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Isoinertial Strength Training in Older Adults: A Systematic Review

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Abstract
The maintenance of skeletal muscle and its ability to generate greater nerve stimuli are favoured by the use of isoinertial equipment, since these allow greater tendon and neuromuscular performance together with better metabolic dynamics in the face of loss of lean mass (sarcopenia) and muscle strength (dynapenia) in older adults, due to multifactorial effects such as: increase in catabolic cytokines that cause protein degradation, atrophy, hormonal disorders, increase or decrease in fat mass. The purpose of this study was to establish the neuromuscular effects of isoinertial strength training by older adults. A review of the scientific literature on the effects of isoinertial training on neuromuscular performance in older adults is presented through a database search (PubMed/MEDLINE, ScienceDirect, ProQuest). The isoinertial training mechanism generates positive changes in motor unit recruitment, strength and power levels, maintaining neuromuscular and tendon function in older adults.

Keywords: aging, eccentric training, isoinertial exercise, older adult, sarcopenia.

Introduction

Changes have been identified at the hormonal, neuronal and muscular levels as a result of the changes linked to age and functional performance in the elderly, (Algilani et al., 2014; Strasser et al., 2018; Ticinesi et al., 2019; Vandervoort, 2002). These changes produce a decrease in muscle strength and power (Latham et al., 2009; Vandervoort, 2002), and are associated with variation in motor neurons, the capacity for protein synthesis, and changes in cartilage, joints and tendons (Fernández-Argüelles et al., 2015). On the other hand, impacts on the neurological system have been seen including changes in the size and number of motor units, dendritic ramifications, and weakness in motor nerve conduction (Foldvari et al., 2000). Thus, strength is affected around the third decade of life and continues to decline progressively (Granacher et al., 2008), depending on multiple factors such as age, sex, and physical activity, among others (Russ et al., 2012; Vandervoort, 2002).

According to scientific data, a significant decrease in strength of 1 to 1.5% per year between the ages of 50 and 70 has been established (Vandervoort, 2002), as well as changes and degeneration of the spine that can produce stability, posture, function and dynamism problems (Borde et al., 2015; Mitchell et al., 2012; Russ et al., 2012). Therefore, the motor performance of the elderly depends on developing resistance through training programmes, which aim to maintain the characteristics by keeping up muscular strength through eccentric dynamics, as a fundamental basis of the adaptive physical condition that aims to maintain the number and diameter of myofibrils, especially those of type II, as a result of the production of power (Maroto-Izquierdo et al., 2017; Wonders, 2019) as an essential factor in human functional capacity.

For this reason, muscular mechanical performance through negative (eccentric) contractions in tension training justifies the use of isoinertial action equipment. This equipment aims to increase strength, improve musculotendinous elongation (Guilhem et al., 2010; Hedayatpour and Falla, 2015; Schoenfeld et al., 2017) and increase power production as well as metabolic efficiency, together with a lower cardiovascular requirement, generating strategies that combat sarcopenia (Hedayatpour and Falla, 2015), due to loss of muscle mass and strength, decreased bone mass, fragility, depression, sleep disturbances and the incidence of falls (Granacher et al., 2013; Petré et al., 2018; Sañudo et al., 2019).

As described by recent studies, the ability to apply eccentric resistance throughout the full range of motion generates satisfactory strength gains compared to traditional training (Bogdanis et al., 2018; Sánchez-Moreno et al., 2017; Yamada et al. al., 2012), which would lead to performing work with a lower ideal energy expenditure in clinical and sports rehabilitation processes (Aboodarda et al., 2016; Guilhem et al., 2010; Pareja-Blanco et al., 2014) . Speaking more specifically of the older adult population, there has been research designed to study the best way to achieve satisfactory results for strength gain.

Likewise, it has been suggested that isoinertial exercises can lead to improvements in terms of hypertrophy and functional adaptation, which are related to contractile capacity and muscle elongation in the elderly population (Maroto-Izquierdo et al., 2017). Similarly, studies have revealed that isoinertial training can improve aspects of muscle function, such as: strength, power, neuromuscular activation and structural improvement (Bruseghini et al., 2019).

Therefore, the purpose of this review becomes important when establishing the neuromuscular effects of isoinertial strength training in older adults.

Methodology

Using a descriptive cross-sectional study of articles published using a narrative review, a search was carried out between March and September 2020 in databases such as PubMed/MEDLINE, ScienceDirect and ProQuest. Published studies that were not in Spanish or English were excluded.

Search strategy

A search for publications was performed using the MeSH tool, using keywords such as aging, flywheel training, sarcopenia, strength training, eccentric overload, older adults. Subsequently, a new search was carried out using Boolean (logical) operators such as: “isoinertial” OR “isoinertial training” OR “Training eccentric overload” AND “Flywheel training*”, “Older adults*” OR “senior training*” AND “Strength training”, “muscle *” AND “neuromuscular function”, “skeletal muscle” AND “older adults*” OR “training*”, “muscle coactivation” AND “seniors*” OR “older adults*”, “sarcopenia” AND “aging*” OR “Older adults*”

Selection process

300 articles were found, from which duplicate studies and those that did not meet the study’s objectives (exclusion criteria) were eliminated, giving a final total of 70 publications.

Of the remaining articles that included resistance exercises, those (n = 20) which performed training that did not include inertial overloads were eliminated. Finally, of the 50 articles that met the inclusion criteria proposed by the researchers, 18 were used for this review (Figure 1).

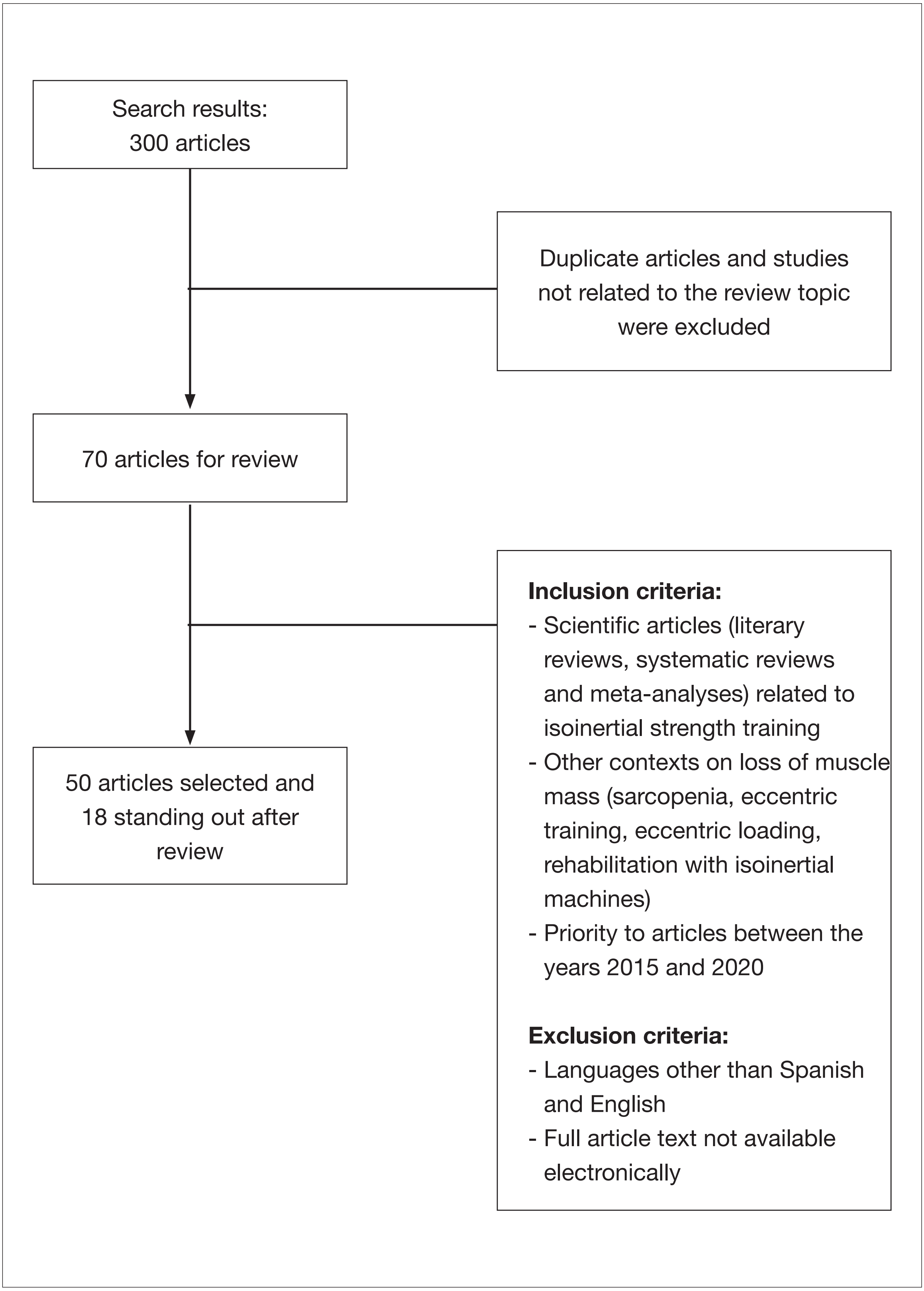

Figure 1
Flow chat for the article selection.

Results

Articles on randomised clinical trials, literature reviews, systematic reviews and meta-analyses were found covering interventions using isoinertial strength training in older adults between 60 and 75 years of age, as well as those including this population in rehabilitation and sport processes, and sports-people, highlighting characteristics pertinent to neuromuscular adaptation, articles highlighted by the scientific contribution of the intervention. Likewise, the usefulness of documents related to strength training and isoinertial exercises that might be useful is highlighted (Table 1).

Table 1

Results of the neuromuscular effects of isoinertial training.

Author(s)	Year	Effects of isoinertial training (results)	Sample characteristic
(Beato et al.)	2020	Hypertrophy - Increased strength and power. Maintenance of lean mass in the face of sarcopenia	Older adults
(Kowalchuk and Butcher)	2019	Maximise muscle size, strength and power	Review study
(Suchomel et al.)			
(Bruseghini et al.)	2019	Increased anatomical cross-sectional area (quadriceps). Lean tissue preservation	Older adult subjects
(Fisher et al.)	2020	Improves muscle speed and strength. Reduces the incidence of lower limb injuries (especially the biceps femoris)	Sports and rehabilitation
(Hedayatpour and Falla)	2015	Increased passive muscle tension. Maintenance of force levels	Review study
(Illera-Domínguez et al.)	2018	Increase in strength and power in the knee (28% knee extension CIVM) - Hypertrophy of the quadriceps	Young people
(Lastayo et al.)	2017	Low energy cost - High muscle force production - Reduces losses in muscle size, strength and mobility. Reduces the risk profile for falls in older adults	Older adults
(Maroto-Izquierdo et al.)	2017	Functional and anatomical changes and improvement in performance	Sports-people
(Norrbrand et al.)	2010	Increased MVC and specific strength of the training. Higher mechanical stress	Healthy, non-active men
(Núñez et al.)	2018	Improvements in lower extremity muscle volume and functional performance	Young male team sports players
(Onambélé et al.)	2008	Increased tendon stiffness of the gastrocnemius. Improvement in the individuals' postural balance	Older adults
(Petré et al.)	2018	Increased strength and power. Hypertrophy	Sports-people
(Sañudo et al.)	2019	Improves balance, functional mobility and muscle power	Older adults
(Tesch et al.)	2017	Useful tool to improve neuromuscular function in both clinical and healthy populations	Healthy, sedentary, or physically active people and populations with muscle wasting, disease, or injury
(Tous-Fajardo et al.)	2016	Improvement in CD capacity, linear velocity, and reactive jumping	Sports-people
(Walker et al.)	2016	Increase in maximum force production, work capacity, and muscle activation	Strength-trained men
(Wonders)	2019	Muscle activation - tendon elongation and stiffness	Athletes in rehabilitation

Note. MVC: maximum voluntary contraction; CD: change of direction. Source: prepared internally.

Discussion

Sarcopenia and the older adult population

This review of isoinertial training in the older adult population has been set up in accordance with the effects of muscular and general deterioration in human beings, since, by the year 2030, it is estimated that there will be an increase of approximately 71 million adults aged 65 and over in countries like the USA who will have functional alterations due to musculo-skeletal impairment (US Census Bureau International Database, 2015). For this reason, the decrease in the practice of physical exercise has effects on muscle composition, fat mass and the progressive reduction of strength (Walston, 2012), the latter being a physiological capacity that must be kept healthy, since it is a fundamental part of the conservation of the locomotion and functional mobility of the elderly. For this reason, the loss of lean mass and the deterioration of muscle strength in adults, together with increasing age, produces a decrease in endurance capacities, which can be improved through active and healthy lifestyles (Aagaard et al., 2010; Papadopoulou, 2020; Shafiee et al., 2017).

On the other hand, the maximum muscle strength of individuals declines continuously from the fifth decade of life and increases from the seventh decade (Hughes et al., 2018; Kosek et al., 2006). This decrease in muscle strength is related to reduced motor function, mitochondrial damage, increasing age, and impaired balance, which are affected along with a greater risk of falls and bone injuries due to fractures (Campbell and Vallis, 2014; Gschwind et al., 2013; Lastayo et al., 2017). Similarly, it is strongly associated with poor health and mortality, according to studies conducted using the measurement of grip strength and the strength of the muscles of the lower extremities (Grgic et al., 2020; Newman et al., 2006; Zeng et al., 2016).

Strength training and ageing

There is evidence of strength training as an alternative and a solution to the physiological deterioration of skeletal muscle (Papa et al., 2017). This is the case for the study by Kosek et al. (2006), in which it is shown that muscle training is the most promising method to reduce or reverse the effects of sarcopenia, performing work at an intensity of 80% of a maximum repetition, which achieves satisfactory effects on the strength after 3-4 months in older adults, producing adaptations of neural properties that play a prominent role in the training described (Fragala et al., 2019; Onambélé et al., 2008; Unhjem et al., 2015). For this reason, within strength training, along with the use of elements and machines, the isoinertial method stands out, it appears to be safe, practical and effective in increasing eccentric strength (development rate) and power (Maroto-Izquierdo et al., 2017; Núñez et al., 2018; Wonders, 2019) with overload, which allows age-related changes to be reduced and, likewise, improves the quality of life of individuals (Kowalchuk and Butcher, 2019; Lee and Park, 2013; Sañudo et al., 2019), maintaining skeletal muscle mass and improving neural stimulation through strength training as an essential factor of health and well-being (Stewart et al., 2014; Voet et al., 2019).

Similarly, when referring to the training dosage parameters, there are variables of time, intensity and speed of execution, which generate benefits in short periods (Burd et al., 2012; Cadore et al., 2014). Among them, the intensity parameter stands out as a predisposing factor in muscular adaptations towards the maintenance of nerve impulses (Fragala et al., 2019; Granacher et al., 2008; Gschwind et al., 2013; Illera-Domínguez et al. al., 2018; Kowalchuk and Butcher, 2019), which explain the best increase in strength. This is why training with isoinertial equipment favours eccentric action, which is characterised by the lengthening of the muscles (musculotendinous stretching) towards the breaking force under tension, due to the ability to apply constant and unlimited resistance through of all phases of contraction, resulting in increased power output. For this reason, the mechanical activity of acceleration and deceleration of the concentric and eccentric type through the equipment described achieves an increase in the tension (intensity) in the muscles, during contractions, according to the speed of execution and the force produced (Suchomel et al., 2019).

Eccentric strength training

Among the benefits of strength training and specifying the work on the eccentric phase, isoinertial training provides an adequate stimulus based on negative resistance (Herzog et al., 2015) in the deceleration phase of the movement and in the various squat exercises, bicep curl or knee flexion, which achieve greater neuromuscular stimuli (Katz, 1939; Meylan et al., 2008; Núñez et al., 2018; Wonders, 2019). Consequently, intervention with isoinertial devices in older adults supports the importance of its practice, adapting the musculo-skeletal system to higher rates of recruitment and impulses towards the motor unit during resisted stretching (Beato et al., 2020; Kowalchuk and Butcher, 2019), taking advantage of positive adaptations that counteract the effects of sarcopenia (Konopka and Harber, 2014; Liao et al., 2019), improving the internal muscular environment (increase in the frequency of nerve impulses) (Camera et al., 2016; Conceição et al., 2018; Gehlert et al., 2015; Remaud et al., 2010).

Isoinertial training in older adults

The reliability and validity of isoinertial strength training in older people is a strategy that has shown significant effects at the neuromuscular level (Solà-Serrabou et al., 2019). Therefore, the eccentric muscle contraction, in conjunction with the inertial overload, generates a regulation and induction of satellite cells at the molecular level that favour better performance in the recovery of the fibrillar microinjury produced by training (Cermak et al., 2013). It also helps to maintain muscle mass together with a greater protein synthesis, caused by musculotendinous activity, which helps to support the increase in the transverse cross-sectional area and the hypertrophic effect (Hody et al., 2019). It also entails an increase in the speed, duration, tension and amplitude of concentric movement during the contraction, with a slight deceleration by the muscle of the energy (kinetic), prior to the action produced in the eccentric phase (Tesch et al., 2017).

In relation to the above, the muscle and tendon have mechanical properties that allow the production of greater force and power, as well as the generation of maximum activation at the end of the muscle lengthening or elongation phase in a higher proportion than for the concentric, leading to the effect of repeated loads causing an increase in the level of tendon stiffness with less energy expenditure, thereby generating greater efficiency of directed work within a training programme with the older adult population (Bruseghini et al., 2019; Douglas et al., 2017).

Isoinertial Machines

The isoinertial exercise modality was developed in order to prevent the loss of muscle and bone mass in astronauts as a result of the lack of gravity and the impossibility of exercising the various muscle groups, (Aboodarda et al., 2016; Petré et al., 2018; Sañudo et al., 2019), this consists of performing concentric and eccentric movements against a constant resistance (Fisher et al., 2020), generated by the action of a flywheel, which produces greater strength gains in the eccentric phase than the concentric (Petré et al., 2018; Tesch et al., 2017).

Thus, earlier, less sophisticated, isoinertial machines were developed, but they maintained the same ability to generate concentric and eccentric contractions using the same flywheel. Therefore, and thanks to technology, this methodology has been developed and applied in various general populations, not only for training purposes but also as an important aid in muscle gain in older people, who, due to age go through a process of sarcopenia, as well as in sports, physical rehabilitation (Lienhard et al., 2013) and/or cardiopulmonary procedures (Tesch et al., 2017).

In the same way, the fundamental principle of isoinertial machines is similar to the reversible toy known as a Yo-Yo (Figure 2) (Bogdanis et al., 2018; Granacher et al., 2013; Kowalchuk and Butcher, 2019; Lee and Park, 2013). This consists of a rope anchored to a flywheel system for flexion and extension movements of body parts, and the aim is to pull the rope by unrolling it from the flywheel system using springs. "The system rotates in the reverse direction, rewinding the rope, which the person performing the exercise must oppose" (Fisher et al., 2020). Consequently, the intensity of the inertia will depend on the force applied during the exercise and the diameter, and thus circumference, of the flywheel (Figures 2 and 3) (Petré et al., 2018; Sañudo et al., 2019), which increases the demands on eccentric activity after a concentric action due to the inertial loads. The work done is recorded using a rotary encoder including the various variables such as power (Watts), power range (Watts) and speed (m/s).

Figure 2
Squat isoinertial machine.

Figure 2
Fixed radius pulley (top) and isoinertial tapered pulley (bottom).

It should be noted that the eccentric force depends on the concentric force that is applied and that, because the isoinertial activity is free of weights and the effects of the force of gravity, the machine guarantees that the energy used during both movements is practically identical; hence its name (Kowalchuk and Butcher, 2019).

On the other hand, one of the advantages of using isoinertial exercises in older adults or in people who require rehabilitation is that, with this Yo-Yo method (Petré et al., 2018), the energy cost is low (in comparison with other types of exercises for muscle gain), since the person is working in both the concentric and eccentric phases, but in the latter phase the energy expenditure is one fifth of that required in the concentric phase (Illera-Domínguez et al., 2018; Tous-Fajardo et al., 2016).

Likewise, with regard to the usefulness of isoinertial exercises, published work has shown that in adults over 70 years of age, power gains of up to 28% can be obtained (Bruseghini et al., 2019; Walker et al., 2016), managing to improve the levels of body stability and decreasing the progression in the loss of bone density (Bruseghini et al., 2019). However, no data have been found to support improvements in cardiovascular capacity in older adults (Tesch et al., 2017).

Conclusions

The isoinertial training mechanism produces positive changes to the recruitment of motor units, strength and power levels, maintaining the composition of lean tissue, neuromuscular and tendon function in older adults against the ageing process, due to the greater performance of the eccentric contraction and its progressive tension, with a low energy cost and at the same time being an effective alternative in the therapeutic and functional field.

Future directions of research

Establish the isoinertial training parameters in the methodological process to justify its application to various populations, as well as to determine the levels of inertia and the friction resistance force.

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