Physical Activity Patterns Associated With Cardiorespiratory Fitness and Reduced Mortality: The Aerobics Center Longitudinal Study

John R. Stofan, MS, Loretta DiPietro, PhD, MPH, Dorothy Davis, Harold W. Kohl III, PhD, and Steven N. Blair, PED

ABSTRACT

Objectives. This study examined cross sectionally the physical activity patterns associated with low, moderate, and high levels of cardiorespiratory fitness.

Methods. Physical activity was assessed by questionnaire in a clinic population of 13 444 men and 3972 women 20 to 87 years of age. Estimated energy expenditure (kcal · wk^{-1}) and volume (min · wk^{-1}) of reported activities were calculated among individuals at low, moderate, and high fitness levels (assessed by maximal exercise tests).

Results. Average leisure time energy expenditures of 525 to 1650 kcal · wk^{-1} for men and 420 to 1260 kcal · wk^{-1} for women were associated with moderate to high levels of fitness. These levels of energy expenditure can be achieved with a brisk walk of approximately 30 minutes on most days of the week. In fact, men in the moderate and high fitness categories walked between 130 and 138 min · wk^{-1}, and women in these categories walked between 148 and 167 min · wk^{-1}.

Conclusions. Most individuals should be able to achieve these physical activity goals and thus attain a cardiorespiratory fitness level sufficient to result in substantial health benefits. (*Am J Public Health.* 1998;88:1807–1813)

Cardiorespiratory fitness is inversely related to chronic disease morbidity and mortality.[1-3] Prospective data from the Aerobic Center Longitudinal Study provide evidence of steep, inverse gradients for all-cause and cardiovascular disease mortality across relative levels of low (least fit 20% of the cohort), moderate (next 40%), and high (most fit 40%) cardiorespiratory fitness.[1,4] These studies show a reduction of approximately 60% in the rate of death when comparing the moderate fitness and the low fitness groups, with a further reduction of 8% seen in the high fitness group relative to the low fitness group. The hypothesis that cardiorespiratory fitness provides protection against early mortality is strengthened by the observation that initally unfit men in the cohort who became at least moderately fit by a subsequent exam had a 65% reduction in all-cause death rate relative to their peers who remained unfit.[5] These findings and others[6-9] provide evidence of higher cardiovascular disease morbidity and mortality risks among sedentary and less fit individuals and indicate that such risks can be reduced by improvements in cardiorespiratory fitness or physical activity level. Indeed, even regular physical activity that may not be of sufficient intensity to achieve high levels of cardiorespiratory fitness can result in substantial health benefits.[4,5,10,11]

Recently, public health emphasis has shifted from the traditional structured exercise program[12] to the goal of increasing levels of daily physical activity to achieve better health and function.[10,13-16] Although studies measuring physical fitness provide compelling support for the position that sedentary living is a health hazard, these fitness data do not easily translate into readily communicable recommendations or clinical practice guidelines. For example, the general public cannot be advised to become moderately fit without being provided with the necessary behavioral recommendations. Therefore, we analyzed cross-sectional data from a large sample of the Aerobic Center Longitudinal Study cohort on whom extensive physical activity information and objective cardiorespiratory data were collected. The purpose of this report is to describe the physical activity patterns that are associated with levels of low, moderate, and high cardiorespiratory fitness in men and women, in order to develop and substantiate meaningful physical activity recommendations that are empirically derived and related to significant reductions in mortality risk.

Methods

Subjects

Study participants were 13 444 men and 3972 women, ranging in age from 20 to 87 years, who underwent at least 1 comprehensive preventive medical examination at the Cooper Clinic in Dallas, Tex. Medical examinations included a physical examination, a

At the time this study was conducted, John R. Stofan was with the John B. Pierce Laboratory, New Haven, Conn. He is now with the Gatorade Sports Science Institute, Barrington, Ill. Loretta DiPietro is with the John B. Pierce Laboratory and the Department of Epidemiology and Public Health, Yale University School of Medicine, New Haven, Conn. Dorothy Davis is with the School of Public Health, University of South Carolina, Columbia. Harold W. Kohl III is with the Baylor Sports Medicine Institute, Baylor College of Medicine, Houston, Tex. Steven N. Blair is with the Division of Epidemiology and Clinical Applications, Institute for Aerobics Research, Dallas, Tex.

Requests for reprints should be sent to Loretta DiPietro, PhD, MPH, The John B. Pierce Laboratory, 290 Congress Ave, New Haven, CT 06519 (e-mail: ldipietro@jbpierce.org).

This article was accepted April 30, 1998.

self-administered personal and family medical history, a resting electrocardiograph (ECG), anthropometry, blood pressure measurements, blood chemistry analyses, and an assessment of cardiorespiratory fitness by a maximal exercise treadmill test.[17] Data for the present analysis were taken from the most recent examination of each participant between 1987 and 1993. This particular study population was selected because the physical activity questionnaire was expanded in 1987, allowing more complete data on physical activity to be used for the analyses presented here.

All participants were free of known chronic disease, as determined by the following criteria: no reported personal history of heart attack, hypertension, stroke, or diabetes; no resting ECG abnormalities; and no abnormalities on an exercise ECG. In order to exclude individuals with possible subclinical or undetectable disease at baseline, those people taking heart-rate-altering drugs or those unable to achieve at least 85% of their age-predicted maximal heart rate on the treadmill test were excluded from the analyses. Details of the clinical procedures and additional exclusion criteria have been described in previous reports.[1,4,5]

Physical Activity

As part of a comprehensive medical history questionnaire, leisure time physical activity was assessed from a series of questions regarding participation in 10 specific exercise-related physical activities within the previous 3 months. Participants were asked to quantify the frequency (times $\cdot$ wk^{-1}) and duration (min $\cdot$ session^{-1}) of their participation in activities such as walking, jogging, treadmill exercise, cycling, stationary cycling, swimming, racquet sports, aerobic dance, and other sport-related activities (e.g., soccer, basketball). For activities such as walking, running, and cycling, speed (i.e., average time per mile) and distance were also queried to provide an approximate indicator of intensity.

Participants also were assigned to 1 of 3 age-specific activity categories based on their reported physical activity pattern. Those who reported no exercise-related physical activities within the previous 3 months were classified as inactive; participants reporting either 20 minutes or more of vigorous activity on 3 or more days per week or 30 minutes or more of moderate activity on 5 or more days per week were classified as regularly active; and those reporting some activity, but not enough to meet the criteria for regular activity, were classified as irregularly active.[10]

Weekly energy expenditure from reported physical activity was estimated among each of the 3 fitness levels via activity-specific metabolic equivalent values.[18] These values are classified as multiples of one metabolic equivalent value or the ratio of the metabolic cost of a given activity divided by resting metabolic rate. For example, one metabolic equivalent is defined as the energy expenditure required for sitting quietly, which, for an adult of average height and weight, is approximately 3.5 mL of oxygen $\cdot$ kg^{-1} $\cdot$ min^{-1} or 1 kcal $\cdot$ kg^{-1} $\cdot$ h^{-1}. The metabolic equivalent value for a given activity was multiplied by the reported minutes per week of participation and then summed over all reported activities to derive an estimate of weekly leisure time energy expenditure, expressed as kcal $\cdot$ kg^{-1} $\cdot$ wk^{-1}. Whenever possible, the speed (and, thus, intensity) of an activity was accounted for in energy expenditure calculations. For example, walking at a pace of 30 min $\cdot$ mile^{-1} was equivalent to 2.5 metabolic equivalents, whereas a more brisk walk at a pace of 15 min $\cdot$ mile^{-1} was equivalent to 4.0 metabolic equivalents.

Cardiorespiratory Fitness

Cardiorespiratory fitness was measured by performance on a maximal treadmill exercise test.[17] Treadmill speed was set initially at 88 m $\cdot$ min^{-1}, with a grade of 0% for the first minute, a grade of 2% for the second minute, and grades thereafter increasing by 1% each minute for 25 minutes. After 25 minutes, the grade did not change, but the speed was increased 5.4 m $\cdot$ min^{-1} until the test was terminated. Subjects were tested to volitional exhaustion and were encouraged to give a maximal effort. Total treadmill time (in seconds) was the indicator of cardiorespiratory fitness in the analysis. Treadmill time using this protocol is highly correlated with measured maximal oxygen uptake, which is a widely accepted indicator of cardiorespiratory fitness, in both men ($r = 0.92$)[19] and women ($r = 0.94$).[20]

Subjects were assigned to quintiles of cardiorespiratory fitness based on the sex- and age-specific distribution of maximal treadmill time in the study population.[1,5] Quintiles 2 and 3 and quintiles 4 and 5 were then combined to form 3 relative levels of cardiorespiratory fitness: low (quintile 1), moderate (quintiles 2 and 3), and high (quintiles 4 and 5). Maximal oxygen uptake values associated with the levels of relative fitness were estimated from the treadmill test by means of maximal treadmill time and known equations based on treadmill speed and grade.[21]

Data Analysis

Univariate statistics (means and frequencies) were generated for all study variables among the 3 relative levels of cardiorespiratory fitness. More than 25% of the study population reported engaging in multiple activities, which attenuated the amount of time spent in any one activity. Therefore, to obtain the most specific amount of a given activity associated with each fitness level, we calculated the volume (min $\cdot$ wk^{-1}) of a reported activity from the frequency and duration of the activity, but only among subjects reporting that particular activity alone. For example, the weekly volume of walking was calculated solely among the men and women who reported walking as their only activity. Chi-square analyses tested the association between activity patterns and fitness level or age group. Mean differences in reported energy expenditure and volume of activity among the 3 fitness levels were tested via analysis of variance.[22] If significant main effects were found, post hoc analyses using orthogonal contrasts were performed to test specific differences in the study variables among levels of cardiorespiratory fitness. Bivariate analyses were stratified by sex and, whenever possible, by age group (20–39, 40–49, 50–59, and 60 years or above). Complete data on speed were available for walking, jogging, and treadmill exercise, so multivariable analysis of variance tested the independent association between the mean volume of these 3 activities and level of fitness while adjusting for the effects of age, body mass index, and speed of the activity. Multivariable modeling was conducted separately for men and women.

Results

Participants were primarily White (96%) and of middle to upper socioeconomic status. Only 10% of the study subjects were current smokers, while 34% reported a past history of smoking. Other selected descriptive characteristics of the study sample are presented, by level of fitness, in Table 1. Body mass index showed an inverse graded association with level of relative fitness for both men and women ($P < .05$). Also for all men and women, estimates of maximal oxygen uptake were consistent with age-specific norms for low, moderate, and high levels of physical fitness.[23] Among the entire cohort, the median exercise frequency was stable across fitness levels (3–5 d $\cdot$ wk^{-1}), although men at the high fitness level reported a longer exercise history (i.e., years exercising) than anyone else in the study cohort (Table 1).

Prevalence of Selected Activities

Overall, approximately 67% of the men and 65% of the women reported at least 1 exercise-related activity during the previous

TABLE 1—Descriptive Characteristics of Men and Women at the Low, Moderate, and High Cardiorespiratory Fitness Levels

	Men, Mean (SD)			Women, Mean (SD)		
Characteristic	Low (n = 1064)	Moderate (n = 3837)	High (n = 8543)	Low (n = 293)	Moderate (n = 1110)	High* (n = 2569)
Age, y	46.1 (10.5)	46.9 (10.5)	47.6 (10.6)	44.7 (10.7)	45.6 (11.1)	45.2 (11.2)
Body mass index, $kg \cdot m^{-2}$	31.1 (5.6)	27.5 (3.7)	25.2 (2.6)	27.4 (6.3)	23.9 (3.9)	21.8 (2.7)
Maximal treadmill time, min	10.9 (2.7)	15.7 (2.6)	22.1 (3.8)	7.3 (1.9)	10.9 (2.2)	17.0 (4.1)
Oxygen consumption, $mL \cdot kg^{-1} \cdot min^{-1}$[a]	30.7 (3.9)	37.6 (3.8)	46.9 (5.5)	23.3 (3.9)	29.3 (3.6)	38.9 (6.4)
Years exercising	5.9 (9.5)	7.2 (9.3)	12.4 (10.0)	5.8 (9.7)	4.8 (6.7)	9.0 (8.1)

[a]Estimated from treadmill speed, grade, and time.[21]

3 months. Among all men and women, respectively, 32% and 27% reported only 1 activity, 23% and 23% reported 2 activities, 9% and 10% reported 3 activities, and 3% and 5% reported 4 or more activities. The number of reported activities tended to vary by level of fitness for men and women; people at the highest fitness level were more likely to report 2 or more activities than those at moderate or low levels of fitness ($P < .001$; Table 2).

One third (33%) of the men and 35% of the women reported no activity and thus were classified as inactive. Thirty-four percent of the men and 37% of the women were classified as irregularly active, whereas 33% of the men and 28% of the women met criteria for being regularly active. Activity patterns varied somewhat by age group among the men; older men were less likely to report inactivity and tended to engage in more regular activity than younger men ($P < .001$; Table 3).

The proportion of men reporting no activity was inversely related to level of fitness and ranged from 68% at the low fitness level to 21% at the high relative fitness level (Figure 1). In contrast, the prevalence of reported activities such as walking, jogging, stationary cycling, and treadmill exercise tended to increase with level of fitness. These patterns were similar among women (Figure 1).

Estimated Energy Expenditure

Estimated energy expenditures were 3.5, 7.1, and 22.0 $kcal \cdot kg^{-1} \cdot wk^{-1}$ for men and 3.3, 6.9, and 20.8 $kcal \cdot kg^{-1} \cdot wk^{-1}$ for women in the low, moderate, and high fitness categories, respectively (Table 4). In general, estimated weekly energy expenditure was higher with higher levels of relative fitness ($P < .01$). This graded relationship was consistent for men and women across all age categories (Figure 2), although the statistical relationship between weekly energy expenditure and the highest level of fitness varied significantly by age group. For instance, among men, the weekly energy expenditure associated with the high fitness level was approximately 30 $kcal \cdot kg^{-1} \cdot wk^{-1}$ up to 49 years of age, as compared with 26 $kcal \cdot kg^{-1} \cdot wk^{-1}$ among men 50 years old or older ($P < .001$). A similar interaction was noted for women, among whom approximately 31 $kcal \cdot kg^{-1} \cdot wk^{-1}$ was associated with high fitness levels for those 20 to 39 years of age, as compared with 27 $kcal \cdot kg^{-1} \cdot wk^{-1}$ for those 40 to 49 years old ($P < .01$), 25 $kcal \cdot kg^{-1} \cdot wk^{-1}$ for those 50 to 59 years old, and 21 $kcal \cdot kg^{-1} \cdot wk^{-1}$ for those 60 years old or older. These data show a decline in the amount of weekly leisure time energy expenditure necessary to attain higher relative fitness levels with increasing age that is most likely attributable to a lower absolute fitness level at older ages. Differences in energy expenditure tended to be substantially greater between the moderate and high levels of fitness ($P < .001$) than between the low and moderate fitness levels, presumably as a result of a greater number of higher intensity activities reported among those of higher cardiorespiratory fitness.

Volume of Selected Activities

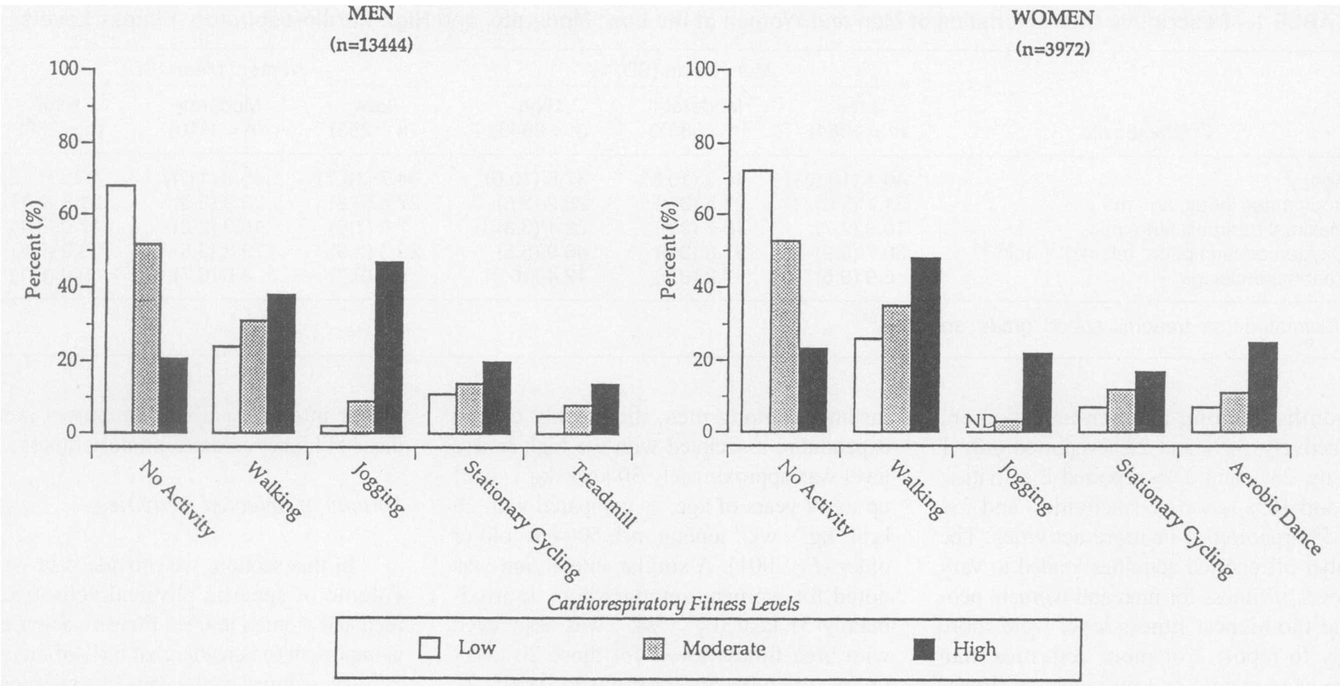
In this section, we provide data on the volume of specific physical activities for men and women in the 3 fitness categories. It is important to consider that 68% of men and 72% of women in the low fitness category reported no activity (Table 2). The volume of activity reported here is for those who actually reported each specific activity. Data on the frequency and duration of specific reported activities for men and women indicate that most of the exercise-related activities were performed in 3 to 5 weekly bouts of approximately 30 to 50 minutes' duration. Among men who reported only walking, the age-adjusted volumes of walking associated with low, moderate, and high levels of fitness were 112, 130, and 138 $min \cdot wk^{-1}$, respectively ($P < .001$) (Table 4). Among men, there was little difference in the volume

TABLE 2—Prevalence (%) of Reported Activities Among Men and Women at the Low, Moderate, and High Fitness Levels

	Men			Women		
No. of Activities	Low (n = 1064)	Moderate (n = 3837)	High (n = 8543)	Low (n = 293)	Moderate (n = 1110)	High (n = 2569)
0	67.8	51.7	20.7	72.3	52.6	23.4
1	20.1	26.6	35.6	14.0	24.9	28.8
2	8.7	15.8	27.3	9.2	16.5	27.5
3	2.8	4.7	11.6	3.8	4.8	13.2
≥4	0.6	1.2	4.8	0.7	1.2	7.1

TABLE 3—Prevalence (%) of Reported Inactivity, Irregular Activity, and Regular Activity Among Study Men and Women

	Men			Women		
Age Group, y	No Activity (n = 4469)	Irregular (n = 4526)	Regular (n = 4449)	No Activity (n = 1397)	Irregular (n = 1483)	Regular (n = 1092)
20–39	36.0	34.6	29.4	36.2	37.0	26.7
40–49	35.8	31.4	32.8	35.2	38.5	26.3
50–59	30.2	35.7	34.1	32.6	38.1	29.2
60+	27.2	34.5	38.3	37.1	33.0	29.9



Note. ND = no data reported.

FIGURE 1—Prevalence of selected activities among men and women in the low, moderate, and high fitness categories.

of jogging reported between those at the low and moderate fitness levels (83 vs 90 $min \cdot wk^{-1}$); however, the volume of jogging associated with the high level of fitness was significantly greater (140 $min \cdot wk^{-1}$) ($P < .01$). Among men reporting only treadmill exercise, the volumes of treadmill exercise associated with low, moderate, and high fitness were 88, 90, and 94 $min \cdot wk^{-1}$, and the volumes of stationary cycling were 69, 76, and 80 $min \cdot wk^{-1}$, respectively. After adjustment for age, body mass index, and speed (and, when appropriate, treadmill grade), the overall association between walking, jogging, or treadmill exercise volume and cardiorespiratory fitness was statistically significant ($P < .01$). The adjusted volumes for walking (101, 130, and 142 $min \cdot wk^{-1}$), jogging (139, 105, and 138 $min \cdot wk^{-1}$), and treadmill exercise (76, 98, and 100 $min \cdot wk^{-1}$) among those at the low, moderate, and high fitness levels were altered somewhat, especially in the low and moderate fitness categories. This was presumably due to the additional influence of body mass and speed on volume of weekly activity in the lower fitness groups.

Among women who reported only walking, the volumes of walking associated with low, moderate, and high levels of fitness were 128, 148, and 167 $min \cdot wk^{-1}$, respectively ($P < .01$; Table 4), and the amounts of jogging associated with moderate and high levels of fitness were 92 and 154 $min \cdot wk^{-1}$ ($P < .01$). The volumes of aerobic dance were 117, 132, and 171 $min \cdot wk^{-1}$ ($P < .05$), and the volumes of stationary cycling were 50, 74, and 84 $min \cdot wk^{-1}$ for those at the low, moderate, and high levels of fitness, respectively. After adjustment for age, body mass index, and speed, walking (140, 150, and 172 $min \cdot wk^{-1}$) and jogging (123 and 152 $min \cdot wk^{-1}$) volumes increased slightly among women in the lower and moderate fitness categories.

TABLE 4—Age-Adjusted Weekly Leisure Time Energy Expenditure ($kcal \cdot kg^{-1} \cdot wk^{-1}$) and Volume ($min \cdot wk^{-1}$) of Selected Activities Associated With Low, Moderate, and High Fitness Categories

	Men, Mean (SEM)					Women, Mean (SEM)				
Activity	No.	Low	Moderate	High	P^a	No.	Low	Moderate	High	P^a
Total energy expenditure	35 444	3.5 (0.6)$_a$	7.1 (0.3)$_b$	22.0 (0.2)$_c$	.0001	3 972	3.3 (1.1)$_a$	6.9 (0.6)$_b$	20.8 (0.4)$_c$	.005
Walking (>15 $min \cdot mile^{-1}$)	1 035	112.3 (7.8)$_a$	129.7 (3.6)$_b$	137.5 (2.3)$_b$	.0001	486	128.3 (15.2)$_a$	148.3 (5.9)$_a$	167.4 (3.2)$_b$	.01
Jogging (<15 $min \cdot mile^{-1}$)	1 750	82.5 (23.5)$_a$	89.7 (5.9)$_a$	139.6 (1.7)$_b$	.01	165	. . .	91.5 (21.3)$_a$	154.3 (4.6)$_b$	.01
Treadmill exercise	396	87.8 (9.3)$_a$	89.7 (3.8)$_a$	94.4 (1.9)$_a$	.05	82	92.5 (20.6)$_a$	105.6 (8.8)$_a$	112.8 (4.2)$_a$	NS
Aerobic dance	57	106.3 (19.2)$_a$	105.4 (8.2)$_a$	115.4 (4.1)$_a$	NS	164	116.7 (22.8)$_a$	132.4 (8.8)$_a$	170.5 (4.0)$_b$	.01
Stationary cycling	589	68.5 (5.6)$_a$	76.1 (2.6)$_{a,b}$	79.8 (1.5)$_b$	.05	106	49.5 (14.7)$_a$	74.4 (5.4)$_{a,b}$	83.5 (3.0)$_b$	.01

Note. Energy expenditure was calculated among the entire cohort. Activity volume for each activity was calculated for only those respondents reporting that particular activity alone. Means sharing the same subscript are not significantly different at $P < .05$, based on orthogonal contrasts.

[a]Value for overall model.

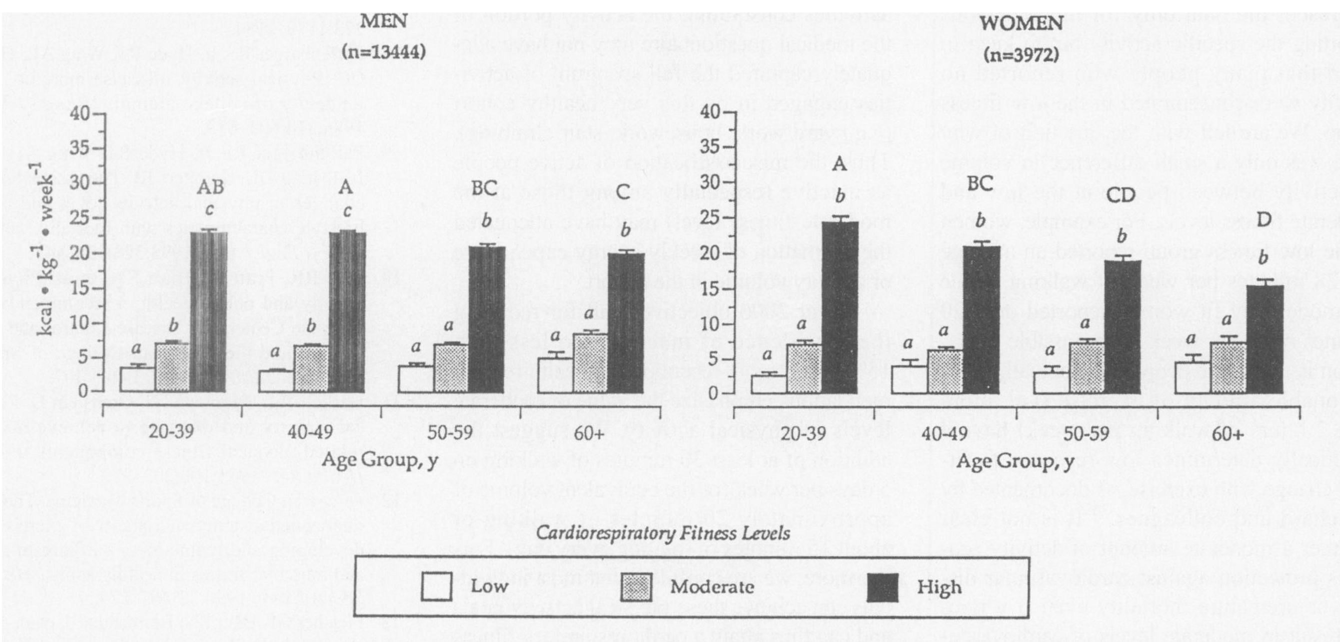
Discussion

Prospective data from the Aerobic Center Longitudinal Study[1,4,5] have provided consistent evidence of a graded inverse relationship between relative level of cardiorespiratory fitness and risk of both cardiovascular disease and all-cause mortality. In this section, we describe the patterns of self-reported physical activity behaviors that are associated with these levels of fitness in the same study cohort and discuss the implications of our findings for the physical activity–fitness–mortality relationship.

The physical activity patterns reported among this study population were generally comparable to activity patterns reported among the general US population, although the prevalence of inactivity was slightly higher in this cohort (33% for men and 35% for women) than that recently reported in the 1990 Behavioral Risk Factor Surveillance System data (29% for men and 32% for women).[24] For both men and women, the prevalence of inactivity was higher and estimated weekly energy expenditure was lower among those at the lowest level of cardiorespiratory fitness than among their more fit counterparts. In previous analyses using data from this same cohort, the lowest level of cardiorespiratory fitness was associated with a disproportionally greater risk of both cardiovascular disease and all-cause mortality relative to moderate or high levels of fitness.[1] Moreover, men who subsequently changed from this low level to moderate or high levels of fitness over the 5-year follow-up decreased their risk of cardiovascular disease mortality by 52% and their risk of all-cause mortality by 44% in comparison with their peers who remained unfit.[5] Together, these data support the contention that a sedentary lifestyle is a major contributing factor to early mortality. More important, data from the present analysis suggest that modest levels of physical activity are associated with the moderate level of relative cardiorespiratory fitness that has been shown to translate into a substantial reduction in mortality risk. Furthermore, the greater reductions in mortality risk seen in the high fitness category do not appear to require training levels associated with competitive athletes; rather, they can be achieved by 1.5 to 3.0 hours of activity per week.

Here we have reported that average estimated weekly leisure time energy expenditures of approximately 7 to 22 $kcal \cdot kg^{-1} \cdot wk^{-1}$ for men (approximately 525–1650 $kcal \cdot wk^{-1}$ for a man weighing 75 kg [167 lb]) and 7 to 21 $kcal \cdot kg^{-1} \cdot wk^{-1}$ for women (approximately 420–1260 $kcal \cdot wk^{-1}$ for a woman weighing 60 kg [133 lb]) were associated with moderate to high levels of cardiorespiratory fitness. The amount of leisure time physical activity required to expend this much energy can be achieved easily by most people with a brisk walk of approximately 30 minutes on most days of the week. In fact, in our analyses, men in the moderate to high fitness categories walked between 130 and 138 $min \cdot wk^{-1}$ and women in these categories walked between 148 and 167 $min \cdot wk^{-1}$.

There is convincing evidence from other studies[7,8,25] that physical activity is associated with protective effects and decreased risk of cardiovascular disease and coronary heart disease mortality. Studies of Harvard alumni[8,9,25] indicate that adopting a physically active lifestyle involving walking, climbing stairs, and playing sports delayed all-cause mortality and extended longevity up to 1.6 years. Sedentary alumni who expended less than 1500 $kcal \cdot wk^{-1}$ were at a 39% higher risk of early death than their more active counterparts.[25] Also, men who adopted activities of at least moderate intensity (4.5 or more metabolic equivalents) decreased their 8-year mortality risk by 23%,[9] and those who increased their overall physical activity to 1500 $kcal \cdot wk^{-1}$ or more reduced their 11-year risk by 28%[25] relative to those men who remained considerably less active. In the most recent analysis from this same Harvard alumni cohort,[7] mortality generally declined with increasing weekly energy expenditure (i.e., greater physical activity), with the mortality rate stabilizing at approximately 3500 $kcal \cdot wk^{-1}$. Thus, men who expended 1500 $kcal \cdot wk^{-1}$ or more per-



Note. These data include people reporting no activity. Data were estimated according to Ainsworth et al.[18] Mean values among the fitness categories sharing the same lowercase letter *(a, b, c)* are not significantly different; age-group-specific mean values among men and women in the high fitness group sharing the same uppercase letter (A, B, C, D) are not significantly different, based on orthogonal contrasts.

FIGURE 2—Mean estimated energy expenditure among men and women according to age group.

forming moderate to vigorous (i.e., 6 or more metabolic equivalents) activity were at a lower risk of early death by 13% to 25% relative to those expending less than 1500 kcal · wk^{-1}.

Volume estimations from reported physical activity in the Aerobic Center Longitudinal Study cohort were fairly similar among individuals at low and moderate fitness levels (Table 4), suggesting that physical activity may not be entirely responsible for the protective effect on early mortality. It is important to note that the minutes of participation for each of the specific activities shown in Table 4 were calculated only among those who reported engaging in that activity. These data thus involve reportedly active people. There were, however, 4436 men and 1390 women who reported no activity, and approximately 70% of these individuals were in the low fitness category. If these inactive persons were considered in each of the specific activity analyses, the average volume in the low fitness category would be much lower, and there would be a greater difference in minutes per week of activity between people in the low and moderate fitness categories. This complicated the interpretation of the volumes of specific activities for the 3 fitness groups. We considered calculating the minutes of weekly activity including inactive people in the denominator (they would contribute 0 minutes to the numerator) but decided that this would also create problems in the interpretation of the data. In the end, we decided to present the data only for those persons reporting the specific activity but to keep in mind that many people who reported no activity were concentrated in the low fitness group. We are left with the question of why there was only a small difference in volume of activity between people at the low and moderate fitness levels. For example, women in the low fitness group reported an average of 128 minutes per week of walking, while the moderately fit women reported only 20 minutes more per week. One possible explanation is that some people who actually get a reasonable amount of exercise (i.e., more than 2 hours of walking per week) have a genetically determined low response to fitness change with exercise, as documented by Bouchard and colleagues.[26] It is not clear whether a moderate amount of activity provides protection against cardiovascular disease or premature mortality even if it does not result in moderate levels of cardiovascular fitness. This is an important question that needs to be addressed in future studies.

Blair and colleagues[5] subsequently reported that men from the Aerobic Center Longitudinal Study cohort who were initially unfit but modified their behavior and became fit by their subsequent exam reduced their risk of mortality substantially relative to men who remained unfit. Thus, while heredity may have been an important confounder in the earlier analysis, clearly, mortality risk was also influenced by changed behavior and increased fitness. Evidence from other reports on physical activity change and reduced mortality risk[9,25] alleviates the concern that heredity and selective survival have an overriding role in the physical activity–fitness–mortality relationship. Indeed, data from the Harvard alumni and Aerobic Center Longitudinal Study cohorts support the claim that modifications in behavior also have a significant role in lowering mortality risk.

According to recent public health recommendations,[10,15,16] every US adult should engage in 30 minutes or more of moderate-intensity physical activity on most, or preferably all, days of the week. Additional American College of Sports Medicine/Centers for Disease Control and Prevention recommendations[10] suggest that individuals who can expend approximately 200 calories per day (or 1000–1400 kcal per week) can expect many of the health benefits associated with physical activity. This suggested amount of energy expenditure corroborates our values for people in the high fitness category but is greater than the amount presented for the moderate fitness level (which also was related to a substantially lower risk of early mortality in this cohort relative to the lowest level). We suspect that the 10 leisure time activities constituting the activity portion of the medical questionnaire may not have adequately captured the full spectrum of activities engaged in by this very healthy cohort (e.g., yard work, housework, stair climbing). Thus, the misclassification of active people as inactive (especially among those at the moderate fitness level) may have attenuated the estimation of weekly energy expenditure or activity volume in the cohort.

Year 2000 objectives call for reducing the prevalence of inactivity to less than 15%,[27] and more recent public health recommendations emphasize the value of moderate levels of physical activity. We suggest the addition of at least 30 minutes of walking on 5 days per week (or the equivalent volume of approximately 20 minutes of walking or about 15 minutes of jogging every day). Furthermore, we are confident that most individuals can achieve these physical activity goals and can thus attain a cardiorespiratory fitness level sufficient to result in important and substantial health benefits. □

Acknowledgments

This study was supported in part by National Institutes of Health grants AG06945 and AG09872.

We thank Kenneth H. Cooper, MD, for establishing the Aerobics Center Longitudinal Study, Cooper Clinic physicians and technicians for assistance with data collection, Cooper Clinic patients for their participation, and Carolyn E. Barlow, MS, for data management and analyses.

References

1. Blair SN, Kohl HW III, Paffenbarger RS, Clark DG, Cooper KH, Gibbons LW. Physical fitness and all-cause mortality: a prospective study of healthy men and women. *JAMA*. 1989;262: 2395–2401.
2. Sandvik L, Erikssen J, Thaulow E, Erikssen G, Mundal R, Rodahl K. Physical fitness as a predictor of mortality among healthy, middle-aged Norwegian men. *N Engl J Med*. 1993;328: 533–537.
3. Slattery ML, Jacobs DR Jr. Physical fitness and cardiovascular disease mortality: the US Railroad Study. *Am J Epidemiol*. 1988;127:571–580.
4. Blair SN, Kampert JB, Kohl HW III, et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA*. 1996;276:205–210.
5. Blair SN, Kohl HW III, Barlow CE, Paffenbarger RS, Gibbons LW, Macera CA. Changes in physical fitness and all-cause mortality: a prospective study of healthy and unhealthy men. *JAMA*. 1995;273:1093–1098.
6. Ekelund LG, Haskell WL, Johnson JL, Whaley FS, Criqui MH, Sheps DS. Physical fitness as a predictor of cardiovascular mortality in asymptomatic North American men: the Lipid Research Clinics Mortality Follow-Up Study. *New Engl J Med*. 1988;319:1379–1384.
7. Lee I-M, Chung-Cheng H, Paffenbarger RS. Exercise intensity and longevity in men: the Harvard Alumni Health Study. *JAMA*. 1995; 273:1179–1184.
8. Paffenbarger RS Jr, Hyde RT, Wing AL, Hseih CC. Physical activity, all-cause mortality, and longevity of college alumni. *N Engl J Med*. 1986;314:605–613.
9. Paffenbarger RS Jr, Hyde RT, Wing AL, Lee I-M, Jung DL, Kampert JB. The association of changes in physical activity level and other lifestyle characteristics with mortality among men. *N Engl J Med*. 1993;328:538–545.
10. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 1995;273:402–407.
11. Haskell WL, Montoye HJ, Orenstein D. Physical activity and exercise to achieve health-related physical fitness components. *Public Health Rep*. 1985;100:202–212.
12. American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Med Sci Sports Exerc*. 1990;22:265–274.
13. Fletcher GF, Blair SN, Blumenthal J, et al. AHA statement on exercise: benefits and recommendations for physical activity programs for all Americans. *Circulation*. 1992;86:340–344.
14. Blair SN, Kohl HW III, Gordon NF. Physical activity and health: a lifestyle approach. *Med Exerc Nutr Health*. 1992;1:54–57.
15. NIH Consensus Conference. Physical activity and cardiovascular health. *JAMA*. 1996;276: 241–246.

16. *Physical Activity and Health: A Report of the Surgeon General (Executive Summary)*. Washington, DC: US Dept of Health and Human Services; 1996.
17. Balke B, Ware RW. An experimental study of physical fitness in Air Force personnel. *US Armed Forces Med J*. 1959;10:675–688.
18. Ainsworth BE, Haskell WL, Leon AS, et al. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc*. 1993;25:71–80.
19. Pollock ML, Bohannon RL, Cooper KH, et al. A comparative analysis of four protocols for maximal treadmill stress testing. *Am Heart J*. 1976;92:39–46.
20. Pollock ML, Foster C, Schmidt D, Hellman C, Linnerud AC, Ward A. Comparative analysis of physiologic responses to three different maximal graded exercise test protocols in healthy women. *Am Heart J*. 1982;103:363–373.
21. American College of Sports Medicine. *Guidelines for Exercise Testing and Prescription*. Philadelphia, Pa: Lea & Febiger; 1986.
22. Proc GLM. In: *User's Guide: Statistics, Version 6*. Cary, NC: SAS Institute Inc; 1992.
23. Pollock ML, Wilmore JH, Fox SM. *Exercise in Health and Disease: Evaluation and Prescription for Prevention and Rehabilitation*. Philadelphia, Pa: WB Saunders; 1984.
24. Casperson CJ, Merritt RK. Physical activity trends among 26 states, 1986–1990. *Med Sci Sports Exerc*. 1995;27:713–720.
25. Paffenbarger RS Jr, Kampert JB, Lee I-M, Hyde RT, Leung RW, Wing AL. Changes in physical activity and other lifeway patterns influencing longevity. *Med Sci Sports Exerc*. 1994;26:857–865.
26. Bouchard C, Tremblay A, Despés JP, et al. The response to exercise with constant energy intake in identical twins. *Obes Res*. 1994;2:400–410.
27. *Healthy People 2000. National Health Promotion and Disease Prevention Objectives*. Washington, DC: US Dept of Health and Human Services; 1990. DHHS publication PHS 91-50212.