

# Gluteus Medius: Applied Anatomy, Dysfunction, Assessment, and Progressive Strengthening

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## SUMMARY

ONE OF THE MORE COMMON DEFICITS IDENTIFIED BY REHABILITATION SPECIALISTS AND STRENGTH AND CONDITIONING PRACTITIONERS IS WEAKNESS OF THE GLUTEI MUSCLES, PARTICULARLY THE GLUTEUS MEDIUS (GM). GLUTEAL WEAKNESS CAN REDUCE ATHLETIC PERFORMANCE AND PRECIPITATE A NUMBER OF LOWER EXTREMITY INJURIES. IN THIS ARTICLE, WE DISCUSS THE ANATOMY AND FUNCTION OF THE GM MUSCULATURE, PRESENT A REVIEW OF THE CURRENT LITERATURE PERTAINING TO GM CONDITIONING, AND RECOMMEND AN EXERCISE MODEL BASED ON CURRENT STRENGTHENING GUIDELINES.

## INTRODUCTION

The gluteus medius (GM) muscle is a primary hip abductor, providing frontal plane stability for the pelvis during walking and other functional activities (10, 20). A weak or dysfunctional GM is linked to numerous injuries of the lower extremities

(2,9,11,14,38,43) and abnormalities in the gait cycle (31). Therefore, there appears to be a need to develop specific GM conditioning program guidelines that rehabilitation specialists and strength and conditioning practitioners can use in their practice regardless of the initial level of the client. Such a program would need to progressively overload the GM and involve active mobilization, strengthening, proprioception, and finally more functional or sport-specific exercises.

The major focus of this article is to provide a guideline (template) for strength and conditioning specialists to approach the rehabilitation process for athletes with GM-related injuries and improve sports performance. To achieve this goal, in this article, we (a) describe the basic anatomy and function of the GM, (b) describe the factors that weaken the GM and injuries that may occur with such weakness, (c) describe procedures for assessing GM function, (d) list possible strengthening exercises, and (e) review the literature for the experimental studies in this area. Using this information and accepted conditioning practice guidelines, we then present a model that involves a systematic and graduated approach to GM rehabilitation and strengthening.

## ANATOMY, PATHOLOGY, AND ASSOCIATED INJURIES

### ANATOMY OF GM

Gottschalk et al. (19) described the GM as a “broad, thick radiating muscle on the outer surface of the pelvis.” The GM has anterior, middle, and posterior fibers, is curved and fan-shaped, and tapers to a strong tendon (Figure 1). Originating from the outer surface of the ilium between the middle and posterior gluteal lines, the GM inserts on the lateral surface of the greater trochanter of the femur (19,23). The GM abducts the hip joint, the anterior fibers contribute to hip flexion and hip internal rotation, and the posterior fibers to hip extension and hip external rotation (7). The GM is responsible for preventing the opposite side of the pelvis from dropping during the stance phase of gait—commonly referred to as a Trendelenburg gait (7,10)—and plays a major role in providing frontal stability for the entire pelvis during walking and other functional activities (10,20).

### KEY WORDS:

gait; gluteal; injury; stability; strength

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FIGURE 1. Visual representation of the gluteus medius muscle.

## FACTORS CONTRIBUTING TO GM WEAKNESS

A number of factors can contribute to GM weakness. On a medical level, these may include hip rotator cuff tears (24) and congenital dislocation of the hip (31). Lifestyle factors can also cause weakness of the GM. These include the habit of standing with body weight predominantly on one leg with the pelvis swayed sideways and hip joint adducted or of sleeping on one's side with the top leg flexed and adducted over the other leg (3,26). These positions potentially weaken the hip abductor muscles, particularly the GM, as these muscles remain in a somewhat elongated position (beyond resting physiological length) for sustained periods of time. Stretch weaknesses of a lesser severity are often seen in cases of occupational and postural strain, with uniarticular (one-joint) muscles like the GM most often affected (3,26).

## PATHOLOGY

It has been suggested that there exists a relationship between a weak or dysfunctional GM and many lower

extremity injuries (32,43,45). The primary injuries linked to a weak or dysfunctional GM are briefly described below.

**Trendelenburg gait.** A person who has either a unilateral or bilateral GM weakness can develop a Trendelenburg gait. The normal function of the GM during gait is to hold the pelvis up as one leg swings forward. If one leg is swinging forward, the opposite GM (of the stance leg) contracts to prevent the pelvis tilting laterally. With a Trendelenburg gait, the GM can't hold the opposite side of the pelvis up during single leg support, so the pelvis tilts downwards when the swing leg is in the air (Figure 2). This contralateral pelvic drop occurs when the GM doesn't produce a sufficient internal

hip abduction moment to balance the external hip adduction moment that occurs during single leg stance (9). Therefore, those with a Trendelenburg gait will have reduced gait efficiency and running speed and be at greater risk of developing lower back pain as a result of the pelvis not being stabilized during gait, jumping, and landing or when performing unilateral weight training exercises (3).

## Ilio-tibial band (ITB) syndrome.

Commonly found in long distance runners, Fredericson et al. (11) suggested that ITB syndrome may occur as a result of weakness of the GM, which leads to decreased control of thigh abduction and external rotation. Fredericson et al. (11) hypothesized that this sequence of events places the ITB under increased tension, making it more prone to impingement on the lateral epicondyle of the femur, especially during the early-stance phase of the gait cycle. This impingement on the lateral femoral epicondyle is thought to be responsible for the lateral knee pain often experienced in those with ITB syndrome while running. Severe cases of ITB syndrome can persist even when the individual walks or particularly when he or she travels down stairs (11).

## Patellofemoral pain syndrome (PFPS).

Earl et al. (10) described PFPS as an overuse injury characterized by anterior knee pain, often aggravated with stairclimbing, squatting, or sitting for prolonged periods of time. Inhibition or dysfunction of the GM may contribute to decreased hip control, allowing greater femoral adduction and/or internal rotation. This produces a larger valgus vector at the knee, increasing the laterally directed forces acting on the patella and contributing to the patella tracking laterally (9,21).

## Anterior cruciate ligament (ACL) and other knee injuries.

Schmitz et al. (38) showed that the GM helps maintain the transverse plane position



FIGURE 2. Positive Trendelenburg test.

of the hip during times of increased external rotation forces about the hip. Excessive knee valgus or rotation of the femur during landing is a potential mechanism for an ACL injury (22). Therefore, athletes who have high levels of GM control and strength may be better able to counter unwanted adduction and rotational movements during landing. This may be particularly important for female athletes, who experience significantly (6- to 8-fold) greater rates of ACL injury and who may have significantly more knee valgus and/or hip rotation than do males athletes (22).

**Ankle injuries.** A lack of strength in the hip abductors may not allow the individual to initiate the hip strategy in time to counteract a sudden lateral external perturbation. This situation may increase the risk of ankle injury (14). Further support for the role of the GM in the prevention of ankle injury is provided by Beckman and Buchannan

(2), who showed that subjects classed as having hypermobile ankle joints presented a decreased onset latency of the GM. It therefore appears likely that a loss of strength as well as an inability to rapidly recruit the GM may increase the risk of ankle injury.

### MUSCULOSKELETAL ASSESSMENT OF GM

Janda (23) described a system of 6 grades (Table 1; Figures 3 and 4) to assess the strength of the GM. A similar grading system for manual muscle testing, with the addition of half grades, is proposed by Kendall et al. (26). These systems of grading appears to have originally been designed for testing strength in those with neurological dysfunction; hence, grades 1 and 2 indicate the ability to contract the muscle or move the hip in an antigravity position (horizontal plane). In the assessment of a normal population, the most commonly used test is side lying hip abduction. Grades of this test are then recorded in the

range from 3 to 5, indicating the ability to hold against gravity, gravity plus moderate resistance, or gravity plus maximum resistance, respectively. Comparison with the other side can provide an index to the subjects' normal strength and be useful in determining whether the muscle is indeed weak.

Tests of GM strength in more functional or sports-specific tasks are also required and probably more useful in identifying athletic individuals who require strengthening. A summary of some of these is presented in Table 2 (Figures 5 and 6). The Trendelenburg test is probably the most commonly known of these tests and is used to assess the ability of the GM to hold the pelvis level while the subject performs a single-leg stance. Modified versions of the Trendelenburg test have been described, such as that used by Mascall et al. (32) who observed subjects moving from double-leg stance to single-leg stance (with and without

**Table 1**  
Description of common GM musculoskeletal assessment methods

Test	Description	Authors
Supine hip abduction (Grade 0, 1)	Supine with legs extended. Muscle contraction can be palpated and the hip abducted through partial range of motion. Palpation of greater trochanter helps ensure true abduction at the hip joint is taking place without movement of the pelvis.	Janda (23)
Supine hip abduction (Grade 2)	Supine with legs extended. Anterior superior iliac spine (ASIS) and greater trochanter are palpated to ensure true hip joint abduction is occurring. Leg is abducted at hip joint through full range of movement (Figure 3).	Janda (23)
Side lying hip abduction (Grade 3)	Side lying hip abduction (bottom leg bent). Leg extended at knee joint, slightly extended at hip joint. Subject can abduct leg at the hip joint through full range of motion without backward movement of pelvis, flexion or internal rotation of hip (Figure 4).	Janda (23), Kendall et al. (26)
Side lying hip abduction (Grade 4, 5)	Same as above except with resistance from tester applied to lateral aspect of the knee.	Cutter and KerVorkian (7), Fredericson et al. (11), Janda (23), Kendall et al. (26), Mascal et al. (32), Niemuth et al. (34), Tyler et al. (42), Wilson (45)



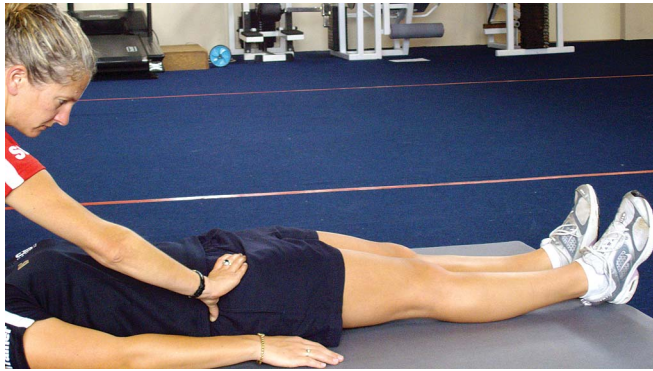


FIGURE 3. Supine hip abduction test.

arm elevation), noting signs of pelvic tilt or lateral sway that may indicate some weakness or lack of control of the GM. The single leg squat is a progression of the Trendelenburg test and is commonly used to assess the ability of GM to hold the pelvis level during a more dynamic functional task (5). A summary of these assessment techniques is presented in Table 2.

It is acknowledged that the manual muscle tests described in Table 1 may be most applicable to assessing GM function in patients with neurological/orthopedic conditions or in sedentary/nonathletic individuals. This is because these tests may exhibit a ceiling effect when used with athletes, whereby a loss of GM strength and or sports-specific GM function in the

athlete may not be observed. However, the tests described in Table 2 still have some limitations when used with athletes because even the tests described in Table 2 do not replicate the short ground contact times, large forces, and velocities that are characteristic of common athletic movements such as sprinting, cutting, and jumping. Thus, a comprehensive assessment of GM function may need to include isometric (25) or isokinetic (29) dynamometry as well as functional tests (30) to adequately assess the ability of athletes to control and produce high levels of force with the GM.

Isometric and isokinetic tests are generally highly reliable (and more reliable than the manual muscle tests described in Table 1) and allow the



FIGURE 4. Side lying hip abduction test.

precise measurement of the torque (strength) of any muscle group (5,6,17,39,41). However, we would recommend isometric over isokinetic testing for the assessment of hip abduction strength because isometric testing is more reliable for assessing hip abduction strength (6,29,39), it is cheaper, and it requires substantially less set-up time than isokinetic dynamometry. If running, jumping, and landing tests are also to be included in the assessment, it can be difficult to observe the quality of the movement as a result of the high velocities of these athletic movements. Thus, these movements should be recorded on video from a number of positions so to assist the rehabilitation specialist and/or strength and conditioning practitioner in observing the movements and therefore accurately and reliably assessing GM function during sports-specific activities. Consequently, further research needs to be conducted to develop tests for assessing GM function in athletes that are more valid, reliable, time- and cost-effective, and exhibit less ceiling effects than those used in practice currently.

## PROGRAMMING CONSIDERATIONS

### EXERCISES FOR STRENGTHENING THE GM

Exercises that have been described in books and articles addressing GM weakness are listed in Table 3. Because some of these exercises are not commonly taught in exercise prescription and instruction classes, the reader may not be familiar with all of these exercises. However, as it is beyond the scope of this article to describe all of these exercises in any depth; the interested reader should consult the appropriate references listed in Table 3 for a more in-depth description.

Most authors prescribed open-chain or single-leg stance exercises to initially strengthen the GM in a side-lying or weight-bearing position. Commonly used exercises include side lying leg lift, standing hip abduction, and pelvic drop. Closed chain exercises are introduced during the later stages of

**Table 2**  
**Description of GM musculoskeletal assessment methods that may be more applicable for athletes**

Trendelenburg Test	With pelvis fixated, subject lifts one leg to stand in single leg stance with the hip and knee flexed at 90 degrees. Subject should not laterally shift the pelvis as the leg is lifted, not balance by side bending the trunk or lift the pelvis at the same time as taking the leg off the floor. Lateral pelvic shift or lowering of one side of the pelvis indicates weakness in the GM (Figure 2).	Janda (23), Kendall et al. (26), Wilson (45)
Double- to single-leg stance	Subject begins standing with two feet on the floor then lifts one leg. Tester watches for notable pelvic tilt on one side, and lateral pelvic shift (Figure 5).	Mascal et al. (32)
Single-leg balance and anterior or frontal overhead reach	Standing in single leg stance, reach one arm overhead to the same side as the lifted leg, noting for signs of pelvic tilt towards this side (Figure 6).	Fredericson and Wolf (13)

rehabilitation, once basic strength has been developed. These include lunges and single- and double-leg squats.

Although it can be seen that many exercises have been advocated for strengthening the GM, a paucity of research has actually been undertaken investigating the benefits of specific GM strengthening on sports performance, injury risk, or pain. The experimental research (Table 4) that

has examined GM strengthening has primarily used it to assist in rehabilitation of injuries or conditions such as PFPS and/or ITB syndrome.

#### PROGRESSION OF EXERCISES

Although many similarities were apparent in the overall design of these 3 GM strengthening studies described in Table 4, several differences also

were observed. Fredericson et al. (11) instructed their subjects in 2 GM strengthening exercises for 6 weeks.



FIGURE 5. Double- to single-leg stance test.



FIGURE 6. Single-leg balance and anterior or frontal overhead reach test.

**Table 3**  
**Exercises proposed to strengthen the GM**

Author	Exercises
Delavier (8)	1. Cable hip abduction
	2. Standing machine hip abduction
	3. Side lying hip abduction (elastic resisted or ankle weighted)
	4. Seated machine hip abduction
Fredericson et al. (12)	1. Side lying leg lift
	2. Pelvic drops
Fredericson and Wolf (13)	1. Wall bangers
	2. Frontal plane lunges (with contralateral or medial reach)
Fullem (15)	1. Side lying leg lifts using elastic resistance
Fullem (16)	1. Balance on one leg while doing activities such as: brush teeth, move soccer ball around above head, bounce tennis ball against wall, dribble basketball
	2. Side lying leg lifts
	3. Elastic resisted hip extension balancing on injured leg
Geraci and Brown (18)	1. Bilateral squat: stable surface
	2. Bilateral squat: unstable surface
	3. Unilateral squat: stable surface
	4. Unilateral squat: unstable surface
	5. Anterior, medial, and posteromedial step down
	6. Anterior, medial, and posteromedial step downs with overhead, side and rotational reach
	7. Anterior, lateral, and posterolateral lunges
	8. Anterior, lateral, and posterolateral lunges with overhead, side bending, and rotational reach
Heller (20)	1. Side lying leg lift
Kendall et al. (26)	1. Side lying hip abduction
	2. Supine hip abduction
Khaund and Flynn (27)	1. Pelvic drops
McCurdy and Conner (33)	1. Single-leg squats-rear foot on bench
	2. Step-ups
	3. Lunges
	4. Unilateral plyometrics

For these 2 exercises, participants initially performed 1 set of 15 repetitions and, during the 6-week period, increased this to 3 sets of 30 repetitions. Mascall et al. (32) used a 3-phase model

for their 14-week rehabilitation program. For the first 5 weeks, participants performed nonweight-bearing exercise only. Training was then progressed to weight-bearing exercise during weeks

6–10. For the final 4 weeks, subjects were performing more functionally specific exercises using a leg press machine and Dyna Band (Crown World Marketing, Buckinghamshire, UK).

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Table 3 continued	
Author	Exercises
Page and Ellenbecker (35)	All elastic resisted:
	1. Abduction (lying on elbows, seated, and standing)
	2. Monster walk
	3. Swiss ball closed chain hip rotation
	4. Abduction pattern
	5. Basic kicking: diagonal
	6. Reciprocal arm and leg
	7. Balance squat with chair
	8. Tuck squat
9. Side-to-side lateral agility	
Pettitt and Bryson (36)	1. Standing elastic band kick on balance disk
	2. Squats on balance disk with elastic band around knees
	3. Lunges
	4. Hip abduction
	5. Sideways stair ascent and descent
	6. Stair depth jumping
Thien-Nissenbaum and Orzechoskie (40)	All elastic resisted
	1. Standing hip and knee extension (bilateral and unilateral)
	2. Supine hip abduction
	3. Standing hip abduction
	4. Standing hip extension with external rotation
	5. Seated internal and external hip rotation
Wilson (45)	1. Arc walk

Tyler et al. (42) also used a 3-phase model, but their rehabilitation program only lasted 6 weeks. Phase 1 consisted of seated hip strengthening exercises, self-stretching, balance exercises, step ups, and upper-extremity reaches. In Phase 2, participants continued their hip resistance exercises, performed lower-extremity reaches, step downs, and increased the difficulty of the balance exercises. In Phase 3, the initial balance and hip resistance exercises were discontinued, with plyometric and agility exercises as well as lunges performed and a return to some sporting activities encouraged. A unique element in Tyler's intervention

was the use of "clinical milestones." Before participants could progress to the next stage, they had to meet certain criteria that indicated they were physically able to progress to more difficult activities. Notably, although the progressions differed, participants in all 3 studies reported a significant reduction in pain after strengthening of the GM. A progressive 3-phase model, as used by Mascal et al. (32) and Tyler et al. (42), seems suitable to rehabilitate and strengthen the GM for return to sporting activities. Such progressions appear consistent with those promoted by other authors for the functional

rehabilitation of the lower extremity. Bomgardner (4) and Lephart and Henry (30) both encouraged a similar (4-phase) functional rehabilitation program, with Phase 1 emphasizing the transition from clinical to functional strength, Phases 2 and 3 agility and proprioception with increasing speed, and Phase 4 sport-specific activities.

#### **DURATION OF PROGRAMS**

The duration of the rehabilitation programs found in the literature also differs between authors. Fredericson et al. (11) and Tyler et al. (42) designed 6-week rehabilitation programs;



**Table 4**  
Interventional research involving GM strengthening and symptom reduction

Study	Subjects	GM assessment method	Intervention exercises	Duration/frequency	Performance changes	Symptom changes
Fredericson et al. (11)	24 university runners with ITBS (14 male and 10 female)	Side lying hip abduction Grade 4–5 using Nicholas Manual Muscle Tester (NMMT)	1. Side lying leg lifts	Six weeks, frequency not stated	Significant increase in hip abductor torque for female (34.9%) and male (51.4%) athletes.	22 of 24 athletes pain-free after 6 weeks, still no pain after 6 months.
			2. Pelvic drops			
Mascal et al. (32)	Two female patients with PFPS	1. Side lying hip abduction Grade 4–5 using a hand held dynamometer	1. Bent knee turnout	Fourteen weeks, frequency not stated	Patient A had a 50% increase in hip abductor strength.	Patient A now pain-free while walking, standing, and stair climbing. Also now able to run 2–3 miles without pain.
			2. Side lying hip abduction			
		2. Moving from double- to single-leg stance			Patient B had a 90% increase in hip abductor strength.	Patient B now able to ascend and descend stairs with only occasional discomfort and to walk 45 minutes nonstop without pain.
		3. Prevention of pelvic motion in transverse plane during abduction/external rotation movement of the hip	3. Quadruped external rotation abduction			
		4. Maintenance of static bridge position against manual rotational displacement force applied to pelvis in transverse plane	4. Isometric hip abduction			
			5. Upper-extremity exercises in single-leg stance			
			6. Bilateral standing hip abduction			



Table 4 continued						
Study	Subjects	GM assessment method	Intervention exercises	Duration/frequency	Performance changes	Symptom changes
			7. Trunk medial rotation with elastic resistance around waist in position of single leg stance			
			8. Shallow squats			
			9. Single leg squats (on leg press to 90° then standing)			
			10. Shallow lunges (with elastic around the knee)			
			11. Stair climbing/cross trainer			
Tyler et al. (42)	35 patients with PFPS (29 women and 6 men)	1. Side lying hip abduction Grade 4–5 using NMMT	1. Seated hip abduction	Six weeks, exercises performed once daily	Significant increase in hip abductor strength (~30%) in both lower extremities of patients with successful outcomes.	21 of 35 patients experienced improvements based on Visual Analog Score pain scales.
			2. Mini squats			
			3. Unilateral stance balance-floor and wobble board			
			4. Step-ups with upper-extremity reaches			
			5. Step downs with lower-extremity reaches			
			6. Lunges			
			7. Plyometric/agility exercises			

however, Mascal et al. (32) chose 14 weeks to strengthen the hip muscles in a rehabilitation program for PFPS patients. Because the authors of all 3 studies reported significant improvements after their respective programs, a strengthening regime lasting between

6 and 14 weeks would appear to be of sufficient duration to significantly improve symptoms (e.g., pain and loss of strength) associated with GM weakness. However, depending on the extent of the GM-related dysfunction, all symptoms may not be alleviated

at this point and further training required.

#### **FREQUENCY, SETS, AND REPETITIONS OF EXERCISES**

Tyler et al. (42) instructed their subjects to complete the strengthening exercises

every day of the 6-week treatment intervention. In contrast, the other authors did not state how often the exercises were performed. As the difficulty of the exercises progresses and the exercises become more complex, strength is increased not just in the GM, but all the glutei muscles; therefore, performing the exercises every day may not be tolerable for many people.

A considerable amount of research in the area of resistance training has investigated the number of repetitions and sets performed, as well as how frequently to carry out a resistance training program. Although consensus may not exist, a Position Stand from the American Council of Sports Medicine suggests that performing at least 2 training sessions a week that involve 2 to 3 sets of between 6 to 15 repetitions per set will lead to considerable increases in muscular strength and endurance (1). However, Prentice (37)

stated that, for rehabilitation, strengthening exercises should be performed on a daily basis initially, with the number of repetitions and sets controlled by the patients' level of pain, swelling, and response to exercise. As healing progresses, the muscle can be exercised every second day so the frequency becomes 3 to 4 times per week. Thus, the exact loading parameters would appear dependent on the person's injury and may vary between individuals.

### PROGRAM DESIGN

On the basis of the literature reviewed, a progressive strengthening program for the GM has been developed. A total of 17 exercises have been included, ranging from nonweight-bearing to functional or sport-specific exercises (Table 5). Before beginning this program, the athlete's GM strength is tested in the side lying position (23). With the leg straight, the

athlete holds full abduction of the hip with slight hip extension and external rotation for 10 seconds. If he or she can successfully perform this movement, he or she can begin weight bearing exercise at Phase 2, exercises 2a (Table 5). If there is movement of the pelvis or if the hip flexes or internally rotates, the athlete must begin the program at Phase 1, exercises 1a until he or she can complete the test successfully.

The main objective of this strengthening program is to progressively overload the GM so that muscular control, endurance, and strength are developed in a systematic manner. The chosen program design is a 3-stage model similar to that of Mascal et al. (32). Within the 3 stages, there are 2 subphases which athletes undertake progressively (Tables 4 and 5). The first stage begins with nonweight-bearing activities, progressing to static weight-bearing activities. The second stage

**Table 5**  
Exercises included in GM-strengthening program with references providing more comprehensive descriptions of these or other similar exercises

Stage	Phase	Exercise	Reference
1	1	(1a) Bent knee turnout	● Delavier (8), Heller (20)
		(1a) Hands and knees leg lift	
		(1b) Side lying leg lifts	
1	2	(2a) Standing hip abduction	● Delavier (8), Kendall (26)
		(2a) Single-leg stance hold with medicine ball press	● Mascal et al. (32)
		(2b) Trunk twist in single leg stance	● Fullem (16)
2	3	(3a) Cable kickback	● Thien-Nissenbaum and Orzechoskie (40)
		(3a) Single-leg squats (machine)	● McCurdy and Conner (33)
		(3b) Single-leg squats: rear foot on bench	
2	4	(4a) Single-leg squats: standing	● Chmielewski et al. (5), Geraci and Brown (18)
		(4a) Single-leg hops forward/lunges	● Geraci and Brown (18), McCurdy and Conner (33)
		(4b) Step downs	● Geraci and Brown (18), Tyler et al. (42)
3	5	(5a) Monster walk	● Page and Ellenbecker (35)
		(5a) Single-leg lateral jumps elastic resisted	● Page and Ellenbecker (35)
		(5b) Lateral jumps on both legs	
3	6	(6a) Ball throwing against wall on one leg	● Fullem (16)
		(6a) Basic kicking: diagonal	● Page and Ellenbecker (35)

progresses to weight-bearing exercises. This second stage will gradually increase the stability challenge offered to the athlete by (a) translating the center of mass horizontally via stepping and/or hopping exercises; (b) reducing the width of the base of support, (c) increasing the height of the center of mass by elevating the arms and/or hand-held weights, or (d) performing the exercises on unstable surfaces, e.g., Bosu balls, wobble boards, etc. The third stage comprises functional exercises one might expect to see in sport, also with 2 levels of difficulty.

Also incorporated in the program are milestones, adapted from Tyler et al. (42), that should be achieved before clients can advance to the next stage of the program (Table 6). The milestones provide a means by which an athlete's

progress can be monitored and training goals/standards achieved, thereby allowing a safe and realistic progression to the next level of the program.

There is no set duration for this program, as the progress for each athlete will differ based on the athlete's initial level of GM weakness or dysfunction and his or her dedication to the program. Although experienced strength and conditioning practitioners may use their discretion when deciding whether the athlete can progress to the next phase, they still need to base this decision on the athletes' ability to (a) complete the set number of repetitions safely, using good form throughout the entire set and (b) attain the specified milestones.

For most of the exercises, the athlete should begin using 15 repetitions per

set with a light resistance. This repetition range is at the higher end of the scale for what is generally agreed to be a suitable range for improving strength and may be more recommended for muscle endurance (1). However, the ability of a muscle to contract repeatedly is important if the injured athlete wishes to return to sport without reinjury and the greater number of repetitions performed will also help the athlete improve his or her control of the GM during functional movement tasks. The proposed rest periods are 1 minute or less, as suggested by Weir and Cramer (44) for exercise sets of 10 to 15 repetitions. Once the athlete has achieved some of the milestones, the repetitions should decrease and the resistance increase to better develop muscular strength and power (1).

**Table 6**  
**GM-strengthening program progressions with milestones.**

	Stage 1	Stage 2	Stage 3
Level 1	Nonweight-bearing (1a) exercises		
Milestone patient must reach to enable them to move onto Level 2:			
In side lying position, athlete can hold their straight leg in full hip abduction with external rotation and extension for 10 seconds, without posterior rotation of pelvis.			
Level 2	Nonweight-bearing exercises (1b)		
Level 3	(1b) plus weight-bearing exercises (2a)		
Level 4	(2a) plus weight-bearing exercises (2b)		
Milestone to be reached to enable client to move onto Stage 2:			
Athlete can hold their pelvis level in single leg stance, without lateral trunk shift, for 30 seconds, maintaining stance knee in line with second toe			
Level 5	(2b)	Compound exercises (3a)	
Level 6		(3a) plus compound exercises (3b)	
Level 7		(3b) plus compound exercises (4a)	
Level 8		(4a) plus compound exercises (4b)	
Milestone to reach to enable client to move onto Stage 3:			
Patient can squat on one leg keeping their pelvis level, knee over second toe and without lateral shift of the trunk.			
Level 9		(4b)	Functional exercises (5a)
Level 10			(5a) plus functional exercises (5b)
Level 11			(5b) plus functional exercises (6a)

Elastic resistance has been included throughout all stages of the GM strengthening program. Although elastic resistance has been widely used in rehabilitation (35,37,40), its use has been criticized (to some extent) because elastic resistance does not match the strength curve of muscles in single joint exercises. Specifically, at the end of the concentric phase where the elastic resistance is at its greatest, the length-tension relationship of muscle suggests the muscle is not in an optimum position for developing maximum force (28). However controversial, the advantage of using elastic resistance exercise is that (a) it is portable, (b) the direction of movement is less restricted than with free weights or machines, and (c) the exercises can often be completed in more functional planes of movement than dumbbells or barbells (35,37,40).

Many variables need to be considered before undertaking any resistance training as part of a rehabilitation program, it is important that the strength and conditioning practitioner consults the injured athlete's rehabilitation specialist before initiating the rehabilitation program. A close working relationship with the rehabilitation specialist should also be maintained throughout the duration of the athlete's recovery so to maximize the athlete's improvement in performance and minimize the chance of any reinjury.

## PRACTICAL APPLICATIONS

A weakened GM may contribute to the development of several lower-extremity injuries. Given that one of the main roles of the strength and conditioning practitioner is to prevent injury in their clients and athletes, knowledge of the anatomy and function of the GM, as well as commonly associated pathologies and injuries, would seem important. Furthermore, having the skills to assess GM function would seem fundamental to this process. This article has introduced these topics but at the same time recognizes that the type of knowledge and proficiency needed in this area may be more specific to other

exercise professions. As such, the strength and conditioning practitioner would benefit from such expertise, and it is suggested that, if feasible, to align oneself with a professional such as a rehabilitation specialist who is willing to share the subtleties of pathology, assessment, and rehabilitation in this area. This approach should allow the practitioner to better serve his or her clients, allowing them to move more freely and reduce their chance of GM-related injury.

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