Physical Activity and Aging

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ABSTRACT: Most human beings experience peak physical performance in their late teens and begin a slow decline in their early 20s, whose course is greatly affected by the activity levels undertaken by individuals in the years that follow. Many studies provide evidence that in developed nations such as the U.S., a sedentary lifestyle contributes significantly to development of the major risk factors for age-related disease, prominent among them obesity, diabetes, and hypertension. Conversely, numerous studies document the benefits of physical activity, and in particular structured exercise programs, not only for reducing disease risk and improving physical performance, but also for enhancing substantially the quality of daily life. Aerobic and resistance training have complementary benefits, and can be undertaken at almost any age and physical condition, given appropriate medical clearance and supervision as warranted.

KEYWORDS: aging; physical activity; physical fitness; exercise; diseases af aging; cardiovascular disease, Alzheimer's disease; activities of daily living; body mass; obesity; muscle mass; quality of life

FITNESS AND AGING: A TWO-WAY STREET

FIGURE 1 is a modification of a graphic that is commonly presented at an aging conference. It leads the audience through some of the pathways by which aging leads to disease. The arrows in the original graphic pointed one way, with increased fatigueability, muscle weakness, decreased endurance capacity, muscle wasting, all leading to decreased physical activity, and then eventually, through other pathways, to diseases such as heart disease. The modification is that some of the arrows now point in both directions. The justification for this modification is the considerable evidence that physical inactivity contributes to many of the adverse changes that occur with aging.

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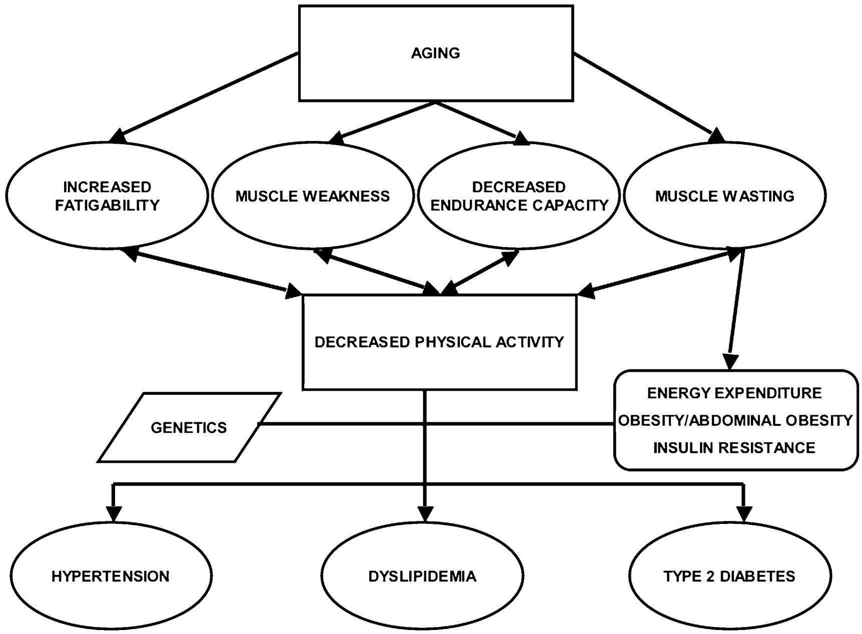

FIGURE 1. A commonly presented figure showing selected pathways by which changes upon aging lead to disease, All of the arrows in the original figure pointed one way, with increased fatigueability, muscle weakness, decreased endurance capacity, and muscle wasting leading to decreased physical activity, and eventually to disease. The *arrows in the middle* have been modified to point in both directions, indicating that physical activity itself (independent of aging) causes increased fatigueability, muscle weakness, decreased endurance capacity, and muscle wasting.

Physical inactivity speeds up the aging process in many people, whereas increased physical activity slows it down in others.

The typical aging curve suggests that most physiological functions improve from birth through the late teens. Most of these functions commonly level off in the mid-20s and then it's generally downhill from there for most physical and cognitive functions. However, the rate of change is not equal among individuals. What is clear is that there are several modifiable mediating factors on the aging curve. Among the key modifiable factors are physical activity, nutrition, body fat, muscle mass, and smoking, each of which can either delay or accelerate the aging process.

Our current understanding of the relationship between lifestyle and disease risk is not particularly new. In the recent biography of Benjamin Franklin by Walter Isaacson,[1] there is a story that demonstrates Dr. Franklin's understanding of the effects of activity and nutrition on health. In his later years, he suffered from gout and kidney stones. In his unique story-telling style, Franklin says to The Gout, which is portrayed as a person, “What have I done to merit these cruel sufferings?” The Gout answers, “Many things. You have eaten and drank too freely, and you have much indulged those legs of yours in their indolence.” “Who is [it] that accuses me?” asks Franklin. “It is I, even the gout.” And Franklin responds, “What? My enemy in person? For you would not only torment my body to death, but ruin my good name, reproach me as a glutton and a tippler? Now all the world that knows me will allow that I’m neither the one nor the other.” The Gout responds, “The world may think as it pleases, but I very well know that the quantity of meat and drink proper for a man who takes a reasonable degree of exercise would be too much for another who never takes any.” In many ways, Dr. Franklin understood the notion of preventive medicine and healthy living, although, like many people today, he did not follow his own advice.

SEDENTARY LIFESTYLE: A FEW REALITIES

The sedentary lifestyle is a major contributor to the leading causes of death among adults in the United States.[2] It has been estimated that about 15% of the 1.6 million chronic health conditions that are newly diagnosed each year are due to a sedentary lifestyle alone, independent of other risk factors.[3] Unfortunately, according to the American Heart Association Biostatistical Fact Sheet for 2002 (FIG. 2),[4] about 30% of the American population performs no exercise at all. About 40% or so does some exercise, whereas only about 27%

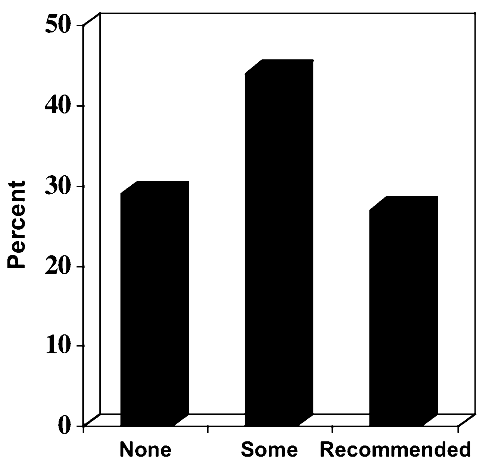

FIGURE 2. The number of adults in the U.S. who meet recommended guidelines for physical activity. (Adapted from the American Heart Association Biostatistical Fact Sheet for 2002.)

of the adult population engages in exercise at the recommended levels that would provide protection against the chronic diseases that occur in aging. The problem of physical inactivity is not only limited to older people but also exists across all age groups. The relative risk of coronary disease associated with physical inactivity, depending on the study, ranges anywhere from 1.5 to 2.5. This risk is comparable to that of high blood cholesterol, hypertension, and cigarette smoking.

The increasing problem of type 2 diabetes may also be related to physical inactivity. Among persons 70–75 years of age, approximately 25% have type 2 diabetes.[5] It is estimated that as many as 25% of all nursing-home residents have diabetes,[6,7] and they tend to be younger than other patients in the nursing home because diabetes accelerates the aging process. The prevalence of diabetes increased to almost 8% in 2001 from 7.3% in the previous year, or an overall increase of about 8%.[8] This increased risk of diabetes is closely linked to the increasing prevalence of overweight and obesity. For example, the prevalence of obesity, defined as a body mass index (BMI) greater than 30 kg/m,^{2} which is the threshold for the category of obesity, was 21% higher in 2000 compared to the previous year.

In the Nurses Health Study,[9] each hour a day spent walking reduced both the risk of developing obesity and diabetes. The reduction in risk is about 25% for obesity and about 35% for diabetes. However, every two hours of daily television watching, or every increase of 2 hours a day, increases the risk. It is noteworthy that the risk was greater from watching television than from being inactive in other sedentary activities such as sitting or driving. Though further research is needed to explain this finding, it might be that when people watch television, they are often eating. It is also noteworthy that the risk for developing diabetes and obesity related to inactivity is independent of other types of activity that the individual does during the day. Even at higher levels of physical activity, for both men and women, the risk of type 2 diabetes and obesity each increase with more television watching.

Though obesity is a problem in older people, it starts in youth, and by middle age, many individuals are overweight or obese. The observation that obesity at a younger age affects health in the senior years is illustrated by the results of the Chicago Heart Association Detection Project.[10] This project followed about 6,700 men and women, aged 36 to 64 at baseline, who had completed a 26-year follow-up by the time they were 65 years or older. The relationships of the baseline BMI, characterized as either normal weight, overweight or obese, to the 26 year follow-up data for various measures of health status were examined. It was found that lifting and carrying groceries, climbing flights of steps or walking several blocks were more difficult among both men and women who were obese when they were younger.

It is important to understand the distinction between the terms "physical fitness" and "physical activity." The key features of each of these separate constructs are listed in TABLE 1. Some studies measure physical fitness

TABLE 1. Physical fitness versus physical activity

Physical Fitness
Measured as capacity to perform or sustain physical work
Measured as performance such as time to complete an event or lift a weight
Measured as a physiological variable such as maximal oxygen uptake or heart rate response
Physical Activity
Measured as habitual patterns of energy expenditure during work or leisure time activities or tasks
Measured by self-report or interview surveys, direct observations, or electronic monitoring devices

TABLE 2. Health-related versus performance-related components of physical fitness

Health-Related Fitness
Cardiorespiratory endurance: Ability to provide oxygen to muscles
Muscle strength: Ability to exert force during a single effort
Muscle endurance: Ability to execute repeated contractions over time
Flexibility: Ability to move through a range of motion
Body composition: % body fat, central vs. peripheral obesity
Performance-Related Fitness
Speed
Agility
Balance
Coordination

whereas others measure physical activity, so it is important to keep these differences in mind when evaluating research findings.

Fitness also falls into two major categories—one related to health and the other to the ability to perform a task or sport. The key characteristics of health and performance-related fitness are shown in TABLE 2. These components of fitness have important distinction. Though speed and agility are needed to play sports, like tennis or golf, *skill* in sports is not a predictor or measure of health.

BENEFITS OF FITNESS FOR AGING ADULTS

In 1998, the American College of Sports Medicine published a statement on exercise and activity for older adults.[11] It concluded that exercise reduces and prevents a number of functional declines in aging. Some of the key points are as follows: Older individuals at any age can generally adapt and respond

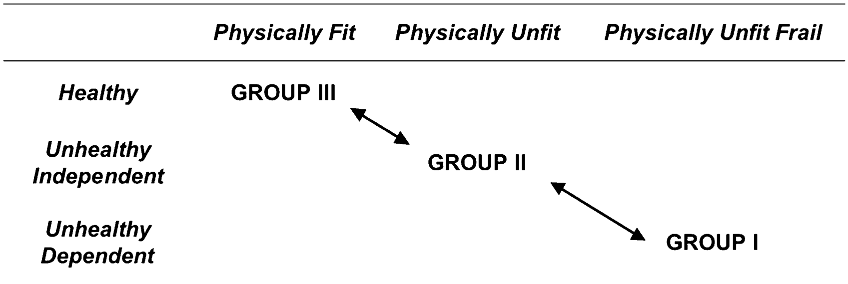

FIGURE 3. World Health Organization health-fitness gradient. Most older adults fall along this continuum, with good health at one end, and physical frailty at the other. Exercise can improve health and fitness status, whereas a lack of exercise will accelerate its decline.

to both endurance and strength training. Aerobic or endurance training maintains and improves cardiovascular function, whereas strength training helps offset the loss in muscle mass and strength associated with normal aging. Regular exercise also results in improvements in bone health, a reduction of risk of osteoporosis, improvement in postural stability, and increases in flexibility. These factors lead to a reduced risk of falls, a major cause of morbidity and mortality in the elderly. Exercise provides many psychological benefits including preserved cognition, alleviation of depressive symptoms and behavior, and an enhanced sense of self-efficacy, the concept of personal control. Individuals feel that they are in charge of their health when they are active. And increased physical activity certainly contributes to a healthy, independent lifestyle with improvements in functional capacity and quality of life.

The World Health Organization (WHO) has presented a health and fitness gradient for categorizing the functional status of older persons (FIG. 3).[12] Most older adults fall somewhere on this continuum. Persons in group 3 are physically fit and healthy; those in group 2 are physically unfit and unhealthy, but still independent, while individuals in group 1 are physically unfit, frail, unhealthy, and dependent on others. What is noteworthy is that individuals can move either up or down this continuum. A key benefit of exercise is that it may enable some older individuals to regain their independence and restore their health, at least to some degree

The WHO guidelines[12] also outlined some of the benefits of physical activity that fall into three broad categories: physiological, psychological, and social. Some physiological benefits are immediate, such as improvement in glucose, catecholamine levels, and improved sleep. The longer-term benefits of physical activity include improvement in aerobic or cardiovascular endurance, muscle strengthening, flexibility, balance, and velocity of movement, which is a critical factor in the definition of frailty.

Immediate psychological benefits include relaxation, reduction of stress and anxiety, and enhanced mood state. The longer-term effects are improvements in some of these quality-of-life measures plus improvements in cognitive ability, motor control, and skill acquisition. These latter benefits would allow older persons to continue to play golf and tennis and other activities they might enjoy. There are also several social benefits that accrue from being active. An important immediate benefit of physical activity is to empower older people to gain a sense of control over what they do and increased involvement in social and cultural activities. One such benefit is "enhanced intergenerational activity," where the older person can play tennis, golf, or go on a ski trip with children or even grandchildren.

Numerous studies support the American College of Sports Medicine's recommendations that older persons stay active. For example, the Honolulu Heart Program followed about 2,600 older men, aged 71 to 93, for 2 to 4 years.[13] During follow-up, 109 of the men developed clinical coronary disease. After adjustment for age and the traditional cardiovascular disease risk factors, men who walked less than 0.25 miles a day had twice the risk of having a clinical cardiac event, than those who walked 1.5 miles a day (FIG. 4). Among those who walked 0.25 to 1.5 miles a day, there was some benefit, but their risk was still considerably higher than that among those who were able to walk even more. These are important health benefits that could be derived simply by encouraging elderly persons to walk more. Though skeptics will always note that this is a cross-sectional study and that the individuals who walked more were healthier at baseline, cross-sectional and randomized stud-

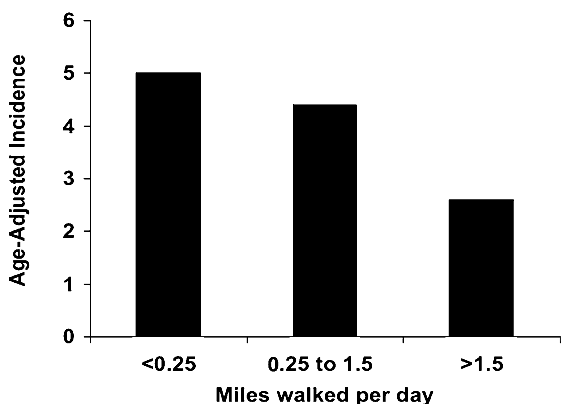

FIGURE 4. Walking and coronary heart disease in elderly men in the Honolulu Heart Program. Men who walked <0.25 mile/day had twice the risk of CHD as those who walked >1.5 mile/day (5.1% versus 2.5%; P <0.01). Men who walked 0.25 to 1.5 mile/day were also at a higher risk than men who walked longer distances (4.5% versus 2.5%; P < 0. 05).

ies alike consistently suggest that physical activity is a building block for good health.

Muscle strength and muscle mass play a significant role in the ability to function on a day-to-day basis, as well as the ability to participate in recreational activities. There is a well-defined decline in muscle mass with age, which is known as sarcopenia.[14,15] In the mid-20s, the loss is about a 4% per decade. By the mid-50s it accelerates markedly to where the loss is about 10% of muscle mass per decade. Most commonly, the loss of muscle tissue is accompanied by an increase in fat tissue. Thus, body composition shifts as an individual ages. Although an older individual may maintain the same body weight over many years, it is most likely that his or her percentage of body fat has increased, while the percent of lean body tissue has decreased.

What therapies are available for reversing sarcopenia, reducing fat, and increasing muscle strength? Some studies have demonstrated that the use of growth hormone and sex steroids will increase lean tissue and reduce fat mass.[16] However, these treatments are often associated with serious adverse side effects. Some animal studies have demonstrated that gene therapy may increase muscle mass. Gene therapy has hope for the future, yet little is available today for humans. One proven option is "gym" therapy. It is widely available, produces many desired physiological outcomes, and has few side effects.

To examine the effects of resistance training, 84 healthy adults, 60 to 83 years old, were randomly assigned to a low-intensity exercise program, a high-intensity exercise program, or a control group.[17] They exercised 3 times

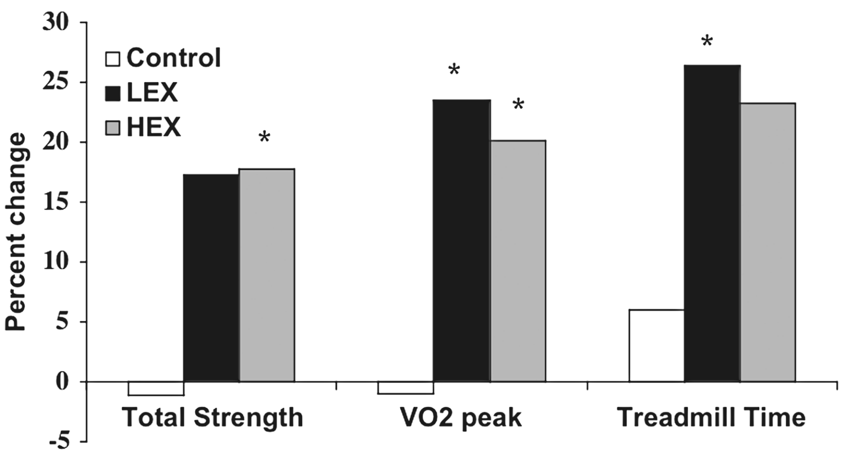

FIGURE 5. Six months of resistance exercise in elderly men and women. * $P < 0.05$ from control group. LEX = low-intensity exercise; HEX = high-intensity exercise. Both exercise groups experienced improvements in muscle strength and cardiovascular endurance capacity.

a week for 6 months, performing 12 resistance exercises each session on weight machines. The low-intensity group exercised at 50% of one repetition-maximum, performing one set. The high-intensity group worked out at 80% of one repetition-maximum. (One repetition maximun refers to the maximal amount of weight that can be lifted one time during strength testing.) After 6 months, in both genders, there were marked improvements in total strength in both intensity groups. Though subjects were doing resistance training, they also reached higher levels of maximal oxygen uptake on a treadmill, and markedly increased treadmill times (FIG. 5). The increases in aerobic capacity and treadmill time were moderately correlated with several measures of leg strength, with Pearson R values ranging from 0.4 to 0.54. There were no substantial differences between the low- and high-intensity resistance groups, suggesting that aerobic endurance is possibly limited by muscle strength. Individuals who lack the muscle strength to walk on the treadmill may not reach the true limits of their maximal aerobic capacity. Resistance training, therefore, may also contribute to increases in aerobic capacity by allowing individuals to reach higher levels of work.

Another study examined the development of disability in a large cohort of elderly men and women who were members of a running club.[18] They were compared to age-matched, community-based individuals who were of comparable health but were not runners. They were followed for 13 years. Among the runners, for both genders, there was a very low increase in their disability scores, compared to those who were not exercisers on a regular basis. Even after adjustment for age, the results were essentially the same. There was a rise in disabilities among the runners in their 80s, so they were not protected forever. But there was a clear-cut advantage among runners in terms of living more years with a lower level of disability or delay in disability compared to controls.

The prevention of disabilities for activities of daily living (ADL) was studied in older persons with osteoarthritis of the knee.[19] Participants were 250 individuals, 60 years or older, who had radiographic evidence of arthritis in the knee, but were free of ADL disabilities at baseline. They were randomly assigned to 18 months of aerobic or resistance exercise, or to an attention control group. The exercise program consisted of 3 months of supervised exercise, followed by a 15-month home-based program. The ADL items consisted of bathing, eating, and dressing. After 18 months, there was a higher risk of developing ADL disability in the controls compared with the exercisers.The greater preservation of ability to perform ADLs was similar in the aerobic and resistance exercise groups.

A recent study[20] evaluated a program of exercise plus behavior management in 153 community-dwelling patients with Alzheimer's disease who were enrolled in a program called Reducing Disability in Alzheimer's Disease or RDAD. It was a 3-month home-based exercise program, including training of a caregiver. Controls received usual care. The exercise program included aerobic, strength, balance, and flexibility exercises. Among the key results, at 3 months, was that more of the patients in the RDAD group exercised at least 60 minutes a week. They also reported fewer days of restricted physical activity and their SF-36 scores for physical role functioning improved at 3 months. After 2 years, they were still better than the routine care group, suggesting that exercise coupled with behavior interventions may have a role in maintaining some degree of function and improvement of quality of life in people with this disease.

Another health issue relevant to older persons is body composition. Obesity is associated with insulin resistance, glucose intolerance, diabetes, hypertension, and coronary disease. Abdominal obesity, the fat around the waist and within the abdominal cavity, may be a critical risk factor for developing these metabolic and cardiovascular diseases. Although abdominal visceral fat is not seen except by MRI or CT imaging, it is believed to be more harmful than other kinds of fat. Reduced abdominal fat is an important feature of the exercise training response and may help to improve cardiovascular health, particularly in reducing the risks of type 2 diabetes and hypertension.

FIGURE 6 shows the results of a study we recently completed (unpublished observations). Men and women, 55 years and older, were randomized to a 6-month exercise program, consisting of aerobic and resistance training. The reduction in abdominal visceral fat is in the range of 22%. At the same time, the change in body weight on the scale was about 2 kilograms. These results suggest that abdominal visceral fat is reduced by exercise training, indepen-

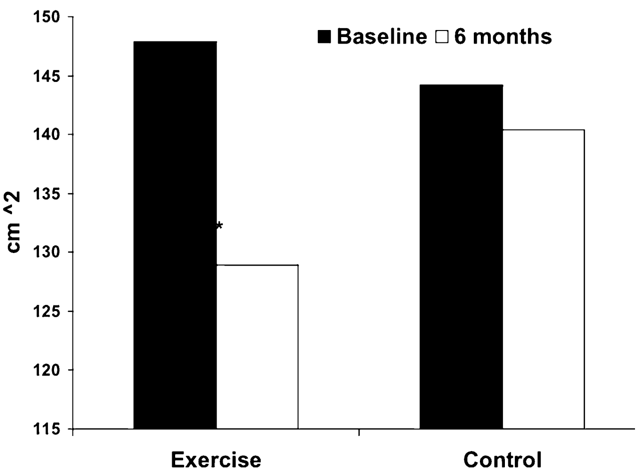

FIGURE 6. Abdominal visceral fat with 6 months of exercise training in older hypertensive men and women (unpublished observations). The reduction in abdominal visceral fat is in the range of 22%. The change in body weight was about 2 kilograms. $N =$ 34 exercisers; $N = 35$ controls. * $P < 0.001$ for the change from baseline.

dent of changes in total body weight. Patients may get discouraged if they are not losing body weight, yet it is likely that they have improved their health because of a reduction in visceral fat.

HOW MUCH EXERCISE, AND WHAT KIND, IS OPTIMAL?

The general recommendation for exercise is that every U.S. adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, and preferably all, days of the week.[21] The 30 minutes of moderate activity can be done either all at once, but those people who are unlikely to put aside the time to do 30 minutes all at once should at least accumulate 30 minutes of activity over the course of the day.

There are also recommendations for a structured exercise program for older adults. These are 3 to 5 times per week, for 30 to 45 minutes, at an intensity that is vigorous enough to raise the pulse rate to 70–80% of the maximal heart rate.[22] Older persons may require longer warm-up periods and longer cool-down periods as their cardiovascular systems adjust to the work and adjust back to the resting state. It is fairly common, in older people, to get a pooling of blood in the legs when they stop exercising suddenly. This can lead to a drop in blood pressure, and often people feel dizzy. If individuals do a long cool down, perhaps 10 to 15 minutes, and gradually taper off exercise, symptoms can be avoided.

The American Heart Association has recommended resistance training for individuals with or without cardiovascular disease.[23] For healthy individuals, the AHA recommends a moderate level at 50% of maximal effort, performing 8 to 10 exercises, 2 to 3 times a week. Persons with cardiovascular disease will eventually get up to this level but they should start at a lower intensity, in the range of 30 to 40% of maximal effort. Our research has shown in selected patients that it is safe to start weightlifting 2 to 3 weeks after myocardial infarction.[24] Patients who have undergone coronary artery bypass surgery should wait about 6 weeks before starting upper-body resistance training, not because of the heart but because time is needed for healing of the sternum. Patients with coronary disease are started at one set of 10 to 15 repetitions. They lift 10 to 15 times, 2 to 3 times a week. Over a course of 2 to 3 months, those with heart disease essentially follow the same exercise prescription, resistance training, as those without heart disease.

The American College of Sports Medicine says that most adults do not need medical consultation before starting a moderate-intensity program.[22] However, those individuals who have been inactive, men over 40, women over 50, and those who have multiple risk factors should see a physician before starting a vigorous program. For these individuals, an exercise stress test is usually warranted, and they should be warned that if they develop symptoms with moderate exercise they must stop and see the doctor. Persons with known disease and other complications should be examined and given the appropriate advice. Nevertheless, most individuals can start at least a moderate-level program without the need for extensive medical testing.

KEY FEATURES OF AEROBIC AND RESISTANCE TRAINING

Aerobic exercise, which includes activities like jogging, walking, swimming, and cycling, increases heart rate and breathing for extended periods of time. Resistance training is the contraction of muscle done against a force. The classic example is weightlifting, although for many older individuals who either do not have access to weight machines or for whom the lowest weight on a machine is too heavy, hand weights, bar bells, dumb bells, and stretching bands are excellent alternatives. Resistance training increases muscle strength and endurance and increases lean body tissue.

Aerobic and resistance training each promote benefits in the health-related fitness factors which were described earlier. The estimated weightings in terms of physiological benefits, however, are often substantially different. Aerobic exercise is more likely to produce increases in maximal oxygen uptake and stroke volume, maximal exercise times, reduction in heart rate and blood pressure at rest and during submaximal exercise, and to burn more calories than resistance training. It also contributes more to reductions in percent of body fat. Resistance training, conversely, has a greater impact on muscle strength and endurance, although these improvements often lead to improvements in aerobic performance in older persons if muscle capacity at baseline is a limiting factor. With resistance training there are benefits on lean body mass and prevention of frailty and falls in older people. For both forms of exercise similar benefits accrue in terms of improvement in bone mineral density, glucose tolerance, insulin sensitivity, and body weight. Although aerobic exercise burns more calories, resistance training increases lean body mass, which will increase basal metabolism.

In summary, let's turn again to the conversation between Dr. Benjamin Franklin and his adversary.[1]

> FRANKLIN: It's not fair to say I take no exercise. What I do very often, going out to dine and returning in my carriage.
>
> GOUT: Flatter yourself no longer that half an hour's airing in your carriage deserves the name of exercise. Providence has appointed few to roll in carriages while he has given to all a pair of legs, which are machines infinitely more commodious and serviceable. Be grateful then, and make a proper use of yours. Observe when you walk that all your weight is alternately thrown from one leg to another, thus accelerating the circulation of the blood. The heat produced in any given time depends on the degree of this acceleration. The fluids are shaken. The humor is attenuated and the secretions are facilitated. All goes well. The cheeks are ruddy and health is established.

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