Clinical Movement Analysis to Identify Muscle Imbalances and Guide Exercise

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MOVEMENT is an essential component of daily life and athletic performance. Human movement is influenced by an individual's structural alignment, muscle flexibility, muscle strength, and nervous system coordination of muscle responses to a changing environment. Observation of human movement can be used to develop strategies for prevention of injuries and enhancement of athletic performance.[1-3] The Overhead Squat Test can be used to qualitatively assess an individual's overall movement patterns. The results of this test can then be related to goniometric measures (muscle flexibility) and manual muscle testing (muscle strength) to develop a comprehensive view of the individual's movement characteristics.[1] The information can provide the basis for therapeutic exercise recommendations for stretching of potentially overactive and tight muscles and for strengthening of underactive and weak musculature. To optimize function, the individual should be progressed to an integrated functional exercise program.[1] The purpose of this report is to explain how to set up and use the Overhead Squat Test with associated measures of muscle length and strength. Common movement patterns observed during performance of the Overhead Squat Test will be explained, along with exercise recommendations for one compensation pattern.

Overhead Squat Test Setup

The Overhead Squat Test involves a two-legged squat with the arms raised overhead (see Figure 1). The athlete is instructed to (a) stand with feet hip-width to shoulder-width apart, (b) toes pointing straight ahead, and (c) arms raised above the head.

Figure 1 The individual performs a series of 5 double-legged squats a total of 3 times. The clinician views the individual from the anterior, lateral, and posterior view to assess for toe out, knee valgus, excessive forward trunk lean, arms falling forward, and foot pronation.

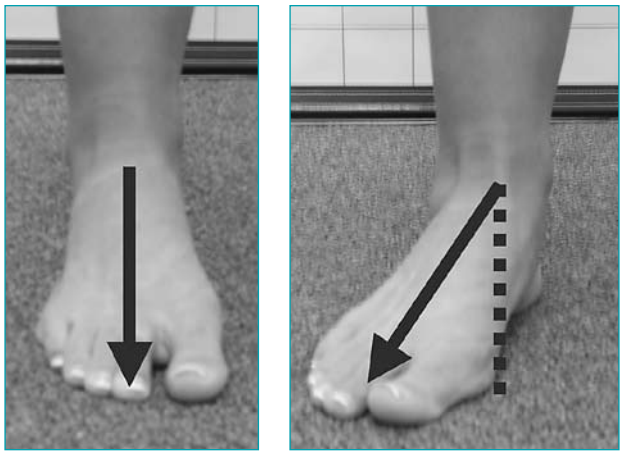
From this start position, the athlete is instructed to squat down as if sitting in a chair. The observation is made from three views: anterior, lateral, and posterior (Figure 1). After performing 5 squats for the anterior view, the athlete performs 5 squats for the lateral view and 5 squats for the posterior view. The clinician notes the movement pattern characteristics by recording whether or not a particular characteristic was identified during performance of the test (Table 1).

Table 1. Movement Pattern Characteristics

View	Movement Pattern Item
Anterior	**Toe Out** Yes ☐ No ☐
	Knee Moves Inward (Valgus) Yes ☐ No ☐
Lateral	**Arms Fall Forward** Yes ☐ No ☐
	Excessive Forward Trunk Lean Yes ☐ No ☐
Posterior	**Flattening of Medial Longitudinal Arch** Yes ☐ No ☐

Overhead Squat Observations

Anterior View: Observations made from the anterior view of the overhead squat are focused at the feet and knees. A common compensation at the feet is the foot turning outwardly (toe-out; Figure 2). When observing for the presence of toe-out, the clinician should assess the position of the first metatarsophalangeal (MTP) joint in relation to that of the medial malleolus. The 1st MTP joint will align with the medial malleolus in a normal foot, whereas the first MTP joint will appear lateral to the medial malleolus with foot turn-out. Table 2 lists potentially overactive/tight muscles and



Normal | Foot Turns Out (Toe Out)

Figure 2 Presence of Toe-Out is noted with the 2nd metatarsophalangeal joint rotates outward and appears lateral to the medial malleolus.

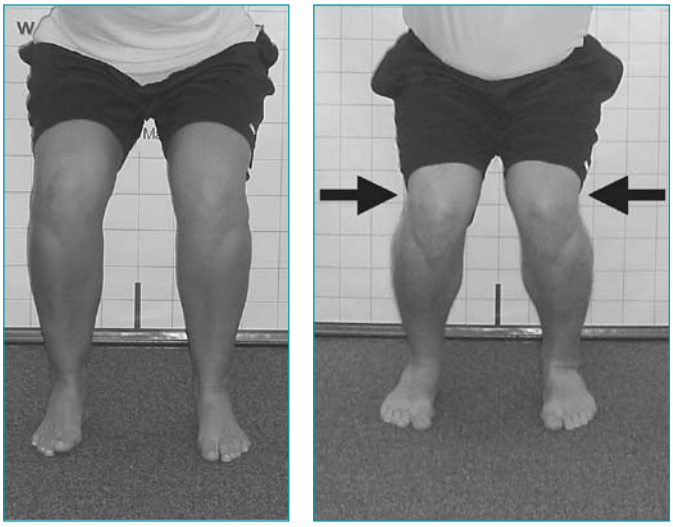
Table 2. Potentially Overactive/Tight Musculature and Underactive/Weak Muscles

Faulty Movement Pattern	Potential Overactive Muscles	Potential Underactive Muscles
Toe out	Soleus	Medial Gastrocnemius
	Lateral Gastrocnemius	Medial Hamstrings
	Biceps Femoris	Gluteus Medius
	Tensor Fascia Latae	Gluteus Maximus
		Gracillis
		Popliteus
Knee moves inward (Valgus)	Hip Adductors	Medial Gastrocnemius
	Biceps Femoris (short head)	Medial Hamstrings
	Tensor Fascia Latae	Gluteus Maximus
	Lateral Gastrocnemius	Gluteus Maximus
	Vastus Lateralis	Vasus Medialis
Excessive forward trunk lean	Soleus	Anterior Tibialis
	Gastrocnemius	Posterior Tibialis
	Hip Flexors	Erector Spinae
Arms fall forward	Latissimus Dorsi	Middle Trapezius
	Pectoralis Major	Lower Trapezius
	Pectoralis Minor	Rhomboids
	Coracobrachialis	Posterior Deltoid
		Rotator Cuff
Flattening of medial longitudinal arch	Peroneus Longus	Posterior Tibialis
	Peroneus Major	Lower Trapezius
	Peroneus Tertius	Medial Gastocnemius
	Lateral Gastrocnemius	Gluteus Medius
	Biceps Femoris	
	Tensor Fascia Latae	

underactive/weak muscles that have been associated with this compensation.[1] Compensations at the knee involve inward or outward movement. Inward movement of the patella over the first MTP joint (toward the midline of the body) during the squatting movement creates valgus stress at the knee (Figure 3). Table 2 lists potentially overactive/tight musculature and underactive/weak muscles that have been associated with this compensation.[1]

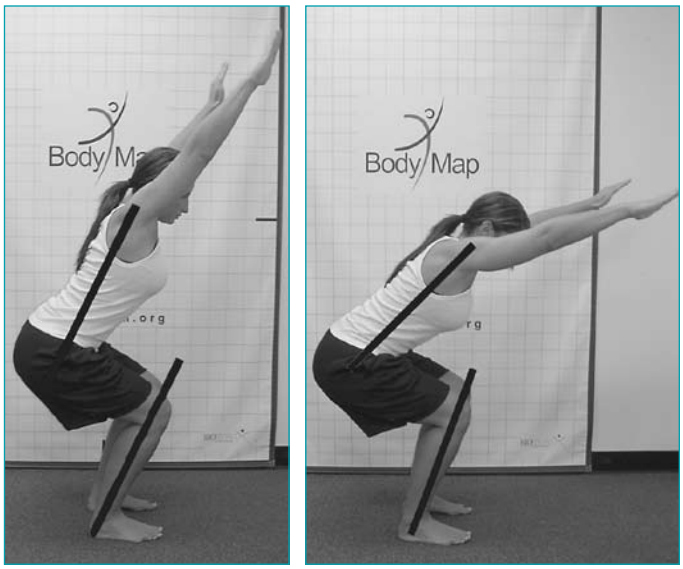
Lateral View: Observations made from the lateral view include the lumbo-pelvic hip complex (LPHC) and upper body positions. Two common compensations are excessive forward leaning and arms falling forward. The trunk should remain parallel to the lower leg during the descent phase of the squat. If the two imaginary lines do not remain parallel, forward leaning is excessive (Figure 4). During performance of the Overhead Squat Test, the arms should be held over the head in an elbow-extended position and parallel to the torso. If the arms move forward in relation to the torso, the observation is designated as "the arms falling forward" (Figure 5). Table 2 lists the potential tight/overactive and underactive/weak musculature associated with these movement compensations.[1]

Posterior View: Observations made from the posterior view include the positions of the feet and the lumbo-pelvic hip complex. Normally, the calcaneus should stay parallel with the lower leg; however, a common compensation seen at the feet is pronation. During the descent phase of the Overhead Squat Test, the clinician may observe flattening of the medial longitudinal arch, along with eversion of the calcaneus in the frontal plane (Figure 6). Table 2 lists the potential tight/overactive and underactive/weak musculature associated with this movement compensation.[1]



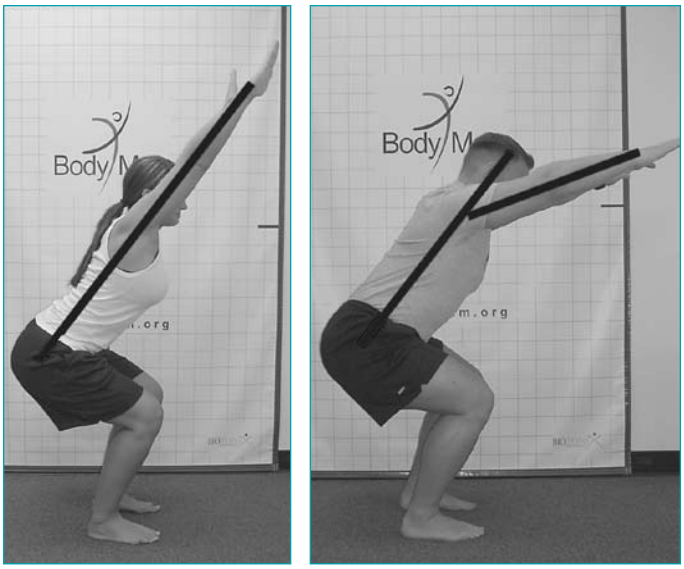
Normal | Foot Turns Out (Toe Out)

Figure 3 **Presence of knee valgus is noted when the patella moves inward during the descent phase of the squat and appear medial relative to the great toe.**



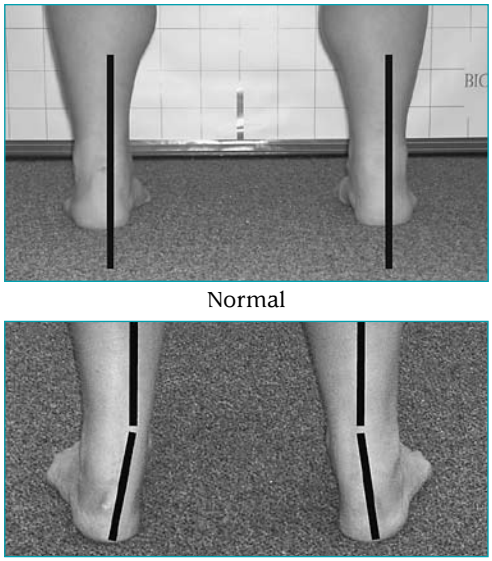
Normal | Excessive Forward Trunk Lean

Figure 4 **Presence of excessive forward lean is noted when the trunk does not appear to be parallel with the lower leg during the descent phase of the squat.**



Normal | Arms Fall Forward

Figure 5 **Presence of arms falling forward is noted when the arms are not maintained parallel to the trunk.**



Normal

Foot Pronation

Figure 6 **Presence of foot pronation is noted when the calcaneus appears everted relative to the lower leg.**

Reliability of the Overhead Squat Test

Intra-rater reliability of observations recorded during subject performance of the double-leg overhead squat motion was assessed in a group of 20 subjects (11 females, 9 males). Photographs were obtained by a digital camera from anterior, posterior, and lateral views at the point of maximum knee flexion. A certified athletic trainer with no previous experience in scoring the Overhead Squat Test examined the digital photographs from all views and determined if the following movement pattern characteristics were present: (a) toe-out (anterior view); (b) inward knee movement (anterior view); (c) excessive forward trunk lean (lateral view); (d) arm fall-forward (lateral view); (e) medial longitudinal arch flattening (posterior view). Analyses were performed on two occasions separated by 48 hours. Prior to analyzing the digital images, the rater underwent a standard instructional training program. Intra-rater reliability was assessed by calculating the Kappa coefficient between scores from the two assessment sessions for each movement characteristic. The Kappa coefficient values ranged from .85 to 1.0 for all movement patterns, except right toe-out (Kappa = .76) and left foot toe-out (Kappa = .75). The findings suggest that the Overhead Squat Test is a reliable tool for identification of faulty movement patterns. Furthermore, individuals without previous experience scoring the Overhead Squat Test can be trained in a single session to reliably perform this assessment.

Exercise Recommendations

The information provided by the Overhead Squat Test, along with associated measures of muscle length and strength, can help the clinician to design an appropriate intervention program. A treatment approach that has been clinically effective involves stretching of overactive/tight muscles, strengthening of underactive/weak muscles, and utilization of exercises that incorporate functional movement patterns.[1] For example, an individual who exhibits inward knee movement while performing the overhead squat may have overactive/tight hip adductors, with the gluteus medius underactive/weak. The clinician could utilize an inhibition technique for the hip adductor complex, such as rolling on a foam roller (Figure 7). Often there are tender points in these muscles that are painful when pressure is applied. Placing constant pressure on the tender points for 30 seconds is thought to decrease muscle spindle activity in the overactive muscle. The next step would be to stretch the inhibited muscle (Figure 8). In this case, one could perform a standing hip adductor stretch for 20-30 seconds. Once the overactive/tight muscle group is inhibited/lengthened, the focus would be directed to activation of the weak gluteus medius. Hip abductor muscles may play a vital role in controlling knee valgus motion, especially in female athletes.[4] An isolated resistive movement pattern could be used to increase activity in the weak muscle (Figure 9). The last component of the intervention would involve activation of the gluteus medius in a functional movement pattern, such as lateral tube walking (Figure 10). This treatment approach can be utilized to address the various compensation patterns identified by the Overhead Squat Test.[1]

Figure 7 **Inhibition of the hip adductors performed using self-myofascial release on a foam roller.**

Figure 8 Lengthening of the left hip adductor group performed using static stretching.

Figure 9 Isolated activation and strengthening of the hip abductors performed during a side lying single leg lift.

Figure 10 Integration of the hip abductors into a functional movement pattern performed during lateral tube walking

In conclusion, the Overhead Squat Test can be a useful for identification of movement dysfunction. This results of this test can be related to clinical measurements of muscle length and strength to develop a corrective exercise plan to improve movement patterns and possibly reduce the potential for musculoskeletal injury. ▮

References

1. Clark M, Corn RJ, Lucett S. *Corrective Exercise Specialist*. Calabasas, CA: National Academy of Sports Medicine; 2005.
2. Ford KR, Myer GD, Hewett TE. Valgus knee motikon during landing in high school female and male basketball players. *Med Sci Sports Exerc*. 2003;35(10):1745-1750.
3. Yu B, McClure SB, Onate JA, Guskiewicz KM, Kirkendall DT, Garrett Jr. WE. Age and 7 gender effects on lower extremity kinematics of youth soccer players in a stop-jump task. *Am J Sports Med*. 2005;33(9):1356-1364.
4. Hewett TE, Myer GD, Ford K, R. Anterior cruciate ligament injuries in female athletes, 10 Part 1. Mechanisms and risk factors. *Am J Sport Med*. 2006;34:299-311.

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