The Bodyweight Squat: A Movement Screen for the Squat Pattern

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SUMMARY

THE SQUAT PATTERN FOUND IN EXERCISES SUCH AS THE BACK SQUAT, FRONT SQUAT, AND DEAD LIFT ARE WIDELY CONSIDERED FOUNDATIONAL EXERCISES USED BY STRENGTH AND CONDITIONING PROFESSIONALS TO IMPROVE STRENGTH AND POWER. BEFORE LOADING AN ATHLETE WITH VARIOUS SQUAT PATTERN EXERCISES, SCREENING AN ATHLETE’S MOVEMENT CAPABILITY WITH A SIMPLE BODYWEIGHT BILATERAL SQUAT MAY GIVE VALUABLE INSIGHT INTO AN ATHLETE’S MOVEMENT CAPABILITY. INFORMATION OBTAINED FROM A BODYWEIGHT BILATERAL SQUAT SCREEN MAY ASSIST THE STRENGTH AND CONDITIONING PROFESSIONAL WITH DEVELOPING SAFER MORE EFFECTIVE STRENGTH-TRAINING PROGRAMS.

INTRODUCTION

The bilateral squat (squat) is one of the most prevalent exercises used in strength training worldwide. The popularity of the squat is certainly a reflection of its practicality. Humans throughout time have used variations of the squat pattern to accomplish various tasks associated with activities of daily living (1,9). A significant amount of research has been dedicated to establish the resisted squat as an effective exercise for enhancing strength and power performances (1,8,14,15,18,19,21), which makes it one of the most widely used exercises for increasing physical strength and power (1). However, given the prevalence of the squat pattern in activities of daily living and strength training programming, what is not as well researched is the use of fundamental movements, such as the squat, to screen an athlete’s movement competency.

Movement competency can be described as an individual’s ability to perform a movement pattern in an optimal manner. Optimal movement may be described as movement that occurs without pain or discomfort and involves proper joint alignment, muscle coordination, and posture (10). Sub-optimal or faulty movement resulting in a faulty movement pattern has been described as a disruption in the normal balance of how muscles support and move joints (26,36). The disruption to the muscle may be the result of a muscle that is too strong or too weak that does not fire or turn on at the right time or lacks the appropriate range of motion to accommodate efficient movement. When disruption of the balance of muscle is present, joint function will suffer and performance may be sacrificed. If the faulty pattern is associated with pain, the motor pattern may change to compensate for any experienced discomfort or pain. A change in a pattern of movement, if performed regularly, will become part of the brain’s program associated with that movement (26,36). Motor programs are simply ways that the brain stores information about movement (10). Therefore, if the change in the movement pattern persists, outlasting the painful episode, movement quality and athletic performance may be sacrificed in the long term (4,12,26,36).

It has been proposed that the ability to perform a bodyweight squat at or below 90° of knee flexion with proper symmetry and coordination is a good indicator of overall movement quality (12). Conversely, the inability to perform a bodyweight squat at or below 90° of knee flexion with symmetry and control may imply generalized stiffness throughout the body, or restricted joint mobility and/or stability (12). The strength and conditioning professional may be qualified to screen fundamental movement competency with a basic understanding of how the foot, ankle, knee, hip, and shoulder joints and the lumbar and thoracic spine function to provide efficient movement. The squat is a fundamental movement pattern that requires mobility at the ankle, hip, and thoracic spine and stability at the foot, knee, and lumbar spine.

This review outlines current evidence from the research literature supporting...
Table 1
Kinematic considerations of the bilateral bodyweight squat

<table>
<thead>
<tr>
<th>Anatomical region</th>
<th>Baechle (5)</th>
<th>Bloomfield (6)</th>
<th>Kinakin (28)</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Neutral position</td>
<td>Held up</td>
<td>Neutral position</td>
<td>Neutral</td>
</tr>
<tr>
<td>Thoracic spine</td>
<td>Flat: maintain torso to floor angle</td>
<td>Angled slight forward and held straight</td>
<td>Flat: maintain torso and shin angle</td>
<td>Slightly extended</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>Flat: maintain torso to floor angle</td>
<td>Curved slightly inward</td>
<td>Flat: maintain torso to shin angle</td>
<td>Neutral</td>
</tr>
<tr>
<td>Hip joints</td>
<td>Flexed</td>
<td>Flexed</td>
<td>Flexed: remain under the shoulders</td>
<td>Flexed and aligned</td>
</tr>
<tr>
<td>Knees</td>
<td>Flexed: knees aligned over the feet</td>
<td>Flexed</td>
<td>Flexed: knees over the feet</td>
<td>Aligned with feet</td>
</tr>
<tr>
<td>Feet/ankles</td>
<td>Shoulder width/remain on the floor</td>
<td>Shoulder width, toes pointing forward</td>
<td>Shoulder width stance</td>
<td>Flat not rolling in or lifting up</td>
</tr>
</tbody>
</table>

Downward and upward movement phases of a bilateral body weight squat

proper bilateral squat technique. Biomechanical rationale is provided to substantiate what qualifies as a proper squat pattern. It is the aim of the authors to confirm the presented criterion of the squat pattern and to support the bodyweight bilateral squat as an effective screening tool to measure an athlete’s movement competency related to the squat pattern.

KINEMATICS AND KINETICS OF THE SQUAT

A bilateral bodyweight squat (squat) can be described as flexing at the hip and knee joints and descending until the top part of the thigh at the hip joint is lower than the knee joint, then ascending by extending the knee and hip joints to return to the start position (27). Each of the major joints of the lower body (i.e., foot, ankle, knee, and hip) and the lumbar and thoracic spine of the upper body require degrees of stability and mobility to ensure a competent squat pattern occurs (36). When screening the squat, it is worthwhile to be familiar with each joint’s primary anatomical function and their contribution to movement efficiency. In addition, it is equally important for the strength and conditioning professional to appreciate the change to force production and efficiency of movement when a break down in stability and mobility appear. The variables that may affect an athlete’s ability to perform a deep bodyweight squat with symmetry, coordination and balance have been identified as anthropometrics, handedness, previous injury, lack of coordination, range of motion and balance (1,3,12,17,19,20,23,36,37).

Table 1 details what the literature considers to be the proper position of each major segment and joint during the upward and downward phase of a bilateral squat. Figure 1 depicts what is considered by the literature to be good squatting form. The sections below explain the kinematic and kinetic qualities of the major joints in the lower body and the trunk region of the upper body. Table 2 provides criteria and optimal viewing position for qualitatively screening a squat.

ANKLE MOBILITY

The ankle joint complex consists of 3 joints, namely the ankle joint, subtalar joint, and the midtarsal joint (26,39). The motions that take place at the ankle joint complex are dorsiflexion, plantarflexion, inversion, eversion, and axial rotation (39). Given the ankle range of motion capability in all 3 planes of motion and because none of the aforementioned motions take place exclusively at one joint, the ankle has been deemed a mobility joint (39).

There are many factors, such as injury, that may influence an athlete’s ability to perform a deep, balanced, and coordinated squat. During the performance of a squat, ankle mobility is critical to ensure a balanced and controlled motion (10). The ability of the athlete to maintain a flat and stable foot position during a deep squat provides the base for good ankle dorsiflexion (4,12). Ankle dorsiflexion is obviously greater when the knee is flexed because of the influence of the 2-joint muscle, the gastrocnemius, which crosses both the ankle and knee joints (4). A benchmark ankle range of motion for a squat was not found, but during the stance phase in gait ankle range of motion was reported to be 25° of motion 15° coming from plantar flexion and 10° from dorsiflexion (19,39). Stiffness in the ankle joint resulting in poor dorsiflexion range of motion may cause the foot and/or knee joints to compensate (4,12,36). The compensation may have negative implications to the stability required at the foot and knee for efficient mobility at the ankle to occur (36). Dionisio et al. (14) have reported that when an athlete performs a deep squat,
the center of pressure in the foot moves toward the heel during the ascent. Implications to squat technique and force production may be adverse if the heels of the squatter are allowed to rise off the ground. Allowing the heels to rise off the ground during a squat has been observed to create compensatory torques about the ankles, knees, hips, and lumbar spine (14,19,29). The compensatory torque has been reported to increase the torque experienced by the hip, knee, and ankle during a competent squat (4,16,18,19,28,36). With the heels raised off the ground during the ascent,

<table>
<thead>
<tr>
<th>Anatomical region</th>
<th>Optimal viewing position</th>
<th>Faulty pattern</th>
<th>Optimal pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Side, front</td>
<td>Movement of the head too far forward or back, movement of the head to either side. Direction of gaze is below a neutral position.</td>
<td>Held straight inline with the shoulders, gaze straight or slightly up.</td>
</tr>
<tr>
<td>Thoracic spine</td>
<td>Side, back</td>
<td>Abducted scapulae and flexion or excessive extension of the thoracic spine.</td>
<td>Scapulae adducted, slightly extended or neutral and held stable.</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>Side</td>
<td>Extension or flexion prior to movement, unstable, extension or flexion at any time during the movement.</td>
<td>Neutral, stable throughout movement.</td>
</tr>
<tr>
<td>Hip joints</td>
<td>Front, side</td>
<td>Mediolateral rotation, lateral dropping.</td>
<td>Stable, no mediolateral movement and no dropping of the hips, should stay aligned with knees.</td>
</tr>
<tr>
<td>Knees</td>
<td>Front, side</td>
<td>Alignment inside or outside the hip. Medial collapse and / or excessive forward movement in front of the toes.</td>
<td>Aligned with the hips and feet, stable, no excessive movement inside or out, forward or back.</td>
</tr>
<tr>
<td>Feet/ankles</td>
<td>Front, side, back</td>
<td>Pronation or supination of the feet, and / or heels lifting off the ground at any time during the movement.</td>
<td>Feet flat and stable, heels in contact with the ground at all times.</td>
</tr>
</tbody>
</table>
the center of pressure is restricted, which may affect the athlete’s ability to perform a balanced, controlled squat. Kovacs et al. (30) reported mean force to be 2.1 and 1.5 times greater ($p < 0.05$) during ankle flexion and extension, respectively, when performing a squat with the heels raised in contrast to the heels being firmly planted on the ground (30). The increased torque alone may not be cause for concern; however the increased torque coupled with faulty alignment of the lower body during a squat jump or squat jump landing, may contribute to unnecessary wear on the joints and degradation in performance. Therefore, the strength and conditioning professional should screen for ankle mobility when the feet of the athlete are stable and planted firmly on the ground.

**KNEE STABILITY**

The knee joint is the largest joint in the body and is a modified hinge joint made up of the tibiofemoral and patellofemoral joints, which enable flexion in a posterior direction and extension in the anterior direction (4,26). The knee has been described as a stability joint, given its ligament and tendon structure and the fact that it operates as a hinge with limited movement capability in the mediolateral or anteroposterior direction (12,17,18,26,36). Given the knees’ predilection for stability, the knees should maintain a position where they are aligned with the hips and feet when performing the squat (5,6,28).

Other authors have performed extensive research into the effects of various joint alignments on knee joint kinetics (1,13,14,16–19,21,24,29,34,37,38,41). When an athlete performs a squat and does not maintain knee alignment with the hips and feet, the ligaments and tendons that stabilize the knee are made vulnerable. The compressive (push together) and shear (resistance to sliding) forces act on the malaligned ligaments and tendons, weakening them over time (17–19,21,37). It has been well documented that excessive shear forces can damage the cruciate ligaments and that too much compressive forces can injure the menisci and articular cartilage (17). During a bodyweight squat, authors have reported patellofemoral compressive forces to be 3.75–4.6 times bodyweight and shear forces ranged from 1.5 to 3.5 times bodyweight (13,16–18,24,38,41).

There are many reasons why the knees may not maintain alignment with the hips and feet during a squat. A frequently reported explanation for the knees failing to maintain alignment has been faulty structure and function of the joints and musculature directly above and below the knee (12,26,36). The biarticular muscles, the hamstrings and rectus femoris, which attach to the hip and knee joints, as well as the gastrocnemius, which attaches to the knee and ankle joints, create a disadvantage in the knee if they are underdeveloped, lack appropriate flexibility, or activate in the wrong sequence (4).

Two of the most commonly reported patterns of movement that may contribute to knee dysfunction and pain are medial or lateral motion of the knees when observing the squat from the front (Figure 2a and 2b) and excessive anterior motion (Figure 3) when observing the squat from the side (4,18,21,26,28,36). Excessive mediolateral movement of the knees or valgus and varus frontal plane movement (Figure 2a and 2b) has been in part attributed to poor pelvic stability and improper function of the rectus femoris, hamstrings and hip abductor and adductor muscles (10,11,36). The kinetic consequence of mediolateral movement of the knee during a squat pattern is not as well understood. Those studies that have quantified mean torque during valgus and varus movement in the frontal plane generally use

![Figure 2](https://via.placeholder.com/150)

(a) Squat pattern with a varus lower leg position. (b) Squat pattern with a valgus lower leg position.
open chain movements (e.g., seated leg extension) not closed chain movements (e.g., bodyweight squat) (11). Therefore, further research is needed to investigate the kinematic and kinetic affects of valgus and varus patterns of movement during a closed chain squat pattern.

Extreme anterior motion of the knees, where the knees move past the toes, is not recommend because of the increased shear and compressive forces experienced at the knee (Figure 3) (21). However, restricting the knees to remain behind the toes during a squat resulted in an increase in anterior lean of the trunk and shank (21). An increase in the forward lean of the trunk has shown to increase the forces in the lumbar spine (21). Further research is needed to quantify the effects of anterior motion of the knees on the various joints and regions of the body to establish a safe guideline. Still, from the research reviewed, some forward motion of the knees, where they move slightly past the toes, is considered normal and necessary for a proper squat pattern to occur (21).

Additionally, a danger to the knee joint occurs when the center of rotation for knee flexion is altered (31), which may occur when the calf and the hamstrings muscles make contact during a deep squat (Figure 4a). The internal torque about the knee and hip occurs in the posterior direction during a deep squat given the majority of the athlete’s mass is moving back and down. The torque about the hip and knee occurs posteriorly to the femur and, as a result, pulls back on the anterior cruciate ligament. If an athlete fails to control the descent of a deep squat and allows the hamstrings and calf muscles to make contact in a ballistic fashion, the posterior torque about the hip and knee has been reported to create a dislocating effect on the anterior cruciate ligament (31). However, if the athlete maintains good knee alignment with the hips and feet and controls the descent of the squat prohibiting the calves and hamstrings to make contact in a ballistic manner, the center of rotation at the knee is not affected (Figure 4b) (31).

**HIP MOBILITY**

The hip joint is a ball-and-socket joint that is capable of motion in all 3 planes: sagittal (flexion and extension), frontal (abduction and adduction), and transverse (medial and lateral rotation) (22). Because of the hip joint’s structure and anatomical function, the hip joint for obvious reasons is considered a mobility joint. One of the primary roles of the hip joint is to provide a pathway for transmission of forces between the lower extremities and pelvis during activities such as squatting (22). Hip range of motion is considerable with flexion between 0 and 135° and extension 0 and 15° (22). During a squat, mean hip range of motion has been reported to be 95° ± 27° of flexion (25). Hip range of motion can appear greater if pelvic and lumbar motion are allowed to take place during squatting (22,25). Posterior movement of the pelvis during the descent and lumbar flexion at the bottom of the squat are movement strategies that have been reported to allow for greater hip mobility (4,22,25,26,28,36). However,
these strategies are not recommended because of the increased stress placed on the lumbar region of the spine. In addition, it has been reported that when an athlete lacks hip mobility, a compensatory pattern of movement is increased trunk flexion (31,32). No studies were found that have quantified the forces about the hip when squatting with poor alignment (i.e., mediolateral rotation of the hip or lateral dipping of the hips). Nonetheless, the literature reviewed did report the effects of squatting with poor hip mobility (10,26,35,36). A study involving 22 healthy male and female adults measured the kinetics of the hip, knee, and ankle during a bilateral squat to a self-selected depth (SQ) and a squat to a chair (CSQ). The maximum hip flexion angle obtained from the CSQ was 7.2% greater than that of the SQ ($p = 0.03$) (20). Consequently, the maximum knee flexion and ankle dorsiflexion angles for the SQ were 20.4% ($p = 0.005$) and 70.7% ($p = 0.001$), greater than those obtained from CSQ (18).

Although the structure and function of the participant’s hips were not assessed, it has been suggested that achieving a greater squat depth via increased knee flexion and ankle dorsiflexion is a compensatory strategy commonly observed in those individuals avoiding the weak musculature that supports hip flexion and extension (36). Therefore, when screening the squat, the strength and conditioning professional should observe the athlete achieving depth through their hips as an indicator of good mobility (12).

**TRUNK (LUMBAR STABILITY AND THORACIC MOBILITY)**

According to researchers, the angle of the trunk in relation to the ground should remain constant throughout the downward and upward phase of the squat movement demonstrating stability and control (5,28). When the trunk is screened, thoracic and lumbar flexion and extension (Figure 5a and 5b) are commonly reported faulty patterns (26,31,36). Given the prevalence of lower back pain and injuries experienced by athletes, it is critical that lumbar stability be maintained throughout the descent and ascent (Figure 5c) during an unloaded and loaded squat (32). When an athlete performs a squat and does not stabilize the lumbar spine and fails to maintain a straight or slightly extended thoracic spine position, an increase in compressive and shear forces of the lumbar spine has been observed (30–33). Squatting with an external load with excessive lumbar extension (curved back) dramatically increases compressive forces (Figure 5a) (40). A $2^\circ$ increase in extension from a neutral spine position increased compressive stress within the posterior annulus by an average of 16% as compared with maintaining a neutral spine position (40). This is particularly

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**Figure 4.** (a) Deep squat pattern with the hamstrings touching the calves at the bottom of the movement resulting in the center of rotation of the knee moving back to the area of contact. (b) A deep squat pattern performed with a controlled descent resulting in no contact between the hamstrings and calves musculature.
important because researchers have found that athletes hyperextend to a significant degree when lifting heavier (60% and 80% of 1RM) loads (40). Further investigation demonstrated that the compressive strength of a vertebral body was reduced by 30% if 10 loading cycles were applied (2,7). Therefore, it is suggested that when screening the trunk during the squat, lumbar stability in a neutral spine position and modest thoracic extension be encouraged to minimize excessive compressive and shear forces on the lumbar spine and promote a positive squat pattern (12,32,33,40).

**HEAD POSITION**

There is a lack of research into the effects of head position on squat kinematics and kinetics. Of the research conducted, the authors found that when the head position and direction of gaze was directed downward, a significant increase in hip and trunk flexion was observed (Figure 6) (15). Movement of the head with a downward direction of gaze during the squat can increase trunk flexion by up to 4.5° (15). Therefore, the concern with maintaining proper direction of gaze and head alignment and minimizing head movement during squatting is to decrease the amount...
of lumbar and thoracic flexion. Because excessive hip and trunk flexion in the squat movement are contraindicated, any deviation of the head and direction of gaze below a neutral position is not recommended and may result in a faulty movement pattern of the hips and trunk (15,26,36).

**DISCUSSION**
There are a number of general considerations to deliberate if the reader is to use a bodyweight bilateral squat to screen an athlete’s movement capability. We have outlined some questions and possible answers in Table 3. The answers to each of these questions should be adapted according to the skill level and age of the athlete being assessed. Further investigation may be directed toward addressing the following questions: Are joint kinematics and kinetics required to accurately screen a squat pattern? What is the reliability and validity of 3-dimensional analysis compared with a standard 2-dimensional video record captured by the strength and conditioning professional? What is the reliability of the squat for screening purposes and how many trials should be assessed to ensure reliable data are collected? When an athlete performs a good bodyweight bilateral squat what load should then be used to safely screen the squat pattern under stress? It is important that the strength and conditioning professional validly and reliably screen the squat pattern given its relevance to sport and sport specific training.

**CONCLUSION**
The literature reviewed promoted foot stability, ankle mobility, knee stability, hip mobility, and trunk stability to enable an athlete to perform a squat pattern correctly. A foundational understanding of the kinematics and kinetics of the ankle, knee, hip, lumbar and thoracic spine, and head were detailed. It was reported that an athlete might use a variety of movement strategies to achieve a deep squat position. However, movement strategies that promote malalignment and poor body position may increase the compressive and shear forces at the ankle, knee, hip, and lumbar and thoracic spine. There are many exercises prescribed by strength and conditioning professionals that involve the squat pattern. Too often athletes are loaded above and beyond what their movement competency can support. A simple body weight bilateral squat can be used to screen the movement capability of an athlete before the strength and conditioning professional prescribes a program that substantially loads the squat pattern.

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**Table 3**
**General considerations for assessing a squat movement pattern**

<table>
<thead>
<tr>
<th>Squat pattern assessment consideration</th>
<th>Possible answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>How fast should the squat be conducted during an assessment?</td>
<td>Have the athlete perform the squat pattern at a self-selected tempo for the descent and ascent. Appropriate for all ages and genders.</td>
</tr>
<tr>
<td>How many repetitions of the squat should be tested?</td>
<td>Five or more repetitions. Appropriate for all ages and genders.</td>
</tr>
<tr>
<td>How often should assessment sessions take place in a training cycle?</td>
<td>At the beginning, middle and end of a new training cycle to ensure any improvements in strength or power do not occur to the detriment of movement ability. For children screens may occur as often as once a month.</td>
</tr>
<tr>
<td>What end range of knee joint range of motion should be expected in the squat?</td>
<td>Top of the thighs are parallel to the floor. Appropriate for all ages and sexes.</td>
</tr>
<tr>
<td>How will the squat be assessed in terms of quality of movement?</td>
<td>It is suggested to use simple 2-dimensional video in conjunction with video analysis software to provide feedback to the athletes regarding their current position and what is considered desirable.</td>
</tr>
</tbody>
</table>

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REFERENCES


