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Swimming, water jogging, and aqua aerobics are lifetime physical activities that provide many health benefits comparable to those of walking and running. Research on the association between swimming and mortality is scarce, however. To evaluate the association between different types of physical activity and all-cause mortality, we studied 40,547 men age 20–90 years who completed a health examination during 1971–2003. Cox proportional-hazards regression was used to estimate the relative risks according to physical activity exposure categories. A total of 3,386 deaths occurred during 543,330 man-years of observation. After adjustment for age, body-mass index, smoking status, alcohol intake, and family history of cardiovascular disease, swimmers had 53%, 50%, and 49% lower all-cause mortality risk than did men who were sedentary, walkers, or runners, respectively ($p < .05$ for each). Additional adjustment for baseline prevalent diseases did not change the inverse association between different activities and all-cause mortality. In conclusion, swimmers had lower mortality rates than those who were sedentary, walkers, and runners.

Keywords: aquatic exercise, physical activity, longitudinal study

Sedentary lifestyle is a major risk factor for premature mortality from all causes, as well as for chronic diseases such as Type 2 diabetes, cardiovascular disease, and cancer (Haskell et al., 2007). People who are physically active have lower mortality rates than sedentary individuals (Wei et al., 1999). Physical activity decreases fasting blood glucose levels and insulin resistance, improves weight management, and decreases blood pressure (Kesaniemi et al., 2001), total cholesterol, and low-density-lipoprotein cholesterol (Halverstadt, Phares, Wilund, Goldberg, & Hagberg, 2007). In 2005, however, only 49.1% of adults met the American College of Sports Medicine physical activity recommendations (Centers for Disease Control and Prevention, 2005).

There is a curvilinear dose-response relationship between the volume of physical activity and all-cause mortality rates regardless of age and body-mass index (BMI; Lee & Skerrett, 2001). Expending 1,000 kcal/week in exercise has been shown to reduce the risk of all-cause mortality by 20–30%, and higher levels of energy expenditure are associated with further reductions in all-cause mortality

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(Lee & Skerrett). The Harvard Alumni Study showed that total physical activity and vigorous activities significantly decrease the risk of coronary heart disease (Sesso, Paffenbarger, & Lee, 2000). Furthermore, increasing leisure-time physical activity is associated with reduced mortality from all causes, as well as chronic diseases (Talbot, Morrell, Fleg, & Metter, 2007), and the benefits derived from leisure-time physical activity persist even after genetic and other familial factors are taken into account (Kujala, Kaprio, Sarna, & Koskenvuo, 1998).

Swimming, water jogging, and aqua aerobics are lifetime physical activities for many people. We have previously shown that swimming provides health benefits comparable to those from walking and running (Chase, Sui, & Blair, 2008). To our knowledge, no study has examined the relationship between physical activity and all-cause mortality across different types of activity such as swimming, walking, and running. Therefore, the goal of this study was to evaluate the association between different types of physical activity and all-cause mortality among men who participated in the Aerobics Center Longitudinal Study (ACLS).

Methods

Participants

The ACLS is a prospective study of the health effects of physical activity and fitness. Data were obtained from a population of adults selected from patients of the Cooper Clinic, a preventive-medicine clinic in Dallas, TX. Participants were self-referred or were sent to the clinic by their employer or private physician for preventive medical examinations and health, nutrition, and exercise counseling. Participants for the current analysis were 40,547 men age 20–90 years who had a health examination during the period 1971–2003. A large majority of participants were White and from middle or upper socioeconomic strata. All participants provided written consent to participate in the examination and the research. The study protocol was reviewed and approved annually by the Cooper Institute's institutional review board.

Clinical Examination

Clinical examinations were completed after a 12-hr fast and have been described in detail elsewhere (Blair et al., 1996, 1989). Briefly, information pertaining to personal and family health histories, personal health habits, and demographic information was obtained from standardized medical-history questionnaires. Height and weight were measured in light clothing and without shoes using a standard clinical scale and stadiometer. BMI was calculated as kg/m^2. Seated blood pressure was recorded as the first and fifth Korotkoff sounds using auscultation methods (Pickering et al., 2005). Fasting serum samples were analyzed for lipids and glucose using standardized automated bioassays at the Cooper Clinic laboratory, which participated in and met the quality-control criteria of the Centers for Disease Control and Prevention Lipid Standardization Program. Hypertension was defined as systolic blood pressure of 140 mm Hg or greater, diastolic blood pressure of 90 mm Hg or greater, or a history of physician diagnosis of the disease. Diabetes mellitus was defined as fasting plasma glucose concentration of 7.0 mmol/L or greater, a history of physician diagnosis, or insulin use. Hypercholesterolemia was defined as total

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cholesterol of 6.20 mmol/L or greater. Personal history of cardiovascular disease (myocardial infarction or stroke), information on smoking habits (current smoker or not), alcohol intake (drinks per week), family history of cardiovascular disease, and physical activity habits (sedentary, walker, runner, or swimmer) were obtained from a standardized questionnaire.

Cardiorespiratory fitness was quantified as the total duration (in minutes) of a symptom-limited maximal treadmill exercise test using a modified Balke protocol (Balke & Ware, 1959). Details regarding the specific speed and grade of each exercise stage have been previously described (Blair et al., 1989). Exercise duration for this protocol is strongly correlated with measured maximal oxygen uptake in men (r = .94; Pollock et al., 1976). Maximal metabolic equivalents (METs; 1 MET = 3.5 ml O_2 uptake · kg^{-1} · min^{-1}) were estimated from the final treadmill speed and grade (American College of Sports Medicine, 2000).

Physical Activity

Physical activity status was categorized into four mutually exclusive groups according to the usual type of physical activity reported during the 3 months preceding the examination (Hootman et al., 2002, 2001). Sedentary participants reported no participation in a run/walk/jog program, strenuous sports, racket sports, bicycling, or swimming. Walkers reported participation in a run/walk/jog program with an average pace of 15 min/mile or slower. Runners participated in a run/walk/jog program and reported an average pace of less than 15 min/mile. For run/walk/jog participants who did not report information about their pace (4–5% of the sample), walking and running status were determined by a question that asked how much time they spent walking during their run/walk/jog program. Walkers were those who reported walking for at least 75% of their run/walk/jog program, and runners walked less than 25% of their run/walk/jog program. Run/walk/jog participants with missing information on pace and who reported walking between 25% and 75% of their run/walk/jog program could not be clearly classified as runners or walkers and were excluded from this analysis. Swimmers were those who exclusively engaged in swimming.

Mortality Surveillance

Vital status was ascertained using the National Death Index and 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 *Tenth Revision* (ICD-10) codes during 1999–2003. The mean duration of follow-up was 13.4 years (*SD* 8.8). We computed man-years of exposure as the sum of follow-up time among decedents and survivors.

Statistical Analysis

Baseline characteristics of the population were calculated by vital-status groups. Differences in covariates were tested using Student's t tests for continuous variables and chi-square tests for categorical variables. Cox proportional-hazards regression was used to estimate hazard ratios, 95% confidence intervals, and mortality rates (deaths per 10,000 man-years of follow-up) according to physical activity exposure categories. Multivariable analyses included controls for baseline measures: age (in years), BMI (kg/m^2), smoking status (current smoker or not), alcohol intake (≥5 drinks/week or not), medical conditions (the presence or absence, separately measured, of cardiovascular disease, hypertension, diabetes, or hypercholesterolemia), and family history of cardiovascular disease (present or not). Cumulative hazard plots grouped by exposure suggested no appreciable violations of the proportional-hazards assumption. All *p* values were calculated assuming two-sided alternative hypotheses; *p* values <.05 were taken to indicate statistically significant comparisons. All analyses were performed using SAS statistical software, version 9.1 (SAS Inc., Cary, NC).

Results

The baseline characteristics of the study participants based on vital status are shown in Table 1. There were 3,386 deaths during 543,330 man-years of exposure.

Compared with survivors, the decedents were older, had lower fitness levels, and had higher prevalence rates of major cardiovascular-disease risk factors. A larger percentage of decedents were sedentary. The prevalence of myocardial infarction, stroke, hypertension, and diabetes was higher in the decedents than in survivors. There were 15,883 sedentary men, 562 swimmers, 3,746 walkers, and 20,356 runners. During an average 13 years of follow-up, 1,747 sedentary men, 11 swimmers, 292 walkers, and 1,336 runners died.

The all-cause mortality rates (per 10,000 man-years) are shown in Figures 1–3, and the multivariate adjusted hazard ratios and 95% confidence intervals for all-cause mortality by physical activity group are shown in Table 2. Swimmers had the lowest death rate, which was about 50% lower than the other activity groups. Men who were swimmers had a 56%, 51%, and 47% lower overall risk of dying than men who were sedentary, walkers, or runners, respectively ($p < .05$ for each).

After adjustment for age, BMI, smoking status, alcohol intake, and family history of cardiovascular disease, swimmers had 53%, 50%, and 49% lower all-cause mortality risk than did men who were sedentary, walkers, or runners, respectively ($p < .05$ for each). Additional adjustment for baseline cardiovascular disease, hypertension, diabetes mellitus, and hypercholesterolemia did not change the inverse association between different activities and all-cause mortality.

Discussion

The principal finding of this report is that swimmers had lower mortality rates than those who were sedentary, walkers, and runners. The inverse associations persisted even after controlling for age, BMI, smoking, alcohol intake, family history, and prevalence of heart attack and stroke, hypertension, diabetes, and hypercholesterolemia. Several studies from our cohort and others show that moderate to high levels of cardiorespiratory fitness are associated with lower mortality rates (Barlow, Kohl, Gibbons, & Blair, 1995; Myers et al., 2004; Sui et

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Table 1 Baseline Characteristics of Study Participants by Vital Status, *M* ± *SD*

Characteristic	All (*N* = 40,547)	Survivors (*n* = 37,161)	Decedents (*n* = 3,386)	*p*
Age	47.1 ± 10.9	46.5 ± 10.6	54.3 ± 11.4	<.0001
Body-mass index (kg/m^2)	26.7 ± 4.1	26.7 ± 4.1	26.7 ± 4.5	.45
Treadmill time (min)	17.6 ± 5.4	18.0 ± 5.2	13.5 ± 5.5	<.0001
Maximal metabolic equivalents	11.5 ± 2.6	11.7 ± 2.6	9.6 ± 2.6	<.0001
Blood lipids (mmol/L)				
total cholesterol	5.4 ± 1.1	5.4 ± 1.0	5.7 ± 1.6	<.0001
high-density lipoprotein	1.2 ± 0.3	1.2 ± 0.3	1.1 ± 0.4	<.0001
triglycerides	1.6 ± 1.4	1.5 ± 1.3	1.8 ± 2.0	<.0001
Fasting blood glucose (mmol/L)	5.6 ± 1.1	5.6 ± 1.0	5.9 ± 1.7	<.0001
Resting blood pressure (mm Hg)				
systolic	123 ± 14	122 ± 14	128 ± 17	<.0001
diastolic	82 ± 10	82 ± 10	83 ± 11	<.0001
Types of physical activity				
sedentary (%)	15,883 ± 39.2	14,136 ± 38.0	1,747 ± 51.6	<.0001
swimmers (%)	562 ± 1.4	551 ± 1.5	11 ± 0.3	<.0001
walkers (%)	3,746 ± 9.2	3,454 ± 9.3	292 ± 8.6	.20
runners (%)	20,356 ± 50.2	19,020 ± 51.2	1,336 ± 39.5	<.0001
Current smoker (%)	6,555 ± 16.2	5,720 ± 15.4	835 ± 24.7	<.0001
Alcohol intake ≥5 drinks/week[a] (%)	12,080 ± 29.8	10,758 ± 29.0	1,322 ± 39.0	<.0001
Abnormal exercise electrocardiogram (%)	3,182 ± 7.9	2,476 ± 6.7	706 ± 20.9	<.0001
Hypertension[b] (%)	13,860 ± 34.2	12,203 ± 32.8	1,657 ± 48.9	<.0001
Cardiovascular disease[c] (%)	833 ± 2.1	560 ± 1.5	273 ± 8.1	<.0001
Family history of cardiovascular disease (%)	10,487 ± 25.9	9,237 ± 24.9	1,250 ± 36.9	<.0001
Diabetes mellitus[d] (%)	2,312 ± 5.7	1,924 ± 5.2	388 ± 11.5	<.0001
Hypercholesterolemia[e] (%)	7,412 ± 18.3	6,480 ± 17.4	932 ± 27.5	<.0001

[a]One unit of alcohol is defined as 12 oz (3.41 dl) of beer, 5 oz (1.421 dl) of wine, or 1.5 oz (0.4262 dl) of hard liquor. [b]Systolic blood pressure of 140 mm Hg or higher, diastolic blood pressure of 90 mm Hg or higher, or previous diagnosis by a physician. [c]Myocardial infarction or stroke. [d]Fasting plasma glucose concentration of 7.0 mmol/L (126 mg/dl) or higher, previous diagnosis by a physician, or insulin use. [e]Total cholesterol of 6.20 mmol/L (240 mg/dl) or higher or previous diagnosis by a physician.

al., 2007; Wei et al., 1999). Most studies show that the most fit participants have mortality rates 50% less than the least fit participants (Blair et al., 1989).

Possible mechanisms for the low mortality rates seen among swimmers involve the health benefits derived from swimming in comparison with other forms of physical activity. Previously, we showed that swimmers have higher cardiorespiratory-fitness levels than walkers and sedentary men (Chase et al., 2008). Swimmers have lower total cholesterol, triglycerides, fasting blood glucose, and resting heart rates, as well as higher high-density-lipoprotein cholesterol than sedentary men, and they

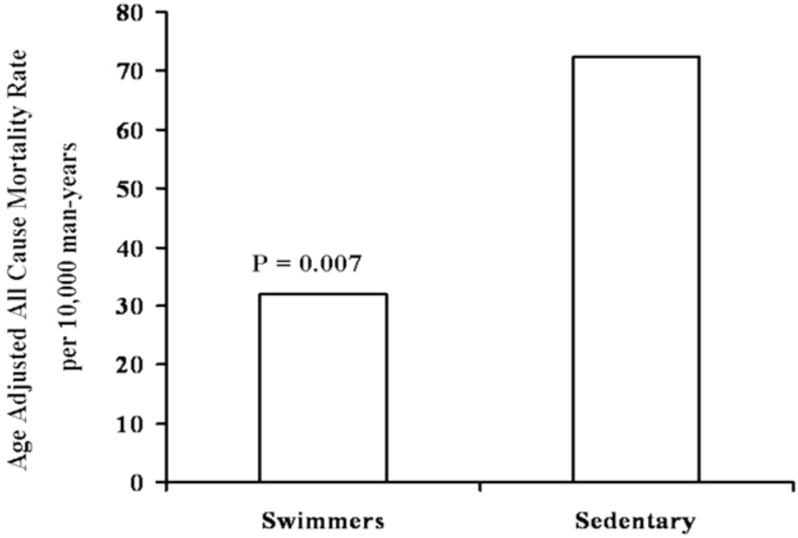

Figure 1 — Age-adjusted all-cause mortality rates (per 10,000 man-years) comparing swimmers with sedentary men in 40,547 men from the Aerobics Center Longitudinal Study, 1971–2003. The numbers of men (and deaths) in swimmers and sedentary men were 562 (11) and 15,883 (1,747), respectively.

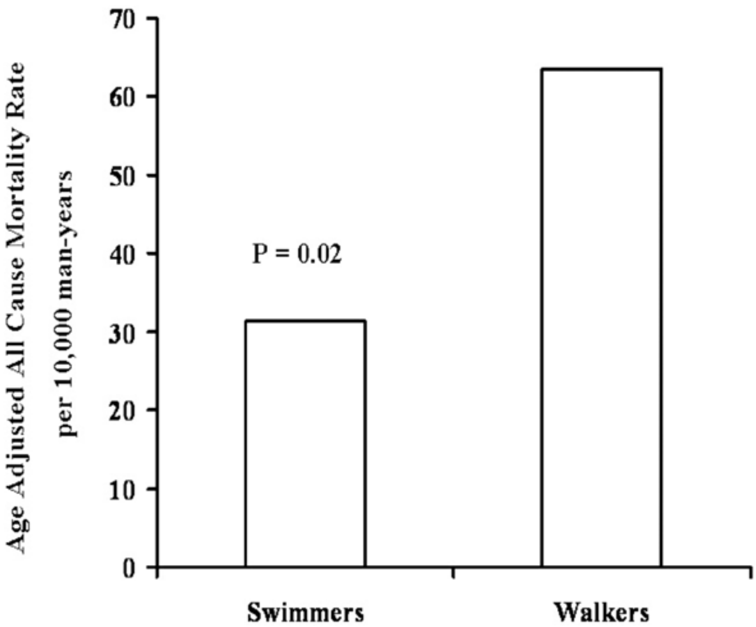

Figure 2 — Age-adjusted all-cause mortality rates (per 10,000 man-years) comparing swimmers with walkers in 40,547 men from the Aerobics Center Longitudinal Study, 1971–2003. The numbers of men (and deaths) in swimmers and walkers were 562 (11) and 3,746 (292), respectively.

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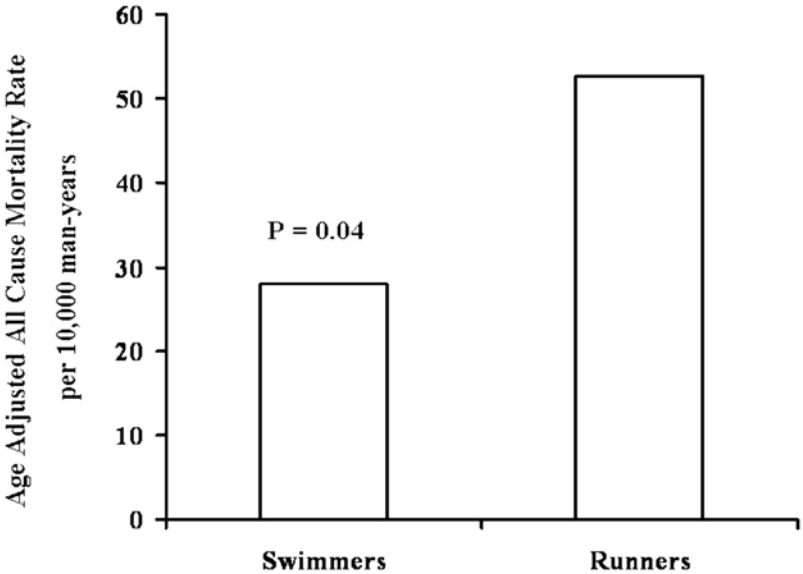

Figure 3 — Age-adjusted all-cause mortality rates (per 10,000 man-years) comparing swimmers with runners in 40,547 men from the Aerobics Center Longitudinal Study, 1971–2003. The numbers of men (and deaths) in swimmers and runners were 562 (11) and 20,356 (1,336), respectively.

Table 2 Hazard Ratios for All-Cause Mortality by Physical Activity Group in Men, Aerobics Center Longitudinal Study, Dallas, TX, 1971–2003

	HR[a]	95% CI[a]	*p*	HR[b]	95% CI[b]	*p*	HR[c]	95% CI[c]	*p*
Sedentary vs. swimmer									
sedentary	1.0			1.0			1.0		
swimmer	0.44	0.24, 0.80	.007	0.47	0.26, 0.85	.01	0.49	0.27, 0.89	.02
Walker vs. swimmer									
walker	1.0			1.0			1.0		
swimmer	0.49	0.27, 0.90	.02	0.50	0.27, 0.92	.03	0.52	0.28, 0.95	.03
Runner vs. swimmer									
runner	1.0			1.0			1.0		
swimmer	0.53	0.29, 0.96	.04	0.51	0.28, 0.92	.03	0.54	0.30, 0.98	.04

Note. HR = hazard ratio; CI = confidence interval.

[a]Adjusted for age. [b]Adjusted by age, body-mass index, smoking status, alcohol intake, and family history of cardiovascular disease. [c]Adjusted for age, body-mass index, smoking status, alcohol intake, family history of cardiovascular disease, and presence of cardiovascular disease, hypertension, diabetes mellitus, and hypercholesterolemia.

have lower total-cholesterol and triglyceride levels, as well as lower resting heart rates, than walkers. Swimmers and runners tend to have similar risk-factor profiles, according to our earlier report.

Aquatic exercise is a lifetime activity that can be enjoyed by a large percentage of the general population, including individuals with chronic diseases (Westby, 2001). People who suffer from arthritis, cardiovascular disease, cancer, and Type 2 diabetes might limit their physical activity (Sundquist, Qvist, Sundquist, & Johansson, 2004). Decreased moderate and vigorous leisure-time physical activity over time increases the risk of all-cause mortality (Talbot et al., 2007). Swimming might be a good alternative exercise for individuals who cannot participate in running or other forms of physical activity.

To our knowledge, this is the first report to examine mortality rates among swimmers in comparison with other types of physical activity and sedentary lifestyle. Our findings are similar to those of other studies related to all-cause mortality and physical activity in comparison with sedentary lifestyle. Leisure-time physical activity might provide health benefits that decrease the risk of all-cause mortality (Talbot et al., 2007). Higher levels of physical activity decrease the prevalence of cardiovascular disease and cancer, which decreases mortality risk.

Several studies have examined the relationship between leisure-time physical activity and all-cause mortality rates. The Baltimore Longitudinal Study of Aging examined men and women age 19–90 years between 1958 and 1996 (Talbot et al., 2007). These participants were from higher socioeconomic classes and high education levels, similar to participants in the ACLS. Lower mortality rates were associated with higher amounts of total leisure-time physical activity and high-intensity physical activity in men. Schnohr, Scharling, and Jensen (2003) looked at the relationship between changes in leisure-time physical activity and mortality rates in 7,023 healthy men and women between the ages of 20 and 79. They found that people who participated in moderate- or high-intensity physical activity had significantly lower mortality rates than those who participated in low amounts of physical activity. Furthermore, men who decreased their levels of physical activity had increased mortality rates in comparison with those who maintained or increased their physical activity levels. Individuals who had higher rates of physical activity over time reduced their risks of all-cause mortality.

The Harvard Alumni Health Study examined 13,485 men who graduated from Harvard University between 1916 and 1950 (Lee & Paffenbarger, 2000). This study showed a strong association between increased longevity and increased rates of physical activity. Walking and climbing stairs were strong predictors of lower mortality rates in comparison with sedentary habits. There was an inverse relationship between higher rates of moderate physical activity and mortality. Sedentary men had greater mortality rates than men who were physically active. The Harvard Alumni Study also examined the relationship between physical activity levels and coronary heart disease and mortality (Talbot et al., 2007). Greater amounts of vigorous physical activity were associated with greater reductions in coronary heart disease. The greatest reductions in coronary heart disease risk were associated with people who performed vigorous physical activity to expend more than 4,200 kJ/week. People who performed this level of physical activity had a 20% reduction

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in coronary heart disease risk; those who expended 2,100–4,199 kJ/ week through vigorous physical activity had a 10% reduction.

Strengths of the current study include the extensive baseline examination to detect subclinical disease, the relatively long follow-up period, and the assessment of different types of physical activity, including swimming. A major limitation of the analyses is the small number of deaths in swimmers (n = 11), although one would expect that the small number would lead to wide confidence intervals and reduce the possibility of finding significant differences between swimmers and the other activity groups. The study population was limited to predominantly White, well-educated, middle- to upper-class men. This limits the generalizability of the study's findings, although it should not affect the study's internal validity. Moreover, there is no compelling reason to assume that the benefits of swimming would be lower in other socioeconomic groups. There was insufficient information about medication use or dietary habits to include these factors in the analysis. Future studies should include such information whenever possible.

In conclusion, swimmers have lower all-cause mortality rates than do men with sedentary habits, walkers, or runners. These lower rates compared with walkers and sedentary men might well be expected, but it is unclear why we also observed lower mortality in swimmers than in runners. Therefore, swimming appears to be a healthful alternative to other types of physical activity. Future research is needed to confirm the findings reported here.

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