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 systematically 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.

Keywords:
Sarcopenia
Resistance exercise
Older adults

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.

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.

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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 2, 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 breakdown 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 of 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 [25]. 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 method for increasing muscle mass and
strength among older people [27,28]. A number of studies have confirmed the effectiveness of resistance training in improving muscle mass, strength, balance and endurance among the elderly. For example, Yarasheski and colleagues [29] found that resistance training could enormously enhance the rate of mixed muscle protein synthesis in physically frail older participants. After three months of weight-lifting exercise, the muscle contractile protein synthesis rates in these sedentary seniors were greatly increased. In a randomized and placebo-controlled trial, including nursing home residents, ten weeks of progressive resistance training increased muscle cross sectional area by 3–9% and improved muscle strength and performance in gait speed and stair climbing abilities [30]. Frontera et al. [31] demonstrated that 2 weeks of progressive resistance training could substantially promote extensor and flexor strength in older participants. In evaluating muscle protein breakdown during sarcopenia and aging, Fry and associates [32] found that regulators of muscle protein breakdown responded similarly in young and older adults following resistance training, suggesting that resistance training could slow the pace of sarcopenia. Therefore, it is reasonable to conclude from these studies that progressive resistance training could effectively improve or prevent sarcopenia among the elderly, via improvements in muscle mass and strength.

3.1 Implications for exercise prescriptions

When designing a resistance exercise program to manage sarcopenia, some specific guidelines should be addressed. The goal is to gradually overload the muscles and make positive adaptations, such as improvement in muscle mass and function [33]. At the same time, sufficient attention should be paid to specific and normal aging-related physiological in order to avoid exercise-related injuries or severe outcomes.

Generally speaking, a progressive resistance training program for sarcopenia should be dynamic and target the major muscle groups using both concentric and eccentric movements [33]. Exercise program that target lower extremity muscles, such as the knee and hip extensors, should be prioritized because they are important in mobility, balance and gait.

3.1.1 Warm-up and cool-down

Warm-up and cool-down periods should be longer for the elderly [34]. Optimal warm-up activities should last 15–20 minutes, whereas 10–15 minutes should be devoted to the cool-down period. Active muscles should be stretched in both periods, and the warm-up session should involve lifting light weights [35].

3.1.2 Intensity

The intensity of the exercises should be based a combination of parameters, such as the individual’s heart rate and energy expenditure [34]. When performing resistance training, the seniors should move the resistance through the entire range of motion and avoid heavy lifting [35]. Specifically, the American College of Sport Medicine (ACMS) [36] recommends resistance training of 65%–75% maximum to increase muscle strength.

3.1.3 Frequency

The guidelines published by ACMS are appropriate to be used among the elderly.

- <3 Metabolic Equivalent (MET): 5 minutes of exercise several times daily
- 3–5 METs: at least twice a day as tolerated
- 5 METs: 3 times a week on alternate days

ACMS [36] recommends that seniors perform resistance training 2–4 days per week. Hence, the average frequency should be 3 days per week and the individual should wait at least 48 hours between training sessions.

3.1.4 Duration

ACMS [36] recommends that seniors dedicate 20–45 minutes for each resistance training session.

3.1.5 Rest periods and physical environments

Longer rest periods between exercise sessions as well as safe physical environments are imperative for seniors [34].

3.1.6 Breathing

Seniors should not hold their breath during resistance training. Lifting belts and abdominal strengthening exercise may be used to help stabilize the torso in order to facilitate breathing [35].

3.1.7 Active muscles

Exercise programs that target knee and hip extension and flexion should both be performed on a regular basis [35]. Antagonistic muscles should also be exercised to keep balance. ACMS [36] recommends including all six major muscle groups (chest, shoulders, arms, back, abdomen and legs) into a comprehensive resistance training programs.

Several studies have elucidated additional details of an optimal resistance training program. Taaffe [33] suggests that 8–12 repetitions should be performed per set. When the individual is able to perform 12 repetitions, the resistance should be increased to a point where only 8 repetitions are possible. A minimum of one set, but preferably 2–3 sets, per exercise session is appropriate with 1–2 minutes of rest between each set. The author also recommends exercising 1–3 days per week, for no more than one hour per session and with at least 48 hours between sessions.

3.2 Implications and application into daily clinical practice

Physical frailty in the elderly, especially the impairment in lower extremity strength, has been widely described in the geriatric literature as declining physiological conditions and has been used to screen and identify high-risk individuals for adverse health events [37]. Physical frailty has also been recognized as an indicator for fall events in the elderly. The significant impact of falls has been well-documented. The elderly who fall increase healthcare costs and patients/family members may also experience emotional challenges. Therefore, physical frailty needs to be addressed to prevent or minimize the occurrence of falls in the elderly.
Sarcopenia, the loss of muscle mass and strength, has a crucial negative impact on seniors’ physical functioning, independence and quality of life. Some biological and lifestyle factors that occur during aging, such as the decreased number of motor units, lower mixed protein synthesis rates and alterations in circulating hormones, contribute to the occurrence of sarcopenia among the elderly. Progressive resistance training involving major muscles is a simple and effective way to counteract sarcopenia.

Some important implications for clinical elder care can be drawn from this review. First of all, geriatric care staff should be knowledgeable about sarcopenia and its tremendously detrimental effects. Strategies should be implemented in a timely manner to delay the process of sarcopenia or to prevent severe negative outcomes. Secondly, as resistance training plays a significant role in sarcopenia management, seniors are strongly encouraged to encourage in moderate resistance exercise, or at least keep physically active. It is vital for geriatric professionals to follow exercise guidelines when advising exercise modalities in order to maximize the exercise benefits and effectively address the severe outcomes of sarcopenia.

4. Conclusion

Sarcopenia, the loss of muscle mass and strength, has a crucial negative impact on seniors’ physical functioning, independence and quality of life. Some biological and lifestyle factors that occur during aging, such as the decreased number of motor units, lower mixed protein synthesis rates and alterations in circulating hormones, contribute to the occurrence of sarcopenia among the elderly. Progressive resistance training involving major muscles is a simple and effective way to counteract sarcopenia.

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References


