Exercise and the Master Athlete—A Model of Successful Aging?

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Exercise as a therapeutic or prophylactic measure is a topic of particular interest in sarcopenia research. Clearly, exercise can be effectively utilized in the treatment of sarcopenia to recover muscle mass and muscle function in older adults. However, perhaps a more important question is the role of exercise in the prevention of age-related decrements in physiological capacities and function. The master athlete has been proposed as an ideal model to determine successful aging due to his or her chronic participation in high-intensity exercise. While extensive research has been conducted describing the age-related decrements in maximal aerobic capacity, the influence of chronic exercise on muscle mass and muscle function has not been as extensively studied. This article reviews the existing evidence concerning the influence of chronic exercise on body composition and skeletal muscle mass, and proposes areas that remain unstudied.

RELATIVE FEW studies have investigated chronic resistance training in older adults. Several studies using Olympic-style weight-lifting performance as the dependent variable demonstrated loss rates in muscle power with age of 1.05%–1.5% per year that were independent of body mass (12,13). While not including any measure of body composition, the close association between muscle mass and muscle performance implies some reduction in muscle mass. This is compelling, as Olympic-style events (the snatch and clean-and-jerk lifts) utilize full-body explosive movements that require high-intensity exercise training for optimal performance (12). Such movements would be expected to optimally recruit type II fibers, and reduced size and number of type II fibers has been shown to explain most of the age-related loss of skeletal muscle mass and strength (14).

Several cross-sectional studies demonstrated significantly greater muscle mass, architecture, and function in strength-trained master athletes compared with sedentary control participants of similar age (15–18). Moreover, the study of Klitgaard and colleagues (15) demonstrated that muscle mass, strength, contraction characteristics, and histology in 68-year-old resistance-trained athletes were equivalent to young untrained participants. One interpretation of this latter finding is that strength training prevents the age-related loss of muscle mass and muscle function at least up to the age of 70 years. However, the cross-sectional nature of the study limits this interpretation, as the athletes could have experienced decrements in mass and strength masked by the design. Regardless, the strength-trained athletes in all 3 studies demonstrated significantly greater muscle mass and muscle performance characteristics than their sedentary peers, supporting chronic resistance exercise as a means to delay and diminish alterations in skeletal muscle mass and function with aging. A more recent study, utilizing...
chronically strength-trained older adults that were not characterized as master athletes, demonstrated significantly greater anaerobic power and physical function in comparison to non-strength-trained older adults (19). In addition, the strength-trained participants were reported to have greater muscle quality as a function of power per muscle volume. This likely relates to the report of less fat intrusion and better muscle architecture in strength-trained older adults (17,18). However, all of these findings suggesting improved skeletal muscle mass and function with chronic resistance training need to be confirmed in longitudinal studies.

The ability of endurance training to influence age-related changes in muscle mass and muscle function has been more commonly studied. Skeletal muscle in older participants clearly adapts to chronic endurance training, both structurally and metabolically (20,21). However, several studies have suggested that chronic endurance exercise is not sufficient to maintain skeletal muscle mass or function with advancing age (15,17,22,23). In these studies, older endurance-trained participants were shown to have similar mass and strength compared with older sedentary participants, and reduced mass and strength compared with either young sedentary or young endurance-trained participants. Moreover, endurance athletes were shown to have reduced speed of movement and myosin heavy-chain composition of the vastus lateralis that were similar to control participants (15). Only one study has shown greater muscle strength, but not mass, in older endurance-trained athletes compared with sedentary age-matched controls (16). However, most of these studies recognized the potential confound of differences in body mass and therefore expressed muscle strength per unit of lean body mass. In most cases, older endurance athletes were stronger than sedentary participants following this correction, which suggests that endurance training may reduce the loss of relative strength with age and implies a greater functional strength. Those studies that did not demonstrate differences in relative strength between endurance-trained and sedentary participants were those with the oldest participants (15,23), suggesting that perhaps the ability of endurance exercise to influence muscle mass and muscle strength diminishes beyond the age of 70 years. In addition, many of the findings related to muscle mass, function, morphology, and histochemistry in endurance-trained athletes (speed of movement, fiber type, myosin heavy-chain composition) could reflect chronic training adaptations rather than an inability of endurance exercise to influence age-related changes (24,25). For example, it could be argued that maintained relative strength reflects maintained muscle mass, as the lower lean body mass seen in the older endurance athletes is a common characteristic of this athletic phenotype (26). Moreover, Sipila and Suominen (17,18) demonstrated much better muscle structure and architecture as determined by ultrasound in older endurance-trained participants compared with sedentary control participants. While this study lacked a young comparison group, it certainly lends support for endurance exercise in the maintenance of skeletal muscle mass and function with advancing age.

It is important to note that the studies cited above investigating muscle mass and muscle strength in endurance-trained athletes focused on lower limb muscles that would be involved in exercise performance. Several longitudinal studies reporting whole body lean mass in older endurance athletes demonstrated significant reductions in lean body mass in the presence of maintained total body mass (27–29). Proctor and Joyner (30) found that approximately 50% of the difference in whole body fat-free mass could be explained by reduced appendicular muscle mass in older compared with younger endurance athletes. Unfortunately, the appendicular measure included arms and legs, so it is unclear if muscle mass of the legs was better maintained than muscle mass of the arms. However, these data imply that endurance training is insufficient for optimal maintenance of muscle mass of the total body, and that endurance athletes would benefit from the addition of resistance exercise to their training regimen. The data of Pollock and colleagues (28) provide the only test of this concept to date, as several participants added resistance training to their exercise regimen during the second decade of the 20-year longitudinal study. While these athletes did not demonstrate improved maintenance of lean body mass compared with those who did not utilize resistance training, there is no description of the type or intensity of resistance training undertaken by the athletes. Therefore, it is difficult to assess the outcome in relation to the type of training undertaken, and the effect of combined programs involving chronic endurance and resistance exercise need to be more closely studied in controlled longitudinal designs.

A common criticism of master athlete models is the extent to which these individuals, capable of amazing physical feats at advanced ages, can be used to infer physical capabilities on a population basis. Doubtless, it is difficult to imagine the average man attempting to climb Mt. Everest at the age of 69,
or the average woman dead-lifting 220 pounds at the age of 80 (31,32). However, the goal of studying master athletes is not to suggest that the average person can or even should be capable of performing such physical feats. Moreover, most people will be unwilling to undertake the quantity and quality of exercise training commonly reported by master athletes. Rather, we hope to discover if chronic exercise can delay or diminish age-related decrements in physical capacities and, if so, identify the minimal threshold of exercise required to achieve this delay or reduction. Perhaps more importantly, we need to determine the extent to which the higher physical function demonstrated in chronic exercisers is associated with compressed morbidity (33,34). Recent evidence in relation to maximal aerobic capacity has suggested that high-intensity training can delay age-associated decrements in VO2max, but that training reductions, appearing to be an inevitable aspect of aging, lead to accelerated losses so that overall loss rates in VO2max are similar between athletic and sedentary individuals (27–29,35,36). Whether the same is true for skeletal muscle mass and function is presently unclear, but it is important to note that chronic endurance exercisers have significantly higher VO2max compared with sedentary participants at all ages (Table 1). Even if loss rates are similar, higher levels of physical function could be expected to delay the onset of physical disability and loss of independence associated with aging. There is clearly a need for data in regard to the latter point.

ACKNOWLEDGMENT

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