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SARCOPENIA AND MUSCLE HEALTH IN AGING: ROLE OF NUTRITION AND FUNCTIONAL ASSESSMENT

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ABSTRACT

Sarcopenia is a progressive disorder of the skeletal muscle, defined by a decrease in muscle mass, strength, and physical performance. Its prevalence has risen among younger adults, although it is typically associated with aging, sedentary lifestyle, poor nutrition, smoking and lack of physical activity. Sarcopenia has been associated with frailty, falls, disability, hospitalization and higher risk of death, and is a significant public health issue. Multiple mechanisms contribute to the development of the condition, age-related muscle fiber loss, anabolic resistance, hormonal decline, mitochondrial dysfunction, oxidative stress, chronic inflammation, and neuromuscular impairment. These changes reduce muscle protein synthesis and accelerate muscle degradation, leading to muscle atrophy and reduced functional capacity. Diagnosis involves assessment of muscle strength, muscle mass, and physical performance using tools such as handgrip strength, gait speed, chair rise test, SARC-F questionaries, short physical performance battery (SPPB), and dual- energy X-ray absorptiometry (DXA). Early detection is crucial to prevent the disease from getting worse and complication arising. Nutrition plays an essential role in prevention and management. Adequate protein intake, especially leucine-rich protein, along with vitamin D, B vitamins, magnesium, vitamin E, and omega-3 fatty acids, supports muscle health and function. Good nutrition and lifestyle changes, regular exercise are still best approach to maintaining healthy muscle mass and quality of life. This review is intended to examine factors that contribute to the development of sarcopenia, methods of evaluation, and nutritional interventions, with emphasis on the need to diagnose sarcopenia early and apply appropriate nutritional interventions to ensure maintenance of muscle health and function.

Indexterms - Sarcopenia, chronic inflammation, gait speed, leucine, Muscle strength.

INTRODUCTION

Sarcopenia is a term that was coined in 1988.The first definition was the reduction of muscle of the appendicular muscle mass of the elderly individuals evaluated by the use of dual energy x-ray absorptiometry (DXA). In 2010 this definition was amended to low muscle mass and reduced muscle function and this was affirmed as it is written in various consensus documents. The correlation of sarcopenia, cachexia and wasting disorders withstands the recommendation of more recent consensus conferences, in particular that rapid screening such as the SARC-F questionnaire, should be used in addition to a formal diagnosis derived by measuring grip strength or chair rise alongside DXA measurement of appendicular muscle bulk (Bauer et al., 2019).Sarcopenia is a progressive and global skeletal muscle disorder that commonly accompanies the process of aging and is associated with an increased risk of several of the negative outcomes including reduced mobility, increased morbidity and mortality. It was already in the field of nutrition and body composition, firstly when it was already in use only several decades ago, but was primarily used to define reduce muscle mass, until it becomes evident that muscle performance was a better measure of outcomes. Around 2010, multiple definition was suggested that included muscle strength and physical performance to the concept of sarcopenia, as well as this definition, portended future result and extended to treatment and the study has become a robust range of medical and surgical specialties. Nonetheless, this growth has not yet been reflected, in many instances, in improved patient attention and enhanced result like decreased falls, fractures, reduced hospitalization and deaths (Sayer & Cruz-Jentoft, 2022) . Pre-sarcopenia is a disorder that is characterized by low skeletal muscle mass but normal muscle function (Dong et al., 2024).Sarcopenia is linked to loss of skeletal muscle strength, which is accompanied by a loss of muscle mass. Sarcopenia is the condition that is usually experienced in the elderly population. But then, contemporary ways of life have contributed to change slowly a rise in its incidence in young adults. Hence, it is now very desirable to establish preventive interventions on young adults who are at high risk of sarcopenia (Dong et al., 2024).A more recent meta-analysis validated sarcopenia. It causes a lot of risk of falls and physical disability in adults. Biologically it has been shown that poor nutrition (lack of protein), lack of exercise, smoking and excessive alcohol consumption are all associated with more muscle loss and dysfunction. In comparison, routine exercise (particularly resistance training) and a high protein diet are protective and are one of the primary measures of preventing the progress of sarcopenia in older adults with sarcopenia can enhance muscle strength and mass the alleviation of the effect of the syndrome. In recent years, sarcopenia has increasingly become a topic of concern in terms of its role as a major challenge to the health of the population, and this has led to efforts to develop further research on the selection of sarcopenia and solution. For instance, some countries study has reported prevalence of sarcopenia among Korean aged adults (≥65 years) at 9.7 percent in men and 11.8 percent in women. The diagnosis and treatment in the early stages of sarcopenia are essential such as early prevention helps to avoid the further worsening of muscles tissues, and delayed treatment is associated with worsened health conditions and higher health care expenses cost. Risk factors and susceptible subpopulation are thus important to be identified to inform the preventive measures and alleviate the burden of sarcopenia (Lee, 2025).

AGEING AND MUSCLE HEALTH:

Sarcopenia was initially reported in 1989 and it has gained relevance in the health sector as a result of the ageing population all over the world. The mass of muscle decreases slowly with age, at an average of approximately 1 to 2 percent per annum beyond 50 years of age and muscle strength even shows a greater decrease. The condition is a major cause of frailty, falls, decrease mobility and loss of independence in the elderly, there are two types of sarcopenia namely primary sarcopenia, which is due to old age and secondary sarcopenia, which is due to disease, lack of exercise or malnutrition.

The structural and functional alteration of muscle fibers and satellite cells is one of the greatest factors that lead to sarcopenia. The skeletal muscles have two major types of fibers, the slow-twitch (type I) fibers of the muscles, which deal with endurance and fast twitch (type II), which deal with strength and power. The type II fibers are lost preferentially with aging which is followed by decrease in number and size of muscle fibers. Motor neurons also deteriorate and the neuromuscular efficiency is diminished. Satellite cells, the cells in the muscles that repair and regenerate, also become ineffective as one age. They are reduced and unable to acquire the capacity to proliferate and differentiate because of the modification of the signaling pathways leading to minimal regeneration of muscle.

The other important cause of sarcopenia is a disproportion between muscle protein synthesis and degradation. When protein synthesis is equal or greater than protein breakdown, the muscle mass is sustained. In elderly age however, synthesis of proteins reduces, as a result of decreased responsiveness to anabolic stimuli like amino acids, exercise, and hormones, a phenomenon called anabolic resistance. This is to large extent as the mTOR signaling pathway is inhibited. Meanwhile, protein degradation is enhanced by activation of the ubiquitin-proteasome system which includes the enzymes of MuRF1 and Atrogin-1. The overall outcome is the negative protein balance which translate into muscle atrophy.

Appearing as chronic low-grade inflammation, commonly known as inflammaging, also contributes to sarcopenia in great deal. Aging has been linked with surge of proinflammatory cytokines including TNF-0 6, IL-6 and IL-1 0. Such cytokines lead to the degradation of muscles by damaging mitochondria activity, decreasing the energy production, and amplifying oxidative stress by producing reactive oxygen species. They also stimulate the mechanisms that leads to protein destruction and to apoptosis (programmed cell death) of muscle cells. This inflammatory condition is further worsened by obesity which enhances the production of cytokines by adipose tissue resulting in a more critical disorder called sarcopenic obesity.

The progression of sarcopenia is also influenced by myokines that are biologically active substance that are released by the muscles cells.IGF-1,IL-15, fibroblast growth factor (FGF-2), hepatocyte growth factor (HGF), and some of their myokines stimulate the satellite cell activity and protein synthesis and promote muscle growth, repair and regeneration. The usefulness of these advantageous myokines decreases, however, with age. On the contrary, myostatin, a negative factor attributed to muscle growth, grows as age advances and suppresses muscle differentiation and protein synthesis. High concentration of myostatin assist in muscle wasting and are believed to be one of the main drivers of sarcopenia.

Aging also increases muscle loss, which is further increased by hormonal changes. Anabolic hormone level e.g. growth hormone, insulin-like growth factor-1(IGF-1), testosterone, and estrogen decrease with age. These hormones play a crucial role in ensuring the maintenance of muscle and strength, and when they are lowered, the speed of protein synthesis slows down and fat is further increased. Moreover, the renin angiotensin system stimulation also leads to muscle wasting through the promotion of inflammation, oxidative stress, and myostatin augmented action. All these hormonal and systemic alterations aggravate the sarcopenic process.

Another significant factor on sarcopenia is mitochondria dysfunction. Mitochondria help in energy production, in the form of ATP that is vital in the contraction and functioning of the muscles. The performance of the mitochondria also decreases with age resulting in decreased energy production and oxidative stress. This does not only impair muscle performance but also causes metabolic disorders like insulin resistance, which worsens muscle loss (Nishikawa et al., 2021).

CAUSES OF SARCOPENIA

Sarcopenia is a complex syndrome, which is caused by the interplay of age related, behavioural, metabolic, and inflammatory factors. The biggest contributor is aging, which is marked by a gradual reduction in muscle mass, especially loss of the fast twitch (type III) muscle Fiber. This is accompanied by impaired muscle protein synthesis, regulation of proteolysis, and muscle quality. Immobilization, including bed rest, may cause a rapid loss in muscle mass and strength, even among young people.

Neuromuscular impairment also plays an significant role. These involve the atrophy of motor cortex, changes in the neurotransmitter function, motor neuron degeneration as well as ensuring motor unit remodelling which leads to reduced muscle functioning. Postprandial anabolic resistance is another mechanism of sarcopenia when aging muscle has a reduced protein synthetic response to nutrition, specifically dietary protein and amino acids. It results in chronic negative protein balance. Protein metabolism dysregulation is a cause of sarcopenia; anabolic signalling is reduced and proteolytic activity is increased, especially via the ubiquitin-proteasome system. There is also involvement of endocrine changes, including a decrease in anabolic hormones, including testosterone, dehydroepiandrosterone, growth hormone and insulin-like growth factor -1 and changes in cortisol, vitamin D and myostatin hyperactivity. Mitochondrial dysfunction and oxidative stress are factors that lead to impaired muscle functioning by reducing mitochondrial content, accumulation of mitochondria DNA damage, reducing ATP production, and increasing the production of reactive oxygen species (Tournadre et al., 2018). Oxidative stress has been identified as a major cause of skeletal muscle aging and indicators of oxidative damage (carbonyls of serum proteins) have been reported to be predictors of physical impairments. Oxidative stress is prone to skeletal muscle since it is highly metabolically active to produce reactive oxygen species (Robinson et al., 2021).

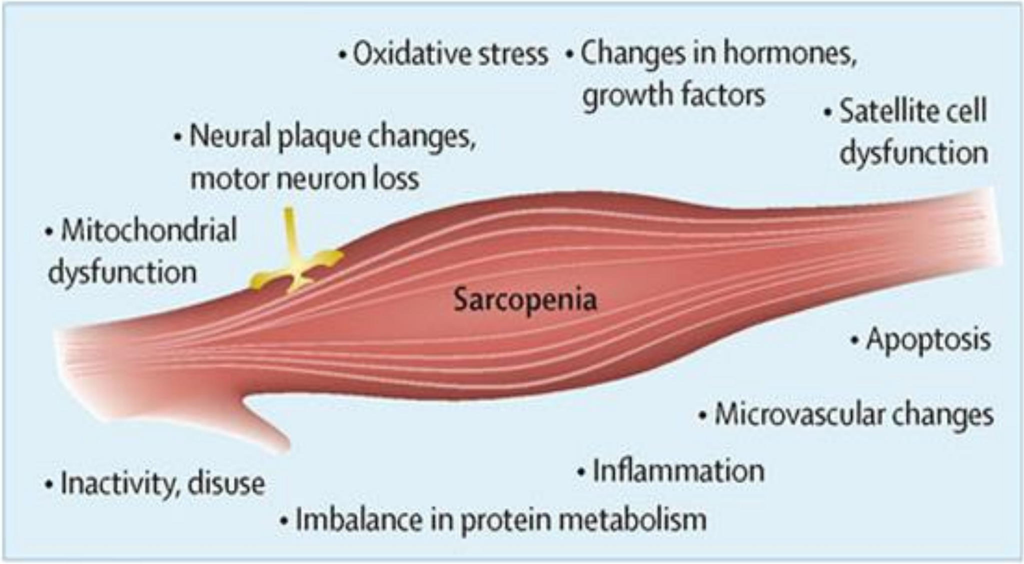

Fig. 1. Multifactorial causes of sarcopenia from Robinson *et al*., 2021

TOOLS TO ASSESS SARCOPENIA

The strength of the muscle plays an significant role in the diagnosis of sarcopenia. It can be evaluated by simple and complicated methods. The hand grip strength test, with measurements by handling dynamometer, is the most extensively used and is strong substitute measure of muscle strength in general. Some of the other tests are quadriceps strength test and knee extension strength test, and the advanced tests are the isokinetic dynamometry to determine the muscle power and torque. Research has showed that muscle strength is more closely linked with mortality and impaired performance in comparison to muscle mass.

Physical measures of performance are complementary to muscle strength measures and give an understanding of functional capacity. The commonly used tools are the short physical performance battery (SPPB) which assesses the gait speed, the ability to stand on the chair and the balance. The other confirmed test are 400-meter walk test and the 6-minute walk test which determine endurance and mobility and the other functional assessments include stair climb test, lift and carry task as well as car task, which assesses performance of daily activities. Ability to perform routine tasks and compensatory strategies are evaluated by such scales as the performance activities of daily living (PALD) and the task modification (MOD) scale (M.Pahor, 2009)

The most recommended measurement methods are gaits speed assessment and SARC-F questionaries, which are both straightforward and practical in primary care and handgrip strength is used in a diagnostic setting according to updated consensus recommendation. Those with a positive screening should be directed to undergo additional diagnostic test since untreated sarcopenia correlates with higher mortality and deterioration of functions and timely diagnosis can lead to decreased morbidity. The objective measurement tools, which should be used to diagnosis, should conform to the international consensus definition including those of EWGSOP, AWGS, FNIH, and IWGS, which usually mandate the presence of low muscle mass, accompanied by low muscle strength and/or poor physical performance. Dual-energy X-ray absorptiometry (DXA) is conditionally recommended to measure lean body mass but the application is limited by cost, availability and direct measurement of muscle tissue is not possible in the DXA. Other techniques like MRI and CT are less practicable in daily use but gait speed and handgrip strength are highly recommended in the evaluation of muscle functioning as they are both valid and convenient to use both clinical and community setting (Dent et al., 2018).

NUTRITIONAL REQUIREMENT FOR MUSCLE HEALTH

The dietary reference was published by the conjunction of the food and nutrition board in 2002, the institute of medicine (IOM), the national academies and health Canada. The energy, carbohydrate, fibre, fat, fatty acids, cholesterol, protein and amino acid intake (Morris and Mohiuddin., 2023). It is a thorough document, providing a range of reference values of nutrient intake of healthy U.S and Canadian individual and communities based on the most scientific knowledge at the time were available (Stomberg et al., 2009).

The dietary reference intakes (DRIs) have a number of reference value: the estimated average requirement (EAR) RDA, adequate intake (AI) and tolerable upper intake level,(*Food and Nutrition Board, Institute of Medicine*, 2001).

1. PROTEIN

The recommended dietary allowance of protein in adults aged 19 years and older is 0.8g/kg of body weight/day, which is about 56g/day for men and 46g/kg for women, and provides a proportion of 10% of total daily energy intake. This recommendation is within the acceptable macronutrient distribution range (AMDR) of 1035 percent of total caloric intake. The RDA was developed mainly on the principle of nitrogen balance, a technique which approximate the protein needs through a comparison of the dietary protein intake of nitrogen against urinary and faecal nitrogen loss, with the aim of achieving a zero state of balance of nitrogen. The adaptation period in nitrogen balance studies is long because of the slow urea turnover and hence it is not easily performed in different levels of intake. Also, there are errors in the measurement of nitrogen intake and excretion that tend to overestimate nitrogen balance. Positive nitrogen balance and real physiological response, including body weight and muscle mass stability, are also inconsistent, which implies low biological validity. Moreover, the body is able to adjust to the low protein consumption by lowering the nitrogen secretion, breaking the association between muscle health and nitrogen balance. There are also errors of estimation in the nitrogen losses that occur in dermal and miscellaneous, which further add variability. Therefore, the nitrogen balance approach might not give a reliable evaluation of protein needs, especially when it comes to preservation of muscle mass and the prevention of sarcopenia (Stomberg et al., 2009).

A healthy eating pattern is suggested to be made of eating numerous protein foods of high biological value to make sure that sufficient supply of amino acids for lean mass development or repair and general quality of food. In other words, the amino acids that make up a food of protein are expected to meet the demand of the consumer and be composed of a diversity of protein food to guarantee nutrient content. Indeed, there has been the change in the direction of the plant-based eating patterns in dietary guidelines to presumably maximize population health to benefit and to sustain in the environment (Burd et al., 2019).

The protein intake of 1.0-1.2g/kg/day is recommended as this in maintaining healthy aging of muscles, and 1.2-1.5g/kg/day of protein intake may be necessary in older adults with acute or chronic illness. Severely ill or malnourished elderly individual may need up to 2.0g/kg/day (Landi et al., 2016).

The new findings indicate that the concentration level of the circulating amino acids required to induce an anabolic effect on the skeletal muscle synthesis could be higher in elderly muscle and that increased doses of leucine are necessary to maintain a healthy anabolic reaction (Welch, 2014).

2. VITAMIN D

Vitamin D also play a significant role in muscle mass and muscle strength either directly, by stimulating vitamin D receptors in muscle, or indirectly, via calcium regulation and signalling, which are vital in muscle contraction. Vitamin D deficiency has been associated with atrophy of type II muscle fibres which are essential to strength and power. Even though recent findings cast doubt on the existence of vitamin D receptors in skeletal muscle of humans, which implies that its actions might be mediated, previous research has demonstrated that changes in the genes of vitamin D receptor are linked to decreased fat-free mass in elderly individual. It is continuously found in several studies that the superiority of vitamins D status correlates with the enhanced muscle strength. Although comparatively less studies have investigated its interaction with the muscle mass, various cross-sectional and longitudinal studies have suggested that there is a positive association between the vitamin D level and total or appendicular muscle mass and also the protective effect against muscle loss over time. Also reduced vitamin D levels are associated with greater fat infiltration into muscle, despite no effect on muscle size. Altogether, proper vitamin D status seems to be beneficial to muscle health and can be used to prevent sarcopenia (Welch, 2014).

(Stockton et al.,2009) carried out a meta-analysis of 17RCTs on the effect of vitamin D on muscle performance. They found there is no significant effect of vitamin D supplementation on muscle strength in adults who had an initial serum 25(OH)D level greater than 25nmol/L. Two randomized controlled trials in participants whose initial serum 25(OH)D levels were low (15nmol/L), have demonstrated an improvement in muscle strength with the addition of 1,000 IU of vitamin D and regular exposure to sunshine. A recent meta-analysis was published in 2014 by (Beaudart *et al* ., 2014) 30RCTs and 5615 participants (mean age 61 years) were included in this meta-analysis. They observed that a small significant increase in muscle strength on vitamin D supplementation, but no vitamin D effect on muscle mass or power (Hughes, 2017).

3. B VITAMINS

One major mechanistic pathway that supports these association is the one carbon metabolism, where folate, vitamin B6, and vitamin B12(cobalamin) control homocysteine metabolism. High levels of homocysteine in the blood have been repeatedly linked to low muscle strength and poor physical performance in cross-sectional and longitudinal studies of elderly individual. This association is also supported by observational data, which have shown that an increased intake or serum levels of vitamin B6, folate, and vitamin B12 are correlated with greater muscle strength, muscle mass, mobility and fewer chances of sarcopenia. More sophisticated methods of analysis, such as Copula Graphical Models, have started to overcome this limitation by establishing both direct and indirect relationships between nutrients, with results showing that vitamin B6 and folate are positively correlated with scores in the short physical performance battery and that vitamin B6 and vitamin B12 are positively correlated with chair rise test performance and no consistent relationship have been found between handgrip strength. The existing body of evidence, taken together, points to a probable, yet not yet conclusive role of B vitamins in the aetiology of sarcopenia, which is why additional mechanistic and interventional research is essential to elucidate causality and therapeutic potential (Robinson et al., 2021).

4. HEALTHY FATS

Muscle mass and strength, which are major constituents of frailty, and are linked with age-related deterioration, are linked to diminished functional mobility, disability, and elevated mortality. Anti-inflammatory effects of polyunsaturated fatty acids (PUFA), especially omega-3 fatty acids(n-3FA) have become significant modulators of muscle health. It has been reported that temporary supplementation of 1.5g of DHA and 1.86g of EPA has been reported to improve postprandial muscle protein synthesis by raising phosphorylation of mTOR and p70S6K, which reduces the anabolic resistance to the circulating amino acids seen in older adults. A cross-sectional study of 247 adults aged > 60 years, found no relationship between total n-3 or n-6 FA intake and lower extremity strength or frailty, but a large study of 417 adults aged > 85 years reported that higher DHA+EPA intake was significantly related with better functional mobility in (OR=0.55;95%CI. It shows that human findings are not very consistent. Supplementation of 1.2g of DHA and EPA over 6 months in postmenopausal women in a randomized double-blind trial caused significant improvements in walking velocity, but did not cause significant changes in grip strength or body composition. There is no imbalance in habitual consumption patterns, with a high n-6:n-3 ratio of about 8-12:1 and low EPA and DHA levels of intake (0.1-0.2g/day) in normal diets. Presented intake of ALA 1.6g/day in men and 1.1g/day in women, of which approximately 10 percent is EPA and DHA, with other guidelines indicating approximately 496-650 mg/day of EPA and DHA. Fish is the main source of food, and it should be taken at least twice a week. In general, n-3 FA can enhance muscle protein metabolism and muscle functional performance, but additional large-scale, longitudinal studies are necessary to determine the potential to prevent sarcopenia (Mangano et al., 2013).

5. VITAMIN E

Initial observational study shows that the use of vitamin E in muscle health, especially in sarcopenia, Cohort studies including the InCHIANTI (Invecchiare in Chianti) and the women's health and ageing study showed that lower circulating levels of vitamin E were linked in decreased muscle strength in older adult in cross-sectional studies. But later studies have been varied; one study by the TwinsUK study cohort found no significant effect of dietary vitamin E on muscle function including leg explosive power. Although vitamin E, because of its antioxidant qualities, can potentially play a role in the reduction of oxidative stress-induced muscle deterioration, the existing evidence base is still insufficient and inconclusive, indicating that additional research is required to elucidate its role in the aetiology of sarcopenia (Robinson et al., 2021a).

The current research revealed that increased intake of PUFA and micronutrients (iodine, polyunsaturated fatty acid, vit E and manganese) as well as food products like nuts and seeds, milk and milk products and fish and fish products are linked to increased skeletal muscle mass and strength .We thus recommend the need to increase the types of dietary nutrients and the quantity of dietary nutrients in older adult's diets especially protein and a range of micronutrients such as fish and nuts which may aid in preserving the high muscle mass and functioning in the elderly (Khanal et al., 2021).

6. MAGNESIUM

The role of magnesium in the pathophysiology of sarcopenia is critical because magnesium is involved in the energy metabolism, neuromuscular functioning and processed of muscle contraction-relaxation. Observational and interventional studies have revealed every time a positive correlation between Mg status and skeletal muscle mass, muscle strength , and physical performance in various age groups. An increase in dietary Mg and serum Mg levels are associated with better measures of grip strength, fat-free mass and leg explosive power and has an inverse relationship with inflammatory biomarkers such as C-reactive protein has antioxidant and anti-inflammatory effects and deficiency is linked to high production of reactive oxygen species (ROS), low-grade inflammation, insulin receptor(INSR)- impairment and glucose uptake, which ultimately lead to muscle dysfunction and sarcopenia development. In elderly individuals, both cohort studies, including the InCHANTI cohort, demonstrate a high level of correlation between Mg levels in the circulation and muscle performance, and supplementation studies suggest increased muscle strength and functional performance, including gait speed and balance. Also, Mg wasting during long-term physical exercise can increase muscle exhaustion and decreased performance capacity. Despite a lack of consistency in the findings in athletic population, the general evidence is that sufficient Mg status is necessary to maintain muscle function and could have a preventive effect against sarcopenia, and should be investigated further to justify optimal intake and therapeutic interventions (Castiglioni et al., 2024).

CONCLUSION

Sarcopenia is a chronic and multi-faceted disorder marked by bone muscle mass, strength, and functionality loss, mostly related to aging but closely becoming common in this generation due to the modern lifestyle. Over the years, its definition has changed to merely considering muscle mass to include muscle strength and physical performance, which are currently considered more valid predictors of adverse health outcomes. A combination of biological and lifestyle factors, such as anabolic resistance, hormonal changes, mitochondria dysfunction, chronic inflammation, and dysfunctional neuromuscular activity, leads to the development of sarcopenia Such mechanisms cause a negative protein balance, impaired muscle regeneration and eventually muscle atrophy. The behavioural factors that contribute to its progression include poor nutrition, physical inactivity, smoking and excessive alcohol consumption. The nutritional status is an important factor in the prevention and treatment of sarcopenia. Sufficient protein intake and adequate levels of essential micronutrients like vitamin D and B, magnesium, and omega-3 fatty acids facilitate muscle protein synthesis, strength, and overall performance. Exercise, in combination with appropriate nutrition, is one of the most effective methods that can be used to overcome muscle loss and enhance outcomes. In conclusion, sarcopenia is a major issue of community health because it is linked to frailty, disability, falls and mortality. The timely identification of vulnerable groups and preventive measures, especially in nutrition and physical activity, are important to reduce burden and enhanced quality of life throughout the lifespan.

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