Chapter 6

Rehabilitation in Sarcopenic Elderly

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Additional information is available at the end of the chapter

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Abstract

Sarcopenia is a complex problem and an important emerging field in rehabilitation of the elderly. In 2010, the European working group on sarcopenia in older people (EWGSOP) described sarcopenia as a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength, associated with a risk of adverse outcomes such as physical disability, poor quality of life and death. This field of rehabilitation has been defined as 'evaluative, diagnostic and therapeutic interventions whose purpose is to restore functional ability or enhance residual functional capability in elderly people with disabling impairments'. With growing numbers of frail older people, there is an increasing need for appropriate geriatric rehabilitation services. Definitely, sarcopenia needs a specific rehabilitation program to improve muscular mass and strength that must be integrated with a global approach with the aim to recover postural assessment, amplify sensory-motor systems, in order to gain the necessary information for proper motor planning, to reduce risk of falls. Several physical agents in medicine permit to treat sarcopenia, like vibrations or electrical stimulation. The aim of this chapter is to give an overview about rehabilitative medicine for sarcopenia, highlighting the state of the art, presenting the most significative clinical researches and giving some inputs to set a rehabilitation protocol.

Keywords: sarcopenia, physical energies, complex sensory-motor rehabilitation program, vibrations, electrical stimulation

1. Introduction

Sarcopenia (from the Greek sarx 'flesh' and penia 'loss') is a term used for the first time by Rosenberg to describe the age-related decrease in muscle mass. In fact, aging is associated with a progressive decline in muscle mass that can lead to a decrease in muscle quality and strength.

In 2010, the European working group on sarcopenia in older people (EWGSOP) described sarcopenia as a syndrome characterised by progressive and generalised loss of skeletal muscle mass and strength, associated with a risk of adverse outcomes such as physical disability, poor quality of life and death [1]. The reduction in muscle mass is associated with longer hospitalisation, increased need for rehabilitation care after hospital discharge, infective complications, prolonged duration of mechanical ventilation and higher mortality. There are several approaches to treat sarcopenia and it was demonstrated that, regardless of the type of intervention, treatment improves the quality of life preventing falls, disability and loss of independence among elderly patients [2]. Among interventions, resistance training has been shown to be the most effective to reduce the effects of sarcopenia, this because it induces skeletal muscle hypertrophy and enhances muscle strength; unfortunately, resistance training is not always feasible in sarcopenic elderly people [2]. Therefore, in these cases, physical therapies come to the rescue, i.e. vibrations or electrical stimulations. Particularly, it is possible to use focal vibrations, which excite the afferents coming from the neuromuscular spindle, leading to the activation of the proprioceptive sensory system. Electrical stimulation too is an alternative, even more effective than exercise alone, in strengthening muscles in sarcopenic patients [3]. These alternative approaches to exercise offered a safe addition to a traditional, high-intensity volitional strengthening program with the aim to implement muscular mass and strength. It is also a necessary adequate sensory-motor and functional recovery program to reach an acceptable walking ability. The ability to walk is the key to any human movement, despite the fact the human movements are not limited to bipedal locomotion; bipedal locomotion is a fundamental part of daily life and is a prominent target of public health physical activity guidelines [4]. In order to get a better walking performance and a postural global improvement, two integrate procedures may be used: normalisation of the foot-ground reaction to control vertical and shear forces on the foot during the stance phase; second one is the microgravitary environment that determines the sensory-motor and functional recovery of the posture during walking activity in combination to the development of proprioceptive information from periphery to the cortical central system [4]. Definitely, sarcopenia needs a specific rehabilitation program to improve muscular mass and strength that must be integrated with a global approach with the aim to recovery postural assessment, amplify sensory-motor systems, in order to gain the necessary information for proper motor planning, to reduce risk of falls.

2. Background

Aging, as mentioned, is characterised by a progressive loss of skeletal muscle mass and strength, thus leading to the loss of functional capacity. In sarcopenia, the loss of skeletal muscle mass must be due to a chronic disruption in the balance between muscle protein synthesis and degradation.

In active and healthy elderly patients, the mechanism underlying the loss of muscle mass does not seem to be bound to a disorder of protein metabolism in the basal state (fasting). Rather, it was proposed that muscle in the elderly presents a deficiency in the ability to regulate protein synthesis in response to an anabolic stimulus, such as physical activity or food intake [1].

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According to epidemiological data in literature, the prevalence of sarcopenia in people ranging in ages from 60 to 70 turns out to be 5–13%, while in patients over 80, it varies between 11 and 50% [2]. In 2000, the number of people worldwide over the age of 60 years was estimated at 600 million, a value that is forecast to rise to 1.2 billion in 2025 and 2 billion in 2050 [5]. Making an approximate estimate about the prevalence, people with sarcopenia nowadays are more than 50 million that should increase to over 200 million in the next 40 years.

The impact of sarcopenia in elderly affects multiple aspects; in fact, its influence can be seen in terms of morbidity [6], disability [7], increasing in costs related to health care [8] and mortality [9].

The underlying causes of sarcopenia and frailty are multifactorial. Although the progressive loss of muscle mass that occurs with aging is well-known for many years, but it is only with the latest techniques and prospective-longitudinal studies that changes related to aging in muscle composition have begun to be described [10].

Several reviews have highlighted cellular and molecular mechanisms underlying the weakness and muscle atrophy related to aging [11]. It has been seen that the loss of muscle strength and mass are the consequence of a progressive atrophy due to a loss of individual muscle fibres associated to a reduction of some motor units; this implies fat and other non-contractile tissue (i.e. fibrous tissue) infiltrations which involves a reduction of 'muscle quality' [1].

Therefore, changes in musculoskeletal age are initially neuromuscular and subsequently others several factors intervene (**Figure 1**) such as neural transmission, protein synthesis and

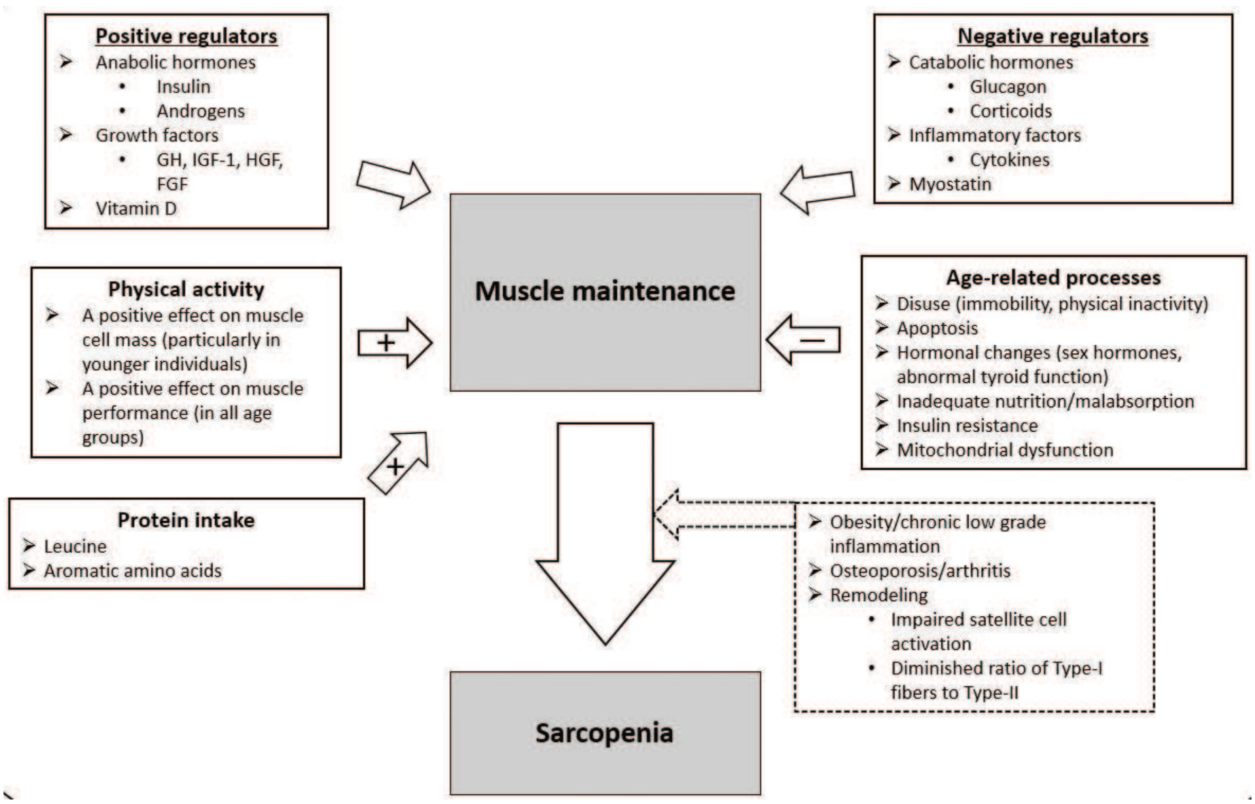

Figure 1. Factors that affect the muscle maintenance and/or the onset of sarcopenia. + positive influence, − negative influence. GH growth hormone, IGF-1 insulin-like growth factor 1, HGF: hepatocyte growth factor, FGF: fibroblast growth factor.

degradation, muscle architecture, composition of muscle fibres, increasing in production of reactive oxygen species, apoptosis of muscle cells, alteration in excitation-contraction coupling and metabolism [11].

In generic terms, sarcopenia is the age-associated loss of skeletal muscle mass and function; this decline is progressive and generalised with the possible risk of adverse outcomes such as physical disability, poor quality of life and even death [12, 13]. The causes are multifactorial and can include disuse, changing endocrine function, chronic diseases, inflammation, insulin resistance and nutritional deficiencies. The pathogenic mechanisms underlying sarcopenia are different from acute muscular atrophy resulting from disuse, cachexia, denervation or other conditions.

In order to make the diagnosis of sarcopenia, the European working group on sarcopenia in older people (EWGSOP) recommends verifying the simultaneous presence of both low muscle mass and reduction in muscle function (understood as strength or performance). Thus, the diagnosis requires the satisfaction of the criterion 1 in combination of criterion 2 or criterion 3 (**Table 1**).

The reason why are necessary at least two criteria for the diagnosis is that the force does not depend only on the muscle mass and also the relationship between strength and mass is not linear [14]. In fact, alterations in muscle quality have a central role in the loss of strength in elderly. Hughes et al. [15] showed that only a variation of 5% in strength depends on muscle mass. Muscle weakness may lead to reduced function, decreased physical activity and immobility, thus leading to secondary muscular 'ex non usu' atrophy. Consequently, diminished muscle mass is the result, but also the cause of age-related loss of strength. This is due to increased levels of pro-inflammatory cytokines and to a damage of type 2 muscle fibres. Furthermore, the growth in muscle mass is not directly related to an increment in strength, which may be increased even in the absence of a visible variation of muscle mass [16]. Neurological changes, hormonal and metabolic milieu, pro-inflammatory cytokines, fat infiltration (lipotoxicity) may conduce to a progressive muscle weakness in elderly [13]. Therefore, defining sarcopenia only in terms of loss of muscle mass is too simplistic and may be of limited clinical value. Precisely for this reason, some authors argue that the term dynapenia would be preferable to describe the loss of strength and function associated with aging [17]. However, 'sarcopenia' is a term so widely spread that replacing it could generate more confusion.

Sarcopenia staging, which reflects the severity degree of the disease, is a concept that can be of assistance in clinical management of the condition; specifically, the EWGSOP suggests a division into 'pre-sarcopenia', 'sarcopenia' and 'severe sarcopenia' (**Table 2**). 'Pre-sarcopenia' stage is characterised by low muscle mass without influencing on muscle strength or physical

Diagnosis is based on documentation of criterion 1 plus criterion 2 or 3
1. Low muscle mass
2. Low muscle strength
3. Low physical performance

Table 1. EWGSOP diagnostic criteria.

Stage	Muscle mass	Muscle strength	Performance
Pre-sarcopenia	↓		
Sarcopenia	↓	↓	**Or** ↓
Severe sarcopenia	↓	↓	↓

Table 2. EWGSOP stages of sarcopenia.

performance; this phase can only be identified by techniques that measure muscle mass accurately (see later). Concerning to standard populations, 'sarcopenia' stage is characterised by low muscle mass with low muscle strength or low physical performance. The last stage, when the three criteria (low muscle mass, low muscle strength and low physical performance) are present concomitantly, is defined as 'severe sarcopenia'. Recognising different stages of sarcopenia is essential to choose the most appropriate treatment and setting, thus enabling the achievement of therapeutic goals. Staging also allows to program scientific research focused on a particular stage or to evaluate any changes over time [18].

Generally, all the syndromes associated with prominent muscle loss are described as sarcopenia. Only research on the etiopathological mechanisms of age-related sarcopenia can lead to distinction from secondary forms, so the most appropriate therapy for each of them can be chosen such as cachexia, frailty and sarcopenic obesity.

The parameters of sarcopenia are muscle mass and function. The measurable variables are mass, strength and physical performance; for diagnostic and research purposes, it is important to identify the best diagnostic test that is able to measure them accurately. It is also important to recognise changes by repeating the same measures over time in the same individuals [18].

Only a few clinical trials are underway to evaluate the potential for sarcopenia treatments compared to the great impact that reduced mobility and functionality have on the quality of life of older people. The absence of standardised primary outcomes is a major challenge for the design of such studies. For intervention trials, EWGSOP presently recommends three primary outcome variables: muscle mass, muscle strength and physical performance (**Table 3**). Further studies could lead to the finding of outcomes currently considered secondary, but which may play a central role in the diagnostic and prognostic phase of this clinical condition.

Among methods of evaluation computed tomography (CT) and magnetic resonance imaging (MRI) can distinguish fat from other soft tissues of the body, thus representing validate methods for estimating muscle mass for research scope. The high costs and risks related to exposure to radiation (TC), limit their use in clinical practice. Dual energy X-ray absorptiometry (DEXA) distinguishes adipose tissue, bone mineral mass and lean body mass. It can be used both in research and in clinical practice and exposes patients to a smaller quantity of radiations. However, the access to this method is limited for severely obese individuals; furthermore, the equipment is not portable, which limits its use in epidemiological studies on a large scale.

Bioimpedance analysis (BIA) is a test that is not expensive, easy to use, easily reproducible and suitable for both ambulatory patients and bedridden. The bioelectrical impedance measurement

Variable	Exams	Clinical practice
Muscle mass	Computed tomography (CT) Magnetic resonance imaging (MRI) Dual energy X-ray absorptiometry (DXA) Bioimpedance analysis (BIA) Total or partial body potassium per fat-free tissue	BIA DXA Anthropometry
Muscle strength	Handgrip strength Knee flexion/extension Peak expiratory flow	Handgrip strength
Physical performance	Short Physical Performance Battery (SPPB) Usual gait speed Timed up and go test Stair climb power test	SPP Usual gait speed Timed up and go test

Table 3. Measurements of muscle mass, strength and performance in research and clinical practice.

techniques have been studied for many years and the BIA results in standard conditions correlate with the predictions of the MRI [19].

Among measurements to assess muscle strength, it is necessary to emphasise the importance of handgrip test; even if lower limbs are more relevant than the upper limbs in physical function and walking, the evaluation of strength by isometric handgrip has been widely used. Measured under standard conditions, with a well-studied model of dynamometer hand, it is closely correlated with lower limb muscles power and with the area of calf section.

The short physical performance battery (SPPB) is one of the most valid techniques to measure physical performance. It consists of a brief set of tests evaluating the functionality of the lower limbs. This battery is composed of three different sections. The first one is the assessment of balance in three tests: (a) maintenance of balance in stand position with feet together side-by-side for 10 seconds; (b) maintenance of balance in semi-tandem position (heel of one foot against side of big toe of the other) for 10″; (c) maintenance of balance in tandem position (feet aligned heel to toe) for 10″. The second section evaluates gait speed measuring the time required to walk 4 m linear at a normal pace. Finally, the third one measures the time required to perform five rises from a chair to an upright position as fast as possible without the use of the arms.

Other tests can be used in clinical practice, as they require a very simple execution setting. One of these is the sit to stand test, which evaluates the ability to move from sit to stand position without using arms. The timed up-and-go test (TUG), which evaluates the dynamic balance by measuring the time required to complete a series of tasks (getting up from a chair, walking a short distance, turning around an obstacle, walking back and sitting down again) [20, 21].

Specific mode and intensity of physical activity can act synergistically to maintain and even increase muscle mass, strength and power, both in healthy individual and in elderly patients with limited functionality. These interventions also have been found effective for all ages and there is evidence for similar responses in both female and male [22].

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During aging, a sedentary lifestyle is associated with a decrease in lean body mass and with an increase in fat mass, which ultimately leads to an increase in mortality and functional limitations. This is demonstrated in studies showing the reduction of cardiovascular-related risk and all causes of mortality in individuals highly physically active than those moderately active or worse sedentary.

Physical activity, in particular resistance exercises, is a powerful stimulus to promote muscle protein anabolism, resulting in specific metabolic and morphological adaptations of the skeletal muscle tissue. Resistance type exercise training can effectively increase muscle strength and muscle mass, thus improving physical performance and functional capacity. To stimulate muscle hypertrophy and to increase strength in elderly patients, it is known [23] that the traditional exercise of resistance at low speed (i.e. performing concentric and eccentric to each muscle in 2–3″) is found to be a type of intervention that is safe, feasible and effective. The physiological response to resistance exercises may consist in an increase in protein synthesis, in an activation and proliferation of satellite cells, in a production of anabolic hormones and in a decreased activity of catabolic cytokines. Resistance exercises in elderly subjects appear to lead to an increased number of mitochondria and a reduction in oxidative stress. Recent scientific evidences suggest that muscle performance is a determining factor regarding the functional capabilities. A new and effective approach to increase power in elderly subjects is found to be the fast-contraction-velocity exercise. In addition, the aerobic exercise can generate benefits on elderly muscles through an increment in mitochondrial energy production, increased insulin sensitivity and/or reduction of the oxidative stress [24].

In elderly patients, the clinical relevance of a nutritional and rehabilitative intervention based on exercise, resides with the long-term effects on not only strength and muscle mass but also on the implications concerning functional capacity and risk of developing chronic metabolic diseases. It is well known that the ability to respond to an anabolic stimulus, through the activation of muscle protein synthesis, is kept up even in elderly (though to a lesser extent) [24]. Definitely, it is possible to affirm that resistance-type exercise interventions have been shown effective in increasing skeletal muscle mass, training muscle strength and/or improving functional capacity in elderly [24].

3. Rehabilitation

3.1. Scientific researches

Over the years, we have therefore investigated the effects of exercise and mechanical stimulation in primary prevention and treatment of sarcopenia.

In 2006, the first study [25] evaluated the selective development of muscle strength in 20 female subjects with severe atrophy of the femoral quadriceps muscle, with a mean age of 31 years. Subjects were randomly divided in two groups, named A and B. Group A performed 10 rehabilitation sessions, 5 times per week, lasting 10 minutes each, with mechano-sound vibration (without performing voluntary contraction) with a defined frequency of 300 Hz. Group B performed 10 sessions of strengthening every other day through isokinetic Cybex equipment at 90°/second in concentric-eccentric mode. The evaluation was performed at first visit (T0), after the treatment period (T1) and at a 6 months follow-up (T2) by isokinetic testing (Cybex) with flexion-extension movement of right and left knee at 180 and 60°/second, in both study groups. At T1 evaluation, it was found in both groups a significant increase in muscle strength and working ability as well as an improvement in muscular coordination. The increase in contractile strength in group A was comparable to that obtained with a conventional rehabilitation protocol (group B). Differences between the two groups were the longest duration of treatment effectiveness (about 6 months) and the faster achievement of these results, already during the protocol, in Group A. High speed contractile improvements induced by the local vibrational method appeared more effective; in fact, in group A, contralateral muscle strength improved too, unlike the group B.

In a 2008 study, we compared the efficacy of three methods of training in elderly subjects with postural instability and sarcopenia [26]. Nineteen subjects (11F and 8M, aged between 64 and 80 years) took part in the study. Evaluations at T0 and T1 have been carried out through clinical examination, needle biopsy of the vastus lateralis muscle (measuring specific development of the individual fibres), expression of myosin heavy chains, transcriptional and regenerative capacity profile of satellite cells. Subjects were divided randomly into three groups of six subjects each; group A performed aerobic training (endurance), group B anaerobic training (power), group C mechano-sound vibration at a frequency of 300 Hz. The protocol frequency was three sessions per week for all study groups. The results obtained showed that the development of single fibre strength did not change in any of the training protocols; gene expression profiles showed, for each type of intervention, the stimulation of a specific metabolic pathway, as both resistance and vibration training increased aerobic metabolism, while resistance training stimulated creatine metabolism. All trainings protocols stimulated in a different way the expression of sarcomeric and cytoskeletal proteins; in particular, mechano-sound vibration training has stimulated proteins associated with the Z-line. It was also found that satellite cells contribute to regeneration and trophism of muscle fibre. The results therefore suggested that all training protocols are effective in contrasting the progression of sarcopenia and each one is able to stimulate specific molecular signals. The effects are specific because there is a relationship between the type of exercise and the metabolism stimulated.

In another study, we further evaluated the effect of focused vibration on elderly skeletal muscle [27]. Eleven subjects (5F and 4M, aged between 65 and 82 years), diagnosed with sarcopenia in accordance with the guidelines of the Centers for Disease Control and Prevention (CDC) were evaluated and treated. Inclusion criteria for the study were patients older than 18 years, diagnosis of sarcopenia in absence of joint pathology. Exclusion criteria were cardiovascular and/or metabolic diseases, hereditary or acquired muscular disorders, respiratory and psychiatric disorders, treatment with testosterone or other drugs affecting muscle mass. Mechanical vibrations were applied at local level at a frequency of 300 Hz on thigh muscles for a period of 12 weeks, starting from a 15-minute per session once a week to progressively reach 3 sessions per week. The evaluation consisted of clinical examination, resting ECG and isometric tests. These were carried out the week before the beginning of the study (T0, pre-session), at the end of the therapeutic protocol (T1, post-session) and

16 weeks after the end of treatment (T2, follow-up). Moreover, it was evaluated the body mass index (BMI), the measurement of the circumference of proximal and distal thigh and it was performed the vastus lateralis muscle biopsy. Maximal isometric strength evaluation of lower limb extensor muscles showed an increase in strength since 4 weeks of treatment in women and after 8 weeks in men; increasing strength reached a plateau phase at week 12. As it regards the circumferences, it was found a significant increase of the distal circumference of 0.5–3 cm and a non-significant increase of the thigh circumference at the proximal zone. Vastus lateralis biopsy results showed the increase of muscle fibre section width (T0: 3667 ± 310.7, T1: 4238 ± 357.4 μm^2); changing in myosin chains, which switched from the isoform slow (MyHC-1) to the isoform fast (MyHC-2X). Other interesting observations were the stimulation of genes involved in energetic metabolism (PIK3R3; GSK-3), in protein synthesis and degradation, in calcium homeostasis (ACTA2; MLCB; ARL5A; LCCP; TTID; POP3; RyR3; CHERP) and in oxidative stress processes (P12; PRDX3; MSRA). It was also found a down-regulation of the gene coding for nitric oxide synthase (NOS-1). The results showed that sarcopenic skeletal muscle reduced metabolic power because of several factors, such as a reduction in blood supply, fibrosis processes and atrophy development. Muscle tissue undergoes continuous oxidative phenomena; this leads to imbalance between oxidant and antioxidant capacity; in fact, in elderly, several genes coding for antioxidant factors are down-regulated. The reduced expression of NOS leads to a reduction of the amount of nitric oxide circulating, compromising vasodilatation. Therefore, focused mechano-sound vibration, increasing the expression of genes coding for antioxidant factors, while enhancing the maximal isometric force, can be considered effective in combating sarcopenia.

In a more recent study of 2013, we compared the effectiveness of three types of training on strength and balance ability on a population of elderly male subjects suffering from sarcopenia [4]. In this study, 40 male subjects (mean age 71 years) diagnosed with sarcopenia, in accordance with the guidelines of the CDC, were evaluated and treated. Inclusion criteria of the study were patients over 18 years, sarcopenia diagnosis in absence of joint disorders. Exclusion criteria were cardiovascular or metabolic diseases, hereditary or acquired muscular disorders, respiratory and psychiatric disorders, treatment with testosterone or other substances affecting muscle mass. Forty participants were included randomly into one of the four study groups. Each group performs a specific protocol. Group A carried out a comprehensive sensorimotor training on I-Moove® with 'Reebost' program (for balance and flexibility) for 20 minutes, after warming-up with cycle-ergometer (5 minutes) and stretching of the lower limbs; frequency of sessions was 2 times per week for 12 weeks. Group B performed aerobic endurance training with leg-press and leg-extension: 2 times a week for 12 weeks. Group C underwent training vibration with a frequency of 300 Hz (average size of the transducer of 23.7 cm^2) lasting 15 minutes per session, 1 session a week for the first 8 weeks and 3 sessions per week in the last four weeks; group D (control group) did not perform any kind of rehabilitation program. The assessment was carried out using clinical examination, maximal isometric tests performed on leg-extension equipped with load cell, BMI measurement, gait analysis, stabilometry. At the end of treatment was highlighted statistically significant increase in bilateral isometric force equal to 45% in group B (which performed resistance training) and 43%

in group C, which was treated with mechano-sound vibrations. In the group, which carried out the sensorimotor training on I-Moove (group A), the improvement was only 15%, while no change was observed in the control group. About balance and stability, it was found a significative improvement of the sway area and path length, measured by stabilometry, in groups A and C; no improvements were found in groups B and D. Another observation was the increase in half-step length in all three trained groups (108% in group A, 65% in group B, 92% in group C); step width increased only in the I-Moove group. Significant reduction of 24% in time of contact to the ground was observed only in the vibration training group. The study showed that an overall sensorimotor stimulation produced by focused acoustic vibration and proprioceptive training, carried out with I-Moove, is an effective approach to increase strength and balance in sarcopenic elderly, which could result in a better quality of life.

As a part of primary prevention, we also evaluated the influence of exercise and focused acoustic vibration on blood concentration of some hormones [28]. Aim of the study was to evaluate the effects of focused acoustic vibrations, set to a frequency of 300 Hz, on muscle performance and blood hormone concentrations in healthy young adult males in acute and long-term observations. In this study, 36 male patients (average age 21.5 years) were evaluated and treated; they usually performed moderate intensity level of physical activity (1–2 times per week). The participants were divided into 2 groups: group A performed focused mechano-acoustic vibrations every 3 days for 4 weeks (10 sessions overall); instead, group B performed resistance training every 3 days for 4 weeks (10 sessions). The assessment was carried out every 3 days, during therapeutic session, through haematochemical parameters (to quantify hormone levels), counter-movement jump (CMJ) and maximal voluntary isometric contraction (MVC); assessments were performed before each session, immediately after it and 1 hour after the end of treatment. All subjects also performed isokinetic and MVC tests after 4 weeks of training and at 2 months follow-up. Group A showed a significant increase in growth hormone (GH) and creatine-phosphokinase levels and a reduction of cortisol levels ($P < 0.05$); no change was highlighted in group B. In both groups, it was observed a significant improvement in MVC test ($P < 0.05$). After 4 weeks, the results showed evidence of an increase in isokinetic tests and in maximal strength test in both groups; the improvement persisted in the next 2 months. These results indicate that focused mechano-acoustic vibrations can influence the concentration of particular hormones and can improve neuromuscular performance. The benefit gained is maintained over the medium to long term and it was comparable to what happens after a resistance training treatment.

Other authors have also studied the effectiveness of vibration therapy in improving strength and muscle tone in patients suffering from sarcopenia. Wei et al. [29] try to determine the optimal combination of frequency and exposure time of a whole-body vibration (WBV) training program to improve muscle performance in elderly with age-related muscle loss. A total of 80 community-dwelling older adults with sarcopenia were randomly divided into four groups, 20 patients each: first group treated with WBV set to low-frequency and long duration (20 Hz × 720 seconds), second group treated at medium-frequency and medium duration (40 Hz × 360 seconds), third group set to high-frequency and short duration (60 Hz × 240 seconds) and control group did not perform any training. The treatment period lasted 12 weeks and a follow-up was scheduled at additional 12 weeks. There was a significant time per group

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interaction effect in isokinetic knee extension at 180°/second. The study found significant time effects in all muscle strength outcome variables. Comparing second group (WBV set at 40 Hz for 360 seconds) with control group, the authors found that the percentage of change from baseline values were significant on isokinetic knee extension tests (at 180 and 60°/second). Therefore, they concluded that the best combination for WBV exercise is to set medium frequency and medium duration (40 Hz × 360 seconds), because of it shows the best outcome among all other combinations tested; moreover, the improvements in knee extension performance can be maintained for 12 weeks after cessation of WBV training.

The effectiveness of electrostimulation in rehabilitation has been long known, especially in muscle strengthening. Kern et al [30] analysed (at functional, structural and molecular level) the effects of electrical stimulation training on healthy seniors with normal lifestyle, without routine sport activity. The study found that electrical stimulation was able to improve muscle torque and functional performances and it increased muscle fibres and most importantly fast fibres, which are related to the power of skeletal muscle. At molecular level, electrical stimulation induced up-regulation of insulin-like growth factor 1 (IGF-1) and modulation of MuRF-1, a muscle-specific atrophy-related gene. Furthermore, it induced up-regulation of relevant markers of differentiating satellite cells and of extracellular matrix remodelling, which might guarantee shape and mechanical forces of trained skeletal muscle as well as maintenance of satellite cell function, reducing fibrosis. This study provide evidence that electrostimulation is a safe method to counteract muscle decline associated with aging.

In 2015, Barberi et al. [31] analysed some downstream pathways activated by IGF-1. They demonstrated that electrical stimulation increases not only anabolic pathways, but it also reduces muscle catabolism. Extracellular matrix during physical exercise shows remodelling processes. The authors demonstrated that this occur also with electrostimulation, due to enhance of collagen expression; in fact, they observed an up-regulation of three different forms of collagen (I, III and VI) in electrical stimulated muscle. The question was if this increase in collagen was due to stimulated fibrosis by electrical stimulation. However, biopsy did not demonstrate any accumulation of fibrotic tissue. Further supporting the morphological evidences, Barberi et al. analysed miR29, one of the most important controllers of fibrosis. Actually, the electrical stimulation regulates miR29, which might down-regulate fibrosis. Then authors verified electrical stimulation in increasing activity of satellite cells, such as physical exercise. In fact, electrostimulation increased the number of these cells, and this is also demonstrated by the increase of their molecular markers (myogenin, miR-206 and miR-1). In conclusion, the electrical stimulation can be applied to elderly sarcopenic patients, which might not carry out normal physical activity, modulating similar factors associated with exercise. In particular, IGF-1 once stimulated through electrostimulation, activates anabolic pathway, increasing protein synthesis and satellite cells. All these modifications lead to an increase in muscle performance.

As part of a bio-progressive rehabilitative approach, treatment of sarcopenic patients may not be limited to muscle strengthening or pain resolution. It appears clear; therefore, the need for a global approach to the patient, which also guarantees postural and gait rehabilitation. To do this, we usually consider the use of SPAD® (dynamic anti-gravitary postural system), the function of which is to provide postural stability and to increase exteroceptive and proprioceptive sensitivity. SPAD® [32] is composed by a conveyor belt, surmounted by a lifting structure, which forces the patient to walk in a straight line on a treadmill, while six proprioceptive blocks (four anterior and two on the back) act on the rotation components.

In a 2008 study [33], the aim was to define the possibility of using SPAD system in elderly rehabilitation. Group A was treated with SPAD system, while group B performed a proprioceptive rehabilitative protocol on Galileo platform (WBV at 28 Hz). Patients were evaluated at the beginning of the treatment (T0), at the end (T1) and at 6 months follow-up (T2) through gait analysis, stabilometry and isokinetic test (Cybex® system). After treatment period, both groups showed a significative improvement in gait alignment, a reduction of sway area and ellipse surface in stabilometry and a significative improvement in isokinetic tests. At follow-up evaluation, better results were found in group A (maintenance of previous results) than in group B, especially in gait and balance. These results show the effectiveness of both treatments suggested, with a better outcome at follow-up in the group that performed a rehabilitative protocol with SPAD system. In conclusion, it can be stated that SPAD treatment allows to comprehensively address the problem of postural disability evident in aging, as it acts on deep spine muscles, improving lower limb muscles tone and associating a motor-vestibular rehabilitation. This means a greater capacity of mobility with a better quality of life for elderly people.

3.2. Rehabilitative protocols

Scientific data illustrated above and those collected by our personal experience allowed us to summarise that each type of physical agents in medicine has a proper applicability in terms of cost/benefit ratio. To modulate muscle activity, enhancing muscle tone, the approach applied is:

Step 1. Focused mechano-acoustic vibrations

Step 2. Focused mechano-acoustic vibrations + SPAD

Step 3. Electrical stimulation + whole-body vibrations + SPAD

With regard to the focused mechano-acoustic vibration, the frequencies related to effects on muscles can be schematically summarised as follows:

- 120 Hz, muscle relaxation
- 200 Hz, strengthening of slow muscle fibres
- 300 Hz, strengthening of fast muscle fibres

Therefore, the treatment protocol we recommend, using Vibration Sound System®, in elderly patients suffering from sarcopenia, consists of 200 Hz for 10 minutes, 300 Hz for 10 minutes and 120 Hz for 5 minutes, applied with segmental strips in standing and/or supine position (**Figure 2**). The aim of this treatment is muscle strengthening and corticalisation.

Integrated protocols involve the use of focal vibrations in combination with active exercises and systems that increase proprioceptive stimulation to determine the synergy between stimuli.

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Figure 2. Focused mechano-acoustic vibrations, in supine position.

For example, if the clinical conditions of the patient permit it, we work with Vibration Sound System® to carry out eccentric exercises in upright position.

Treatment goals include increased strength through muscle hypertrophy and improved flexibility. This is also achieved through stretching exercises that improve the absorption of energy and the muscular movement range, and thus the power. Therefore, the reduction of the risk of falling, as well as the improvement of coordination, is achieved.

Another type of integrated protocol, to recover kinetic and kinematic characteristics of gait, includes the use of Vibration Sound System® with a proprioceptive system called Synergy Mat (Human Tecar® Unibell srl, Calco, Italy). It is composed by mats and pillows and it allows training, rehabilitation and natural and harmonious re-education of the body. Different surfaces give the possibility to work barefoot on different levels of instability, responding to the needs of personalised training and rehabilitation (**Figure 3**). Different densities correspond to different level of movement absorption, providing protection of the joints and increasing energy expenditure time. The variety of interchangeable elements that composed the Synergy Mat set (mats and pillows) provides many combinations of routes adapted to the user-specific needs.

To better understand the potential of vibrations and even the feasibility to integrate them with other rehabilitative systems (such as synergy mat), **Table 4** provides a list of protocols related to specific objectives and a brief description of exercises.

Figure 3. Another possible way to use focused mechano-acoustic vibrations in association with synergy mat.

Aim	Frequencies	Description
Muscle relaxation	50–120 Hz for 10 minutes (applied with an hand piece)	Treatment of tender points and fatigue
	120–200 Hz for 10 minutes (applied with an hand piece)	Treatment of trigger points and taut bands
Muscle strengthening, upright position	200 Hz for 10 minutes 300 Hz for 10 minutes 120 Hz for 5 minutes (applied with segmental strips)	Strengthening of slow muscle fibres Strengthening of fast muscle fibres Deconditioning
Muscle strengthening and corticalisation	200 Hz for 10 minutes 300 Hz for 10 minutes 120 Hz for 5 minutes (applied with segmental strips)	Working with squats through active work or isometric muscle contraction
Proprioceptive exercise in combination with *Synergy Mat* (Human Tecar® Unibell srl, Calco, Italy)	60–80–100–120–140–160–180–200–220–240–260–280–300 Hz, to increase every 2 minutes (applied with segmental strips)	Mono- and bipedal walking on unstable proprioceptive platforms

Table 4. Treatment protocols proposed using mechano-acoustic vibrations.

As mentioned, the second-line treatment we suggest for sarcopenia is the association of focused mechano-acoustic vibrations with SPAD® (**Figure 4**). This system has two alternative and complementary support systems: pneumatic and mechanical, which allow using consistently rates of body weight support even higher than 50%. The aim of this therapy is the recruitment of specific muscle chains, postural reprogramming and optimisation of motor coordination with restoration of the proprioceptive stimuli and physiological recovery of gait motor patterns. Therefore, the goals are both mechanical (partial decompression of lumbar spinal structures during the walk due to the microgravitary environment created) and proprioceptive (automatic-induced adaptations related to walking, once the mechanical action of relieves has achieved the percentage of body weight support established).

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Figure 4. SPAD® system.

Third-line treatment consists of whole-body vibrations, electrical stimulation and SPAD.

Currently available WBV devices (**Figure 5**) deliver vibrations at a range of frequencies from 15 to 60 Hz and displacements from <1 to 10 mm. Considering several combinations of amplitudes and frequencies with current technology, it is clear that there are a wide variety of WBV protocols that could be used in elderly patients suffering from sarcopenia. The duration of treatment varies between individuals as well as frequencies (range 15–45 Hz); moreover, sessions of short duration (2–20 minutes), interspersed in variable-duration periods of rest, are recommended. The exercise on WBV platform would have to be performed in standing with hips and knees in slight flexion, to ensure better transmissibility of the forces to hips and spine. **Table 5** shows our WBV protocols to treat sarcopenia.

Neuromuscular electrical stimulation is defined as the use of electrical stimulation to activate muscles through intact peripheral nerve. Conventional exercise programs to increase strength are based on the overload principle of eliciting a small number of contractions of high-intensity (at least 70% of a maximal contraction 3–10 repetitions or fewer) in a treatment session performed 3–5 times per week. The same frequency of sessions can be applied when using electrical stimulation to increase strength in healthy and healthy-but-injured patients.

Our therapeutical approach involves the use of alternating currents of medium frequency produced by Horizontal Therapy (Hakomed®, **Figure 6**). The rationale is that each induced frequency generates a specific effect; for strengthening, in example, the frequencies at which muscles have to work are 20 or 100 Hz. In particular, our protocol for sarcopenia consists of a stimulation at 20 Hz for 30 minutes per session; this program includes a stimulation phase and a rest phase of 30 seconds each.

Figure 5. Whole-body vibrations (WBV).

Aim	Parameters	Protocol
Strength training	*Frequency*: 15–12 Hz. *Duration*: 3–5 minutes. *Amplitude*: medium to high, depending on comfort.	Starting position: exercises out of force and power series alternately. Sets of 10, three sets per exercise. 10-to-20-second rest between sets. 1–3-minute rest between the sets. Additional weights 70% of individual's maximal strength.
Stretching/balance exercises	*Frequency*: 15–30 Hz. *Duration*: 3–5 minutes for each exercise. *Amplitude*: low to medium.	Starting position: in standing, carry out exercises from balance and stretching series. The number of repetitions is individually tailored. Importantly, the whole body is gradually brought to an end-of-range stretching position. Balance: placing one foot alternately on the lowest position, slightly lift the other foot and hold at 5 Hz without support for 5–30 seconds.
Power training	*Frequency*: 18–30 Hz. *Duration*: 5–6 minutes. *Amplitude*: medium to high.	Carry out exercises without weights, concentrating on speed and changes in direction.

Table 5. Treatment sequence for the use of whole-body vibration in sarcopenia.

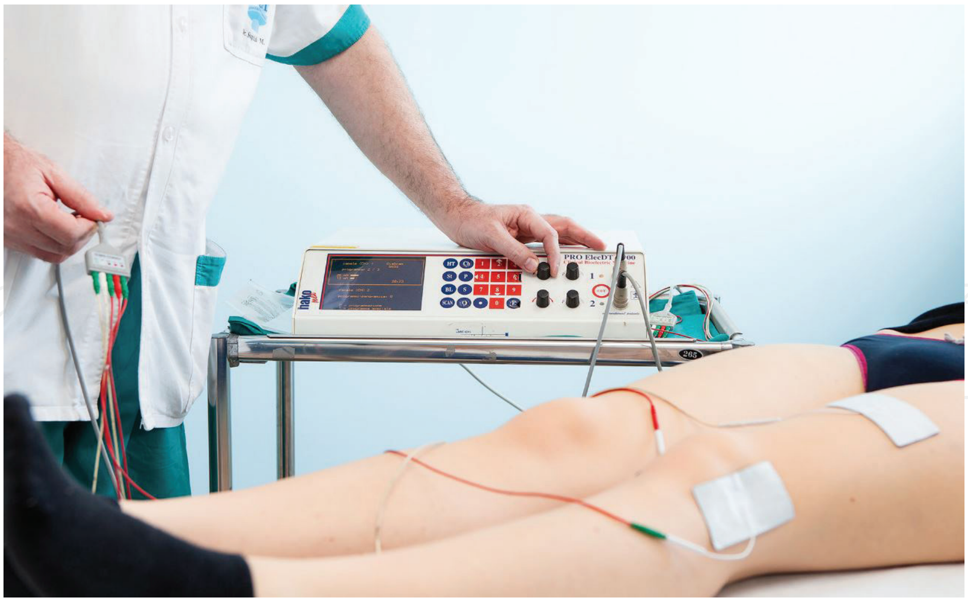

Figure 6. Horizontal therapy.

4. Conclusions

Sarcopenia is a complex problem and an important emerging field in rehabilitation of elderly. The progressive and generalised loss of skeletal muscle mass and strength is associated with the risk of physical disability, poor quality of life and death.

For these reasons, adopting the correct therapeutic solutions results of fundamental importance; to do this is necessary to know, not only the possible pharmacological interventions, but also the therapeutic possibilities that can be used thanks to the increased knowledge in the field of physical therapy. The role of rehabilitation specialist must be to integrate various therapeutic options in order to set a more suitable rehabilitative approach with the purpose of recovery postural assessment and amplify sensory-motor systems.

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