Strength training in older athletes

Juan Francisco Marcos Becerro

Instituto Longevidad y Salud. Madrid.

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Summary

Aging is associated with a gradual and progressive mass loss function and muscle strength, called sarcopenia. This implies that the ability to perform activities of daily living decreases and also means an increased risk of falling and bone fracture.
Strength training can counteract deficiencies related to the progression of age due its ability to increase muscle mass and strength, even in advanced stages of life.
In older people, strength training improves cardiorespiratory fitness, muscle activity, body composition, mood, cognition, quality of life, among other benefits.
It is recommended multimodal training, including progressive strength training (EPF), traditional weightlifting training, and/or balance training, to reduce risk factors of suffering falls and fractures and to improve cognitive functions in healthy elderly, or those at risk to suffer from dementia. However, most authors recommend a combination of strength training and endurance, both healthy and frail subjects.
The recommended components of strength training are: a training period of 50-53 weeks, although the best is to keep it throughout life, with a frequency of three sessions per week, with a volume between two and three sets per exercise and between seven and nine repetitions per set with a load of 51 to 69% of 1RM,wotj a 120 seconds period of resting time between sets and 2.5 seconds between repetitions.
This review outlines how this type of training can improve the functional condition in elderly.

Key words:
Training. Force. Aging. Older. Athlete. Elderly.

El entrenamiento de fuerza en los deportistas mayores

Resumen

El envejecimiento se asocia a una pérdida gradual y progresiva de la masa, de la función y de la resistencia muscular, denominada sarcopenia. Esto implica que disminuye la capacidad de realizar las actividades de la vida diaria, y también significa un aumento del riesgo de caída y de fractura ósea.
El entrenamiento de fuerza puede contrarrestar las deficiencias relacionadas con la progresión de la edad por su capacidad para aumentar la masa y la fuerza musculares, incluso en edades avanzadas de la vida.
En las personas mayores, el entrenamiento de fuerza mejora la capacidad cardiorrespiratoria, la actividad muscular, la composición corporal, el estado de ánimo, la cognición, la calidad de vida, entre otros beneficios.
Se recomienda realizar entrenamiento multimodal, lo que incluye el entrenamiento de fuerza progresivo (EPF), el entrenamiento tradicional del levantamiento de peso, y/o el entrenamiento del equilibrio, para disminuir los factores de riesgo a sufrir las caídas y las fracturas y para mejorar las funciones cognitivas en los mayores sanos, o en los que están en riesgo a sufrir la demencia. No obstante, la mayor parte de autores recomiendan una combinación de entrenamiento de fuerza y de resistencia, tanto en sujetos sanos como frágiles.
Los componentes del entrenamiento de fuerza recomendables son un período de entrenamiento de 50-53 semanas, aunque lo mejor es continuarlo durante toda la vida, con una frecuencia de realización de tres sesiones por semana, con un volumen de dos-tres series por ejercicio con siete a nueve repeticiones por serie y todo ello realizado con una intensidad de carga del 51 al 69% de la 1RM, intercalando un periodo de reposo de 120 segundos entre las series y de 2,5 segundos entre las repeticiones.
La revisión expone las formas de este tipo de entrenamiento para mejorar la condición funcional de las personas mayores.

Palabras clave:
Entrenamiento. Fuerza. Envejecimiento. Deportista mayor. Tercera edad.

Correspondence: Juan Francisco Marcos Becerro
E-mail: jfmarcosb@yahoo.es

Muscle function in older people

The natural ageing process is associated with the gradual and progressive loss of muscle mass, strength and resistance, known as sarcopenia, a process that is an inevitable consequence of ageing[1]. Recent studies suggest that mitochondrial dysfunction, a reduction of sensitivity to insulin, and a drop in resistance are related to physical inactivity and with the increase of adiposity, instead of just with ageing[2]. Various studies have revealed that regular exercise can normalise some aspects of mitochondrial dysfunction related to age, whilst improving muscle function, by encouraging the synthesis of myofibrillar proteins[2,3]. A balanced diet that contains the right amount of proteins is also effective in improving a reduction in muscle mass, muscle strength and its functional capacities related to age[4].

However, the combination of correct nutrition along with the regular performance of exercise is considered to be an optimum strategy for maintaining muscle function[5].

With age, the capacity for the human organism to perform everyday activities diminishes, largely due to the reduction of muscle mass, which has a significant effect on health[6]. This is related to the reduction of spinal motor neurons and the alterations of the muscular mechanical function (reduction in the maximum stimulation frequency and loss of elasticity) of the muscular fibres of the lower extremities (types I and II)[7].

Muscle strength reduces gradually from 30 to 50 years old. At 60 years old, this reduction speeds up by 15% and can reach 30% by 80 years old. The final consequence is a considerable alteration to balance and an increased risk of falling, with the possibility of suffering various fractures[8].

Training can counteract age-related strength deficiency[7]. The crucial factor in maintaining strength is the increase of muscle mass and this can be achieved with strength training (ST). Some authors recommend using multi-modal exercise programmes such as those recommended by the American College of Sports Medicine and the World Health Organisation, combining progressive strength training (PST), aerobic exercise, flexibility and balance training, performed with the aim of improving health[9], reducing risk factors of suffering falls and fractures[10], and improving cognitive functions in healthy older people. They can also be useful for people at risk of suffering from dementia.

Multi-modal programmes have better effects than those achieved using the components independently[11].

Strength training in older people

In older people, ST improves the cardio-respiratory capacity, muscle activity, body composition, mood, cognition and quality of life, and greater haemodynamic activity can be seen in MRI scans. In people affected by cerebrovascular accident, ST improves muscle strength, including the maximum voluntary strength[12], the function of the upper and lower limbs and performance in functional tests.

According to Cruickshank, *et al.*[13], the benefits on strength are clear after performing ST on individuals suffering from Parkinson's disease, and in lesser degree, on those with multiple sclerosis. There is also some evidence suggesting that ST has a positive effect on the progression of the illness and mobility in people with Parkinson's disease. In men, progressive strength training significantly restores the expression of steroideogenic enzymes that have reduced with age and levels of sex steroid hormones[14]. In older women, ST increases the strength of the respiratory muscles and other muscles in the body, as well as performance in the sitting to standing test[15]. In those affected by hypertension, it improves arterial pressure and hand grip strength, and these benefits are maintained over 14 weeks of not training[16]. According to Carneiro, *et al.*[17], ST increases the flexibility of different joint movements in older women, including an improvement in the frontal hip flex.

ST performed with the components indicated in Table 1 is effective in improving muscle morphology[12].

The training variables should not be the same for groups of healthy older people, for those with limited mobility or for frail people. Results are considered to be those obtained after 6 to 8 weeks of training, and the next stages are programmed in relation to the new MR. As well as hypertrophy, ST should improve the synchronisation of the motor units and training should be performed using increasing loads and reducing the repetitions per series[7].

ST may be performed using weights, sandbags, machines, elastic bands, and the muscles on the body or the weight of another person. The most suitable place for training is at the gym, but it can also be performed in the athlete's home, outside or in water. In water, the load is the weight of the water. According to Koch *et al.*[18], exercises performed in this environment improve cardiovascular performance, body composition, flexibility, balance and muscle strength.

Multi-modal exercise programmes

Gianoudis *et al.*[10] recommend the use of multi-modal exercise programmes that incorporate progressive strength training (PST), traditional weight lifting, and/or balance training to reduce the risk factors of falls and fractures, and to improve cognitive functions in healthy older people, or those at risk of suffering from dementia[11].

Table 1. Strength training components to improve muscle morphology[12].

- Training period: 50-53 weeks.
- Frequency: three sessions a week.
- Volume: two-three series a week, of seven to nine repetitions per series.
- Intensity: 51 to 69% of 1MR.
- Rest: a resting period of 120 seconds between the series and of 2.5 seconds between repetitions.

Table 2. Predictors/factors involved in postural instability during the dynamic activities[19].

- Capacity to generate strength from the ankle muscles.
- Weakness of flexors, of extensors, and of hip abductors.
- Reduction of the moment and the power of the flexors and the extensors of the knee, the dorsal flexors and the ankle plantar flexors.

Postural instability plays a considerable part in the risk of falling, and among the predictors or factors involved in postural instability during dynamic activities the factors described in Table 2 can be found[19].

Joshua *et al.*[19] assessed the effectiveness of a customised programme (PST) of progressive strength training with sandbags to improve balance, with various stability limits, in older non-frail people with balance deterioration, in comparison with traditional balance exercise (TBE) and a combination of both (COMBI). In terms of time, all the groups (PST, TBE and COMBI) revealed a significant improvement in balance stability limits over the 6 months of training. However, among the groups, the PST displayed more significant changes in scores than the TBE group.

On the other hand, the results of the study by Beurskens *et al.*[20] reveal that intense bilateral strength training and unilateral training can be used to improve balance, to increase the maximum production of isometric strength, and to improve the reduction of performance during bilateral muscle contractions in older people.

Power training in older people

Falls suffered by older people are a major problem for public health due to their high prevalence and the serious consequences they have. Approximately 95% of all hip fractures that occur each year are attributed to falls, and between 20-30% of those that fall and suffer a hip fracture die within 1 year.

Muscle strength and power are two important conditions in maintaining balance. Therefore, it has been suggested that the power of the lower extremities (the result of muscle strength through speed) may be more influential than strength when walking in the recovery of balance and to avoid falls, following an excessive postural alteration. In fact, people that suffer from falls have less muscle power in the lower limbs than those that do not fall.

Pamukoff *et al.*[21] ensure that strength training (ST) is more effective than power training (PT) in the recovery of balance with just one step, which is why they recommend ST in the treatment of balance in older people. An important objective for older people is remaining independent when performing everyday tasks. During ageing, muscle power reduces earlier and more quickly than strength. Power is related more intensely to functional state than strength[22]. As well as age, other alterations such as a reduction in voluntary neuromuscular activation cause modifications to the nervous system which reduces power. People over 80 years old can perform the explosive strength exercise at an intensity of between 75 and 80% of 1 MR[22]. The strength exercise with an intensity of around 60% of 1 MR, performed as quickly as possible (between 33 and 60% of the speed of the maximum movement without strength), can also improve power[22].

According to Rajan and Porter[22], even older people that attend rehabilitation programmes are capable of performing high-speed power training (PT).

Strength and resistance training (concurrent) in healthy and frail older people

Strength training is an effective intervention in improving muscle strength, power and muscle mass in healthy and frail older people[24]. Moreover, resistance training results in an improvement of the VO_2max and the sub-maximum resistance capacity of these people[25], and therefore a combination of strength and resistance training (concurrent training) for older people is the most effective way to improve neuromuscular and cardiorespiratory function.

Concurrent training performed at a moderate frequency (twice a week) may promote significant increases in muscular hypertrophy, in strength and in the power of older people. Strength training should be performed at moderate to high intensity (from 60-80% of 1MR) and at moderate volume (between 2 to 3 series per exercise). Furthermore, resistance training should be performed at moderate to high intensity (between 60-85% of VO_2max) and the volume should be moderate (between 25 and 40 minutes). For the concurrent training protocols, in which strength and resistance training are performed on the same day, the gains of strength and resistance may be optimised by performing the strength training before resistance training, in the sequence of the exercises within the session. Moreover, twice a week may be an optimum frequency to promote an increase in the muscle mass and strength, as well as to improve the cardio-respiratory aptitude in older people that have been previously trained with the concurrent.

In terms of improving the functional capacity of older people, the prescription of concurrent strength training and resistance training should include high-speed strength training, designed at improving muscle power, given that muscle power has been associated with functional capacity in older people.

As well as the positive effects of concurrent training on the functional capacity of healthy older people, another issue that should be

researched more thoroughly are the potential benefits of combining strength training with resistance training in the functional capacity of physically frail people, given that this intervention improves the general physical condition of this demographic by maintaining independence and preventing disability or other adverse outcomes.

Based on current knowledge, it would appear that interventions with exercises that include resistance training, strength training and muscle power training should be recommended to frail older people with the aim of improving their functional capacity. One important fact is that concurrent training performed on alternate days may optimise O_{2peak} adaptations (the consumption of sub-maximum oxygen) in both sexes, a fact that is possibly attributable to the prolonged recovery period (at least 24hrs) between subsequent training sessions[26].

According to Beurskens *et al.*[20], bilateral deficit (BLD) is a neurophysiological phenomenon that is characterised by a reduction of the capacity to generate strength during synchronised bilateral contractions, when compared to the sum of identical unilateral contractions. Intensive strength-resistance training (concurrent) increases the bilateral MIF (maximum isometric force production) and reduces BLD after training, due to its bilateral characteristics, whilst balance training increases unilateral MIF and the BLD, due to its predominantly unilateral nature in older people. As such, Beurskens *et al.*[20] suggest that intensive bilateral strength training, as well as unilateral training interventions in the exercise, to improve balance, can be used to increase the maximum production of isometric strength and to improve the reduction of performance during bilateral muscle contractions in older people.

Circuit training

Aside from the conventional strength training described, older people benefit from circuit training. As its name suggests, the circuit is nothing more than a series of stations - around 10 - and a specific type of exercise is performed at each.

Generally, the intensity of the exercises does not exceed 50% of 1 MR, though some participants reached 90% without displaying any significant alterations. In the first case, the number of repetitions is very high, around 15, which entails an effective load of around 30 seconds, the same time that should be spent resting between each of the exercises.

An essential requirement when organising the stations is to ensure that when one works a muscle group from the upper part of the body, the next station should work the muscles in the lower part of the body. Even though the order can and should be chosen by the athlete or the trainer, Table 3 presents a circuit training scheme.

A suitable load is around 75% of 1 MR, which is the load produced by the contraction of the muscles used that oppose the contraction of the target muscles. The complete lap around the circuit can be performed once or various times (up to four). In the latter case, a 3-6 minute rest is required before starting the next lap. The duration of this kind of circuit may vary between 20 to 30 minutes each day and there are numerous benefits obtained from performing it.

Table 3. Circuit training system.

- Neck muscles.
- Left branchial biceps.
- Right branchial biceps.
- Back muscles.
- Forearm muscles.
- Crural quadriceps.
- Deltoids and other shoulder muscles.
- Calf muscles.
- Major pectoral muscle.
- Abdominals.

According to Skidmore *et al.*[27], there are three kinds of circuit strength training: traditional (TCT), aerobic circuit strength training (ACST) and circuit strength training combined with interval training (CSTIT). TCT has the capacity of producing high levels of blood lactate (BL), heart rate (HR) and perceived exercise rate (PER), meaning its use can be recommended to individuals that perform recreational activities. For this reason it is advisable to include adequate resting periods within load sessions to reduce the risk of suffering from injuries resulting from their use or through an excess of training. CSTIT is a training method that allows more work to be done in less time, with the aim of achieving multiple physical components in one exercise session. Blood lactate (BL) can be a good indicator of the intensity of the exercise when comparing the different training protocols in the circuit. Habitual CSTIT training may lead to increases in strength and muscle resistance, and improvements to cardiovascular performance.

According to Elsisi *et al.*[28], circuit training (TCT) applied over 12 weeks in older women has beneficial effects by increasing bone density and mineral content.

Romero Arenas *et al.*[29] indicate that high intensity strength circuit training leads to larger muscle mass and bone mineral density in older people. These improvements are similar to those observed in traditional heavy-load training, with the advantage that circuit training with heavy loads requires less time than traditional strength training. Furthermore, only circuit training with heavy loads results in major adaptations in the cardiovascular system and in the body composition (reduction of fat mass)[29]. To optimise the prescription of circuit training with loads, it would be advisable to identify the most effective combination of intensity, volume, work resting ratio, the weekly frequency and the sequence of the exercise to promote neuromuscular and cardiorespiratory

Table 4. Guidelines for performing circuit training with loads[29].

- Perform at least 2 sessions a week, to which resistance training may be added (walking, jogging, running, etc.).
- The training load of each session should oscillate between 30 and 50 minutes.
- The intensity of the load, to promote hypertrophy, may vary between 60-85% of 1MR. To develop power, the load may be 40% of 1MR, performed at high speed one day a week.
- The rest period between each of the exercises should be 30 seconds.

adaptations, and those to the body composition of older people. These authors recommend performing circuit training with loads according to the guidelines in Table 4.

Other effects of circuit training

Circuit training (CT) reduces fat mass, the body mass index (BMI), plasma uric acid, total cholesterol, triglycerides and the nitrogen balance, and increases the metabolic equivalent (MET) and flexibility of overweight and obese women[30]. Likewise, it has been observed that a CT programme improves the symptoms of depression resulting from a stroke, by modifying branched chains amino acids (isoleucine, leucine and valine) and free tryptophan[31].

Administering vitamin D supplements along with circuit training performed for 12 weeks has positive effects upon the profiles of blood lipids and stomach fat in older women affected by type 2 diabetes and deficient in vitamin D[32]. According to the Shabani group[33], circuit strength training improves the levels of glycated haemoglobin (HbA1c) in the blood, for which it could be a recommended treatment for type 2 diabetes, and Fett *et al.*[30] indicate that the use of CT with aerobic exercise should be considered when it comes to treating obesity in women, though other authors such as Paoli *et al*.[34], consider that high-intensity circuit training is more effective in improving blood pressure, lipoproteins and triglycerides in middle-aged overweight women, than aerobic exercise alone or low-intensity circuit training.

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