Sports Medicine
https://doi.org/10.1007/s40279-020-01260-5

CURRENT OPINION

Selection of Resistance Exercises for Older Individuals: The Forgotten Variable

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Abstract
Resistance training has been widely recommended as a strategy to enhance the functional autonomy and quality of life in older individuals. Among the variables that comprise a training session, the selection of exercises stands out as an important consideration for the elderly. Although a wide range of resistance exercise options exists, current guidelines generally do not indicate which exercises should be included and which muscles should be prioritized when prescribing training for older individuals. Therefore, given the lack of evidence-based information on the topic, this paper endeavors to establish recommendations to help guide the prescription of resistance exercises for older adults.

Key Points

Current recommendations on exercise selection in a resistance-training program for older adults are imprecise.

Due to joint impairments and injuries related to aging, the prescription should be based on individual needs as well as the safety and efficiency of the exercises; with higher caution than in younger healthy adults.

Primary attention should be given to strengthening the lower body musculature in order to maintain and improve the active quality of life of the elderly. The current work endeavors to give specific instructions on how to select the exercises for that.

1 Introduction

Biological aging is associated with a reduction in muscle mass and muscular strength, reflecting reduced quality of life and increased risk of mortality [1, 2]. Resistance training (RT) has been recommended as a strategy to counteract these age-related neuromuscular impairments, to improve muscular fitness [3–6], to compress morbidity time [7], and increase active life expectancy [8, 9]. Despite the plethora of positive adaptations provided by regular RT practice reported in the literature, it is worthy to note the responses are dependent on the proper manipulation of program variables, including exercise selection [10]. However, there is a dearth of research-based information for practitioners to help guide RT prescription in regard to exercise selection for older individuals. For example, recommendations from current RT position stands only indicate that older individuals should perform multi- and single-joint exercises for upper and lower-body larger muscle groups on machines and free weights [3, 4, 6, 11]. These recommendations do not specify which exercises should be performed nor which muscles should be prioritized. Moreover, no mention is made as to the potential safety issues associated with different exercises.

In the expensive, multicenter LIFE intervention for older adults to prevent mobility disability [9, 12], no upper limb exercise was included, and training for the lower limbs was almost exclusively home-based and consisted of low-volume and low-intensity exercises performed with ankle weights. No description was presented regarding the correct execution of the exercises, nor regarding the progression of the

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Published online: 01 February 2020

intensity of load [12]. Other large multicenter trials focused on improving general health of the elderly also describe the exercises vaguely, with little to no rationale presented as to why such exercises were selected [13, 14].

Although the health-related benefits of a physical activity program for elders are well established [3–6, 11, 15], it is important to note that increased muscular strength (muscle quality as well [16]) appears to be the outcome most closely associated with improved functional capacity and wellness [1, 4, 5, 17]. To help facilitate greater attendance and adherence to RT programs in older adults, it is important that guidelines for exercise selection are established for this population – which is a current gap in the current literature. Therefore, the present paper aims to provide evidence-based recommendations on the selection of resistance exercises for older adults, with a focus on matching their needs and abilities with the advantages/drawbacks of specific exercises.

2 Exercises for the Lower Body

When selecting exercises for older individuals, primary attention should be given to strengthening the lower body musculature. The age-related reduction in muscular strength and muscle mass tends to be more pronounced in the lower- versus upper limbs [18]. The weakness of the lower limbs can compromise activities of daily living, leading to a loss of functional independence and increasing the risk of injury from falls [19]. The reduced ability to walk can predict subsequent disability, and, in this sense, older adults who have difficulty walking have a greater risk for mortality [20, 21]. Therefore, the practice of lower body exercises is vital for the aging adult.

Among the lower limb exercises, the squat is considered a primary closed kinetic chain movement [22–24] and can help to improve functionality in older adults. Recently, Lima et al. [25] observed significant functional improvements in a cohort of older women following a 7-week period of squat and deadlift exercise performed at 65% of 1 repetition-maximum. Bezerra et al. [26] also showed an improvement in markers of functional performance in elderly women after 24 sessions of velocity-based squat training. Despite its many fitness-related benefits, the traditional free-bar squat is a complex movement; therefore, not every older individual will be able to perform the exercise as advancing age compromises balance and coordination. In these cases, practitioners should regress the movement by reducing degrees of freedom. A viable alternative in this regard is to perform the squat on a Smith machine, which limits movement in three-dimensional space and, therefore, makes this variation easier and potentially safer than the free-bar squat. Although the free-bar squat induces greater muscular activation compared to the Smith machine squat [27], the differences may not reflect greater gains in strength and muscle mass after a period of training [28]. Another viable alternative is the hack squat, whereby the spine is supported by the backrest of the machine. The hack squat is also easier to perform than the free-bar squat, because the machine predetermines the movement trajectory. After proficiency and strength are attained in these movements, the older individual potentially can progress to free-weight versions of the squat for greater functional benefits.

All the above-mentioned squats variants will increase overload on the spine and thus may not be a prudent choice in the most fragile older individuals and/or for those with a history of spinal injury or marked postural deviation. In such cases, holding dumbbells, elastic bands (fixed under the feet, for instance), or kettlebells with hands can be employed during squatting. In frail older adults or those with very low levels of muscle strength, squatting with their own body weight often will be sufficient to induce positive muscular adaptations [29]. If needed, the performance of the squat can be facilitated using a chair, in which the older individual alternates from sit-to-stand exercise. For those who have further difficulty or very low levels of muscular strength and/or poor balance, the practitioner can assist during movement by holding the individual's hands.

The leg press is another closed kinetic chain exercise that also effectively activates the quadriceps and gluteus maximus [30–32]. Given that the leg press places a minimal load on the spine, it is a suitable alternative for older individuals who are unable to perform squats and their variations and can serve as a springboard for progression to more challenging exercises.

During the squat (and its variations) and leg press, the activity of the vastus is considerably greater than of rectus femoris [22, 33–35]. This is due to the biarticular nature of the rectus femoris, which simultaneously carries out hip flexion and knee extension during the multi-joint lower body movements. This ultimately results in suboptimal development of the rectus femoris when exclusively using these exercises [36, 37]. For example, Earp et al. [36] observed that 8 weeks of squat training elicited significant increases in the three vasti muscles, but no change was seen for the rectus femoris (+ 1.0%). Similar findings were observed by Kubo et al. [37] following 10 weeks of full and half squat training.

The rectus femoris plays an important role in ambulation [38, 39]. During the walking cycle, the rectus femoris is involved in both the ground foot and swing phases [40, 41]. It is also an important muscle for postural balance since hip flexion is a strategy for restoring balance. Therefore, complementary exercises such as the knee extension ideally should be included for greater improvement of the rectus femoris. Single-joint knee extension has been shown to elicit greater activation and development of the rectus femoris compared to closed kinetic chain exercises [35, 42]. The seminal study

by Fiatarone et al. [43] demonstrated that 8 weeks of high-intensity knee extension RT increased leg strength by 174% and improved gait speed by 48%; most impressively, 3 of the 10 participants were able to walk without the assistance of their canes. Moreover, Santos et al. [17] observed a positive association between increased knee extension strength after an 8-week RT period and improvements in walking speed in older women.

Although knee extension exercise is usually performed on machines, alternative strategies can be adopted for those without access to fitness facilities. Individuals may sit on a chair or a surface high enough for the feet not to touch the floor, and place elastic bands and/or ankle weights on the lower leg. Applying manual resistance training can also be a viable approach, whereby a professional applies resistance with the hands against the knee-extension movement. Although such strategies may present some difficulty in progressing intensity of load, they can be an appropriate option for eliciting adaptations in the early stages of RT [44]. In addition, it is noteworthy that the training angles near maximum knee extension are those that present the greatest compressive force in the knee joint [45, 46]. Thus, in cases of an existing knee-related injury, it may be prudent to avoid reaching full knee extension.

Hip extension is a very important movement for many daily activities such as walking, sitting, and standing [38, 39]. The gluteus maximus and hamstrings are primary hip extensor muscles. Although the gluteus maximus is adequately targeted in closed kinetic chain exercise such as the squat and leg press [32, 37], the hamstrings are only moderately activated in these exercises [22, 47], resulting in an imbalanced development between the quadriceps and hamstring muscles [32, 37, 48, 49]. Illera-Domínguez et al. [48] observed that, after 4 weeks of squats, there was a 9.8% increase in the vastus medialis, 8.8% in the vastus medialis and lateralis, and 4.7% in the rectus femoris muscles; however, there was no statistically significant increase for any of the hamstring muscles. Kubo et al. [37] also observed no hypertrophic increases of the hamstrings after 10 weeks of squat training in young men. Specific to older adults, Orssatto et al. [49] reported that knee extension torque increased after 12 weeks of 45° leg press training, but there was no increase in knee flexion torque, suggesting that using leg press alone may induce an imbalance in knee forces. The combined results suggest that closed kinetic chain exercises (squat and 45° leg press) should not be used in isolation in the elderly.

To enhance functional performance for the elderly, hamstrings-specific exercises such as the leg curl and stiff-legged deadlift should be included in RT programs. The leg curl is a single-joint, easy to perform exercise. It is usually carried out on machines, although non-machine based alternatives such as manual resistance technique, elastic bands, and ankle weights can be used to provide external overload as well. On the other hand, the stiff-legged deadlift is a free-weight exercise that requires maintaining a neutral alignment of the spine, which can be difficult for many older adults. In addition, loading is applied perpendicular to the spine, which increases the potential for spinal injury [50]. Thus, care should be taken when prescribing the stiff-legged deadlift for elderly individuals, particularly in those who are frail or suffering from back ailments.

The gluteus medius is a very important hip abductor [51, 52] that helps to stabilize the hip during walking [53]. Studies demonstrate a relationship between gluteus medius weakness, knee pain, and knee osteoarthritis [54, 55]. Specific hip abduction exercises are required to strengthen the gluteus medius such as abductor chair or hip abduction with some external resistance (e.g., in a low pulley, or with elastic bands). Alternatively, hip abduction can be performed from either a standing or lying position using anklets attached to the distal portion of the lower limbs. The hip adductor muscles are also important for maintaining proper hip stabilization, as well as playing a role in preventing urinary incontinence (involuntary loss of urine) in the elderly. The adductor muscles can be developed with closed-chain exercises such as the squat and leg press [32, 37]; a wide stance during squatting has been shown to be particularly beneficial for targeting the adductors [34]. Similar strategies for performing hip abduction (i.e., machine or alternative ways) may be used for carrying out the adduction exercise, which can be useful if additional adductor development is desired.

Finally, the gastrocnemius and soleus (also known as triceps surae) are primarily responsible for plantar flexion. These muscles also help to maintain balance in the standing position and participate in ambulation [38, 56, 57]. The standing calf raise provides a favorable length-tension relationship for the gastrocnemius, thereby placing it in an optimal position to produce force. Alternatively, the seated calf raise renders the gastrocnemius actively insufficient [58], thus allowing the soleus to take over a greater percentage of the work. Combining both standing and seated calf raises, therefore, maximizes triceps surae function and development (Table 1).

3 Exercises for the Upper Body

If the lower body muscles are important to basic ambulatory aspects of daily living in an elderly population, the upper body muscles are equally important for performing instrumental lifestyle activities such as bathing, dressing, feeding, cleaning, cooking, and others. The literature clearly indicates that lower upper body strength is associated with impairments in instrumental activities of daily living and health in older adults [59, 60]; disability in such activities

Table 1 Example of exercises that may be included in a whole-body resistance exercise session

Basics	Complementaries
Squat	Hip adduction/abduction, flexion/extension
Knee extension	Calf-raise
Knee flexion	Elbow flexion/extension
Chest press	Core/abdominal specifics
Seated low-row	

Consider that all mentioned exercises can be performed in different fashions, depending on available structure, and the functional and orthopedic condition of the elder. As example: squat can be performed in a free-bar, in a Smith or hack machine, with weights or elastic bands on hands, or sit-to-stand in a chair or platform

is associated with an elevated risk of premature mortality [21, 61]. For example, McGrath et al. [21] observed that decreased handgrip strength might increase the odds for an older individual to develop functional limitations in eating, walking, bathing, dressing, transferring and toileting, and the presence of these disabilities was associated with higher hazard for mortality. Moreover, research indicates that muscular endurance of the upper body is predictive of cardiovascular events [62]. Accordingly, maintaining upper body strength of the muscles involved in these instrumental activities is critical for maintaining functional capacity during aging. To perform these daily instrumental tasks, specific movements such as pushing, pulling, lifting, holding, trunk flexion, trunk rotation and stabilization are necessary.

The glenohumeral joint is critical for carrying out upper body movements in three-dimensional space. The major muscles responsible for shoulder joint movement are the pectoralis major, deltoid and latissimus dorsi. The pectoralis major is optimally activated during shoulder adduction in the transverse plane. Therefore, the bench press is a good option for activation of the pectoralis major. In addition, it provides considerable activation of the anterior head of the deltoid and triceps brachii, which also play roles in shoulder joint function. Since the bench press is performed with a free barbell, its performance requires considerable balance and motor coordination. If the older individual does not possess these attributes, regression to a machine-based chest press becomes a viable alternative.

Regarding the latissimus dorsi, available exercise choices are those that involve shoulder extension and shoulder adduction in the sagittal and frontal planes, respectively. The latissimus dorsi is optimally activated during shoulder adduction in the frontal plane [63], making the lat pulldown a good exercise option. The lat pulldown also activates the teres major and lower trapezius fibers. Given that the exercise also involves elbow flexion, the biceps brachii, brachialis, and brachioradialis muscles receive substantial activation as well. However, the lat pulldown requires a shoulder abduction above 90 degrees. This movement reduces the subacromial space, especially when combined with internal shoulder rotation; thus, the structures in this space becomes compressed, increasing the risk of injury. Therefore, those with existing shoulder dysfunction (e.g., bursitis and/or tendonitis) may have difficulty performing the lat pulldown.

Moreover, the mid/upper back scapular muscles (trapezius and rhomboid muscles) are not satisfactorily stimulated in the lat pulldown. In this case, movements in the sagittal plane, such as the seated row can be performed for a complete stimulation of the associated musculature. Some older individuals may have difficulty keeping their spine aligned during performance of the non-supported seated row (e.g., performed on a cable pulley). If so, the row may be performed on a machine that provides support for the anterior trunk; however, this reduces involvement of the erector spinae muscles, thereby warranting targeted training of this muscle group. Alternatively, rows can also be performed with free weights. Although this version effectively targets the back musculature, it requires greater body awareness to perform the exercise with correct technique, especially to maintain spinal alignment, which can be problematic in older individuals with cognitive issues.

The deltoid is a versatile and important muscle for shoulder mobility, moving the joint in three-dimensional space. The shoulder press is a common exercise used to strengthen the deltoid. However, the performance of the shoulder press requires external rotation of the shoulder joint, which places the anterior fibers of the deltoid in a better position to oppose gravity, and reduces activation of the middle and posterior fibers [64]. In addition, the shoulder press requires a shoulder abduction above 90 degrees. This position induces the lateral region of the humerus to come into greater contact with the acromioclavicular joint and can thus cause impingement with repeated use. Therefore, some older individuals may have discomfort performing this exercise. Moreover, the anterior head of the deltoid is activated during the bench press, while the posterior head is activated in the row; thus, specific exercises focused on targeting the deltoid perhaps may not be necessary when multi-joint push/pull exercises are performed for the upper body. On the other hand, the prevalence of shoulder pain increases with aging, thus impairing the ability to perform daily tasks and diminishing quality of life in older individuals [65]. Those who experience recurrent shoulder pain may benefit from strengthening exercises. Generally speaking, afflicted individuals should focus on exercises that work the internal and external rotators of the shoulder, which can be performed in a pulley apparatus or with elastic bands. The supraspinatus is worked during the lateral raise mainly during the first 30° of shoulder abduction, so it generally does not need direct work [66].

The muscles responsible for elbow flexion and extension can be developed from the performance of multi-joint

exercises. For example, the triceps brachii are synergists in the bench press, as are the elbow flexors during rows and the lat pulldown. To some extent, this participation is able to induce positive adaptations regarding the increase in strength and muscle mass of the elbow flexor and extensor muscles [67], whereas when potentiate these adaptations are the aim, the addition of single-joint exercises may be necessary [68].

Aging may induce changes in spine sagittal alignment, such as increased kyphotic curvature and reduced lumbar lordosis [69]. These changes are, at least in part, related to weakness of muscles responsible for body support [70]. In general, the abdominal muscles are essential for stabilization of the spine, especially the lumbar region, and are important for maintaining the posture [70]. The spine is naturally an unstable structure, with the muscles around it being responsible for providing its stability. Thus, there is a strong association between vertebral fracture and function of trunk muscles in older women [70]. Trunk muscles contribute to the stabilization of the center of mass during movements of the upper and lower body limbs during activities of daily living, thus allowing better functional performance [71]. Sit-to-stand movement requires balance control and coordination between the trunk and lower limbs. For lifting, the abdominal muscles need to generate a rapid stabilizing counterbalancing force to prevent the pelvis from tilting anteriorly and the spine from hyperextending. Abdominal muscles include the rectus abdominis, transverse abdominis, internal oblique, and external oblique. These muscles, when weakened, are associated with low back pain [72]. Accordingly, strengthening exercises are recommended due to their beneficial effect for alleviating chronic low back pain [73].

The main dynamic role of the rectus abdominis is to perform trunk flexion [74]. Consequently, the basic exercises of trunk flexion are important for strengthening this muscle. The obliques assist the rectus abdominis in trunk flexion, but the obliques are important in the rotational movements of the trunk and the lateral inclination of the spine. This way, rotational movements are effective to activate the obliques, but it is noteworthy that rotational movements will impose greater stress on intervertebral discs. However, some older adults may have difficulty performing the crunch. In this case, isometric exercises such as the front plank may be a viable alternative, since they activate the rectus and obliques [75]. In the frailer elderly who have difficulty performing the front plank, the exercise can be regressed by supporting the arms higher (i.e., in a bench).

4 Conclusion

Making decisions about selecting resistance exercises for older individuals should be based on specific needs as well as the safety and efficiency of the exercises. The recommendations provided herein should be used to guide resistance exercise prescription in an elderly population, and then customized based on the given individual. In general, when no major musculoskeletal problems are present, an elderly individual may perform a program that contains the following exercises or their associated variations: squat, knee extension, knee flexion, calf-raise, chest/bench press, seated row, and front plank.

Compliance with Ethical Standards

Funding No external sources of funding were used in the preparation of this article.

Conflict of Interest Alex S. Ribeiro, João Pedro Nunes and Brad J. Schoenfeld declare that they have no conflicts of interest that are relevant to the content of this article.

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