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Selecting Hip Strengthening Exercises for Healthy Aging

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Muscle strength is necessary for the elderly population, to preserve their health and prevent injuries and illnesses, and to maintain their physical independence. With regard to this last point, lower-limb strength is essential, and it has been suggested that, among the large muscle groups, the gluteal muscles are the most important. Gluteus strength is necessary for elderly people. Different exercises yield differences in EMG data for the gluteal group. In summary and based on these results, resistance training exercises can be prescribed for older people from among a range of structural and functional exercises.

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INTRODUCTION

Age-related losses of skeletal muscle mass (sarcopenia) and of functional capability, strength and power (dynapenia) are manifest as muscle changes in older adults (23,63,40). Lower-limb muscles have a greater propensity to lose mass and functional capability, thereby impairing physical function (47). One of the most important consequences is balance loss and an increased risk of falling (63,29). Elderly people aged over 65 have a very high risk of suffering a fall due to both dynamic and static balance ability loss. Several studies have estimated that one-third of people older than 65 years will suffer a fall; the risk for those over 80 is eight times higher. One half of fallers could suffer repeated falls with fatal consequences (32,33). By 2020, the annual direct and indirect costs of fall injuries are expected to reach $54.9 billion in the United States (19).

Data emphasize the importance of the multifactorial nature of falls in the elderly population, as the decline in skeletal muscle strength in lower limbs reduces stability control. Additionally, older adults must make greater muscular efforts than young people when they negotiate obstacles (25). The higher demands on lower-limb muscles while stepping and/or walking may increase fatigue, placing elderly individuals at a higher risk of falling (25). The gluteus muscles are contributors to support and progression at all walking speeds (39), they stabilize the pelvis and provide balance in walking (59) and reduce several musculoskeletal types of injuries (28). The gluteal group is one of the most important muscle groups in providing lateral stability. Consequently, possessing a well-developed gluteal group will delay these previously mentioned complications and lead to a healthier old age (22).

The gluteus muscles are very important in stabilizing the pelvis, creating a stable base for lower-limb kinetic chain movements thereby avoiding aberrant patterns of motion that can lead to several injuries (28). For example, weakness of the gluteus medius will cause the axially-loaded leg to adduct, the femur to rotate internally, and the tibia to rotate externally, thereby placing the knee in a valgus position (56) and increasing the risk of the musculoskeletal pain in the lower extremity (52). In the same sense, significant gluteus medius muscle weakness is common in arthroscopy patients and exercises have been suggested to strengthen the gluteus medius while other exercises are to be avoided (53). Although further research into the matter is required, Himmelreich et al. (27) suggested that low back pain is associated with changes in the level and duration of the gluteus maximus activity during different functional activities. These alterations suggest a compensatory recruitment

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pattern by the gluteus to provide lumbo-pelvic stability (27). For instance, Marshall et al. (41) found that side-bridge endurance and gluteus medius co-activation are variables that influence the lower back during periods of prolonged standing.

These data demonstrate the importance of the recruitment/activation time of the gluteal muscle group. Consequently, Janda, among others, developed a specific test to detect possible alterations in the synchronization of movement patterns (30,31) This test establishes the stereotypical activation patterns during prone hip extension. Early activation of the spinal erectors and hamstring muscles has been interpreted for assessment of musculoskeletal dysfunction. Janda describes the normal movement patterns in this sequence: i) activation of gluteus maximus; ii) hamstring activation; iii) spinal erectors, first contralateral and lastly ipsilateral (30,31).

Fall risk is particularly severe in older adults, who have difficulty in recovering postural stability in the frontal plane (59, 44). Thus, strengthening muscles which provide lateral stability could reduce fall risk among the elderly. A combination of hip strategy and gluteus medius strength exercises will help improve balance control in healthy, active individuals (35). Specifically, Chulvi-Medrano et al. (13) showed how an intervention program that combined strength and balance produced improvements in dynamic and static balance performance in women over 65 years of age. The authors concluded that the combination of the two types of training helps improve dynamic and static balance.

As our society continues to age, the preservation of physical functions is a topic of increasing concern, with research investigating how to prolong functional independence, improve motor performance, and reduce the incidence of injuries and fall risk. This review presents the functional role of the gluteal region and a selection of exercises to strengthen said muscle area to prevent injury resulting from falls among the elderly.

FUNCTIONAL ANATOMY OF THE GLUTEAL REGION

First, it is necessary to give a brief review of the functional anatomy of the gluteal region. The existence of functional subdivisions in the gluteus muscles appears to be supported by the research findings because muscle activation is not homogeneous throughout the entire muscle (gluteus). The functional anatomy of the gluteus is divided into three parts, with three distinct muscle fiber directions. Their activation depends on the degree of hip flexion (17). Anatomically, three muscles can be distinguished: *gluteus maximus, gluteus medius* and *gluteus minimus* (55).

Gluteus maximus

The gluteus maximus muscle arises from the dorsal segment of the ilium, from the thoracolumbar fascia, from the posterior surface of the sacrum and the sacrotuberous ligament, and is inserted into the gluteal tuberosity of the femur and the iliotibial tract. When the insertions of the gluteus maximus are analyzed mechanically, one can see that it plays an important role in hip extension and lateral rotation (66). In addition to its main insertions, the gluteus maximus also inserts into the iliotibial tract and consequently plays a role in stabilizing the knee when extended (66). It is important to note that the gluteus maximus plays a significant stabilizing role in core stability, forming part of the hip muscles that contribute to core stability (1).

Anatomically, the gluteus maximus has been described as being connected to the lumbar paraspinal muscles by the thoracolumbar fascia, allowing it to transfer loads from the lumbo-pelvic region to the lower extremities (55). The human gluteus maximus plays a very important role in deambulatory actions such as walking, running and climbing (67). The gluteus maximus is active while lifting weights because it has an important role in extending the hips and stabilizing the pelvis (43).

Gluteus medius

The gluteus medius muscle originates on the gluteal surface of the ilium, between the iliac crest and the posterior and anterior gluteal lines, and inserts into the lateral surface of the greater trochanter in the tendinous area. It is a key muscle of the abduction and internal rotation of the hip and playing an important role in postural stability particularly in frontal plane stability during functional tasks (55). The gluteus medius provides lateral stability in several functional and common activities such as walking (17,26) because it is responsible for preventing the opposite side of the pelvis from dropping during gait; if this muscle is weak it can give rise to an orthopedic condition known as Trendelenburg gait. This dysfunction is characterized by the whole trunk swaying across the affected limb while weight-bearing because the abductors are incompetent and pelvis drops to the opposite side. McGill et al. (43) suggested the importance of muscles such as the gluteus medius and quadratus lumborum in the generation of frontal plane torque to support the torso and pelvis in asymetrical lifting activities and in balance.

Weakness in the gluteus medius can also lead to the risk of other lower-limb injuries, such as ankle injuries, anterior cruciate ligament injury, patellofemoral pain syndrome and illiotibial band syndrome (56). Several authors have proposed the existence of functional subdivisions in the gluteus medius (GM) muscle, including O'Dwyer et al. (49) who found higher GM activation in the anterior GM subdivision during abduction and internal rotation. However, more data are required to confirm which types of movement or exercise causes greater recruitment in different sections of the muscle and to determine how subjects with lower-limb pathologies may respond to these exercises.

Gluteus minimus

Finally, the gluteus minimus originates on the gluteal surface of the ilium and inserts into the greater trochanter (its function is similar to that of the gluteus medius: separation and internal rotation; these muscles tilt the pelvis toward the supporting leg in monopodal stances) (55,46).

THE IMPORTANCE OF STRENGTHENING EXERCISES

Anatomically, the gluteus muscle is a large muscle mass which covers the back of the hip. Despite the great functional importance of the gluteal region, the strengthening of this area has traditionally been focused on aesthetics goals in youth and in elderly has remained as a secondary muscle in training programs. However, the gluteal region plays an important role in the stability of the hip (57), and the strength training in elderly will confer greater improvements in dynamic balance control, mobility, and coordination while performing daily life tasks such as chair rise performance or lifting weights (9).

When prescribing lower-extremity functional exercises for the elderly, multi-joint, closed-kinetic chain, weight-bearing exercises (such as the squat or lunge) are recommended because the movements involved most closely resemble those used in common activities (20,21,61). On the other hand, these exercises require a considerable level of pelvic stability. Furthermore, it has been suggested that 40% to 60% of one repetition maximum (1RM) (3), and 66% or more (4) of the maximal effort (maximum voluntary isometric contraction) of a muscle must be trained before strength gains can be achieved or between moderate (5-6) and vigorous (7-8) intensity on a scale of 0 to 10 (10). Therefore, the exercises chosen must also meet this requirement.

Exercise selection

When designing a muscle training program, the importance of exercise selection is recognized. In attempting to strengthen a muscle, localized forma should be assumed to be very difficult to complete muscle isolation, since muscles operate globally and joint actions involved in exercises require the participation of muscular chains. For example, the gluteus has a close relationship with the spinal erectors, acting as a powerful synergist which, for example, is known to become increasingly important when a subject carries out more than 12 lumbar extension repetitions in the variable angle roman chair (14).

At this point we will give a general overview of the exercises that can strengthen the gluteal region, for all exercises are recommended to maintain neutral hip position for maximum activation of the gluteus maximus (38):

a) Calisthenic exercises. Exercises which use the subject's own body weight.

As the majority of studies have focused on rehabilitation, the exercises examined used the subject's own body weight; in other words, they were calisthenic. The prone hip extension is the exercise traditionally prescribed to train the gluteus maximus. This exercise reproduces the principal action of the gluteus maximus – the extension of the hip – and is used as a clinical test to evaluate the function of the extension pattern, given the existence of connections which give rise to a determined activation order which is regarded as proper function (64). However, there are studies using electromyographic analysis that did not find consistent or stereotype activation patterns (36). Equally, it should also be noted that there is evidence that when 8-12 repetitions of the lumbar extension exercise are exceeded, the gluteal musculature (a synergist of the movement) plays a more important role, while the activity of spinal erectors falls (14). However, a delay in the activation of the gluteus maximus in the extension of the hip increases the functional demand on the hamstrings, especially the biceps femoris, thereby also increasing the risk of overloading and injuring them (8). In response to this dysfunction, during the prone hip extension movement, muscular activation can be increased in asymptomatic subjects by a proper use of verbal instructions which lead to relaxation of the hamstrings and activation of the gluteus maximus (37). Another strategy with the same purpose was developed by Chance-Larsen et al. (8), who provided evidence that abdominal hollowing as a prior step to prone hip extension leads to an increase in gluteal activity and

favours its recruitment prior to that of the biceps femoris.

One final strategy to favour the activation of the gluteus (and reduce the activity of the semitendinosus) during hip extension exercises involves performing the extension movement with knee flexion or lateral hip rotation, or with a combination of the two (61).

In addition to supine hip extension exercises, other exercises are effective in strengthening the gluteus. For instance, quadruped hip extension, which is prescribed as appropriate for gluteal strengthening (2), is not recommended for elderly people, especially if they are affected by knee pain (e.g., ostheoarthrosis). To avoid risks in the elderly, we proposed an adaptation of this exercise in bipedestation position, and using the abdominal hollowing combined with knee flexion and lateral hip rotation with elastic bands.

Some studies suggest that single-limb stance exercises cause significant gluteus activation (56,16,34). In this regard, the single-limb deadlift, together with the single-limb squat have been shown to be extremely effective in activating the gluteal muscles. The authors attributed these results to the demands of lumbo-pelvic region stability, balance, control of eccentric hip flexion and concentric hip extension, which are the main functions of the gluteus maximus (56,16). On this topic, Krause et al. (34) measured muscle activation of the gluteus maximus close to 50% of the maximum in the performance of the single-limb squat. In this study, the authors also used an unstable surface (AIREX®) and observed a tendency towards increased muscle activation when using it, although the increases were not statistically greater than those obtained when using a firm surface. Much care must be taken when these exercises, when applied to elderly population because of the added fall risk in unstable environments.

The results published by Distefano et al. (16) show the same trend. The authors analyzed the electromyographic signal from 21 subjects who performed 12 specific exercises (using their own body weight) to strengthen the gluteal region. Their results support the use of the single-limb deadlift and the single-limb squat as the exercises which produce the greatest levels of gluteus activation (>50% of the maximum voluntary isometric contraction), more than those produced by the side-lying hip abduction, the lateral band walk, lunges and/or hop exercises. For example, Chulvi-Medrano (12) measured the muscle activity of the lumbar paraspinal muscles during single-limb exercises. During the performance of these exercises, there were no elevated lumbar activations, suggesting the possibility that other muscle groups may participate in the task to a significant extent. Unfortunately, this descriptive study did not include the gluteal muscle group.

The gluteus medius is also heavily involved in falling tasks or lateral lunges. Mercer et al. (46) recorded higher levels of muscular activity in the lateral step than in the forward step for the lateral leg during the ascent phase and for both legs during the descent phase (46). Thus, monopodal exercise while controlling fall risk might entail one level of more intensity in the gluteus region strengthening in elder people. Therefore, exercises such as the super slow walk should be included. In this exercise, the person walks with great strides very slowly, which increases the time in monopodal stance and requires the activation of the gluteal region to stabilize the hip and dynamic balance control.

b) Resistance training exercises. Exercises which involve performing movements against external resistance provided by loads greater than the subject's bodyweight.

It is a reasonable assumption that calisthenic exercises will increase the activity of the gluteus when an external load is added and, consequently, the strengthening effects of the exercise will also increase. Therefore, these exercises will not be described again in this section. We recommend including closed kinetic chain exercises that allow functional muscle recruitment patterns to occur throughout multiple joints and are very similar to daily activities.

Exercises with guided machines

When the participation of the gluteus maximus in the leg press exercise is analyzed, the variant of the leg press with the feet positioned above the height of the hips is the variation which places the highest demand on gluteus activity at intensities close to 80% (1 repetition maximum) (15). The authors of this study attributed these results to the existence of greater hip flexion which causes an increase in the stretch of the gluteus maximus. It thereforefacilitates its mechanical participation to compensate for the deficit caused by the shortening of the rectus femoris (primary force during the leg press), which will harm the functional efficiency of this muscle. Another descriptive study by Anders (2) recorded EMG data for 12 subjects with strength training experience. In this sample, the exercises performed showed very similar EMG data with the exception of the vertical and horizontal leg presses which elicited the lowest levels of activity. The EMG results for the single leg squats and the quadruped hip extensions that did not use an additional load were similar to those for resistance exercises. Thus, it appears that the use of ankle weights could

Table 1. Classification in the selection of exercises

Structural exercises	Functional exercises
Aim: Increase muscle mass; Increase strength	Aim: Improve the muscle recruitment time and pattern in the muscle chains that involve the gluteus
Between moderate (5-6) and vigorous (7-8) intensity on a scale of 0 to 10	Intensities below 50% (1-RM) or below moderate intensity are sufficient.
Squat	Modified side plank
Deadlift	Modified front plank with leg extension
Lunge	Single limb squat
Side Lunge	Single limb deadlift

N.B.: Whenever it is possible for the elderly to perform the exercise, takie into account their specific conditions such as hypertension, orthostatic changes, osteoporosis and osteoarthritis, which may cause discomfort or incompatibilities.

increase the efficacy of this exercise in strengthening the gluteus.

We did not find any study which examined the muscle activity of the gluteus during the use of guided strengthening machines that are specifically designed to target the gluteal region. Boeckh-Behrens and Buskies' book includes EMG data which identified the leg curl exercise with raised thighs as the best machine exercise for the strengthening, followed by the posterior leg raise in the multifunctional hip exercise machine (5). These authors highlighted three factors which affect the gluteus when a subject performs in a guided machine exercise: first, optimum trunk control; second, the machine enabling the hip joint to stretch; and finally, the axis of the machinecoinciding exactly with the anatomical axis of the hips (5).

Free weight exercises

The squat is an exercise where the quads contract hard in terms of mean electromyographical signal (normalized to MVC) (41) and gluteus maximus (7) involved in the knee extension and hip extension, respectively. As it is a multi-joint exercise, various trainers and researchers have suggested various modifications to emphasize the activity of certain involved muscles (e.g., gluteus maximus). In this regard, Caterisano et al. (7) reported that the gluteus maximus is the only muscle that changes its activity depending on the degree of knee flexion during the squat. The electromyographic data showed activity of 16.9% (of total electrical activity) for the partial squat; 28% (of total electrical activity) for the squat to a depth where the thighs were parallel to the floor; and 35.4% (of total electrical activity) for the full squat (7). It should be noted that the scientific literature warns against performing complete knee flexion during the squat due to the negative effects this could have on the passive structures (11). This is something that it is particularly important to keep in mind when using the exercise with the elderly. With regard to foot stance, McCaw and Melrose (42) detected greater muscle activity in the gluteus maximus and the abductor during the performance of the squat using foot stances up to 90% of the maximum stance width. More recently, Paoli et al. (52) obtained similar results, measuring an increase in gluteus maximus activity in parallel to an increase in the stance width.

Therefore, we propose the inclusion of the partial squat with a minimum separation of the feet equivalent to the width of the hips for increasing recruitment of the gluteus maximus and reduced risk of musculoskeletal pain and fall risk in elderly.

Lastly, it is reasonable to assume that if external weight were added to dead-weight exercises and the single-limb squat, the level of muscle activation would increase and consequently the strengthening effects will also increase. But it can also mean a significant increase in risks for the elderly as well as an exercise hardly affordable for most.

c) Other forms of exercise. Other forms of exercise not covered by the two previous categories can also strengthen the gluteal region.

For example, recently the inclusion of vibration training has been shown to lead to an increase in strength and balance in the elderly, especially if it is combined with other strategies such as resistance training (54,58,50). Consequently, it should be considered as a complementary training tool. It must be noted that there is an evident lack of studies which analyze muscular activity in the gluteal region during stances in a vibration platform. In this sense, the mean power frequency of the EMG in gluteus medius muscles decreased during the vibration-intervention (4-min long, 2-mm vertically-vibrating), indicating muscle fatigue, particularly in the hip region (62).

Finally, it is important to note that this type of exercise involves mainly the hip extensor muscles, thereby

strengthening only one of six hip movements. As a result, an exercise solely focusing on strength in one pattern may create imbalances in other important hip movements such as rotation (28).

Division in the selection of exercises

When selecting exercises, there are two main criteria which must be considered (Table 1). On the one hand, there are structural exercises which will lead to an increase in the strength and size of the gluteus; these exercises involve a load greater than 50% of one maximum repetition. On the other hand, there are functional exercises which will improve the recruitment/activation times and patterns of the muscle chains that involve the gluteal muscle group to stabilize the hip while performing dynamic movements with the upper/lower limbs. These exercises do not require loads above 50% of one repetition maximum, but can be optimal for core training including the gluteus maximus (24).

CONCLUSION

In summary, this review allows the following conclusions to be drawn:

1. The proper strengthening of the gluteal region enables the elderly to improve dynamic balance, especially in situations of lateral imbalance; to increase functional mobility and performance in daily life tasks; and to reduce risk of some musculoskeletal disorders in lower extremities and the low back.
2. The full-squat exercise and the quadruped exercise (performing a leg raise on the ipsilateral side) are the exercises which generate the highest EMG values for the gluteus (58). However, they are not recommended for the most elderly, for whom they must be adapted.
3. The gluteal region undergoes significant activation when the subject performs multi-joint exercises which involve flexion and extension of the hip and moderately high loads (>60% 1RM), as during the squat (structural exercise).
4. Exercises performed with single-limb support will increase activity in the gluteal region, principally due to stability demands. This activity will increase further if additional hip flexion and extension movements are performed, such as single-limb deadlifts and single-limb squats (functional exercise).
5. The prone hip extension exercise is an adequate alternative for strengthening gluteus maximum, if it produces the appropriate recruitment order.
   This information is useful as it enables the selection of exercises and variations of these exercises to adequately strengthen the gluteal region, both for therapeutic and preventative training. It will also permit appropriate progressions in the exercise programs to be determined for the functional strengthening of the gluteal region.
6. A review of the research literature enabled us to emphasize the following limitations:
   a) The descriptive studies using EMG were carried out using surface electromyography, which may not be entirely valid, given the risk of crosstalk.
   b) On the other hand, the position of the body during the execution of the exercise is important as it can influence the recruitment pattern, and there are few studies which have controlled this variable (65).

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