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Review

The etiology and exercise implications of sarcopenia in the elderly

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ABSTRACT

An increasing aging population greatly impacts health care services worldwide. A large percentage of healthcare expenditures for seniors arise from the negative outcomes of muscle loss, also known as sarcopenia. Aging-related losses of muscle strength and quality impair balance, walking ability and endurance and cause negative events such as falls, incident disability and frailty. This review systemically explores the significance of sarcopenia in the elderly and addresses several important physiological mechanisms of sarcopenia. The implications of crucial exercise regimens that improve muscle strength and delay the onset of sarcopenia are also discussed.

A rapidly expanding aging population is one of the factors that impacts health care services across the globe. According to statistics from the U.S. Bureau of the Census, the number of people who are 65 years or older (seniors) equaled 43.1 million in July 2012, representing 15% of the U.S. population. By 2050, it is projected that there will be about 83.7 million seniors representing almost 20% of the population [1]. Health care expenditures for seniors in the U.S. are expected to increase six-fold by 2040 [2] and a high percentage of health care costs for seniors arise from the negative outcomes of lean muscle mass loss [3].

This review explores the impact of sarcopenia, which refers to the loss of muscle mass and the decline of muscle quality with increased age [4], on the mobility and independence of the elderly. The physiological causes of sarcopenia and the implications of exercise regimens to improve muscle strength or to delay sarcopenia are discussed.

1. Significance of sarcopenia

The term of "sarcopenia" was first introduced in 1989 to describe a progressive, generalized loss of skeletal muscle mass and accompanying decline in muscle strength and performance with increasing age. Sarcopenia is associated with many negative outcomes, such as disability, frailty, comorbidities, hospital admissions and death [4–6].

The prevalence of sarcopenia with advanced age has been well-documented. Baumgartner and colleagues [7] utilized data from a population-based study and analyzed the epidemiology of sarcopenia among the New Mexico elderly. The prevalence of sarcopenia was 13–14% in persons under age 70 and >50% in those older than 80. In a 7.8 year longitudinal study, Forbes and Reina [8] reported an average loss of 0.25 kg/year of lean muscle mass among the participants aged 22–53.

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The significant consequences of sarcopenia have also been well-recognized. Roubenoff [9] investigated the close relationship between muscle mass and strength and found that sarcopenia was important in functional deterioration, including declines in gait and balance, increased fall risks, and loss of independence [10]. Murphy and colleagues [11] examined the time-course of sarcopenia determinants and found that low functioning, lack of physical activity and a high body mass index predicted transition toward sarcopenia, which was more likely to lead to death. Szulc and associates [12] assessed the degree of sarcopenia by the relative appendicular skeletal muscle (RASM) mass index. They found that a decreased RASM value among elderly men was associated with a lower bending strength. Therefore, the authors concluded that sarcopenia in older men was associated with impaired balance and an increased risk of falling. The relationship between sarcopenia and functional status was also investigated in the New Mexico Study[7], which revealed that people with sarcopenia had 3–4 fold higher rates of disability, significantly greater risks of falling, and were more likely to use assistive devices [7]. Metter et al. [13] found that sarcopenia could act as a significant predictor of all-cause mortality.

The loss of muscle mass and quality also has metabolic and physiological consequences. Sarcopenia may influence the body's thermoregulation process in both cold and warm environments [14] and may contribute to age-associated glucose intolerance [15].

Therefore, sarcopenia not only has detrimental effects on physical functioning, but also impacts skeletal and metabolic health. Sarcopenia greatly diminishes the overall quality of life [3].

2. Etiology of sarcopenia

Sarcopenia, like many other problems that occur with aging, is a multifactorial condition. Factors that contribute to the occurrence of sarcopenia in the elderly include motor units, protein metabolism, hormones and lifestyle [9].

2.1. *Motor units*

The loss of alpha motor units from the spinal cord is thought to be the most crucial contributor to sarcopenia [9]. Many studies support this idea. Yuan et al. [16] found from direct microscopic observation that the number of motor neurons in the spinal cord decreased with aging. Similarly, McNeil and colleagues [17] found differences in the number of motor units in the tibialis anterior of young and older men. Their results indicate that age-related motor unit loss may contribute to sarcopenia, but seldom limits mobility or independence until a critical threshold is reached. Concomitant with the decreased number of motor units, the increased size of the remaining motor units and the loss of muscle fibers have also been identified as significant contributing factors to sarcopenia [18].

2.2. *Protein metabolism*

The balance between protein break down and synthesis rates is crucial in maintaining muscle mass and studies show that there is a direct relationship between sarcopenia and changes in muscle metabolism. Balagopal et al. [19] found that mixed muscle protein synthesis was reduced by 30% with advanced age. However, the reduction of muscle protein synthesis appeared to be selective. Specifically, whereas synthesis rates of mixed muscle proteins and myosin heavy chains decreased by more than 40% in the elderly; sarcoplasmic protein synthesis rates were maintained or increased with age. Several studies have investigated this selectivity, suggesting [20] that it might be due to decreased number sof messenger ribonucleic acid (mRNA) for protein translation. Therefore, it is quite likely that the selective decrease in protein synthesis plays an important role in the development of sarcopenia.

2.3. *Hormone factors*

Many hormones have metabolic effects on muscle mass and function. A convincing body of evidence indicates that the aging process alters the circulating concentrations of several important muscle-building hormones [3]. For brevity, this review will concentrate on two important anabolic hormones: testosterone and growth hormone (GH).

2.3.1. *Testosterone*

Multiple studies indicate that the level of bioavailable free testosterone decreases with age [21]. Specifically, free testosterone levels decrease approximately 3% per year between the ages of 73 and 94 [22]. Additionally, studies show that aging decreases the sensitivity of target tissues, such as muscle, to testosterone [23]. Clinical studies indicate that among the elderly both the decreased level of testosterone and the insensitivity of muscle tissues to testosterone contribute to sarcopenia [24].

2.3.2. *Growth hormone (GH)*

Since GH is important in muscle mass growth and maintenance, this hormone has been given much attention in recent sarcopenia studies. Multiple studies found that the level of circulating GH decreases with age. For example, Veldhuis and colleagues [25] found that most of their study participants' GH levels declined by approximately 50% between the ages of 20 and 70. Some studies have shown a link between the declining GH levels and the loss of muscle mass in the elderly [26]. However, the specific role of the decreased GH levels in sarcopenia occurrence and the feasibility of GH supplementation in sarcopenia management are still unclear and need further investigation.

2.4. *Lifestyle factors*

It has been well-documented that physical inactivity and muscle disuse promote the loss of muscle mass and worsen the degree of sarcopenia [9]. Studies also show that the decline in food intake and protein consumption among the elderly contribute to muscle atrophy and the severity of sarcopenia [21].

3. Exercise management and implications

Progressive resistance training has long been identified as the most promising imethod for increasing muscle mass and