Muscle Mass and Strength: Relation to Function in Population Studies

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ABSTRACT The use of the term sarcopenia to describe the age-related loss in skeletal muscle and its functional consequences is relatively recent. However, interest in the relationship of muscle mass to strength and function predates the concept of sarcopenia as researchers have attempted to understand differences in mass and strength between men and women, young and old. Most of these studies are cross-sectional comparisons in which muscle mass and strength tend to be linearly related, so that those with more muscle tend to be stronger. This article focuses instead on some potential problems with the sarcopenia-function association in old age and presents what little data exist from longitudinal population studies addressing the effect of sarcopenia over time. J. Nutr. 127: 1004S–1006S, 1997.

KEY WORDS: • sarcopenia • muscle mass • aging

BODY WEIGHT AS A DETERMINANT OF MUSCLE MASS

In relatively sedentary populations, such as the elderly, a major determinant of muscle mass is body weight. Forbes (1987) suggests that lean mass is logarithmically related to body fat. Thus, heavier individuals have greater lean mass, and because strength is related to mass, heavier individuals of all ages are also generally stronger when asked to perform simple tests of muscle strength. Viitasalo and colleagues (1985) demonstrated this using random samples of Finnish men drawn from three age groups: 31–35, 51–55 and 71–75 y of age. Although the older men had poorer isometric knee extension strength at each weight, within each age group the heavier men had greater strength.

This union of muscle and body weight poses a challenge to the sarcopenia hypothesis in several ways. First, adjustment for body size may alter the relationships observed between mass and strength, minimizing or eliminating age and sex differences, for example, in strength (Reed et al. 1991). There is little agreement in the literature over whether such adjustments are appropriate or not. Second, change in body size will influence muscle mass, just as it influences levels of fat and bone. In a longitudinal study of change in urinary creatinine in 260 men aged 60 y or older from the Baltimore Longitudinal Study on Aging, those men who were heavier initially had greater baseline muscle mass. Over time, the entire group lost weight. Urinary creatinine declined with weight loss and was relatively constant across weight tertiles, suggesting that weight history will affect level of muscle mass as well as current weight (Muller et al. 1995).

Lastly, despite the association with greater strength, heavier body weight is associated with poorer functional health status (Launer et al. 1994), suggesting that the relationship of muscle to function may not be linear.

SHOULD MUSCLE MASS AFFECT FUNCTIONAL STATUS?

Functional status in old age may be characterized by observation of performance of functional tasks or by the report of physical function in interview format (Guralnik et al. 1989). Both performance tasks and self-reporting predict health outcomes, but it is unclear which is the better determinant of need for care and services. Muscle mass and strength have generally been assessed using performance measures, such as walking speed, chair-rises or stair-climbing. Rantanen (1994) studied approximately 250 75-y-old Finnish men and women; muscle strength showed strong correlations with difficulty performing stair climbs. However, Avlund and colleagues (1994) found less striking associations between isometric strength and reported function in a similarly aged Danish population. Neither study included measurement of muscle mass. Few other studies have examined the relationships between strength and either reported function or performance measures.

It is not surprising that the association of sarcopenia should differ between these two measures of function because reported function is more influenced by volition. Furthermore, each type of functional task has its own set of muscular requirements, and it is unclear whether there is generalization from one task to another even within observed or reported function. As a result, we are not sure whether gains in mass or strength alone, even if they result in improved performance on observed testing, will influence everyday function. This is a second challenge for the sarcopenia concept.

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LONGITUDINAL STUDIES OF SARCOPENIA IN POPULATIONS

There are very few longitudinal studies of age-associated loss in muscle and its effect on function. Apart from clinical trials to increase muscle mass (Fiatarone et al. 1990), most longitudinal studies have examined change in strength only, particularly grip strength and lower extremity strength.

**Grip strength.** Clement (1974) measured repeated grip strength in a French population of 369 men and 162 women twice over 5 y; 109 men and 55 women were retested a third time. Extrapolating the data, longitudinal loss in grip strength was estimated to be about 60% from ages 25 to 90 y and to accelerate with very old age. No mass measurements were included.

This finding parallels the work of Bassey and Harries (1993), who examined longitudinal change in grip strength over 4 y in 620 men and women ages 65 y and older. Over the course of the study, grip strength declined 12% in men and 19% in women. Although no mass measurements were available in this study, loss of strength was significantly related to the poorer hand function.

Data from the Baltimore Longitudinal Study of Aging (Kallman et al. 1990) showed that grip strength declined with age from age 20 to 90 y, again with losses in strength accelerating in very old age. However, not all subjects lost grip strength as they aged; 48% of subjects less than age 40 y, 29% of those aged 40±59 y and 15% of those older than 60 y had no decline in grip strength over 9 y. Interestingly, the stronger the subject was initially, the greater the decline in strength over time. Although cross-sectional data related this decline to forearm circumference, longitudinal data showed no relationship between change in muscle mass as assessed by 24-h creatinine excretion and change in grip strength.

In a study of loss of fat-free mass and grip strength performed in non-elderly elite army trainees, there was also little relationship between change in muscle mass and change in grip strength. These researchers postulated a threshold in the relationship of change in muscle and loss of grip strength such that only with very extreme losses in muscle mass could decrements in grip be seen (Johnson et al. 1994). In the longitudinal studies of relatively healthy older persons, it is unclear whether such extreme losses would be seen.

In summary, there are longitudinal changes in grip strength, but there is little evidence from observational studies linking this decline in grip strength to change in muscle mass per se, and there are virtually no studies that relate change in mass and to change in performance or observed function.

**Lower extremity strength.** What about lower extremity strength? Among 463 participants in the Evergreen Study, poorer knee extension strength was associated with a 2.5-fold increase in risk of death over 4–5 y of follow-up (Laukkanen et al. 1995). Thus, lower extremity weakness, like diminished grip strength, is an indicator of poor health. However, carefully designed studies of subjects in which health status was controlled have not shown consistent declines in strength over time. For example, Aniansson et al. (1983) found declines in knee extensor strength in a small group of representative men (n = 19) and women (n = 21) between ages 70 and 75 y. When a subgroup of these men was retested 5 y later (n = 9), body cell mass (as measured by potassium-40) declined by 6%, whereas muscle strength for knee extension had declined by 25%–35% over the same period. Hypertrophy of muscle fibers was documented and thought to be a compensatory adaptation for loss of motor units (Aniansson et al. 1983 and 1992), which was hypothesized to be the major determinant of strength loss. A second small study included 14 healthy survivors studied over 8 y (4 men and 10 women). In this group, isometric quadriceps strength was well preserved, with only ~0.3% change per year (Grieg et al. 1993).

These studies are based on small numbers with differing results and suggest a need for further examination of the relationship of mass, strength and function in the lower extremity.

CONCLUSION

Influences on muscle mass are multifactorial (Fig. 1). Many of these are factors characterized by change over time that can be best understood in the context of longitudinal studies. With the advent of dual energy X-ray absorptiometry, a technology exists for measurement of muscle mass in populations of older subjects that can be linked with existing methodologies for measurement of strength, performance and function. Studies utilizing these modalities should help to identify the factors accelerating the loss of muscle and the decline in strength in old age and to identify interventions that would alter this trajectory and the optimal timing for these interventions. Sarcopenia is likely to contribute to disability in old age, but its relative importance among the multiple risk factors for disability is yet to be determined.

LITERATURE CITED


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