How Much Physical Activity Should We Do?  
The Case for Moderate Amounts and Intensities of Physical Activity

Steven N. Blair and Jon C. Connelly

A sedentary and unfit way of life leads to increased risk for several chronic diseases and premature mortality. Sedentary and unfit individuals are also more likely to develop functional limitations as they age. The precise type, amount, and intensity of physical activity required for protection needs further investigation. Traditional exercise recommendations suggest a threshold of activity that is necessary for protection, although current evidence does not support a dichotomous view of this issue. Clinical and epidemiologic studies show a continuous dose-response gradient of outcome variables across a wide range of activity or fitness levels. Moderate amounts and intensities of physical activity are associated with improved health and reduced risk of morbidity and mortality when compared with low activity or fitness. The major public health emphasis for physical activity recommendations and programming should be to encourage the most sedentary and unfit 20 to 25% of the population to become at least moderately active, and this can yield substantial benefits for the population.

Key words: physical activity, physical fitness, health, exercise programming

Research on the health and functional effects of habitual physical activity over the past 50 years follows two principal themes. Since the early work of Morris and Crawford (1958) on the role of physical inactivity in the development of coronary artery disease, population-based studies on physical activity and health have refined, tested, and extended the exercise hypothesis regarding the risk of the disease. This body of work over the past half century has led to consensus that sedentary living leads to coronary artery disease and perhaps to some cancers, stroke, non-insulin-dependent diabetes mellitus, and other health problems (Blair, 1994; Blair, Kohl, Gordon, & Paffenbarger, 1992; Bouchard, Shephard, & Stephens, 1994). The second principal theme in exercise science research has focused on the relation of exercise on improvement of physical fitness, usually measured as maximal oxygen uptake (VO₂max). Physical fitness is a broad concept, encompassing several specific types of fitness including strength, flexibility, and balance. We define fitness more narrowly for this report, although we recognize the importance of musculoskeletal fitness for function and for some conditions such as osteoporosis. Physical fitness, as used in this report, refers to aerobic power.

Most of the research on physical activity and health focuses on aerobic exercise; thus, we have more data on aerobic fitness. At about the same time Morris and Crawford published their first papers on physical activity and health, Karvonen and colleagues reported on the association of different intensities of exercise on heart rate at rest and work (Karvonen, Kentala, & Mustala, 1967).

These two research themes have developed within different methods and traditions of medical research. Physical activity and health studies were conducted by epidemiologists, and the work on exercise and fitness was done by physiologists, although Karvonen himself (Pekkanen et al., 1987) did studies in both areas and a few others also bridged the two thematic areas. The population-based research is observational in nature, with both cross-sectional and longitudinal studies reported, and physiologists used the experimental method.

Exercise training studies by physiologists manipulated the frequency, intensity, and duration of the training session and observed the effects on VO₂max (Burke & Franks, 1975; Pollock, 1978; Sharkey & Hollemann, 1967; Shephard, 1968). Quantification of the exercise training stimulus led to precise statements of exercise dose required to produce given changes in fitness. This approach came to be called exercise prescription, and by the mid-1970s specific parameters for frequency, intensity, and duration of exercise were accepted (American College of Sports Medicine [ACSM], 1975).

Epidemiologists conducting studies on physical activity and health typically relied on questionnaires to obtain self-reports of a study participant's habitual level of physical activity. Questionnaire assessments ranged from simple global questions (Kaplan, Seeman, Cohen,
Knudsen, & Guralnik, 1987) to extensive individual interviews that required 30-45 min to complete (Leon, Connett, Jacobs, & Rauramaa, 1987). Most often, the summary measure of physical activity used in analyses was an estimate of total energy expenditure or a physical activity index where an individual was assigned to one activity category on a multiple category scale. These summary measures frequently derive from aggregating multiple bouts of activity over the day, week, month, or year. Some of the assessment approaches distinguish between different intensities of activity (Leon et al., 1987; Morris, Clayton, Everitt, Semmence, & Burgess, 1990; Paffenbarger, Hyde, Wing, & Hsieh, 1986; Paffenbarger, Wing, & Hyde, 1978), but many others do not (Hein, Suadicani, & Gystelberg, 1992; Kaplan et al., 1987; Shaper & Wannamethee, 1991). Studies using both types of assessment show similar results in that the relative risk for coronary artery disease is approximately two times higher in sedentary groups when compared with active individuals (Powell, Thompson, Caspersen, & Kendrick, 1987). Some studies, notably those by Morris et al. (1990; Morris, Pollard, Everitt, & Chave, 1980), indicate that vigorous activity is required for protection, but this finding is not observed in other reports (Leon et al., 1987; Paffenbarger et al., 1986).

Several recent studies report the use of physical fitness as the exposure variable in research on the effect of sedentary habits on health (Blair et al., 1989; Ekelund et al., 1988; Hein et al., 1992; Slattery, Jacobs, & Nichaman, 1988). The advantage of these studies is that physical fitness can be more objectively measured than physical activity. This presumably leads to less misclassification and may give a more precise estimate of the impact of sedentary habits on morbidity and mortality. Indeed, the relative risks for all-cause and cardiovascular disease mortality in unfit compared with fit men and women reported in some physical fitness studies are substantially higher than those from physical activity studies. The summary relative risk for coronary artery disease in sedentary individuals in comparison with active persons is approximately 1.9 (Powell et al., 1987). The relative risks for cardiovascular or coronary artery disease mortality in the least fit compared with the most fit is 6.0 or more in recent reports (Blair et al., 1989; Ekelund et al., 1988; Lie, Mundal, & Eriksen, 1985), although some fitness studies report less effect of low levels of fitness (Hein et al., 1992; Slattery & Jacobs, 1988).

A number of studies in recent years combined some elements of the two research themes of physical activity and health and exercise training experiments on VO2max. These combination studies were designed to investigate possible mechanisms whereby activity might prevent disease and include research on the effects of exercise on blood pressure, lipoprotein pro-

file, or other risk factors for chronic disease (Duncan, Gordon, & Scott, 1991; Hagberg, Montain, Martin, & Ehsani, 1989; Krall & Dawson-Hughes, 1994; Paternostro-Bayles, Wing, & Robertson, 1989; Wood et al., 1983). Most of these projects used the standard exercise prescription described by the ACSM as the training stimulus, although others evaluated various combinations of frequency, intensity, and duration. It is still common, however, for scientists and clinicians to consider two somewhat competing views of the effects of physical activity: one on the role of physical activity in promoting health and the other on physical activity to improve fitness. We disagree with this approach of categorizing physical activity as contributing to health or fitness. We think physical activity works through multiple biological pathways to improve both health and function. Some of these mechanisms affect key elements in pathophysiology of disease. For example, a small amount of activity might favorably influence some aspect of the fibrinolytic system, thus reducing risk of clinical coronary events. Higher amounts or more vigorous activity strengthen the myocardium, thus improving fitness and chances of surviving a heart attack. Virtually all physiological effects of physical activity are transitory, which indicates the need for a continuation of an active lifestyle.

The brief background review presented here gives rise to issues relevant for public health policy discussions related to physical activity recommendations: (a) What is the appropriate dose (frequency, intensity, duration, and total amount) of activity that should be recommended to the public? and (b) Is the intensity of exercise important and, if so, does the recommended intensity differ for health and fitness outcomes?

The purpose of this report is to review and summarize evidence from different research themes and attempt to reconcile the reports into a unified and cogent recommendation for the type and amount of physical activity necessary for health and function. Space does not permit an exhaustive review of the literature in the many areas considered in this report. We selected several recent representative studies as well as a few classical investigations from past decades. The principal focus of the report is to evaluate the evidence that relates to benefits of moderate amounts and intensities of physical activity.

**Moderate Amounts of Physical Activity**

Health benefits of a moderate amount of physical activity can be evaluated from studies in which several levels of activity are specified so that the relation of dose of activity to reduction in risk is available. Several recent studies provide sufficient data to address this issue.
Physical Activity Dose and Mortality Reduction

Recent population-based studies report mortality risk for several physical activity categories, which allows for an assessment of the dose-response gradient.

British civil servants. Morris et al. (1990) studied 9,376 male civil servants (45-64 years of age and free of diagnosed heart disease) who were engaged in sedentary or physically light office work. The men were followed for an average of 9 years to evaluate the association of activity history with coronary attacks and deaths due to coronary events as well as all-cause mortality (all reported as age standardized rates/1,000 man-years). Within the vigorous category of sports and games, there was a dose response for frequency of activity as shown by a break between the categories “no vigorous sports” (standardized rate of coronary attack = 5.8), 1 to 3 and 4 to 7 episodes in previous 4 weeks (standardized rate = 4.5 and 4.1, respectively), and > 8 episodes (standardized rate = 2.1). Previous sports played, recreational work, and quantity of walking did not have a protective effect on coronary attack rate; however, fast walking (> 4 mph) did result in a lower coronary attack rate when compared with walking at a slower pace.

Harvard Alumni Study. The Harvard Alumni study used school records, as well as questionnaires, to investigate physical activity and lifestyle characteristics of 16,956 Harvard alumni (Paffenbarger et al., 1986). Personal and family medical history, specific lifestyle habits, and routine physical activity history were collected by questionnaire. Activity was measured in this study as reports of city blocks walked, stairs climbed, and types of sports played and time spent in sports participation. A physical activity index was computed for estimates of energy expenditure and categorized into levels of kilocalories expended per week.

This study shows an inverse relation between all-cause mortality and increment of reported physical activity. The risk of death in men with an activity index of 3.500 kcal/week was less than half that associated with the least activity (< 500 kcal). The men in the activity index ranges of less than 2,000 kcal/week had a 38% greater risk of death over the 12- to 16-year follow-up period than those in the higher index ranges. Although physical activity was associated with lower all-cause mortality, cardiovascular and respiratory diseases showed the strongest specific disease association. Data corrected for age and adverse behavioral and clinical characteristics revealed a 31% higher risk of cardiovascular mortality in sedentary men compared with men who were active.

The British Regional Heart Study. This prospective study assessed the relation between physical activity and risk of nonfatal heart attack (Shaper & Wannamethee, 1991). A standardized questionnaire was administered to 7,735 men (40-59 years of age) by research nurses at the practices of 24 general physicians. Physical activity was characterized according to the participants’ involvement in regular walking or cycling, recreational activity, and sporting (vigorous) activity. A physical activity index with arbitrary units (0 to 36) assigned each man to an index category based on frequency and type (intensity) of physical activity reported on the questionnaire. All participants were placed into six broad groups of the activity index representing inactive (0-2), occasional (3-5), light (6-8), moderate (9-12), moderately vigorous (13-20), and vigorous (> 21) activity levels. Study results showed a significant decline in heart attack risk across activity index categories. The groups reporting moderate and moderately vigorous activity experienced less than half the rate of heart attacks as the more sedentary men.

Multiple Risk Factor Intervention Trial. This multicenter study evaluated a multifactor intervention for decreasing all-cause mortality and, more specifically, events and deaths due to coronary heart disease in a high-risk population (Leon et al., 1987). Extensive clinical and physical data (including risk factor assessment) were collected on 12,866 men 35-57 years of age. Leisure-time physical activity (LTPA) was assessed at baseline. Physical activity intensity was classified as light (2.4 kcal/min), moderate (4.5-5.5 kcal/min), and heavy (6.0 kcal/min or more). Total LTPA was reported as mean minutes per day at baseline with participants classified into tertiles.

There were 37% fewer fatal coronary heart disease events and sudden deaths in the middle tertile as compared with the lowest tertile of LTPA. Combined fatal and nonfatal major coronary heart events were 20% lower in the high versus low LTPA groups. Overall, mortality rates in the high LTPA group were similar to those in the middle tertile of LTPA.

Physical Fitness Dose and Mortality Reduction

Population-based follow-up studies on the relation of physical fitness to mortality are also available. Several of these studies report mortality rates by multiple categories of fitness, which allows for examining the dose-response relation of physical fitness to coronary heart disease events and all-cause mortality.

U.S. Railroad Study. During the period from 1957 to 1960, data were collected on 3,043 White men aged 22-79 years and free of preexisting heart disease (Slattery et al., 1989). The men were reexamined from 1962-1964. The men completed a submaximal treadmill test at 5% grade for 3 miles/hr for 3 min on both examinations. Fitness variables determined at the time of the test were resting heart rate, exercise test heart rate, and exercise test performance (3-min test heart rate x test systolic blood pressure/100). Other study variables included blood pressure, serum cholesterol, smoking his-
tory, and age. After adjustment for age, smoking, blood pressure, and serum cholesterol, exercise test heart rate remained a significant independent predictor for both coronary heart disease and all-cause mortality. There was a trend toward a dose response across the four categories of fitness, but significant differences were seen only between the two highest response categories and the bottom two categories.

**Lipid Research Clinics Study.** As a part of the Lipid Research Clinics Prevalence survey (Ekelund et al., 1988), fitness data were collected on 4,276 White males aged 30-69 years. Follow-up of the participants averaged 8.5 years. All participants completed a modified Bruce submaximal treadmill test to collect data for assessment of fitness. The endpoint of the test was the attainment of 90% of a participant's predicted maximal heart rate or the inability to continue because of chest pain, fatigue, dyspnea, leg pain, EKG abnormalities, or decreased systolic blood pressure.

After adjustment for age and cardiovascular risk factors, men with a lower level of physical fitness had a higher risk of death from cardiovascular and coronary heart disease. Mortality from cardiovascular disease was 8.5 times higher in the quartile with the lowest level of fitness compared to the highest fit quartile. Mortality from coronary heart disease was 6.5 times higher in the least fit versus the most fit quartile.

**Norwegian business men.** Lie et al. (1985) investigated the relation of physical fitness to death and incidence of coronary heart disease in 2,014 apparently healthy men 40-59 years of age. Extensive clinical and physical data from the baseline examination allowed for exclusion of men with known or suspected heart disease from the analysis. Follow-up was for a 7-year period. Physical fitness level was assessed by cycle ergometry. Initial workload on the cycle ergometer varied from approximately 100-200 W depending upon age and population. Cumulative work performed (sum of work performed at each load) divided by body weight (in kilograms) was the fitness variable. There was an inverse gradient for all-cause mortality, as well as death and events due to coronary heart disease, across fitness quartiles. As with the other studies reviewed, the least fit group had a disproportionate number of all-cause deaths and coronary events.

The 17-year follow-up of this cohort was reported recently (Sandvik et al., 1993). In this extended follow-up, there were 271 deaths with 52.8% of the deaths due to cardiovascular disease. The unadjusted risk ratio for mortality from cardiovascular disease in this study is 4.8 when participants from the least fit quartile are compared to the highest fit quartile. The adjusted relative risk of death from cardiovascular disease in the most fit quartile compared to the least fit quartile is 0.41. The corresponding relative risks for quartiles 2 and 3 compared to quartile 1 are 0.45 and 0.59, respectively. A major observation in this extended follow-up was the decline in risk across fitness quartiles 2-4. The authors concluded that physical fitness is a graded, independent, long-term predictor of mortality from cardiovascular diseases in apparently healthy men.

**Aerobics Center Longitudinal Study.** A large group of men and women completed a preventive medical examination at the Cooper Clinic in Dallas, Texas and were followed for approximately 8 years after their baseline assessment (Blair et al., 1989). All participants had a maximal exercise test on a treadmill, which provided an estimate of aerobic power at the start of follow-up. Age-group and sex-specific treadmill time distributions were used to assign study participants to fitness quintiles. Age-adjusted all-cause death rates were calculated for low- (1st quintile), moderate- (2nd and 3rd quintiles), and high- (4th and 5th quintiles) fitness categories per 10,000 person-years of follow-up. The rates were 64, 26, and 20 across low- to high-fitness categories for men and 40, 16, and 10 for women.

A recent report from this study shows substantial benefit from changing from low to moderate physical fitness. Blair et al. (1995) followed 9,777 men who completed two examinations at the Cooper Clinic, with physical fitness determined by maximal exercise testing. Initially low fit men (the bottom 20%) who improved to being at least moderately fit had a 44% lower all-cause death rate and a 52% lower cardiovascular disease death rate than men who were persistently unfit. The benefit of improving fitness was present in all age-groups, and was comparable to the benefit of smoking cessation. The amount of physical activity necessary to improve from low to moderate fitness is estimated to be that recommended by the ACSM and the Centers for Disease Control and Prevention (Pate et al., 1995).

**Physical Activity, Fitness, and Risk Factors**

Population-based studies of 20 years ago show a steep inverse gradient for several coronary artery disease risk factors across categories of physical activity and physical fitness. Hickey, Mulcahy, Bourke, Graham, and Wilson-Davis (1975) examined 15,171 men (25-74 years of age) as part of a risk factor screening program. They compared serum cholesterol, blood pressure, relative weight, and cigarettes smoked per day across three levels of LTPA and found that highly active men had lower levels of all risk factors than sedentary men. Moderately active men had intermediate values. In a similar cross-sectional study, investigators from the Cooper Clinic (Cooper et al., 1976) reported steep declines across five physical fitness categories for cholesterol, triglycerides, glucose, uric acid, and blood pressure. These trends held after adjustment for differences in body composition. Participation in moderate-intensity activities, such as walking instead of driving a short distance, climbing
stairs, parking away from the destination, and getting off the bus early and walking, was associated with favorable risk factor profiles in 5,930 adult men and women who were surveyed in community screening centers in five California cities (Sallis, Haskell, Fortmann, Wood, & Vranizan, 1986).

A walk of only about 1 mile per day may improve bone health according to a study by Krall and Dawson-Hughes (1994). They measured bone mineral density and habitual walking habits in a group of 239 postmenopausal women. Women who walked more than 7.5 miles per week had higher mean bone density of the whole body and of the leg and trunk regions than women who walked less than 1 mile per week. The women who walked more than 7.5 miles per week also had less decline in bone density than sedentary women during a 1-year follow-up.

Wood et al. (1983) conducted a 1-year exercise training study with 81 sedentary men, aged 30-55 years, with concentrations of plasma lipoprotein as the primary outcome variable. Exercise training was a traditional walk-jog program at 70-85% of maximal capacity. Lipoprotein concentrations were calculated for quartiles of weekly running mileage (0-3.9, 4-7.9, 8-12.9, and 13+ miles/week for quartiles I through IV, respectively). Some of the variables, particularly high-density lipoprotein cholesterol (HDL-C)/total cholesterol and HDL2 mass, showed a strong linear trend across weekly mile-

Figure 1. Summary of the results from six studies in which fitness level was determined (three studies) or activity level assessed by questionnaire (three studies) in individual populations. Follow-up was generally between 7 and 9 years except that of Sandvik et al. (1993), which had a 16-year follow-up. The low-level group for each study represented in this figure was the activity/fitness level next to the least active/fit group. The high level represents the group that was the most active/fit for the particular study. If the study participants were grouped by quintile, the moderate group is the average of the 3rd and 4th quintiles.
age quartiles. A little exercise appeared to be more beneficial than none, and men with higher running mile-age levels had an even greater change.

**Summary of Research on Amount of Activity or Fitness**

The principal finding relevant to the present discussion is that the difference in mortality rates between the least active or fit group and the next most active group is substantial. Further declines in mortality risk are evident in most studies at higher levels of activity or fitness, but the greatest difference in risk between adjacent activity or fitness groups is between the first two activity or fitness categories. This point generally holds true for studies of physical activity and fitness in relation to specific clinical causes of death. Data from three of the studies investigating fitness and from three studies of activity in relation to death due to cardiovascular disease are summarized in Figure 1. An apparently greater effect is seen at the highest levels of activity or fitness in five of the six studies but, again, the greatest relative change between two activity categories is between the sedentary and the low-fitness/activity level.

**Moderate Intensity of Physical Activity**

Evidence is presented in the preceding section on the dose-response gradient for the relation of the amount of physical activity or fitness to mortality and clinical status. Next we examine the association of the intensity of exercise training to improvements in physical fitness and other clinical variables.

**Exercise Training Intensity and Aerobic Power**

Rate of energy expenditure has been one of the keystones of exercise programming for nearly 40 years. One of the first papers on the issue was published in 1957 (Karvonen et al., 1957). This report gave rise to the now nearly universally applied “Karvonen equation” for establishing exercise intensity: maximal heart rate - resting heart rate x a specified percentage. Karvonen and colleagues (1957) stated that 60% was the minimum proportion of heart range during training that is required for an increase in fitness. This paper is a classic and provided an important stimulus to the scientific investigation of exercise training. However, in retrospect, there are some critical features of the design and methodology that should temper the widespread generalization of the results that occurred.

The study population was six male students aged 20-25 years. One of the students repeated the training experiment, which resulted in data from seven training experiments. The training was running on a treadmill for 30 min per day for 4 or 5 days per week. The experiment lasted 4 weeks. Three participants trained at 60% of their heart rate range, and four experiments were done with training at 71-75% of the heart rate range. Submaximal running speed (at a constant heart rate) improved in only 1 of 3 participants who trained at 60% and in all 4 participants who trained above 70%; and this appears to be the primary data on which the 60% minimum training criterion was established. However, 2 of the 3 participants who trained at 60% reduced their maximal heart rate, and all 3 participants reduced their resting heart rate and increased their heart size. Thus, it appears that at least some adaptation occurred in those who trained at 60%, although it is clear that those who trained above 70% had more improvement.

Many early training studies that investigated the role of exercise intensity had similar design features to the Karvonen et al. (1957) study. That is, study participants were young men, usually high school or college students, and training was relatively short term, from 4-10 weeks (Burke & Franks, 1975; Faria, 1970; Sharkey, 1970; Sharkey & Holleman, 1967; Shephard, 1968). Exercise intensities in these studies ranged from exercise heart rates of 120-180 beats per minute, in studies where intensity was described by heart rate, to 39-96% when intensity was described as a fraction of aerobic power. All intensity groups showed some evidence of improvement in fitness in all of these studies, although in some cases this improvement was not statistically significant for the lowest intensity training group. Lack of statistically significant findings for some of the studies is not surprising given the likely low statistical power resulting from the small sample size (less than 10 in all but one study). Furthermore, these young men were healthy and relatively fit at baseline.

**Summary: Early studies.** A summary of some of these early exercise training studies is presented in Table 1. We believe that instead of concluding that 60% or some equivalent minimal intensity training threshold is required, it is more appropriate to state that “exercise training intensity > 60% is needed to improve significantly the aerobic power of healthy and fit young men over a training period of 4-10 weeks.” It also should be noted that even in this select population some improvement was seen in the low-intensity training groups.

**Summary: Later studies.** It is reasonable to conclude from the early studies cited above that training intensity does have a direct impact on the amount of improvement in aerobic power. Furthermore, high-intensity activity is increasingly important at higher levels of fitness, such as in young and healthy persons (Pollock, 1978; Pollock & Blair, 1981; Wenger & Bell, 1986). It also is clear that low to moderate intensity exercise (40-60% of aerobic power) results in an improvement in fitness, especially in middle-aged and older men and women who are not particularly fit at baseline (Duncan et al., 1991;
<table>
<thead>
<tr>
<th>Authors</th>
<th>Participants</th>
<th>Training</th>
<th>Intensity (low, moderate, high)</th>
<th>Fitness variable</th>
<th>Summary</th>
<th>Comments</th>
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<tr>
<td>Sharkey &amp; Holleman (1967)</td>
<td>16 college men aged 18-19 years</td>
<td>10-min walks, 16 sessions/week on treadmill at 3.5 mph with grade adjusted to target heart rate</td>
<td>3 target heart rates (in beats/min): 120, 150, 180; and control</td>
<td>Balke treadmill test, pre- and post-training</td>
<td>Improvement at high and moderate intensities were significantly different from the low intensity and control groups.</td>
<td>The Astrand-Rhyming nomogram prediction of aerobic capacity also showed highly significant changes.</td>
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<tr>
<td>Shephard (1968)</td>
<td>39 sedentary participants aged 19-31 years</td>
<td>Treadmill at 1 of 3 speed/grade settings and combinations of duration-frequency (per week)</td>
<td>Treadmill speed/grade combinations were set to meet 38, 75, and 96% of estimated average aerobic power of group.</td>
<td>Simple step test, 18 in., double step, 10/min for 5 min, 10-min rest and repeat at 2 x first rate</td>
<td>Predicted gain in aerobic power: high = 19%, moderate = 15.3%, and low = 11.8%</td>
<td>Results derived from a prediction equation and showed an inverse relation of level of fitness and training response at constant intensity.</td>
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<tr>
<td>Faria (1970)</td>
<td>40 college men aged 18-24 years</td>
<td>Bench stepping until reaching a target heart rate, 5 days/week for 4 weeks</td>
<td>3 target heart rate ranges (in beats/min): 120-130, 140-150, and 160-170; control</td>
<td>Physical work capacity test (PWC-180) by cycle ergometer, score is cumulative, work performed to reach pulse of 180</td>
<td>Training PWC-180 increased significantly in the 140-150 and 160-170 groups compared to 120-130 and control groups. No significant difference between the 140-150 and 160-170 groups.</td>
<td>Authors suggest the possibility of a threshold for training heart rate. They also suggest that it may not be necessary to take training beyond a heart rate of 150.</td>
</tr>
<tr>
<td>Sharkey (1970)</td>
<td>Study 1: 18 college men aged 18-24 years; Study 2: 18 adult men aged 29-39 years</td>
<td>3 x 2 random factorial design, cycle ergometry 3 days/week for 6 weeks</td>
<td>Exercise to accumulate total work (7,500 or 15,000 kpm) at target heart rates: 130 (125 in adults), 150 (145 in adult), and 170 (165 in adults)</td>
<td>Astrand-Rhyming step test, Balke treadmill test, Sjøstrand physical work capacity test (PWC-170) by cycle ergometer</td>
<td>Students: no significant differences seen in either intensity or duration; adult men: significant difference for highest intensity (step test only). Also, significant interaction by duration of test.</td>
<td>In young, relatively fit men, training intensity does not influence training effects when workload is held constant. Duration did not affect training change with constant intensity.</td>
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<tr>
<td>Burke &amp; Franks (1975)</td>
<td>16 male students aged 16-18 years</td>
<td>Cycle ergometry, 3 days/week for 10 weeks</td>
<td>Exercise at percentage of maximal heart rate to accumulation of set work (12,000 kpm): 65%, 75%, and 85%</td>
<td>VO₂max determined by cycle ergometry.</td>
<td>Significant difference in training effect between two highest intensities and control. Training effect seen in low intensity but was not significant.</td>
<td>Authors suggest that minimum intensity necessary for training effect at constant accumulated work is 75% of maximal heart rate.</td>
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</tbody>
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### Table 2. Summary of studies to determine intensity of physical activity necessary for significant reduction of risk factors for cardiovascular disease

<table>
<thead>
<tr>
<th>Authors</th>
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<th>Training</th>
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<tbody>
<tr>
<td>Duncan et al. (1991)</td>
<td>102 sedentary premenopausal women, 20-40 years of age</td>
<td>Walking: 3 intensities, 5 days/week, 24 weeks, 13 sedentary controls</td>
<td>Speed of walking: 8.0 km/hr, 6.4 km/hr, and 4.8 km/hr</td>
<td>Exercise treadmill test for VO₂max</td>
<td>Significant dose response increase in VO₂max across all groups, increase similar in all three groups</td>
<td>Authors conclude that vigorous exercise in women is not necessary to obtain meaningful benefit in their lipoprotein profile.</td>
</tr>
<tr>
<td>Foster et al. (1989)</td>
<td>24 healthy female participants 67-89 years of age</td>
<td>Walking: 2 intensities at least 3 days/week for 10 weeks, 100 calories expended each session</td>
<td>% Maximal heart rate reserve (HRR); low = 40% HRR and high = 60% HRR</td>
<td>Exercise treadmill test for VO₂max and exercise maximal heart rate-pressure product</td>
<td>Significant increase in VO₂max in both groups, pre- versus posttest, but no difference between groups. Low-intensity exercise prescription provides adequate training response in older women, particularly at the initiation of program.</td>
<td>Low-intensity exercise prescription provides adequate training response in older women, particularly at the initiation of program.</td>
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<tr>
<td>Gaesser &amp; Rich (1984)</td>
<td>16 nonsmoking, nonobese male participants 20-30 years of age</td>
<td>Cycle ergometer at 1 of 2 intensities, 3 days/week for 18 weeks, initial energy expenditure = 300 kcal/day (calculated)</td>
<td>% baseline VO₂max: low = 50 min at 45% and high = 25 min at 80-85%</td>
<td>Exercise treadmill test for VO₂max</td>
<td>Significant increase in VO₂max in both groups, pre- versus posttest, but no difference between groups. Inverse correlation of HDL-C, pre- versus posttest. Significant mean fat loss in both groups.</td>
<td>Threshold was 45% of baseline VO₂max. Exercise induced change in HDL-C is dependent upon pretraining level.</td>
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<tr>
<td>Gossard et al. (1986)</td>
<td>64 sedentary, but apparently healthy, men 40-60 years of age</td>
<td>Home-based walk/jog or jog, 5 times per week, 12 weeks; initial energy expenditure for both groups: 300 kcal/day</td>
<td>% baseline VO₂max: low = 42-60% and high = 63-81%; derived from exercise heart rate range, target rates were 60 and 75%</td>
<td>Exercise treadmill test for VO₂max</td>
<td>Significant increase in VO₂max of both low and high compared to control at 6 and 12 weeks; high-intensity group was significantly greater than low group at both 6 and 12 weeks</td>
<td>Authors conclude that low-intensity exercise in home augments functional capacity. Authors report adherence exceeded 90%. Note that adherence was monitored closely.</td>
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<tr>
<td>Tanaka (1992)</td>
<td>42 men and 22 women 16-60 years of age</td>
<td>Supervised cycle ergometer (1 hr), 3 days/week for 10 weeks</td>
<td>% baseline VO₂max, single intensity of 50% VO₂max or lactate threshold</td>
<td>Exercise treadmill test for VO₂max</td>
<td>Significant improvement in aerobic work capacity, lipid profiles, and augmentation of baroreflex</td>
<td>Author states that training at 50% of VO₂max (above which lactate begins to accumulate) is better in patients because it can be easily determined by the break-point of rate-pressure product.</td>
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<td>King et al. (1991)</td>
<td>160 women and 137 men 50-65 years of age, sedentary and free of cardiovascular disease</td>
<td>High-intensity group and home-based, low-intensity home-based; walk, jog, some cycle and treadmill for total of 12 months</td>
<td>% peak treadmill heart rate: high = 73-88% (3 days/week for 40 min) and low = 80-73% (5 days/week for 30 min)</td>
<td>Exercise treadmill test for VO₂max</td>
<td>Significant increase in VO₂max and treadmill time in all groups compared to control (adherence-specific)</td>
<td>Study supports efficacy of individually prescribed home-based exercise training in enhancing functional capacity.</td>
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</table>
Foster, Hume, Byrnes, Dickinson, & Chatfield, 1989; Gaesser & Rich, 1984; Gossard et al., 1986; King, Haskell, Taylor, Kraemer, & DeBusk, 1991; Tanaka, 1992). Several investigators over the past decade have reported that lower intensity exercise increases aerobic power. Results from studies cited to illustrate this point are shown in Table 2.

**Exercise Training Intensity and Changes in Clinical Status**

Low to moderate exercise intensity is associated with favorable status on coronary artery disease risk factors and other clinical variables. Cross-sectional analyses show less overweight, lower lipid levels, and higher bone mineral density in individuals who regularly participate in walking or other moderate-intensity physical activity (Krall & Dawson-Hughes, 1994; Sallis et al., 1986). Training experiments also show improvements in several clinical and health variables in men and women who participate in moderate-intensity physical activity. Training at 40-60% of aerobic power reduces mildly elevated blood pressure (Arakawa, 1993; Hagberg et al., 1989; Koga et al., 1992). In fact, the ACSM's (1993) position stand on the issue indicates that low to moderate-intensity exercise reduces blood pressure as much, or more, than higher intensity exercise.

Cycle ergometer exercise at approximately 40% of maximal aerobic power (about 2 METs for the 10 women with Type II diabetes in the study) resulted in an acute reduction in blood glucose and insulin levels (Paternostro-Bayles et al., 1989). Some improvement was noted after 20 min of exercise at this level, and greater effects were seen after 40 min of exercise. Duncan et al. (1991) trained 102 initially sedentary premenopausal women in a walking study. Women were assigned to a control group or to one of three walking groups (walking 3 miles per day at 3, 4, or 5 mph). All three walking groups increased HDL-C (0.08 mmol/L), and there was no difference between the 3 mph and 5 mph groups.

King and colleagues (1991) evaluated three exercise training programs (high-intensity group-based, high-intensity home-based, and low-intensity home-based) relative to a no-exercise control group in 357 men and women 50-65 years of age. All exercise groups improved their fitness relative to controls, and there were no significant differences among exercise groups (see Table 2). These investigators also studied the influence of the training programs on psychological outcomes (King, Taylor, & Haskell, 1993). Several psychological outcomes improved in exercisers compared with controls, and these beneficial changes were not related to exercise intensity.

**Exercise Intensity and Mortality**

There is a paradox regarding the importance of exercise intensity in terms of mortality reduction. Morris and colleagues (1980, 1990) have consistently found that vigorous exercise (> 7.5 kcal/min) is required for protection against heart attacks. Both light sports (such as bowling, dancing, golf, and yardwork) and strenuous sports (such as running, swimming, tennis, and skiing) are associated with lower mortality in men in the Harvard Alumni Study, although strenuous sports have a greater effect on mortality risk (Paffenbarger et al., 1978). More recently, changes in physical activity in relation to subsequent mortality is reported for the Harvard men (Paffenbarger et al., 1993). In these analyses, participating in moderately vigorous sports play (> 4.5 METs) appears to be necessary for risk reduction. To complicate matters further, the most recent report from this study (Lee, Hsieh, & Paffenbarger, 1995) suggests that an even higher intensity activity (≥ 6 METs) is required for extension of longevity.

Other recent epidemiological studies have shown reductions in mortality risk with moderate-intensity physical activity (Lindsted, Tonstad, & Kuzma, 1991; Scragg, Stewart, Jackson, & Beaglehole, 1987; Slattery et al., 1989). Shaper and Wannamethee (1991) showed an inverse gradient for heart attack risk across a six-category physical activity index. Their index was constructed from a questionnaire that combined frequency and intensity of exercise. However, about one half the risk reduction they observed was between the first category (inactive) and the next category (regular walking or recreational activity only). Thus, there is an implication that low to moderate intensity activity provides some benefit. Leon et al. (1987) examined all-cause and coronary heart disease rates across tertiles of LTPA in high-risk men participating in the Multiple Risk Factor Intervention Trial. Men in the second and third tertiles had lower death rates than men in the least active tertile. The tertiles were created from estimates of total energy expended in LTPA, so they were based on a combination of light, moderate, and heavy intensity activities, and it was not possible to completely separate the independent effects of each. Approximately 80% of the total activity in each of the tertiles was spent in light or moderate activities, so it may be reasonable to assume that heavy intensity activity had little influence on the results.

Many population-based studies on activity and mortality used somewhat nonspecific questionnaires, and it is not possible to disentangle the separate effects of intensity and frequency of exercise (ACSM, 1993; Hein et al., 1992; Rakowski & Mor, 1992; Salonen, Slater, Tuomilehto, & Rauramaa, 1988). Most of these studies used very general or global questions, which probably separated those who did no activity from those who did.
some. Given that no more than 10-20% of adults, at least in the United States, are vigorously active, and that there is a strong inverse gradient of coronary heart disease mortality across total physical activity categories (see Figure 1), it is likely that individuals placed in the intermediate activity groups get little vigorous exercise.

Recent studies confirm that low to moderate intensity exercise training can increase physical fitness and result in improvements in several different clinical and health variables. These changes are especially apt to occur in individuals who are initially sedentary and unfit. Physical fitness may increase more with high-intensity training than with low- to moderate-intensity training, although some studies have shown just as much gain in aerobic power in the latter group. Studies have shown comparable enhancements in variables such as HDL-C, blood pressure, body composition, and psychological outcomes across exercise intensity groups.

The effect of moderate-intensity activity on mortality is less clear. The lack of certainty may be due to the means of categorizing activity intensity. The studies of Morris report vigorous activity (intensity likely to exceed 6 METs) as protective against fatal coronary heart disease. They also report risk reduction in individuals 55-65 years of age who had the next lowest level intensity of activity (say, 4.5-6.0 METs); we conclude that this is moderate activity. Lee et al. (1995) included brisk walking in their vigorous exercise group (≥ 6 METs); thus, from both of these studies, walking appears to provide protection against premature death. In the study by Leon et al. (1987), there was little difference in the percentage reported for the categories of moderate or heavy intensity across tertiles of total LTPA. The differences in activity among the three tertiles of LTPA (and, therefore, a difference in death rates) were in the total amounts of activity in each category. It is clear, however, that moderate intensities of activity are associated with reduction in mortality in at least some studies.

Ebisu (1985) assigned 53 young male college students to one of four groups in an exercise training experiment. One group served as controls, and the other three groups trained by running 3 days per week. All groups ran the same distance each day. One group ran the entire distance in one session, one group split the distance into two runs, and the third group performed three runs to obtain the requisite distance. All three groups increased their VO\textsubscript{2}max by approximately 8% and improved their 1.5-mile run times by approximately 10% relative to the control group, and there were no significant differences among the running groups. Changes in HDL-C were evaluated, and only the three times per day running group showed a significant improvement.

DeBusk, Stenestrand, Sheehan, and Haskell (1990) conducted an 8-week training study with 36 initially sedentary middle-aged men. One half of the men were randomly assigned to a traditional jogging program for 30 min per day for 5 days per week. The rest of the men did the same amount of jogging but in three separate 10-min sessions, separated by at least 6 hr, for 5 days per week; thus, the two groups did the same total amount of exercise over the course of the study. Both groups significantly improved their performances on a maximal exercise test on a treadmill, and the improvements were comparable in the two treatment groups.

These two studies suggest it is the total daily energy expended in exercise that determines the amount of improvement in physical fitness. Continuous exercise over 20 to 40 min, which is the usual recommendation, may not be necessary for physiological adaptation. The minimal length of each exercise session is not known, but the study by DeBusk et al. (1990) suggests that it is no more than 10 min. It seems possible that even shorter bouts, say 5 min, in which a steady state is achieved in submaximal exercise might also improve fitness, but this remains to be established.

### Accumulation of Physical Activity

Although not related to the question of impact of moderate amounts and intensities of physical activity, the issue of the value of accumulated activity also is important for public health policy and programs. The traditional exercise prescription stresses the importance of continuous aerobic activity as a requirement for physiological adaptation. This criterion has been questioned, and some recommendations now advise that the accumulation of activity over the course of the day is acceptable (Pate et al., 1995). More research is needed to evaluate the question, but two reports from well-controlled studies provide support for the accumulation hypothesis.

### Summary and Conclusion

The weight of available evidence shows an inverse gradient of risk of clinical disease across strata of physical activity or physical fitness. This trend is seen for total amount of activity or fitness and for intensity of activity. The conclusion is clear that some activity is better than none and that low- to moderate-intensity activity is better than remaining sedentary. The optimal dose and intensity of activity cannot be specified. It does seem that greater amounts of activity or fitness and perhaps higher intensity activity provide greater benefits for reduction of clinical disease than does lesser amounts; however, the effect is less clear for reduction of mortality. Research on the health and functional benefits of multiple short exercise sessions over the course of the
day is encouraging. The implication for public health recommendations is that sedentary individuals can be encouraged to accumulate their physical activity rather than obtain it all in one dose. This may be less intimidating and more acceptable to some people.

Recent statements on physical activity and health from the United States provide an expanded concept of appropriate physical activity programs (American Heart Association Prevention Conference III, 1993; Fletcher et al., 1992; Pate et al., 1995). These position papers recognize the health benefits of moderate amounts and intensities of physical activity, and suggest that an accumulation of multiple bouts of activity over the day can be helpful. These concepts do not replace earlier recommendations from these groups but are viewed as an extension of previous recommendations. The new recommendations provide more flexibility in designing and implementing physical activity programs, whether by public health agencies or by individuals; thus, this review confirms health benefits of physical activity. These benefits extend across a broad range of activity categories, with some activity being better than none and more (at least up to a point) being better than less. Current evidence is not sufficient to specify precisely minimal, optimal, or hazardous levels of exercise, and future research undoubtedly will help clarify these issues. Nonetheless, there are adequate data to support a call for action to increase physical activity levels in most industrialized societies.

The major public health problem of sedentary living is concentrated in the least active and unfit 20-30% of the adult population. This group has an increased mortality of at least two-fold, and it may well be higher if the physical fitness studies are correct. Risk can apparently be substantially reduced if these individuals become at least somewhat active and moderately fit. Thus, the public health policy should be to encourage the most sedentary and unfit to do something, perhaps with a strategy of making gradual changes over time. It may be that with continued support from their physicians, families, friends, and employers, many of these individuals might progress to higher levels of activity and further reduce their risk of chronic disease.

References


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E-mail: sblair@cooperinst.org