An Evolution of Exercise Physiology: Effects of Exercise on Functional Independence with Aging and Physical Disabilities

Much of our knowledge of exercise physiology has been derived from studies utilizing subjects who were relatively young, physically active, and in good health. Indeed, many of the now classic studies on physical performance were performed on college or professional athletes, as well as those engaged in world-class and Olympic competition. To a large extent, these studies have led to the development of techniques and protocols for exercise testing and prescription. They also helped to identify the likely benefits of participating in regular exercise, as well as potential risks for performing particular activities. It is unfortunate, however, that much less is known about the role of regular exercise in maintaining health, physical fitness, functional independence, and rehabilitation potential in elderly individuals and in individuals who have various physical disabilities. Although more exercise physiology studies are being performed on older individuals and those with physical disabilities, we still know little about how one’s “fitness threshold” (the level of fitness required to maintain functional independence) can be accurately determined, and how appropriate exercise can be prescribed to maintain fitness above this threshold level. Loss of functional independence can be devastating to the individual involved, as well as family and friends, and negatively impacts upon societal interactions. It also imposes a great financial burden on society. Since regular, appropriate exercise is known to improve, or decrease the rate of loss of muscular, cardiovascular, pulmonary, and metabolic function, this could potentially reduce one’s so-called “biological age,” which could translate to adding years to one’s functional independence.

After the second decade of life, aging is associated with a general and progressive decline in muscle mass, which can eventually reduce strength and endurance to the point where one’s functional status becomes inadequate. As indicated above, maintaining an active lifestyle is known to decrease the rate at which muscular and other physiologic functions are lost. However, when gait and balance become impaired, activities of daily living (ADLs) are more difficult to perform, and there is increased risk for falls and injury. Thus, in a sense, the physiologic effects of aging can lead to disability, even though there was no accident or disease cause. Therefore, if appropriate and sufficient physical activity is not maintained with aging, there will be a progressive loss of functional status, a greater dependency upon others for ADLs, and an increase in susceptibility to musculoskeletal, cardiovascular, and pulmonary diseases. Of course, the weight gain associated with aging and sedentary lifestyle also increases the stress for performing ADLs, and increases risk for medical problems.
It is clear that sufficient muscle strength and endurance are essential for maintaining functional independence. However, cardiovascular, pulmonary, and metabolic function are instrumental in providing the energy for muscle contractions. Therefore, not only are tests of muscle performance required when evaluating physical capability, but also required are tests of the ability to provide energy for physical activities. In this regard, the maximal oxygen uptake of the individual (VO$_2$max) has become the “gold standard,” since it indicates the capacity to supply energy aerobically during physical activities. It is directly related to the functional capacities of the cardiovascular, pulmonary, and muscular systems. Determination of VO$_2$max via exercise stress testing provides our best single measure of physical fitness, since it denotes the capacity to pick up, deliver, and consume O$_2$, and to perform work. Thus, the higher one’s VO$_2$max, the greater is the physiologic reserve and the lower will be the relative stress experienced for performing given activities. The magnitude of one’s VO$_2$max is influenced by many factors, including activity level and age. However, regardless of physical activity level and fitness status, in most individuals it usually peaks in the late 20s along with muscle function. Unfortunately, it is followed thereafter by an inevitable progressive decline at a rate that tends to be inversely related to physical activity level. In this regard, it is possible for a highly active 80-year-old person to have the same VO$_2$max as a sedentary 60-year-old person, thus, exhibiting a 20-year lower “biological age”!

When one already has a physical disability due to an accident or disease, aging further contributes to the loss of functional status, and creates more of a dependency on others for performing ADLs and societal activities. This is especially true for people who rely on their arms for wheelchair locomotion. Physical activities for these individuals tend to be more stressful due to the use of their relatively small and weak upper-body musculature. To make matters worse, the performance of several ADLs include lifting the body weight with the arms. The high relative stress encountered can discourage, or prevent, them from participating in daily activities, and may lead to an even more sedentary lifestyle and further loss of fitness. The vicious cycle created, sometimes termed the “debilitative cycle,” can lead to a rather rapid loss of functional independence, as well as numerous secondary medical problems. Also, this population is particularly susceptible to weight gain due to the relatively low daily energy expenditure. Thus, it should be recognized that even small gain in body weight can incapacitate individuals with marginal muscle strength. It is anticipated that problems relating to loss of functional independence in these persons could be expected to increase as medical advances enhance their longevity, unless there can also be a corresponding maintenance, or increase, of their physical fitness level.

It is important to recognize that elderly individuals and those with various physical disabilities (e.g., spinal cord injury, stroke, multiple sclerosis, and Parkinson’s Disease) oftentimes exhibit physiologic response patterns to exercise that can be quite different (even paradoxical) to those of young, healthy, individuals. These differences can be attributed to factors including age, impaired autonomic nervous system function (especially the sympathetic division), loss of muscle mass, as well as diminished cardiovascular and pulmonary function. In addition to the physical characteristics of the individual, the mode of exercise can also greatly influence metabolic and cardiopulmonary response patterns. For instance, considerable response differences are elicited by arm exercise (e.g., wheelchair propulsion, arm cranking) performed by individuals with spinal cord injury in comparison to leg exercise (e.g., treadmill, leg cycling) performed by nondisabled individuals. Furthermore, unique responses have been found for functional electrical stimulation-induced leg cycling exercise, using the paralyzed leg musculature of individuals with spinal cord injury. It must also be recalled that those with impaired sympathetic nervous system function tend to exhibit attenuated heart rate and blood pressure responses both at rest and during given exercise tasks. Although such responses are typically associated with superior levels of physical fitness in young, healthy individuals, these same responses can be associated with inferior physical fitness levels of these particular persons. Therefore, it is essential that differences in physiologic response patterns for various populations and exercise modes be understood and taken into consideration when interpreting the results of exercise stress tests.

From the above discussion, the importance of regular, appropriately prescribed exercise for maintaining functional independence in elderly individuals and those with physical disabilities should be realized. On the other hand, it is also essential to further develop the assistive technology field to provide devices to accomplish ADLs and societal activities with minimal muscle effort and energy expenditure. An example of such a device is the lightweight sports wheelchair, which has made wheelchair
propulsion markedly less stressful, and has improved the rehabilitation outcome of many individuals. Of course, the combination of well-prescribed therapeutic exercise and better-designed assistive devices is desirable for optimal outcome.

The field of exercise physiology for individuals who are aging and those with physical disabilities continues to evolve. However, much more knowledge is needed to gain a better understanding of physiologic responses unique to these populations so that specialized techniques for exercise testing and prescription can be developed. It is essential to identify factors that contribute to the maintenance of health and functional independence so that medical problems and dependency upon others for ADLs can be minimized. This can lead to improved personal lifestyle and marked reduction in health care costs. I therefore conclude that the allocation of additional funds to bolster research in this important field would be well worth the investment.

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