Eccentric resistance training for older adults: a narrative review of possibilities and limitations

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doi: 10.18176/archmeddeporte.00180

Recibido: 14/04/2023
Aceptado: 28/08/2024

Summary

Introduction: Resistance training is used to delay or mitigate the deleterious effects of aging. Eccentrically enhanced resistance training has gained notoriety for its beneficial results in adults. However, evidence on the effects of inertial training in the elderly is limited. Objective: to conduct a narrative review of the scientific literature to describe the possibilities and limitations of eccentric resistance training for the elderly.
Material and method: No specific search methods were used, only studies related to the research topic. Databases used included PubMed, Scopus, Scielo, and Google Scholar, with no date restrictions.
Results: Compared to isometric and concentric actions, eccentric actions are characterized by generating higher levels of force with lower muscle activation, metabolic cost, and subjective perception of effort, preferential recruitment of fast-twitch fibers (type IIx), greater hypertrophic effect, cross-education, cortical activity, and the potential for delayed onset muscle soreness.
Conclusion: Inertial training appears to be effective and suitable for maintaining physical function and reducing the number of falls in the elderly. However, devices developed for this type of training do not yet appear to be fully adapted for the elderly, which may constitute limitations for the use of eccentric strength training in the elderly.

Key words:
Aging. Muscle strength. Resistance training.

Entrenamiento de fuerza excéntrico para adultos mayores: una revisión narrativa de posibilidades y limitaciones

Resumen

Introducción: El entrenamiento de fuerza se utiliza para retrasar o mitigar los efectos perjudiciales del envejecimiento. Este tipo de entrenamiento con énfasis excéntrico ha ganado notoriedad por sus resultados beneficiosos en adultos. Sin embargo, la evidencia sobre los efectos del entrenamiento inercial en los adultos mayores es limitada. Objetivo: realizar una revisión narrativa de la literatura científica para describir las posibilidades y limitaciones del entrenamiento de fuerza excéntrico en la población de edad avanzada.
Material y método: No se emplearon métodos de búsqueda específicos, únicamente se incluyeron estudios relacionados con el tema de investigación. Se consultaron bases de datos como PubMed, Scopus, Scielo y Google Scholar, sin restricciones de fecha.
Resultados: En comparación con las acciones isométricas y concéntricas, las acciones excéntricas se caracterizan por generar niveles más altos de fuerza con menor activación muscular, menor gasto metabólico y percepción subjetiva de esfuerzo, reclutamiento preferencial de fibras de contracción rápida (tipo IIx), un mayor efecto hipertrófico, educación cruzada, actividad cortical y el potencial para el dolor muscular de inicio tardío.
Conclusión: El entrenamiento inercial parece ser efectivo y adecuado para mantener la función física y reducir el número de caídas en la población de edad avanzada. Sin embargo, los dispositivos desarrollados para este tipo de entrenamiento aún no parecen estar completamente adaptados para los adultos mayores, lo que puede constituir limitaciones en la aplicación del entrenamiento de resistencia excéntrica en esta población.

Palabras clave:
Envejecimiento. Fuerza muscular. Entrenamiento de resistencia.

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Introduction

Aging is a natural and inexorable process characterized by a progressive loss of physiological and neuromuscular functions[1,2]. Among these changes are the reduction of muscle strength and mass, the development of metabolic diseases, decreased functional capacity, and quality of life[3-5]. These factors lead to increased exposure to physical inactivity and sedentary behavior, which are associated with falls and fractures[6]. It is estimated that one in three individuals aged 65 or older experiences a fall once a year, and this incidence of falls tends to increase with advancing age[7].

These changes limit the independence of the elderly, as activities of daily living become more difficult to perform. One non-pharmacological alternative used to delay and/or improve the quality of life of the elderly is physical exercise[8,9]. Regular physical exercise has proven effective in controlling the decline in bone mineral density[10], reducing falls[11,12], improving body composition[13,14], physical function[15] and sleep quality[16,17].

One of the training methods that has gained prominence is inertial training, which is performed on a specific device to generate eccentric overload[18]. Most studies on inertial training have been conducted with young adults or athletes[19-22].

This type of training promotes muscular adaptations equal to or even superior to other training methods[23,24]. Therefore, eccentric training appears to be a good option for exercise in the elderly population[25]. However, information on the effects of inertial training in the elderly has received limited scientific attention, considering the ample evidence of its effectiveness in general and athletic populations. Thus, this study aims to conduct a narrative review of the scientific literature to describe the possibilities and limitations of eccentric resistance training for the elderly.

Material and method

In this study, a narrative review was understood as one that does not employ explicit and systematic criteria for the search and critical analysis of the literature. Therefore, the search for studies in this review did not need to exhaust information sources by using sophisticated and exhaustive search strategies.

The search for articles was conducted in the following databases: PubMed, Scopus, Scielo, and Google Scholar, without date restrictions. The search terms included "Flywheel inertial overload," "Excentric enhanced resistance training," "Eccentric enhanced strength training," and "Eccentric." All articles in English and Portuguese were considered, with a focus on human subjects. After reading the title and abstract, all articles not specific to the theme were excluded. Subsequently, full-text articles were read to obtain relevant and clear information that could contribute to and clarify the proposed objective. In addition, the reference lists of selected articles were consulted to include studies that might have relevance to the discussion proposed in this study.

Basic concepts and methodological considerations

Eccentric muscle action occurs when a force applied to the muscle exceeds the momentary force produced by the muscle itself, resulting in the forced lengthening of the muscle-tendon unit during contraction[26], in other words, it lengthens under tension. Eccentric actions are among the most common types of muscle actions in sports or daily life activities, such as descending stairs or sitting in a chair[27]. Additionally, they are responsible for supporting the body's weight against gravity and absorbing shocks or storing elastic recoil energy in preparation for subsequent contractions[28].

Eccentric training has been shown to be an excellent stimulus for triggering morphological and functional adaptations[29], such as generating higher levels of force with lower muscular activation and metabolic cost, preferential recruitment of fast-twitch muscle fibers (type IIx), greater hypertrophic effects, cross-education, and cortical activity[30]. It has also proven to be attractive for populations with chronic diseases[31], neurological conditions[32], the elderly[33-35] and clinical rehabilitation[36-38], as the modality provides a strong mechanical stress at a lower metabolic cost.

Among the proposed methods to provide eccentric overload in resistance training[39,40], the inertial flywheel device has stood out as a valid strategy for achieving acute and chronic improvements[41-43]. The characteristic of this device is to produce resistance throughout the entire range of motion using the inertial flywheel. During the concentric phase, the applied force unwinds a cable attached to the flywheel and begins to store kinetic energy, which increases with the rotation speed. At the end of the concentric action, the cable is rewound, and during the eccentric action, at the end of the range of motion, the individual must apply maximum effort to slow down the movement[42,44].

Physiological mechanisms: possibilities and limitations

Due to specific physiological and mechanical properties, eccentric muscle actions have gained prominence due to the high mechanical stress they create and their lower metabolic demands, enabling them to produce higher levels of muscular force compared to other types of muscle actions[45,46].

In addition to sarcomere length and cross-bridge formation, the speed of movement contraction affects the force developed by a muscle. In concentric actions, the force generated by the muscle tends to be inversely proportional to the speed of movement[46]. However, in eccentric actions, the force initially increases and then remains constant with an increase in the stretching speed[46]. However, in eccentric actions, the force initially increases and then remains constant with an increase in the stretching speed[45]. Consequently, force generation is greater during eccentric actions.

Although there is no consensus explaining the superiority of force production in eccentric actions, several hypotheses have been proposed. These include increased cross-bridge strength, non-uniform sarcomere length, and the involvement of the titin protein in muscle activation[46-48].

Another noteworthy aspect is that eccentric actions have the potential to generate greater mechanical stress, leading to the belief that they can also induce more significant hypertrophic increases. Some studies, when equating the volume or total work of sessions, have shown that eccentric, concentric, or traditional training can all lead to muscle hypertrophy increases[48-51], However, hypertrophic gains were greater in eccentric training[42,52-57].

Furthermore, the training modes differ in terms of the specific region that tends to hypertrophy. Eccentric actions tend to induce greater increases in the distal part of the muscle and result in a more considerable increase in fascicle length, indicating the addition of sarcomeres in series. In contrast, concentric actions induce muscle hypertrophy in the middle part of the muscle and lead to more significant changes in the pennation angle, reflecting the addition of sarcomeres in parallel[41,48,50]. Eccentric exercise can alter the length-tension relationship to a longer muscle length, which appears to enhance injury prevention and athletic performance[45,50].

The literature indicates that eccentric actions differ from other types of muscle actions in terms of neural control strategies[41,58,59]. Eccentric actions show reduced central nervous system activation due to a regulatory mechanism that stimulates autogenic inhibition and limits the rate of neural discharge in motoneurons and motor unit activation, as fewer units are required to perform the same work as in concentric actions[29,60]. This reduced neural activation has implications for fine motor control, making eccentric coordination more challenging, especially for untrained individuals[27,45].

Another characteristic of eccentric action is greater cortical excitability and faster activation compared to concentric action[27], due to its forced lengthening feature. In addition to the reduced activation of the number of muscle fibers, there is preferential recruitment of fast-twitch motor units (type IIx) during eccentric action[27,41]. It is worth noting that cross-education provides a more significant stimulus to the contralateral limb during eccentric actions compared to concentric actions[61], proving effective in inducing structural and strength adaptations in the untrained contralateral limb[62,63].

One of the primary benefits of eccentric actions lies in their physiological nature. They are less metabolically demanding than concentric or isometric actions[27,45] since they require fewer recruited motor units, resulting in lower oxygen consumption, lactate accumulation, and energy expenditure[51,59]. The energy expenditure required for eccentric exercise is approximately four times lower than that required for the same exercise performed concentrically[27].

Eccentric training has been shown to lead to a lower perceived effort compared to traditional training in the elderly, despite supporting higher training loads[64]. Consequently, due to the reduced oxygen and energy demand during eccentric actions, untrained individuals can complete eccentric training sessions without significant physical strain.

Despite the mentioned advantages, there is concern about the applicability of eccentric training due to its potential associated unwanted effects[27]. During eccentric actions, the muscle is subjected to high mechanical stress, reduced recruitment of muscle fibers, and a greater propensity for exercise-induced muscle damage[29]. This leads to micro-injuries to the contractile and structural components of skeletal muscle, inducing more extensive muscle damage, which can manifest as local stiffness and swelling, delayed-onset muscle soreness, and functional consequences. These consequences may include reduced capacity to generate force and impaired proprioception in untrained individuals[27].

However, the evidence suggests that after the second session of eccentric training, the risk of muscle damage is reduced, although the adaptive process appears to be more complete after several sessions. This process of muscle adaptation is known as the "repeated bout effect"[65,66]. The response to eccentric exercise varies according to various factors, such as muscle architecture and typology, biological individuality, age, sex, among others. Therefore, it is recommended that the prescription of eccentric training be appropriately tailored to everyone[64].

Considerations on eccentric training for older adults: potential benefits and limitations

The benefits arising from eccentric training have been widely reported in the scientific literature[18,67]. Compared to isometric and concentric actions, eccentric actions are characterized by generating higher levels of force with lower muscle activation, metabolic cost, and subjective perception of effort, preferential recruitment of fast-twitch muscle fibers (type IIx), a greater hypertrophic effect, cross-education, and cortical activity[30]. Therefore, eccentric training appears to be an excellent non-pharmacological treatment strategy for the elderly[35].

Aging is a gradual and inevitable process, characterized by a global functional decline in the body[68]. It is associated with numerous physiological and morphological changes, related to declines in strength and muscle mass, mobility, functional capacity, and susceptibility to chronic diseases, impacting activities of daily living and quality of life[69,70].

The progressive decline in muscle strength with aging is well-documented in the literature[71]. It is well-established that a higher level of strength preservation occurs in eccentric actions compared to isometric and concentric actions in adults and the elderly[72]. Additionally, eccentric actions facilitate greater force production compared to other types of muscle actions[73]. This suggests that eccentric training programs are beneficial for older adults with reduced levels of strength, especially beginners.

It is worth noting that eccentric actions are inherent in daily activities, whether to store elastic recoil energy in preparation for subsequent contractions or to decelerate movement[28]. Acts like descending stairs or sitting in a chair are examples of eccentric actions and everyday movements that can result in falls in the elderly[74]. Thus, maintaining and improving eccentric muscle strength can reduce the risk of falls, maintain mobility, postural stability, and independence in older adults.

Another advantage of eccentric exercise compared to concentric exercise for older adults is the lower metabolic cost and cardiorespiratory load for the same exercise, as many mitochondrial changes occur during aging, reducing the muscle's metabolic capacity[75]. Thus, the low metabolic demand and cardiorespiratory load imposed by eccentric exercise prove to be interesting as they allow older adults to train at higher intensity levels without putting additional stress on a compromised mitochondrial system.

It is worth noting that eccentric training induces a lower perceived effort rating compared to traditional or concentric training in older adults, despite using higher training loads[27,64,76]. This suggests that untrained older adults can complete high-intensity eccentric training sessions with a low perception of physical strain, which can contribute to increased adherence and exercise tolerance.

Delayed onset muscle soreness is a concerning condition that can interfere with continued exercise[27]. However, this phenomenon occurs less frequently in older adults, as the aging process is accompanied by a reduction in muscle mass, especially fast-twitch type II fibers[77]. Moreover, eccentric exercises result in an increase in the cross-sectional area of type II muscle fibers[27,41,78]. Therefore, eccentric exercise is considered an attractive option in strength programs to improve and restore the physical function and functional capacity of older adults.

Finally, one criticism of eccentric training, especially with the inertial flywheel device, is the format in which the device was developed, as it was not ergonomically designed for use by the elderly population. This is because, at the end of the concentric contraction, the device jerks when extending the entire cable. Such an action can overload the primary joint involved in the exercise or cause an imbalance, leading to a fall in older adults. One measure to mitigate this situation is the use of a conical-shaped wheel axis. Therefore, it is necessary to develop inertial machines designed for this population to make them more ergonomic and safer.

Conclusion

Eccentric actions display distinct neural, mechanical, and metabolic adaptations, which have generated substantial interest across various research domains. Due to these characteristics, including reduced physiological strain and the preservation of eccentric strength during the aging process, eccentric strength training emerges as an effective and suitable method for sustaining physical function and mitigating the risk of falls in older individuals. Nevertheless, this form of training may initially result in heightened delayed-onset muscle soreness, and the equipment designed for such purposes does not seem to be entirely tailored to the needs of older adults, potentially posing limitations in the application of eccentric strength training within this demographic.

Conflict of interest

Authors report no conflict of interest.

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