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PHYSICAL ACTIVITY AND EXERCISE AS A KEY FACTOR IN SUCCESSFUL AGING

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ABSTRACT

Aging is associated with several changes in body composition and metabolism, including sarcopenia, sarcopenic obesity and decrease in bone mass; aerobic capacity, muscle mass and strength tend to decline progressively. These changes have considerable impact on the ability to perform daily activities, especially when associated with chronic diseases, such as type 2 diabetes, cardio-vascular disease and dyslipidemia, as well as geriatric syndromes, like mobility impairment, falls and frailty. Scientific research has shown that physical activity and exercise can slow the physiological aging clock. Particularly, active elderly people seem to age "successfully" compared to sedentary ones. The aim of our work is to review evidence-based recommendations for physical activity, exercise and diet that would help to preserve muscle mass and strength, and to reduce the gain of fat mass in older adults. Increasing levels of physical activity, in particular resistance training mixed with aerobic exercise, and adequate protein nutrition intake should be an integral component in the prevention and treatment of sarcopenia, sarcopenic obesity and metabolic syndrome in elderly subjects.

Key words: *sarcopenia, physical activity, body composition, energy consumption, nutrition, aging.*

GIBALNA AKTIVNOST IN VADBA KOT KLJUČNA FAKTORJA PRI USPEŠNEM STARANJU

IZVLEČEK

Staranje je povezano s številnimi spremembami v telesni zgradbi in metabolizmu kot so npr. sarkopenija, sarkopenična debelost in zmanjševanje kostne gostote. Posledično se progresivno zmanjšujejo aerobna kapaciteta ter mišična masa in moč. Te spremembe odločilno vplivajo na sposobnost opravljanja vsakdanjih aktivnosti, še zlasti v povezavi z morebitnimi kroničnimi boleznimi kot so npr. sladkorna bolezen tipa 2, kardio-vaskularne bolezni in dislipidemija pa tudi raznimi geriatričnimi sindromi kot so motnje v gibanju, padci in krhkost. Znanstvene raziskave so pokazale, da gibalna aktivnost in vadba lahko upočasnita fiziološko uro staranja. Predvsem se zdi, da se aktivni starostniki starajo »bolj uspešno«, kot pa sedentarni. Namen članka je pregled priporočil, pridobljenih na osnovi raziskav in dokazov, za gibalno aktivnost, vadbo in prehrano, ki bi pomagali starejšim odraslim ohraniti mišično moč in maso ter hkrati zmanjševati maščobno maso. Povečevanje stopnje gibalne aktivnosti, predvsem vadbe za moč v povezavi z aerobno vadbo, ter ustrezna prehrana bogata s proteini, bi morale biti integralne komponente pri preprečevanju in obravnavi primerov sarkopenije, sarkopenične debelosti ter metaboličnih sindromov pri starejših osebah.

Ključne besede: *sarkopenija, gibalna aktivnost, telesna zgradba, poraba energije, prehrana, staranje*

INTRODUCTION

Aging is associated with major changes in body composition, including an increase and redistribution of adipose tissue and a decrease in skeletal muscle mass (sarcopenia) and bone mass, events that begin generally around the fourth decade of life (Fiatarone Singh, 2002).

Recent population trends (Swinburn et al., 2011) indicate an alarming rise in the prevalence of obesity among older adults, potentially adding a complementary condition that compounds the risk of poor health outcomes. The interplay between sarcopenia and rising trends in obesity in aging population emerged more than 20 years ago as an important public health concern in geriatrics (Evans & Campbell, 1993). The prevalence of sarcopenia and sarcopenic obesity increases with age, thus, muscle mass and strength lead to a progressive decline (Zamboni, Mazzali, Fantin, Rossi, & Di Francesco, 2008). These changes have considerable impact on the ability of performing daily activities (Batsis, Mackenzie, Lopez-Jimenez, & Bartels, 2015; Baumgartner et al., 2004) and have also significant consequences in health and functioning of the individual, because of their association with chronic disease's expression and severity, as well as with mobility impairment, risk of falls and frailty.

Changes in muscle, fat and bone surely relate to an excess / incorrect energy consumption, decreased energy expenditure in physical activity, or both factors in combination. However, in elderly subjects, other mechanisms are involved, such as changes in hormones regulating metabolism, like growth and sex hormones (Sakuma & Yamaguchi, 2012).

This declining need for energy due to a reduction in the amount of lean body mass and a more sedentary lifestyle, together with an inappropriate dietary intake, is the first step in the development of malnutrition in the elderly.

The main age-related changes in body composition and physiologic function which appear to influence nutrient requirements in older adults are listed in Table 1 (Blumberg, 1997). Dietary intervention has to be considered a key part of the demographic challenge of an aging population and should be a fundamental part of the public health policy necessary to reduce chronic diseases and compress morbidity (Bendich & Deck-

Table 1. Examples of Age-Related Changes in Body Composition and Physiologic Function that Influence Nutrient Requirements (modified from Blumberg, 1997).

Changes in body composition or physiological function	**Impact on nutrient requirements**
Decreased muscle mass	Decreased need for energy
Decreased bone density	Increased need for calcium and vitamin D
Decreased immune function	Increased need for vitamin B6, vitamin E and zinc
Increased gastric pH and decreased gastric motility	Increased need for vitamin B6, folic acid, calcium, iron, zinc, fiber and water
Decreased skin capacity for cholecalciferol synthesis	Increased need for vitamin D
Increased wintertime parathyroid hormone production	Increased need for vitamin D
Decrease calcium bioavailability	Increased need for calcium and vitamin D
Decreased efficiency in metabolic use of vitamin B6	Increased need for vitamin B
Increased oxidative stress and homocysteine levels	Increased need for beta-carotene, vitamin C, vitamin E, folate, vitamin B12 and B6
Decreased vitamin absorption	Increased need for food choices with high nutrient density

elbaum, 2015), as well as physical activity and exercise, capable of slowing down the physiological aging clock (Taylor et al., 2004).

METHODS

Relevant medical literature was identified from searches of PubMed and references cited in appropriate articles identified. Search terms used included sarcopenia, aging, physical activity, elderly, exercise, body composition, aging metabolism, nutrition. More detailed search terms were used following the identification of relevant mechanisms and to identify epidemiological studies. Selection of articles was based on peer review, journal and relevance.

AGE-RELATED CHANGES IN BODY COMPOSITION AND BODY METABOLISM

Sarcopenia, commonly associated with fat infiltration into muscles (sarcopenic obesity), is very common, with a prevalence of ~5 % in persons aged 65 years and as high as 50 % over the age of 80 (Janssen, 2010). It leads to a decline in muscle strength and power, supported also by altered muscle energetics, changes in tendon insertion, altered muscle coordination and decreased blood flow in the capillary bed of the muscle. Fat infiltration into muscle (myosteatosis) is associated with decreased strength and an increase in the prevalence of disability (Rolland et al., 2009).

As an adequate nutrient intake is essential to maintain muscle mass, the decline in food intake with aging plays a role in the development of sarcopenia. In particular, maintenance of muscle mass requires adequate protein intake; it is postulated that older persons require at least 1.2 g / kg of protein a day (Morley et al., 2010).

From a metabolic point of view, the most important consequence of sarcopenia is the decrease in energy expenditure (in particular for physical activity) and basal metabolic decline; moreover, the ability to increase or decrease energy expenditure to counterbalance overeating or undereating is impaired with an increased susceptibility to energy imbalance (both positive and negative) (Roberts & Rosenberg, 2006). A decline in basal metabolic rate (BMR) with aging is well recognized (Poehlman, 1992), associated to a loss of fat free mass (FFM) and a gain of fat (FM), a less metabolically active tissue.

A longitudinal study by Keys, Taylor, and Grande (1973) documented a decline in BMR with age of 1 – 2 % per decade. Other studies examining the role of aging on resting metabolic rate (RMR) and substrate oxidation (Frisard et al., 2007; Krems, Lührmann, Straßburg, Hartmann, & Neuhäuser-Berthold, 2005) indicate a reduction in RMR with age greater than what would be predicted from the observed modification of FM and FFM, suggesting that the lower RMR of older adults may be due in part to slowed organ metabolic rates (St-Onge & Gallagher, 2010).

The lowering of FFM and the increase of FM, in particular of visceral adipose tissue (VAT), is related to an increased risk of cardiovascular disease, type 2 diabetes, hyperlipidemia, hypertension and malignancy (Donohoe, Doyle, & Reynolds, 2011).

The association of central adiposity to poor health is related to VAT accumulation and associated with hyperinsulinemia and insulin resistance. VAT secretes a number of adipokines and inflammatory cytokines (TNF- α, IL-6, IL-1β) that can up-regulate nuclear factor-κB (NFκB), which leads to an increase in nitric oxide (NO), a substrate for reactive oxygen species (ROS) (Sonnenberg, Krakower, & Kissebah, 2004).

Moreover, excess adiposity is associated with a state of low-grade chronic inflammation, which interfere with adipose cell differentiation and adipokines pattern secretion, resulting in dysfunctional adipose tissue (Paniagua, 2016). Increased VAT is associated with elevated free fatty acids, impaired hepatic insulin clearance, resulting in hyperinsulinemia, increased gluconeogenesis, and elevation of very-low-density lipoprotein secretion (Matsuzawa et al., 1995).

In this state the subject presents a pro-inflammatory, pro-coagulant and insulin resistant state typical of the metabolic syndrome (Despres & Lemieux, 2006).

PHYSICAL ACTIVITY AND AEROBIC / ANAEROBIC EXERCISE

Regular physical activity is one of the most important protective factors against the development of chronic diseases (Harridge & Lazarus, 2017): sedentary individuals show an higher incidence of cardiovascular disease, diabetes mellitus, obesity as well as different malignancy. On the contrary, physical activity is inversely related to all-cause mortality in older adults (Brown et al., 2012).

Besides being active or un-active, also the total amount and intensity of physical activity is important. The physiologic adaptations to aerobic and resistance exercise are different: aerobic exercise improves cardiovascular function, that increase peak oxygen consumption without significantly changing strength, whereas resistance exercise improves neuromuscular adaptations, leading to an increase in strength, without significantly changing peak oxygen consumption. Despite lower baseline values, the available data suggest that older individuals have the same relative improvement in maximal strength and maximal aerobic capacity to resistance training and aerobic training regimens, respectively (Lambert & Evans, 2005). These physiologic adaptations may integrate with each other when the two types of training are performed together (Wilson et al., 2012). In a recent clinical trial (Villareal et al., 2017), the effectiveness of aerobic exercise has been compared with resistance exercise and combined exercise in reversing frailty and preserving muscle and bone mass, during weight loss in obese older adults. The authors show that combined aerobic and resistance training seems to provide the greatest benefits with respect to physical function (PF) and relative preservation of lean mass. In particular, the most effective exercise protocol for frail older adults seem to be a multi-component training, performed three times per week, with shorter-duration sessions (30 – 45 min), in order to prevent adverse health consequences (Theou et al., 2011).

PHYSICAL EXERCISE AND CHANGES IN BODY COMPOSITION

Human body is composed of water, protein, minerals, and fat. The total amount of body fat consists of essential fat (detectable in bone marrow, heart, lungs, liver, spleen, kidneys, muscles, and central nervous system) and storage fat, that accumulates in adipose tissue. Lean body mass (LBM), comprehensive of muscles, bones, ligaments, tendons, and internal organs, differences from FFM for the content of a small percentage of essential fat (bone marrow and organs).

Regular physical activity has an overall positive effect on body composition, modifying both FFM and FM, muscle volume, muscle strength, and physical mobility in older people, including overweight and obese individuals (Liao et al., 2017). Many studies describe a non-significant change, reliable to exercise, in FFM (Toth, Beckett, & Poehlman, 1999), even if exercise leads to an increase in skeletal muscle mass, especially if anaerobic one, with a related increase in strength.

According to different studies on elderly people, an aerobic exercise of moderate intensity (VO_{2max}> 60 %), is generally associated to a lowering in total body fat (FM), even in the absence of changes in dietary regime, proportional to the amount of training sessions. In particular, aerobic exercise can induce significant results on the loss of adipose tissue in the abdominal region (VAT) (Kay & Fiatarone Singh, 2006).

In order to estimate VO_{2max} and fitness index, a two-km walking test was developed by the UKK Institute in Finland (Laukkanen, Oja, Ojala, Pasanen, & Vuori, 1992). This test, relatively simple to administer, is a feasible and accurate alternative for determination of cardio-respiratory fitness in adults with both normal body weight as well as in overweight individuals. In Ferrara's population of PANGeA study (a mass population study we conducted with Slovenian colleagues, aiming at identifying the main elements involved in successful aging), applying the UKK-test, we found that fitness index is inversely correlated to waist circumference. In this population, applying a linear regression model, fitness index, independently of gender and age, predicts waist circumference, explaining the 32 % of its variability (R^2 square 0,322, standardized β-coefficient -0,477, $p < 0,001$) (Figure 1, data not published).

PHYSICAL EXERCISE AND CHANGES IN BODY METABOLISM

Even if not associated with a specific dietary regime, aerobic exercise and resistance training may be responsible for different and positive changes in body metabolism:

- improvement in glycemic control (Sigal et al., 2007), due to increases in muscle GLUT4 number and function (Holten et al., 2004),
- improvements in insulin sensitivity (Winnick et al., 2008),
- stimulation of lipid oxidation,
- improvement in lipid profile with increased clearance of atherogenic lipids, specially triglycerides (Katsanos, 2006), reduced levels of total cholesterol and apolipoprotein B (Holme, Høstmark, & Anderssen, 2007), changes in LDL par-

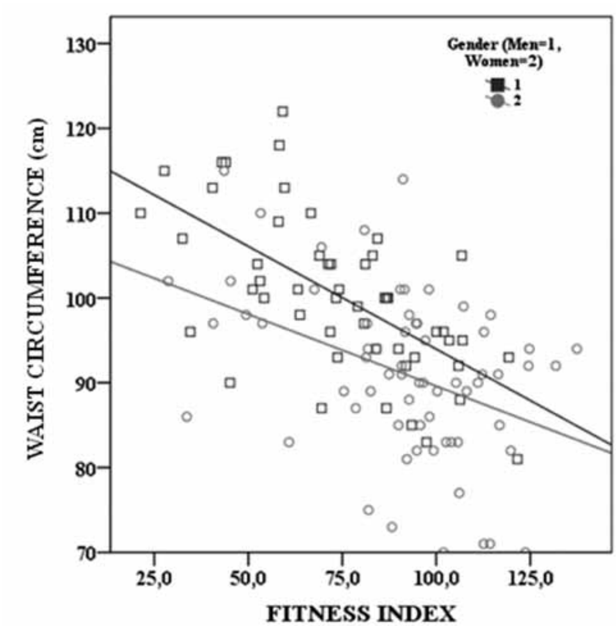

Figure 1. Pearson correlation between fitness index and waist circumference (PANGeA's Ferrara population): Men r=-0,62, p<0.001; Women r=-0,401, p=0,001.

ticle size (more than lower levels) and higher HDL concentration (Kraus et al., 2002),

– decrease of VAT in relation to an increased sympathetic tonus and consequential increased lipolysis (Ismail, Keating, Baker, & Johnson, 2012),
– decrease of VAT and pro-inflammatory state may contribute to improve glucose uptake (Fisher et al., 2011),
– decrease in biomarkers of inflammation like C-reactive protein (CRP) (Strasser, Arvandi, & Siebert, 2012),
– improvement in adiponectin and leptin profile (Simpson & Singh, 2008).

The impact of aerobic exercise on body metabolism is better and more significant if it is characterized by high intensity; strength training can provide up to a 15 % increase in metabolic rate, which is very helpful in terms of weight loss and long-term weight control.

A review published by Strasser provides strong support for the recommendation that physical activity, in particular resistance training mixed with aerobic exercise, should be an integral component in the prevention and treatment of obesity and metabolic syndrome risk factors (Strasser, 2013). Resistance training is an effective way to increase energy requirements, decrease body FM, and maintain metabolically active tissue mass. A consequent improvement in insulin sensitivity and in the lipid profile could reduce the risk of metabolic syndrome and type 2 diabetes and attenuate the development of cardiovascular disease in an elderly population (Ferrara, Goldberg, Ortmeyer, & Ryan, 2006).

PHYSICAL ACTIVITY AND RELATED BENEFITS

It is well established that with increasing age, individuals are more likely to experience functional declines, mobility limitations, and physical disability (Holmes, Powell-Griner, Lethbridge-Cejku, & Heyman, 2009). A large body of literature has supported the interrelationships among various factors affecting physical function (PF) in older adults (Villareal et al., 2011), like physical activity, body composition (fat mass and skeletal muscle mass), muscle capacity (leg strength and leg power), and muscle quality, whose aging-related changes tend to promote a decline in maximal aerobic power and skeletal muscle force production. Although the likelihood of physical limitations and disability increases with age, multiple studies have demonstrated that exercise is an effective intervention strategy for improving PF in older adults (Brady, Straight, & Evans, 2014).

Several intervention trials have reported improvements in PF after a resistance training program in relatively healthy older (Avila, Gutierres, Sheehy, Lofgren, & Delmonico, 2010; Henwood & Taaffe, 2005), as well as older adults with chronic health conditions (Yang, Wang, Lin, Chu, & Chan, 2006). In addition, aerobic training, often a cornerstone of an exercise program, has also been found to be beneficial at improving PF in older adults (Davidson et al., 2009).

The evidence suggests how the pillars of an effective exercise program should be both aerobic and resistance exercise (Chodzko-Zajko et al., 2009) and it is well known that both endurance exercise and resistance training can substantially improve physical fitness and health-related factors in older individuals (Conceição et al., 2014). This helps to maintain and increase skeletal muscle mass and respiratory fitness, with increase in resting metabolic rate and enhanced capacity for lipid oxidation during rest and exercise. Endurance training in particular is purported to be more effective for decreasing FM, resting heart rate and blood pressure, while resistance training has been shown to be more effective for increasing basal metabolism, bone mineral density (BMD) and muscle strength and power (Romero-Arenas, Martínez-Pascual, et al. 2013).

Regular physical activity can have a positive effect on disorders and diseases that affect muscles and bones (such as osteoarthritis, back pain and osteoporosis). Walking provides a modest increase in the loads on the skeleton above gravity and, therefore, this type of exercise has proved to be less effective in osteoporosis prevention. Strength exercises instead, seems to be a powerful stimulus to improve and maintain bone mass during the aging process (Gomez-Cabello, Ara, González-Agüero, Casajús, & Vicente-Rodríguez, 2012).

Many evidences show that physical activity programs aimed at strengthening muscles help the elderly to maintain balance, which decrease the likelihood and severity of falls and fractures, one of major health concerns for many older adults (Howe, Rochester, Neil, Skelton, & Ballinger, 2011).

Compared to sedentary people, older athletes enjoy a wide range of physiological benefits on health:

– a better profile in body composition including a lower accumulation of total and especially abdominal fat; greater volume muscle mass in upper and lower limbs,
– higher bone mineral density (BMD), especially in case of strength training with high-load low repetitions (Romero-Arenas, Blazevich, et al., 2013),
– articulation muscle more resistant to oxidative processes and fatigue,
– a better cardiac output during maximum exercise and improved cardiovascular fitness (Gibala, Little, MacDonald, & Hawley, 2012),
– less cardiovascular and metabolic stress during sub-maximal exercise (Lanza et al., 2008),
– significantly reduced coronary risk profile in relation to lowering of blood pressure (Whelton, Chin, Xin, & He, 2002), improvement in endothelium function (Maiorana, O'Driscoll, Taylor, & Green, 2003); low systemic inflammatory index; improved insulin sensitivity and glucose homeostasis; better lipid profile and lower waist circumference,
– slowed development of disability in old age.

Twenty to forty minutes a day of aerobic training leads to a lower probability to develop metabolic and cardiovascular diseases. Moreover, several studies have shown the beneficial effects of circuit weight training in individuals with CHD. Volaklis et al. combined resistance circuit and aerobic exercise program in patients with coronary artery disease. Subjects improved cardiovascular fitness (VO_2 peak 15.4 %) and muscular strength significantly in all exercises by an average of 28 % (Volaklis, Douda, Kokkinos, & Tokmakidis, 2006).

A Cochrane review of 121 randomized controlled trials of progressive resistance training (PRT) in older people showed that doing PRT 2–3 times per week improved physical function, gait speed, timed get-up-and-go, climbing stairs, and balance, and, more importantly, had a significant effect on muscle strength, especially in the high-intensity training groups (Crocker et al., 2013).

In order to optimize body composition, muscle strength gains and to develop cardiovascular function, Romero-Arenas, Martínez-Pascual, et al. (2013) recommended a circuit weight training with a minimum frequency of 2 sessions per week (with a volume ranging from 30 to 50 minutes) that could be implemented with endurance training.

DIET COMBINED WITH PHYSICAL ACTIVITY AND BODY COMPOSITION

Aging is related with the loss of skeletal muscle and bone mass along with progressive increase of adipose tissue. Recent investigations have attempted to modify these processes with various combinations of dietary and exercise intervention (Iglay, Thyfault, Apolzan, & Campbell, 2007; Kukuljan, Nowson, Sanders, & Daly, 2009).

Increasing the quantity and quality (essential amino acids, specifically leucine) of dietary protein stimulates muscle protein synthesis in the elderly (Børsheim et al., 2008), while protein supplementation at twice the Recommended Dietary Allowance (RDA) does not improve skeletal muscle function or increase muscle mass in healthy elderly weight lifters compared to those on a normal diet (Campbell & Leidy, 2007). Therefore, regular resistance exercises and the habitual ingestion of adequate amounts of dietary protein from high-quality sources are two important ways to slow the progression and treat sarcopenia. Assuming three meals are consumed each day, a relative protein dose of 0.4 – 0.5 g / kg / meal is consistent with recent expert opinions concerning the optimal daily protein intake (1.2 – 1.5 g / kg / day) for healthy older adults (Deutz et al., 2014).

This amount of protein markedly exceeds the RDA for protein (at present set at 0.8 g / kg ideal body mass / day for healthy adults, regardless of sex and age), but it is supported by several larger-scale longitudinal studies (Bartali et al., 2012; Gray-Donald et al., 2014). Several studies have also reported a positive relationship between protein intake and peak bone mass in older adults (Hannan et al., 2000; Sahni et al., 2014).

Increased intake of vitamin D stimulates gene expression and boosts muscle protein synthesis, facilitates neuromuscular function and enhances strength and balance (Muir & Montero-Odasso, 2011). In a recent clinical trial, Rondanelli et al. found a significant beneficial effect of supplementation with whey protein, essential amino acids, and vitamin D compared with placebo in elderly sarcopenic adults participating in controlled resistance training, with a gain of 1.7 kg in FFM. Supplementation attenuated the inflammatory state, as seen by the significant drops in CRP concentrations and leads to a reduced prevalence of malnutrition, assessed with the Mini Nutritional Assessment (MNA) (Rondanelli et al., 2016).

In all individuals older than 70 years of age, vitamin D intakes of at least 600 IU per day (up to 1000 IU / day) are recommended, in addition to the calcium requirement of 1200 mg per day (American Geriatrics Society Workgroup on Vitamin D Supplementation for Older Adults, 2014). For those individuals in whom there is inadequate calcium and vitamin D intake from diet, supplements and/or multivitamins can be used.

A recent review suggests that calcium and vitamin D supplementation, with or without osteoporosis therapy, may decrease the risk of fractures (Tricco et al., 2017). Anyway, the U.S. Preventive Services Task Force (USPSTF) concluded that the current evidence is insufficient to assess the balance of benefits and harms of combined vitamin D and calcium supplementation to prevent bone fractures in premenopausal women or in men (Moyer & U.S. Preventive Services Task Force*, 2013).

CONCLUSIONS

An inevitable consequence of advancing age is the gradual loss of muscle mass and strength, termed sarcopenia, frequently associated with a parallel increase in fat mass. This geriatric condition has known negative impacts on metabolic health, and in later life, the ability to perform everyday activities (Witard, McGlory, Hamilton, & Phillips, 2016).

This review highlights the major benefits of physical activity in the elderly in terms of body composition and metabolism. Active elderly subjects show a slower "aging clock" and a lighter burden of chronic morbidity. Aerobic exercises help to raise heart and lung efficiency and to increase cardiovascular fitness and endurance, while resistance training promotes an increase in muscle mass and bone density. Achieving these goals represents the first step of a realistic strategy for maintaining functional status and independence.

International guideline recommendations suggest that older people should perform at least 150 minutes of moderate physical activity per week and should be less sedentary in order to achieve health benefits (World Health Organization, 2010). Active elderly in particular, seems to develop a "successful aging" compared to sedentary ones.

Developing simple lifestyle interventions and safe, effective and sustainable ways to promote physical activity, aimed to preserve muscle mass and strength with advancing age, is crucial for the care of patients in mid-life and beyond.

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