with all-cause and cardiovascular mortality risks in 55,137 adults, 18 to 100 years of age (mean age 44 years).

METHODS Running was assessed on a medical history questionnaire by leisure-time activity.

RESULTS During a mean follow-up of 15 years, 3,413 all-cause and 1,217 cardiovascular deaths occurred. Approximately 24% of adults participated in running in this population. Compared with nonrunners, runners had 30% and 45% lower adjusted risks of all-cause and cardiovascular mortality, respectively, with a 3-year life expectancy benefit. In dose-response analyses, the mortality benefits in runners were similar across quintiles of running time, distance, frequency, amount, and speed, compared with nonrunners. Weekly running even <51 min, <6 miles, 1 to 2 times, <506 metabolic equivalent-minutes, or <6 miles/h was sufficient to reduce risk of mortality, compared with not running. In the analyses of change in running behaviors and mortality, persistent runners had the most significant benefits, with 29% and 50% lower risks of all-cause and cardiovascular mortality, respectively, compared with never-runners.

CONCLUSIONS Running, even 5 to 10 min/day and at slow speeds <6 miles/h, is associated with markedly reduced risks of death from all causes and cardiovascular disease. This study may motivate healthy but sedentary individuals to begin and continue running for substantial and attainable mortality benefits. (J Am Coll Cardiol 2014;64:472–81)

Running is a popular and convenient leisure-time physical activity with a consistent growth, despite some public concerns about the possible harmful effects of running (1). It is well established that physical activity has substantial health benefits. The World Health Organization and the U.S. government have recently released evidence-based Physical Activity Guidelines, recommending at least 150 min of moderate-intensity or 75 min of vigorous-intensity aerobic activity per week, or an equivalent combination of both (2,3).

SEE PAGE 482

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However, compared with the compelling evidence on moderate-intensity activity and health (4), it is unclear whether there are health benefits to vigorous-intensity activity, such as running, for <75 min per week.

This study was conducted to investigate whether leisure-time running is associated with all-cause and cardiovascular disease (CVD) mortality risks, whether there is a dose-response relation between running and mortality, and whether different patterns of change in running behaviors are associated with mortality.

METHODS

STUDY POPULATION. The Aerobics Center Longitudinal Study is a prospective, observational cohort study designed to examine the effects of physical activity and fitness on various health outcomes. Participants are self-referred or are referred by their employers or physicians for periodic preventive medical examinations at the Cooper Clinic in Dallas, Texas. This cohort is primarily college-educated, non-Hispanic white adults from middle to upper socioeconomic strata (5). The current study participants were men and women 18 to 100 years of age (mean age 44 years) at baseline who received at least 1 extensive medical examination between 1974 and 2002. Among 60,603 participants, we excluded 3,294 individuals reporting myocardial infarction (MI), stroke, or cancer at baseline and 2,172 individuals with <1 year of mortality follow-up to minimize potential bias due to serious undetected underlying diseases on mortality. The final sample included 55,137 individuals (26% women) for analysis of all-cause mortality and 52,941 individuals for analysis of CVD mortality, after 2,196 individuals who died from causes other than CVD were excluded. The Cooper Institute Institutional Review Board reviewed and approved the study annually. All participants gave written informed consent for the examinations and follow-up study.

ASSESSMENT OF RUNNING. Running or jogging activity during the past 3 months was assessed at baseline by the physical activity questionnaire, including 4 questions about duration, distance, frequency, and speed as part of the medical examination. For calculation of the total weekly running time, the average duration of running was multiplied by the frequency. For calculation of the total amount of running, the metabolic equivalent (MET) value for a given speed was multiplied by the weekly running time (6). Participants were classified into 6 groups: nonrunners and 5 quintiles of weekly running time (minutes), distance (miles), frequency (times), amount (MET-minutes), and speed (miles/h) in runners. For complete analyses of running characteristics and mortality, we defined runners as those who reported all 4 detailed running questions and nonrunners as those who did not report any running questions. We also examined the associations between change in running behaviors and mortality in a subgroup of 20,647 participants from the overall sample of 60,603 who received at least 2 medical examinations between 1974 and 2002 and were free from MI, stroke, or cancer at both examinations. We defined 4 categories of change in running behaviors using the baseline and last follow-up examination: "remained nonrunners" were nonrunners at both examinations, "became nonrunners" were runners only at the baseline examination, "became runners" were runners only at the last examination, and "remained runners" were runners at both examinations. Total amount of other physical activities except running (cycling, swimming, walking, basketball, racquet sports, aerobic dance, and other sports-related activities) was classified into 3 groups: 0, 1 to 499, and ≥500 MET-minutes per week based on the Physical Activity Guidelines (3). To reduce confounding bias in the association between running and mortality, the total amount of other physical activities except running was adjusted in all multivariable regression models. Our physical activity assessment has been described elsewhere (7) and was formerly validated and shown to correlate to measured cardiorespiratory fitness and physiological variables (5,8).

ABBREVIATIONS AND ACRONYMS

BMI = body mass index

CVD = cardiovascular disease

MET = metabolic equivalent

PAF = population attributable fraction

CLINICAL EXAMINATION. Physicians conducted comprehensive examinations. Resting blood pressure was recorded using the standard auscultation method. Blood glucose and cholesterol were analyzed using automated bioassays after ≥12 h of overnight fast. Body mass index (BMI) was calculated from measured weight and height (kg/m^2). Cardiorespiratory fitness was assessed using a maximal treadmill exercise test (9). Standardized medical questionnaires were used to assess health behaviors (smoking, alcohol consumption, and leisure-time physical activity), physician-diagnosed medical conditions, and parental history of CVD.

MORTALITY SURVEILLANCE. Participants were followed for mortality from the baseline examination through the date of death for decedents or December 31, 2003, for survivors using the National Death Index. For the analysis of change in running behaviors and mortality, we followed for mortality from the last follow-up examination through the date of death or 2003. Death from CVD was defined by the International Classification of Diseases-9th edition (ICD-9) codes 390-449.9 and ICD-10 Revision codes I00-I78.

STATISTICAL ANALYSIS. Multivariable Cox proportional hazard models were used to estimate hazard ratios (HRs) and 95% CI of mortality across running categories. Population attributable fractions (PAFs) and survival differences for running and other mortality predictors determined by the baseline assessment were estimated, as described by Bruzzi et al. (10) and using the risk advancement period approach (11). We tested effect modification by sex on the associations between running and mortality using interaction terms in the regressions and by comparing risk estimates in the sex-stratified analyses. Based on no significant interactions observed, pooled analyses were performed. The proportional hazard assumptions were satisfied by comparing the log-log survival plots. SAS software (SAS Institute, Inc., Cary, North Carolina) was used for all analyses, and 2-sided p values <0.05 were deemed significant.

RESULTS

There were 3,413 all-cause deaths and 1,217 CVD deaths during the mean (interquartile range) follow-up of 14.7 (6.5 to 21.7) years and 14.6 (6.3 to 21.8) years, respectively. At baseline, runners were more likely to be men, younger, and leaner; were less likely to smoke and participate in other types of physical activities; had lower prevalence of chronic diseases; and had higher cardiorespiratory fitness levels (**Table 1**).

Compared with nonrunners, runners had 30% and 45% lower risks of all-cause and CVD mortality, respectively, after adjustment for potential confounders (**Fig. 1**). These associations were consistent regardless of sex, age, BMI, health conditions, smoking status, and alcohol consumption. We estimated PAFs for running and other mortality predictors, such as smoking, overweight/obesity, and

TABLE 1 Population Characteristics by Quintile of Weekly Running Time

Characteristic	Nonrunners (0)	Quintile of Running Time (min/week): 1 (<51)	2 (51–80)	3 (81–119)	4 (120–175)	5 (≥176)
Female	29.1	12.4	15.5	14.4	15.9	17.9
Age, yrs	45 ± 11	40 ± 9	41 ± 9	42 ± 9	42 ± 9	43 ± 9
Body mass index, kg/m^2*	26.3 ± 4.7	25.2 ± 3.2	25.0 ± 3.2	24.8 ± 3.0	24.6 ± 3.1	23.9 ± 2.9
<25.0	42.3	49.9	53.1	55.4	58.1	67.9
25.0–29.9	40.6	42.6	40.3	39.2	36.4	28.8
≥30.0	17.1	7.5	6.6	5.4	5.5	3.3
Smoking status						
Never	53.9	58.1	54.8	54.1	55.5	54.5
Former	27.3	29.0	32.8	35.4	36.1	38.5
Current	18.8	12.9	12.4	10.5	8.4	7.0
Heavy alcohol drinking†	17.2	19.3	18.2	19.2	18.4	17.9
Total amount of other physical activities except running (MET-min/week)‡						
0	59.0	61.6	69.1	72.4	71.8	72.1
1–499	16.6	11.2	9.9	8.6	8.3	6.6
≥500	24.4	27.2	21.0	19.0	19.9	21.3
Systolic blood pressure, mm Hg	120 ± 15	118 ± 13	119 ± 14	119 ± 14	120 ± 14	120 ± 14
Diastolic blood pressure, mm Hg	81 ± 10	79 ± 9	79 ± 10	79 ± 9	79 ± 9	79 ± 9
Hypertension§	31.6	22.1	22.9	24.0	24.2	23.9
Fasting glucose, mg/dl	99.7 ± 19.1	97.1 ± 11.8	97.5 ± 13.0	97.3 ± 11.8	97.2 ± 11.6	97.0 ± 10.6
Diabetes‖	6.2	3.4	3.3	2.8	3.0	2.9
Total cholesterol, mg/dl	208.5 ± 40.8	200.3 ± 38.4	201.3 ± 38.9	201.7 ± 38.1	200.3 ± 38.4	199.2 ± 37.8
Hypercholesterolemia¶	29.3	20.8	21.1	21.5	21.5	19.6
Abnormal electrocardiogram#	8.7	4.9	4.8	5.1	4.5	5.8
Parental cardiovascular disease	27.6	23.0	23.5	26.2	27.5	27.4
Cardiorespiratory fitness (maximal METs)**	10.2 ± 2.2	12.5 ± 1.9	12.8 ± 2.0	13.2 ± 2.1	13.6 ± 2.2	14.6 ± 2.6

Values are mean ± SD or %. *Calculated as the weight in kg divided by the square of the height in m. †Defined as >14 and >7 alcohol drinks per week for men and women, respectively. ‡Total physical activity levels from other leisure-time activities except running. §Defined as systolic or diastolic blood pressure ≥140/90 mm Hg or history of physician diagnosis. ‖Defined as fasting glucose ≥126 mg/dl, current therapy with insulin, or history of physician diagnosis. ¶Defined as total cholesterol ≥240 mg/dl or history of physician diagnosis. #Defined as abnormal resting or exercise electrocardiogram, including rhythm and conduction disturbances and ischemic ST-T wave abnormalities. **Estimated from the final treadmill speed and grade during the maximal exercise test in a subsample of 50,995 participants.

MET = metabolic equivalent.

chronic diseases. Not running was almost as important as hypertension, accounting for 16% of all-cause and 25% of CVD mortality (Table 2). Also, nonrunners had 3 years' lower life expectancy compared with runners after adjustment for other mortality predictors.

In the dose-response analyses (Table 3), runners across all 5 quintiles of weekly running time, even the lowest quintile of <51 min/week had lower risks of all-cause and CVD mortality compared with nonrunners. However, these mortality benefits were similar between lower and higher doses of weekly running time. In fact, among runners (after nonrunners were excluded in the analyses), there were no significant differences in HRs of all-cause and CVD mortality across quintiles of weekly running time (all p values >0.10). In additional analyses using weekly running times of <60, 60 to 119, 120 to 179, and ≥180 min, we found similar trends with the corresponding HRs of 0.73 (95% CI: 0.61 to 0.86), 0.65 (95% CI: 0.56 to 0.75), 0.71 (95% CI: 0.59 to 0.86), and 0.76 (95% CI: 0.63 to 0.92) for all-cause mortality and 0.46 (95% CI: 0.33 to 0.65), 0.56 (95% CI: 0.43 to 0.73), 0.54 (95% CI: 0.38 to 0.77), and 0.65 (95% CI: 0.46 to 0.92) for CVD mortality, respectively, compared with nonrunners after adjustment for confounders included in model 2. All analyses were adjusted for total physical activity levels achieved by other leisure-time activities besides running (model 2). When we excluded individuals who reported participating in other activities besides running (39%), similar associations between weekly running time and mortality were found (all p values <0.05). Furthermore, we adjusted for possible intermediate variables, such as BMI and medical conditions, on the causal pathway between running and mortality (model 3). The associations were attenuated but remained significant at the lower levels of running time. However, to avoid overadjustment for intermediate variables, we did not adjust for those intermediate variables in the models for other analyses.

Runners across all quintiles of other running characteristics had lower risks of all-cause mortality compared with nonrunners (Fig. 2). Even the lowest quintiles of weekly running distance (<6 miles), frequency (1 to 2 times), amount (<506 MET-minutes), and speed (<6 miles/h) had significantly lower risks of all-cause mortality compared with not running. Similar trends were observed with the risk of CVD mortality.

Among 20,647 individuals who received 2 medical examinations over a mean (interquartile range) interval of 5.9 (1.5 to 8.5) years, 65% of participants remained nonrunners, 14% stopped running, 8% started running, and 13% continued running, indicating that the more consistent group was the inactive nonrunners. Compared with never-runners (nonrunners at both examinations), runners at 1 or both examinations were more likely to have lower mortality risk (Fig. 3). Persistent runners over an

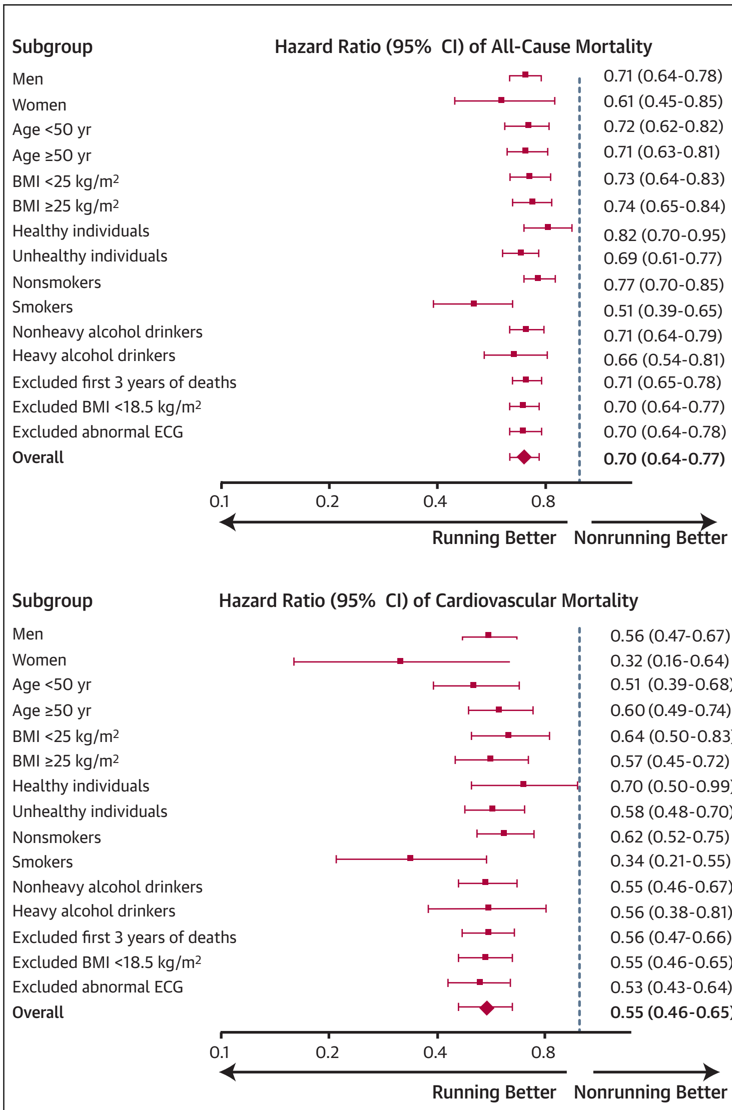


FIGURE 1 HRs of All-Cause and Cardiovascular Mortality by Subgroup

The reference group for all analyses includes nonrunners. All hazard ratios (HRs) were adjusted for baseline age (years), sex (not in sex-stratified analyses), examination year, smoking status (never, former, or current [not in smoking-stratified analyses]), alcohol consumption (heavy drinker or not [not in alcohol drinking-stratified analyses]), other physical activities except running (0, 1 to 499, or ≥500 MET-min/week), and parental cardiovascular disease (yes or no). Unhealthy was defined as the presence of 1 or more of the following health conditions: abnormal electrocardiogram (ECG), hypertension, diabetes, or hypercholesterolemia. Heavy alcohol drinking was defined as >14 and >7 drinks per week for men and women, respectively. BMI = body mass index.

JACC VOL. 64, NO. 5, 2014
AUGUST 5, 2014:472–81

TABLE 2 HRs, PAFs, and Estimated Decreased Life Expectancy by Running and Other Mortality Predictors

	All-Cause Mortality*			Cardiovascular Mortality*		
Mortality Predictor	HR (95% CI)	PAF, %†	Decreased Life Expectancy, yrs‡	HR (95% CI)	PAF, %†	Decreased Life Expectancy, yrs‡
Nonrunner	1.24 (1.13–1.37)	16	3.0	1.40 (1.18–1.66)	25	4.1
Current smoker	1.67 (1.54–1.80)	11	7.0	1.69 (1.49–1.92)	12	6.3
Overweight or obesity	1.16 (1.08–1.25)	8	2.0	1.43 (1.26–1.63)	20	4.4
Parental CVD	1.20 (1.12–1.29)	7	2.5	1.38 (1.23–1.54)	13	3.9
Abnormal ECG	1.55 (1.42–1.70)	7	6.0	2.43 (2.14–2.77)	17	10.7
Hypertension	1.46 (1.36–1.57)	15	5.2	1.94 (1.72–2.18)	28	8.0
Diabetes	1.36 (1.23–1.51)	3	4.2	1.53 (1.31–1.79)	6	5.1
Hypercholesterolemia	1.06 (0.98–1.13)	2	0.7	1.32 (1.18–1.48)	10	3.4

*Hazard ratios (HRs), population attributable fractions (PAFs), and decreased life expectancy were adjusted for baseline age (years), sex, examination year, and all other mortality predictors in the table. The reference category for each HR and PAF analysis includes individuals who did not have the particular mortality predictor. †PAF was computed as $P_c(1 - 1/HR_{adj})$, for which P_c is the prevalence of the mortality predictor among mortality cases and HR_{adj} is the multivariable HR for mortality associated with the specified mortality predictor. P_c (ordered as listed in the table) was 83.7, 28.4, 59.6, 40.9, 19.0, 47.4, 12.6, and 33.9 for all-cause mortality and 86.7, 28.4, 66.7, 46.2, 29.2, 58.0, 16.6, and 41.6 for cardiovascular mortality. ‡Decreased life expectancy was compared by beta coefficients for mortality associated with each year of age, with the beta coefficient difference in mortality for each mortality predictor using the multivariable Cox proportional hazards model.

CVD = cardiovascular disease; ECG = electrocardiogram.

average of 5.9 years, however, had the most significant mortality benefit, with 29% and 50% lower risk of all-cause and CVD mortality, respectively.

DISCUSSION

There were 3 major findings from this study (**Central Illustration**). First, runners had consistently lower risk of all-cause and CVD mortality compared with nonrunners. Second, running even at lower doses or slower speeds was associated with significant mortality benefits. Third, persistent running over time was more strongly associated with mortality reduction.

An earlier study found a 39% lower risk of all-cause mortality in 538 runners who were ≥50 years of age

TABLE 3 HRs of All-Cause and Cardiovascular Mortality by Quintile of Weekly Running Time

		Quintile of Running Time, min/week				
Group	Nonrunners (0)	1 (<51)	2 (51–80)	3 (81–119)	4 (120–175)	5 (≥176)
All-cause mortality						
No. of participants	42,121	2,710	2,584	2,505	2,647	2,570
No. of deaths	2,857	110	116	103	112	115
Person-yrs of follow-up	602,752	41,653	42,197	41,082	40,473	40,426
Death rate*	45.9	31.7	29.7	29.8	31.5	33.8
Adjusted HR (95% CI)						
Model 1†	1.00	0.69 (0.57–0.83)	0.65 (0.54–0.78)	0.65 (0.53–0.79)	0.69 (0.57–0.83)	0.74 (0.61–0.89)
Model 2‡	1.00	0.70 (0.58–0.85)	0.67 (0.55–0.80)	0.67 (0.55–0.82)	0.71 (0.58–0.86)	0.77 (0.63–0.92)
Model 3§	1.00	0.80 (0.66–0.97)	0.76 (0.63–0.91)	0.78 (0.64–0.95)	0.84 (0.69–1.02)	0.89 (0.74–1.07)
Cardiovascular mortality						
No. of participants	40,319	2,628	2,501	2,435	2,567	2,491
No. of deaths	1,055	28	33	33	32	36
Person-yrs of follow-up	575,352	40,497	40,766	39,983	39,275	39,233
Death rate*	17.8	8.0	9.0	10.3	9.1	11.6
Adjusted HR (95% CI)						
Model 1†	1.00	0.45 (0.31–0.66)	0.50 (0.36–0.71)	0.58 (0.41–0.82)	0.51 (0.36–0.72)	0.65 (0.46–0.91)
Model 2‡	1.00	0.45 (0.31–0.66)	0.52 (0.37–0.73)	0.60 (0.42–0.84)	0.53 (0.37–0.75)	0.67 (0.48–0.93)
Model 3§	1.00	0.59 (0.40–0.86)	0.67 (0.47–0.95)	0.82 (0.58–1.16)	0.78 (0.54–1.11)	0.86 (0.62–1.21)

*Death rate per 10,000 person-years adjusted for baseline age, sex, and examination year. †Model 1 was adjusted for baseline age (years), sex, and examination year. ‡Model 2 was adjusted for model 1 plus smoking status (never, former, or current), alcohol consumption (heavy drinker or not), other physical activities except running (0, 1 to 499, or ≥500 MET-minutes per week), and parental CVD (yes or no). §Model 3 was adjusted for model 2 plus body mass index (kg/m^2) and presence or absence of abnormal electrocardiogram, hypertension, diabetes, and hypercholesterolemia.

from the Runners Association database compared with 423 matched nonrunners from the Lipid Research Clinics database after adjustment for baseline age, sex, and functional ability (12). In our subsample of runners ≥50 years of age, we found 29% lower mortality risk, compared with nonrunners. The somewhat greater mortality benefits of running in the earlier study may be because runners from a running club were more likely to be health conscious, and physical activities other than running were not adjusted for in the analyses.

Recently, the Copenhagen City Heart Study found similar mortality benefits in 1,878 joggers, compared with nonjoggers after adjustment for a similar set of confounders used in our analyses (13). In their dose-response analysis, they observed a U-shaped relation between jogging time and mortality. Compared with no jogging, weekly jogging <150 min was associated with mortality reduction; however, ≥150 min of weekly jogging did not show significant mortality benefits, due to the small numbers of deaths and wide confidence intervals in that category. In our current study of more than 13,000 runners, we used quintiles of weekly running time to have an equal number of participants across different doses of running. We found a lower mortality risk in running >150 min/week. However, mortality benefits were slightly less at the highest quintile of weekly running time of ≥176 min/week. Several studies have suggested slightly lower or no mortality benefit at higher doses of vigorous-intensity activities. The Harvard Alumni Study reported a slightly higher death rate in individuals who participated in vigorous sports for ≥180 min/week compared with <180 min/week (14).

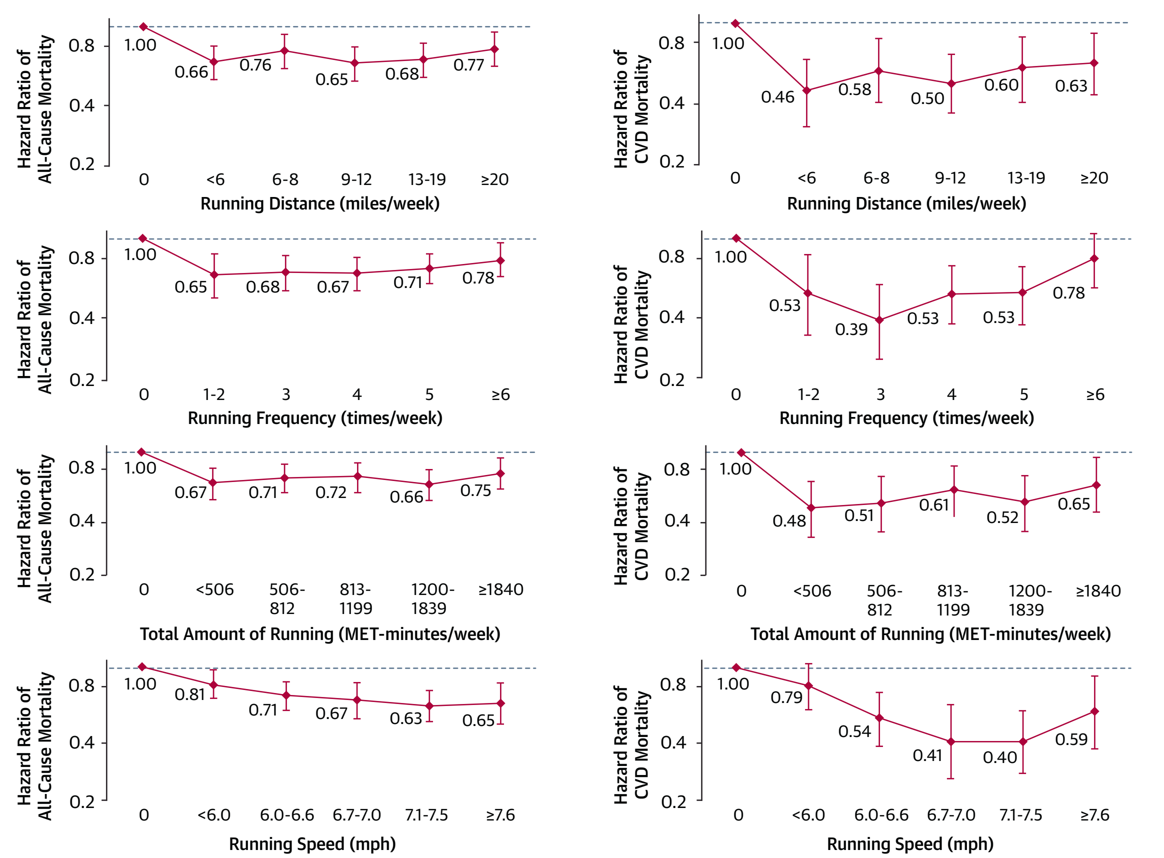


FIGURE 2 HRs of All-Cause and Cardiovascular Mortality by Running Distance, Frequency, Total Amount, and Speed

Participants were classified into 6 groups: nonrunners and 5 quintiles of each running distance, frequency, total amount, and speed. All hazard ratios (HRs) were adjusted for baseline age (years), sex, examination year, smoking status (never, former, or current), alcohol consumption (heavy drinker or not), other physical activities except running (0, 1 to 499, or ≥500 MET-min/week), and parental cardiovascular disease (CVD) (yes or no). The **bars** indicate 95% CI, and HRs are shown next to the **bars**. MET = metabolic equivalent.

JACC VOL. 64, NO. 5, 2014
AUGUST 5, 2014:472–81

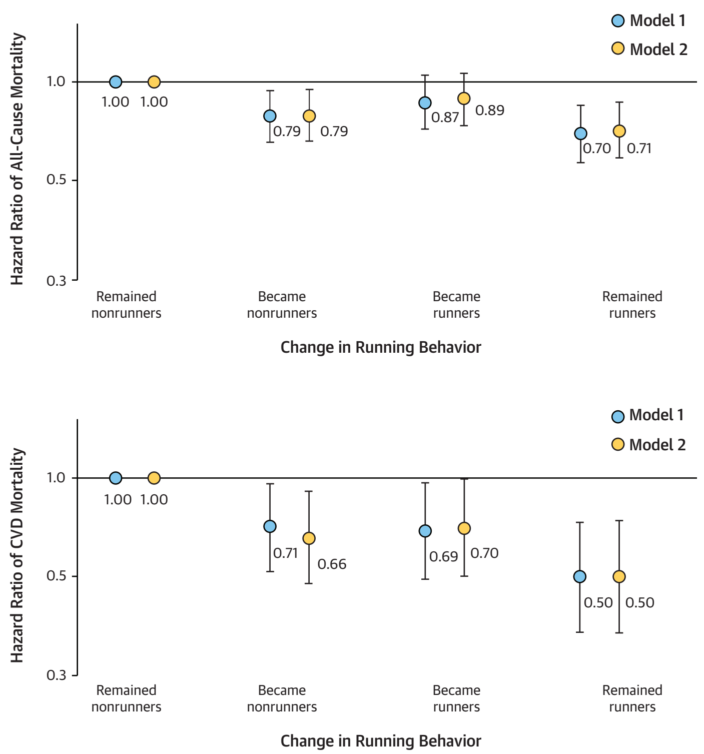


FIGURE 3 HRs of All-Cause and Cardiovascular Mortality by Change in Running Behaviors

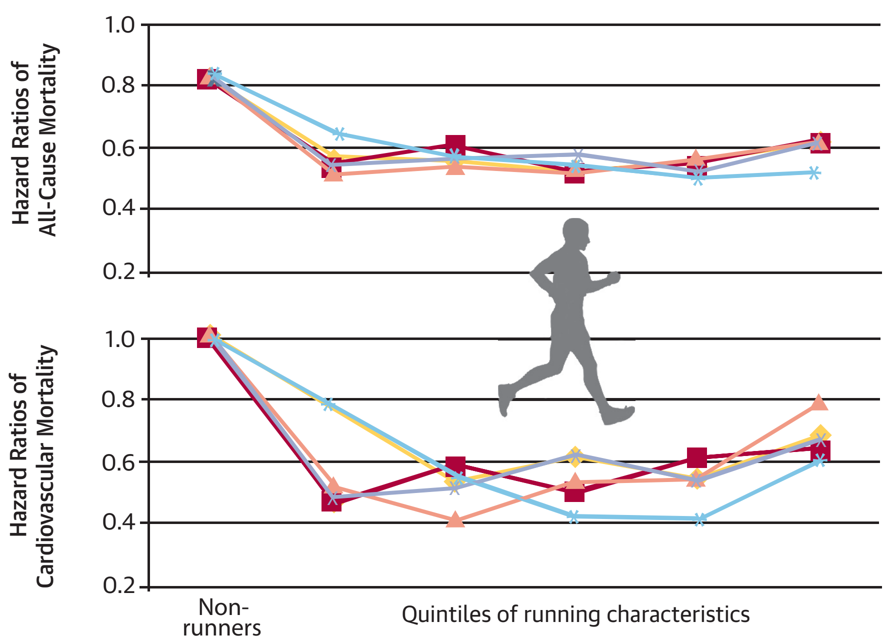
Model 1 was adjusted for baseline age (years), sex, examination year, and interval between the baseline and last examinations (years). Model 2 was adjusted for model 1 plus baseline smoking status (never, former, or current), alcohol consumption (heavy drinker or not), other physical activities except running (0, 1 to 499, or ≥500 MET-min/week), and parental cardiovascular disease (CVD; yes or no). The number of participants (deaths) in remained nonrunners, became nonrunners, became runners, and remained runners were 13,522 (1,013), 2,847 (141), 1,578 (131), and 2,700 (113) for all-cause mortality and 12,885 (376), 2,753 (47), 1,485 (38), and 2,616 (29) for cardiovascular mortality, respectively. The bars indicate 95% CI, and HRs are shown next to the **bars**.

A large study of 416,175 adults found no additional mortality benefits for >50 min/day of vigorous-intensity activities (15). Recent studies have proposed that excessive endurance sports may potentially induce adverse cardiovascular effects, such as arrhythmias and myocardial damage (16–19). In contrast, there are studies showing a linear dose-response relation between running and CVD risk, with more benefits at higher doses of running (20,21). Thus, future studies are needed on this dose-response issue about whether there is an optimum upper limit of vigorous-intensity activities, beyond which additional activity provides no further mortality benefits.

Another short report from the Copenhagen City Heart Study suggested a reduced mortality risk in 96 persistent male joggers (22). Our study now suggests that even less persistent runners (runners at 1 of the 2 examinations over 5.9 years of interval) appeared to have some mortality benefits compared with never-runners. However, persistent runners had the most mortality benefit.

Current physical activity guidelines recommend a minimum of 75 min/week of vigorous-intensity aerobic activity such as running for health benefits (2,3). However, we found mortality benefits with even <75 min/week of running. In additional analyses, we found that a minimum of 30 to 59 min/week of running (5 to 10 min/day) was associated with lower risks of all-cause (HR: 0.72; 95% CI: 0.59 to 0.88) and CVD mortality (HR: 0.42; 95% CI: 0.28 to 0.63), compared with no running. Several large studies have also suggested mortality benefits for <75 min/week of vigorous-intensity aerobic activities (15,21,23,24). This finding has clinical and public health importance. Because time is one of the strongest barriers to participate in physical activity, this study may motivate more people to start running and continue to run as an attainable health goal for mortality benefits. Compared with moderate-intensity activity, vigorous-intensity activity, such as running, may be a better option for time efficiency, producing similar, if not greater, mortality benefits in 5 to 10 min/day in many healthy but sedentary individuals who may find 15 to 20 min/day of moderate-intensity activity too time consuming. However, for the majority of the population who are inactive and may not want to participate in running as a daily routine, a progressive transitional phase (for example, starting with walking) may be useful to reduce injury risk. In the context of population mortality burden, we found that if all nonrunners became runners in this population, 16% of all-cause deaths and 25% of CVD deaths would be prevented, based on the estimation of PAFs. Because several studies reported acute MI or sudden cardiac death during running races, we examined the long-term effects of running on coronary heart disease mortality and sudden cardiac death. Compared with nonrunners, runners had 45% lower risk of coronary heart disease mortality (HR: 0.55; 95% CI: 0.44 to 0.69), after adjustment for potential confounders. In addition, the sudden cardiac death rate was approximately half in runners compared with nonrunners (1.5 vs. 0.7 per 10,000 person-years). Furthermore, runners had a 40% lower risk of stroke mortality (HR: 0.60; 95% CI: 0.39 to 0.92), compared with nonrunners after adjustment for confounders.

Several randomized controlled trials have reported that vigorous-intensity aerobic activities improved



Time (min/wk)	0	<51	51-80	81-119	120-175	≥176
Distance (miles/wk)	0	<6	6-8	9-12	13-19	≥20
Frequency (times/wk)	0	1-2	3	4	5	≥6
Total amount (MET-min/wk)	0	<506	506-812	813-1199	1200-1839	≥1840
Speed (mph)	0	<6.0	6.0-6.6	6.7-7.0	7.1-7.5	≥7.6

CENTRAL ILLUSTRATION **Leisure-Time Running Reduced All-Cause and Cardiovascular Mortality Risk**

Hazard ratios (HRs) of all-cause and cardiovascular mortality by running characteristic (weekly running time, distance, frequency, total amount, and speed). Participants were classified into 6 groups: nonrunners (reference group) and 5 quintiles of each running characteristic. All HRs were adjusted for baseline age (years), sex, examination year, smoking status (never, former, or current), alcohol consumption (heavy drinker or not), other physical activities except running (0, 1 to 499, or ≥500 MET-minutes/week), and parental history of cardiovascular disease (yes or no). All p values for HRs across running characteristics were <0.05 for all-cause and cardiovascular mortality except for running frequency of ≥6 times/week ($p = 0.11$) and speed of <6.0 miles/h ($p = 0.10$) for cardiovascular mortality. Abbreviation as in **Figure 2**.

blood pressure, insulin sensitivity, and blood lipid profile (25-27). There is also convincing observational evidence of the benefits of running in preventing chronic diseases, including coronary heart disease, stroke, hypertension, diabetes, and hypercholesterolemia (20,21,28). Cardiorespiratory fitness is a strong morbidity and mortality predictor (9,29,30), as a possible link between running and mortality (12). We found that runners had approximately 30% higher cardiorespiratory fitness than nonrunners, and there was a linear increase of cardiorespiratory fitness with increasing running time ($p < 0.001$) at baseline (**Fig. 4**). Every 30 min of additional weekly running time was associated with 0.5 MET higher cardiorespiratory fitness after accounting for age and sex ($p < 0.001$). We found no mortality benefits of running after further adjustment for cardiorespiratory fitness, as we have previously observed in total leisure-time physical activity and mortality (7). Therefore, it is possible that the mortality benefits of running may be explained by improved cardiorespiratory fitness. However, running is a behavior and cardiorespiratory fitness is a physiological attribute, which also is affected by other factors such as genotype. Thus, the current findings of no additional mortality benefits at the higher doses of running compared with lower doses of running may be related to other factors besides cardiorespiratory fitness.

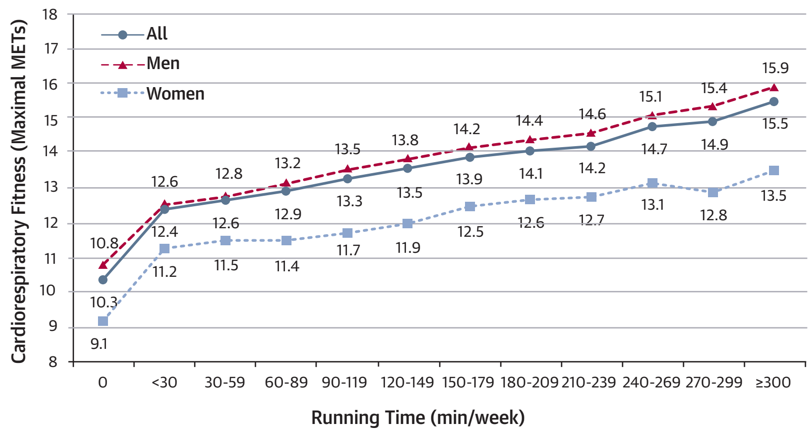


FIGURE 4 **Baseline Cardiorespiratory Fitness by Weekly Running Time**

Cardiorespiratory fitness was estimated from the final treadmill speed and grade during the maximal exercise test in a subsample of 50,995 participants. All p values for linear trend across weekly running time were $<$0.001 after adjustment for age and sex (not in sex-stratified analyses). Abbreviation as in Figure 2.

Strengths of this study include the very large sample size across a wide age range, extensive mortality follow-up, comprehensive analyses, and control of potential confounding factors including other nonrunning activities. In addition, we used various running characteristics to investigate the associations of both baseline and change in running with mortality.

STUDY LIMITATIONS. Our cohort consisted primarily of well-educated white adults from middle to upper socioeconomic strata, which may limit the generalizability of the findings. However, the potential for confounding by race/ethnicity, education, and income may be reduced in this population. Physiological characteristics of our cohort are similar to those of other representative population samples (5). Another limitation is the use of self-reported running during the past 3 months, which is longer than conventional physical activity questionnaires that include the previous 1 week or 1 month. Although running during the past 3 months could be more representative than running during the previous week or month, it may also increase the inaccuracy of self-report of running due to recall bias. People tend to overreport their leisure-time physical activities because it is a socially desirable behavior (31). However, this overreporting bias would likely induce an underestimation of the true mortality benefits of running toward the null hypothesis. Runners are healthier than nonrunners in this population, with lower prevalence of chronic diseases at baseline (Table 1). It is possible that healthy people may run more, which could lead to reverse causality. However, we found consistent mortality benefits in runners in both healthy and unhealthy individuals (Fig. 1). Also, we observed mortality benefits after additional adjustment for medical conditions (Table 3). Another potential limitation is the lack of adequate dietary information.

CONCLUSIONS

We found consistent long-term mortality benefits of leisure-time running. This study underlined that running even at relatively low doses (5 to 10 min/day), below the current minimum guidelines of vigorous-intensity aerobic activity, was sufficient for substantial mortality benefits.

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE: Leisure-time running, even at low intensity or pace, reduces all-cause and cardiovascular mortality independently of sex, age, body mass index, health behavior, and medical conditions. Reduction in mortality is related to continued running activity over time, and running is as important as such other prognostic variables like smoking, obesity, or hypertension.

COMPETENCY IN INTERPERSONAL AND COMMUNICATION SKILLS: Healthcare providers should explain to patients the significant mortality benefits of running even as little as 5 to 10 min daily. Try to motivate patients to start running and to continue running as an attainable health goal.

TRANSLATIONAL OUTLOOK: Further research is needed to determine whether there is an upper limit to the amount of vigorous physical activity, beyond which additional exercise provides no further mortality reduction.

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