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Biology

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UNIT 5: Respiration, Internal Environment, Coordination and Gene Technology

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Scientific article for use with Question 8

1. One of the most striking effects of age is the involuntary loss of muscle mass, strength, and function, termed sarcopenia. Muscle mass decreases approximately 3–8% per decade after the age of 30 and this rate of decline is even higher after the age of 60. This involuntary loss of muscle mass, strength, and function is a fundamental cause of and contributor to disability in older people. A decrease in muscle mass is also accompanied by a progressive increase in fat mass and consequently changes in body composition, and is associated with an increased incidence of insulin resistance in the elderly. Furthermore, bone density decreases, joint stiffness increases, and there is a small reduction in stature (kyphosis). All these changes have probable implications for several conditions, including type 2 diabetes, obesity, heart disease, and osteoporosis.

Potential causes of sarcopenia

2. The etiology of sarcopenia is not clearly understood, but several mechanisms have been proposed. At the cellular level, specific age-related alterations include a reduction in muscle cell number, muscle twitch time and twitch force, sarcoplasmic reticulum volume and calcium pumping capacity. Sarcomere spacing becomes disorganized, muscle nuclei become centralized along the muscle fibre, the plasma membrane of muscle becomes less excitable, and there is a significant increase in fat accumulation within and around the muscle cells. Neuromuscular alterations include a decrease in the nervous firing rate to muscle, the number of motor neurons, and the regenerative abilities of the nervous tissue. Motor unit size also increases. Further, aging is associated with changes in satellite cell number and recruitment, an indication and potential cause of reduced muscle growth.

3. Besides the muscle-specific alterations highlighted, other age-related changes in endocrine function or responsiveness to hormonal stimuli, nutrition or responsiveness to nutrients, and physical activity may be responsible for the development and worsening of sarcopenia. Most likely, sarcopenia is a multifactorial problem. Among all its potential causes, however, a reduction in endocrine function, physical activity and appropriate nutrition are potentially treatable with behavioural interventions or pharmacological agents, and for this reason will be discussed in this review.

Endocrine changes relevant to sarcopenia

4. A variety of hormonal changes are seen during the aging process that may contribute to muscle loss with aging. We have selected the most important changes in relation to their effect on skeletal muscle.

5. The primary and most potent anabolic steroid is testosterone. In about 60% of men over the age of 65, testosterone levels decrease to below the normal youthful values, in a process termed andropause. Unlike the rapid decrease in oestradiol seen with menopause, testosterone concentrations gradually decrease throughout the aging process. Since testosterone increases muscle protein synthesis, muscle mass and strength, it has been proposed that the decrease in testosterone may cause a decrease in muscle protein synthesis and result in a loss of muscle mass.

6. In women, oestradiol levels abruptly decrease during menopause. Very little information is available regarding the role of menopause in sarcopenia. It appears that muscle mass is not affected by the decrease in oestrogens. Cross-sectional studies evaluating the effects of age on lean body mass and appendicular muscle mass have shown that the rate of decline of muscle mass in women does not increase after menopause, suggesting a marginal role, if any, of this event in the development of sarcopenia in women.

7. The ability of muscle tissue to respond to insulin is an important aspect of overall insulin sensitivity. The incidences of insulin resistance and type 2 diabetes increase with aging and sarcopenia may play an important role. Most studies have reported that the prevalence of insulin resistance and glucose intolerance is higher in older individuals when the data are reported per unit of body mass, but these differences disappear if the data are corrected by lean body mass. This suggests that the changes in body composition may drive the increase in insulin resistance with age. Although insulin is usually considered in the context of its ability to increase glucose uptake into cells, there is emerging evidence that insulin resistance of muscle and whole body protein metabolism in the elderly may be an important contributor to sarcopenia.

Physical activity and sarcopenia

8. Another important contributor to sarcopenia is inactivity. Although it is difficult to causally determine the relative importance of a sedentary lifestyle in the development of sarcopenia, it is very well known that short-term muscle inactivity severely reduces muscle mass and strength even in young individuals. Typical examples are bed rest and weightlessness. It is also recognized that these muscle changes can be counteracted by exercise, typically resistance exercise.

9. Aerobic exercise has been shown in several studies to improve VO_2max, mitochondrial density and activity, insulin sensitivity and energy expenditure in young and older individuals. Two studies have also shown that prolonged and intense aerobic exercise can increase muscle protein synthesis in young active individuals. Recent preliminary data suggest that aerobic exercise (40% VO_2max) can also acutely increase muscle protein synthesis in healthy, independent older people. Although aerobic exercise does not induce obvious muscle hypertrophy, some studies have shown that intense aerobic exercise training can induce some degree of hypertrophy, as indicated by increased calf circumference, muscle fibre area, and satellite cell activation.

Nutrition and sarcopenia

10. Malnutrition leads to muscle wasting. It has been shown that aging is associated with a progressive reduction in food intake, which predisposes to energy-protein malnutrition. Further, older people may voluntarily reduce their protein intake in order to comply with reduced fat and cholesterol diets. Recent studies suggest that the protein requirements of older individuals may be higher (~1 g / kg / day) than the level currently recommended by the Institute of Medicine (0.8 g / kg / day). Thus, nutritional interventions are appealing potential means for the prevention and treatment of sarcopenia of the elderly due to the easy applicability and safety.

11. Nonessential amino acids comprise a significant portion of dietary proteins, including the high-quality proteins (e.g. whey, egg) that are typically used to supplement protein-poor diets. Since nonessential amino acids do not appear to be necessary for the acute stimulation of muscle protein anabolism in older people, high-quality proteins may still be inadequate for a dose-effective prolonged treatment of sarcopenia, given the excessive amount of calories that they provide in the form of nonessential amino acids.

Conclusion

12. Sarcopenia is a multifactorial process. A reduction in endocrine function, physical activity and inadequate nutrition all play an important role in the reduction of muscle mass with normal aging. Testosterone replacement therapy could be a useful intervention in hypogonadal older men for increasing muscle mass and strength, although it is not currently recommended. Hormone replacement therapy for menopause, adrenopause or somatopause appears to have a marginal or no positive effect on muscle mass and strength. Exercise training and proper nutrition can have dramatic effects on muscle mass and strength. An optimal intervention program may include an exercise-training schedule that incorporates both resistance and aerobic exercise with adequate intake of total calories and protein. This would not only improve muscle mass and strength, but it would also reduce insulin resistance, which is more prevalent in the elderly. Providing a nutritional supplement of only amino acids or protein might also be beneficial to promote muscle growth by stimulating muscle protein synthesis and increasing the total daily caloric intake, but further investigations are needed.