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ADDRESSING WEAKNESSES IN SQUAT PATTERNS

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ABSTRACT

The squat is one of the most complex strength training techniques performed during traditional weight lifting programs. While multiple variations exist, the most common type is the barbell back squat. However, most individuals perform this movement without prior knowledge or previous instruction on the proper mechanics involved. The following article outlines a squat analysis technique, along with corrective compound and isolation exercises, that can be performed in order to address weaknesses within an individuals' squatting movement pattern.

Keywords: training, squats, exercise technique, performance

INTRODUCTION

One of the most common total-body, strength training exercises is the squat. Mimicking activities of daily living (ADL's) (e.g., sitting, standing, and picking up objects) and many sport-specific movements (e.g., jumping, landing), the squat is an important exercise to increase strength, power, balance, and endurance throughout the lower body and trunk (1,19). Squats have also been linked to sprinting, vertical jumping ability (31), and are a necessary component for more advanced maneuvers such as the clean or snatch (1,3,19). Since the squat is one of the most complex movements to learn, it should not be performed with external resistances until the basic bodyweight movement pattern has been mastered. Prior analysis of squatting techniques have determined that a proper movement can be explained by optimal joint alignment, posture, good balance and coordination, as well as the absence of pain or discomfort (5,19).

Frequently performing complex movements, such as the squat, improperly, along with poor body mechanics and muscular imbalance, is an issue that can quickly become problematic. For example, individuals attempt to perform high-intensity squats without the knowledge of proper form frequently experience injury, imbalance, and compensations of ligaments and soft tissues (5,17,19,21,26). Most injuries are small, such as muscle strains (e.g., lower back, hamstrings, etc.). However, severe injuries (e.g., bulging discs and herniations, ligament tears, etc.) can occur and result in an increased return to play time for athletes or a decrease in daily independent functioning for older individuals. Furthermore, a study by Osugi et al., (23), showed that individuals' with muscular imbalances and weakness,

along with postural issues were at a greater risk for falls. Therefore, it is the purpose of this article to provide a basic squatting analysis that trainers can implement to determine if any weaknesses occur during this complex movement.

Multiple squat analysis checklists exist (2,6,18). However, this article will examine the most common weaknesses and errors that occur in the squat. Additionally, simple techniques will be provided for the trainer to determine if any issues may need to be addressed. Although a squat occurs throughout our daily activities, to perform it properly requires a certain degree of mobility through the joints of the lower extremities (i.e., hip, ankle, and knee) in addition to proper stability of the feet, spinal column, and knees. When performed properly, squats can aid in maintaining muscular strength and endurance needed for healthy joint support; with joint benefits ranging from the ankle to the spine. Any improper muscular strength in these areas can lead to increasing injury prevalence (5,17,19,26). Due to such a wide-array of joints and movements involved in the squat, it is assumable that most individuals may falter during this movement without proper training and instruction.

A study by Willy and Davis, (29), demonstrated that visual feedback and cues during squat pattern training significantly increased hip strength and decreased miscues, such as hip internal rotation and adduction. Therefore, by utilizing simple squat analysis techniques, a qualified trainer can observe an athlete's weaknesses within a few repetitions of a bodyweight squat. Listed below is a simple analysis that trainers can use to effectively examine any weakness or issue that may arise before external resistance is added to a clients' squat.

SQUAT ANALYSIS

To perform a squat analysis, first have the client or athlete stand with their feet approximately hip-width apart, arms by the sides or straight out in front of the chest and head facing towards the trainer. The client may also hold a PVC pipe in each hand, if desired, to mimic a bend-and-lift movement. Next, the individual will perform the squat for approximately 3-5 repetitions while the trainer observes from an anterior view. This will be followed by 3-5 repetitions with the trainer examining the movement from a lateral view. The tempo of the movement should be approximately 2 seconds during both the concentric and eccentric phase, which results in one full repetition being completed every 4 seconds.

The first repetition in the anterior view will be used to determine proper ankle kinematics. The trainer should determine if the ankle deviates from a neutral position (Figure 1A). If the individual does not possess proper stability and strength within the ankle joints, the feet, knees, and hips may negatively compensate leading to an injury or muscular imbalance (7,17,26). If the ankles collapse inward during the movement (i.e., eversion) (Figure 1B), then the soleus, lateral gastrocnemius, and peroneals may be overactive. This movement is typically accompanied by an inward collapsing of the knees as well. Inversion of the feet may also occur during the movement; normally associated with a varus force of the knees (Figure 1C). If any of the aforementioned occurs, trainers should include exercises designed to increase strength in the medial gastrocnemius, tibialis group, sartorius, and the gracilis (1,7,17).

Figure 1 (A) Neutral (B) Eversion (C) Inversion

The second repetition of the anterior view will be used to focus on the knee joint. The trainer should determine whether the knees stay in line with the feet or whether an inward or outward deviation occurs. A common error during squatting is an inward movement of the knee joints, known as a valgus force (Figure 1A), most often accompanied by eversion of the ankle joints. When this occurs, suspected musculature that may be tight or overpowering can include the hip adductors or tensor fascia latae; while weak musculature may include the gluteus maximus and gluteus medius. While collapsing of the knees is improper during squatting, it may also increase risk of injury during sports performance with any lateral, or change of direction type movements. This is due to the muscular imbalances of the inner and outer thigh. A study by Claiborne et al., (6), determined that individuals with greater strength in the hip abductors, knee flexors, and knee extensors were less likely to collapse inwards at the knees during squatting movements. Thus, if a client or athlete displays a valgus movement, then exercises designed to increase hip strength, especially the abductors are advised (e.g., lateral walks and hip extensions). If the athlete displays the opposite effect while performing the squat (i.e., knees outward/varus force) then the abductors (i.e., gluteal group) are suspected to be overpowering of the adductors of the thigh (Figure 1C). In cases, such as these, inversion may be present as well. Training to increase the strength of the adductor group may aid in the prevention of this imbalance with exercises such as plate pushes, cable adductor swings, and the hip adductor machine.

The third repetition will be used to examine the torso and determine if the individual exhibits a lateral deviation from a neutral position (Figure 2). A proper squat should involve the exerciser descending straight downwards with no lateral shift of the torso or difference in weight distribution onto either leg. This movement occurs when there is an issue of side dominance during joint loading of the lower extremities. This may also arise from a stability issue since a squat requires varying degrees of balance. Therefore, individuals' may tend to shift a majority of their weight to a preferred leg for stabilization purposes (1,2,7). A plumb line may help to determine small shifts from neutral during the squat. To correct the execution, a plumb line should be used where the individual is centered in front of the line and have them perform the squat while pausing at the bottom of the eccentric phase to determine any lateral deviations. If any shifts are present, then uni-lateral compound exercises designed to increase strength and stability in the lower extremities should be performed. These may include single-leg squats, lunges, and Bulgarian split-squats.

Figure 2. Lateral Shift

Once the client has been assessed from an anterior view, have them turn to the side and perform another five repetitions. The first repetition will again be performed to analyze the ankle joint. The trainer should determine if the heels stay in contact with the floor during the movement. A proper squat requires optimal dorsi flexion of the ankle to maintain proper mechanics, as well as stability (7,19). If the heels rise from the floor, this may place the individual in a more anterior or forward leaning positioning and may increase torque at the knee and hip joints (11,13,14,19). Usually occurring in individuals with tight plantar flexors, stretching and mobility exercises designed to increase range of motion in the gastrocnemius and soleus should be encouraged if the heels lose contact with the floor.

The second repetition should be used to assess whether the descent of the squat is initiated at the hip (i.e., 'glute dominance') or the knee joint (i.e., 'quad dominance'). Proper mechanics of a squat require a hip flexion movement of approximately 10-15^{o} followed by knee flexion. A 'hip first' movement allows for proper lengthening and eccentric loading of the gluteal group and hamstrings. A simple cue for the trainer to determine which movement the squatter portrays is watching the knees. Typically, the knees of a 'quad dominant' individual will move past the front of the toes fairly early in the eccentric phase; whereas a 'glute dominant' usually does not. 'Quad dominant' clients are also more likely to achieve insufficient activation of the gluteal group, as well as the hamstrings during a squat than a 'glute dominant' individual. By initiating at the knees the individual increases shear and compression forces along the patellofemoral joint, while also increasing improper alignment of the structural ligaments of the knee (13,15). Previous research of a traditional body-weight squat has elicited shear force values of 1.5 up to 3.5 times body mass, and compression forces at the knee joint of up to 4.6 times bodymass (10,13,14,27,30). If the client displays a 'quad dominance', the trainer should re-train the individual with proper mechanics using supplementary exercises such as the hip hinge and good morning. These movements allow the client to provide sufficient activation of the gluteal group and hamstrings using a 'hip first' movement.

The third repetition will determine whether the individual is able to achieve a parallel relationship between the tibia and the

torso (Figure 3). Proper squatting protocol should consist of maintaining the same trunk angle throughout the eccentric and concentric phases of the squat (2,22). During the descent, have the client pause at the end range of the eccentric portion. Next, determine whether the angle of the tibia and upper torso are parallel. A simple way to measure this positioning is with two dowels; by placing one along the outside of the shin and the other along the posterior trunk. If the individual is unable to achieve this positioning then two common problems are suspected: 1) poor squatting mechanics or 2) tight plantar flexors causing a decrease in the ability to properly dorsi flex the ankles. When this issue occurs, it is recommended that the trainer first rule out tight plantar flexors (described above) before re-training the client of proper squatting mechanics.

The final two repetitions from the lateral view will be used to assess the spinal column and head positioning. Stability throughout the spinal column is another key factor of proper squatting mechanics and should not be disregarded during a squat analysis. Previous research has demonstrated significant increases of 16% in vertebral shear and compressive forces with even slight deviations (2^{o}) from a neutral spine position (28). Studies have also indicated that the spinal column is only capable of supporting up to 8-kg before collapsing (3,4,9). However, once exceeded, the musculature of the spine and supporting tissues become reflexive in nature and increase in activity to support the external loading (3,4,9). The musculature involved includes the abdominals, gluteals, paraspinals, latissimus dorsi, pelvic floor, transverse abdominis, and hip girdle musculature (e.g., iliopsoas, quadrates lumborum, and iliacus) (16).

To assess this portion of the squat, the trainer should first determine if the spine excessively arches or rounds forward while descending/ascending. This is one of the most common errors that can be easily assessed visually. If the spinal column shows a lordotic, or arched, curve some of the common compensatory musculature includes an overactive hip flexor group, back extensors, or latissimus dorsi. While at the same time weak abdominals, gluteal group, and hamstrings may contribute to an arched spinal column . If the individual shows an excessively round or kyphotic, arch, the weak muscle groups are primarily the upper back extensors (e.g., erector spinae group, splenius group, spinalis group, etc.) (1,7,17). This rounding of the spinal column may also be caused by a strong training focus on the pectoralis musculature, causing a naturally protracted or internally rotated scapulothoracic joint. In cases, such as these, the following corrective exercises may be useful for the client or athlete to progress towards a stable spinal column: plank variations, bent-over rows, hip hinges, and good mornings.

The final repetition can be used to assess the head positioning of the individual. A proper head positioning consists of a neutral gaze (18). If the client shows an upward gaze and head positioning (Figure 4A) key factors may include tightness or compression in the cervical extensor region (1,7), typically occurring with a strong training focus on the upper trapezius and levator scapulae. While an upward head positioning is incorrect, a downward gaze (Figure 4B) may be even more detrimental to proper squatting mechanics as it may increase trunk and hip flexion (12,19); thereby increasing injury risk to the spinal column during the squat.

Figure 3. Parallel Tibia-Torso relationship

Figure 4 (A) Upward head positioning (B) Downward head positioning

Once assessed, the client may perform some of the following recommended exercises to address any areas of weakness. Supplemental exercises can be beneficial for often seen miscues, imbalances, and instability issues within a typical squat pattern. Starting with these less complex movements will allow for proper strength to be developed in the necessary areas; once accomplished, body mass squats or external resistance squats may be added for performance. It is also important to note that even though trainers may be able to identify and even correct these errors, practitioners should become further educated on the biomechanics and anatomy of the primary joints and musculature active during movement patterns.

CORRECTIVE AND SUPPLEMENTARY EXERCISES

Ankle:

- ***Toe taps & inversion/eversion*:** Begin the exercise with the individual seated on a bench or chair with the legs hip-width apart, knees roughly at a 90^{o} bend and the feet flat on the floor. Next, dorsi flex the feet in opposition for 30-60 seconds then switch to bilateral ankle inversion and eversion for an additional 30-60 seconds while keeping the feet in dorsi flexion. Be sure the heels do not lose contact with the ground during these movements.

- ***Heel raises*:** To perform this exercise, have the individual in a standing positiong with the feet hip-width apart and the feet flat on the ground. Next, bilaterally plantar flex the ankles and rise up onto the balls of the feet. Once the full range of motion has been reached, slowly lower the heels back to the ground.

- ***Eccentric heel raises*:** In a standing position, bilaterally plantar flex the ankles to raise the heels up off of the ground. Next, have the individual lift one foot off the ground and slowly lower the heel of the planted foot back to the ground. For those with stability issues, perform this movement near a stable object in which the individual may hold onto to reduce the risk of loss of balance.

- ***Single-leg heel raise*:** Begin this movement in a standing position, with body mass shifted to one foot. Next, plantarflex the planted foot and rise up on the ball of the foot. To finish the movement, slowly lower the foot to the starting position. Repeat with the opposite foot to prevent any further imbalances.

Hip and knee:

- ***Lateral Walks* (hip abduction):** Place a looped resistance band over the legs, just below the knees. Start by standing in an athletic position (i.e., partial ¼ to ½ squat): standing with the hips and knees slightly flexed, feet facing forward, mass distributed towards the posterior aspect of the foot, and spine in a neutral position. While in this position, keep resistance on the band by abducting at the hips and taking small steps laterally. Keep the knees over the feet while side stepping and avoid any inward collapsing of the knees. Be sure to repeat in the opposite direction.

- ***Side-lying hip external rotation*:** Start with the individual lying on the side of their body with the knees flexed to roughly 90^{o} and the legs stacked on top of one another. Keep the spine, hips and feet in line. Next, externally rotate the top leg at the hip while the feet stay stacked. Control back to the starting position.

- ***Glute-bridge*:** Begin this movement lying supine and knees flexed to roughly 90^{o} so that the feet are resting on the floor, slowly extend the hips through their full range of motion until the body forms a straight-line from the shoulders to knees, and then slowly return to starting position.

- ***Physio-ball glute-bridge*:** Lying supine, place the heels on an exercise ball hip-width apart. The knees should be flexed between 100-120^{o} . The arms should be abducted at the sides for balance. Slowly extend the hips through their full range of motion and then slowly return to the starting position.

- ***Single-leg glute-bridge*:** Have the individual assume a supine position while

flexing one knee to approximately 90° so that the foot is resting on the floor, while the other leg remains fully extended. Begin by extending the hips, while allowing the fully extended leg to rise off the ground as well following the level of the hips. Continue to extend the hips until the body is in a straight line from shoulder to knee, and then slowly control the hips back to the starting position.

- ***Plate Pushes:*** (In order to properly perform this exercise, be certain the ground surface will allow a weight plate to easily slide from side-to-side): Begin by placing a weight plate (start with 5-10 lbs) on the ground in front of the client. Next, have the individual slide the plate along the ground from side-to-side by adducting and abducting at the hip with one fully extended leg, using either the inside or outside of the foot. For those with stability issues, perform this movement near a stable object in which the individual may hold onto to reduce the risk of loss of balance.

Spinal Column:

- ***Good Mornings*****:** Begin by standing erect with the feet hip-width apart and knees slightly flexed. Place a barbell in a traditional back squat position on the upper traps/spine of the scapula. Flex the hips, while keeping the spine neutral and knees slightly flexed, until the upper torso is parallel with the floor. Once this position is reached, slowly extend the hips to return to starting position.

- ***Traditional plank*****:** Assume a push-up like position, but supporting the body on the forearms so that the elbows are directly beneath the shoulders. Hold this position for 30-60 seconds, while progressing to times greater than 60 seconds. Be sure to keep the spine neutral throughout the isometric hold and discontinue the contraction once the hips begin to sag.

- ***Side plank*****:** Lay on the side of the body with the legs extended and feet stacked on top of one another. To begin, push up onto a flexed elbow, which is lined up underneath the shoulder, and forearm resting on the floor in front of the body. Hold this isometric position and avoid any sagging of the hips, by keeping the abdominal wall muscles activated and the spine in a neutral position.

- ***Physio-ball plank*****:** Similar to the traditional plank, this movement utilizes an exercise ball. To begin, place the forearms upon a physio-ball with the shoulders in direct alignment with the elbows to avoid stress to the shoulder capsule. Hold this position for 30-60 seconds, while progressing to times greater than 60 seconds. Be sure to keep the spine neutral throughout the isometric hold and discontinue the contraction once the hips begin to sag.

- ***Suspension plank*****:** Similar to the traditional plank, but the feet or the arms will be placed in the handles of a suspension device. Be sure to keep the hips and spine in a neutral position and avoid any excessive movement of the arms or legs while they are in the device.

Compound Movements

- ***Eccentric Squats*****:** Slow and controlled eccentric squats can be used for a variety of reasons including increasing strength and endurance of the glutes and hamstrings, diminishing contact between the hamstrings and calves during a squat, as well as controlling deceleration of the body during the descent phase of power movements. To perform eccentric squats, have the individual use a slower tempo of

up to 6 seconds for the eccentric phase and a 2-3 second concentric phase. The use of a metronome during training will significantly increase the adherence of this tempo. Be sure a reduced load is used as a slower tempo rapidly induces fatigue which may compromise proper technique.

- ***Hip Hinges:*** This exercise will assist with proper spinal alignment and gives the client/athlete immediate kinesthetic feedback. To perform, place a dowel or PVC pipe along the head, spinal column (thoracic), and sacrum of the individual (Figure 5A). The client will then hold the dowel with one hand at the cervical region and the other at the lumbar region. Next, with a slight knee bend, have the client flex the hips 10-15^{o} while keeping the head, thoracic spine, and sacrum in contact with the dowel (Figure 5B). During this movement, if any of the aforementioned areas lose contact with the dowel then a spinal column issue needs to be addressed. For instance, if the sacrum loses contact with the dowel during the hip hinge, the client might exhibit a kyphotic curvature. If the thoracic region loses contact with the bar, a lordotic curve may be present. This movement will also help with a head-up or head-down position as well. Once, the individual can successfully perform the hip hinge successfully then a traditional bodymass squat with the same dowel placement can be attempted (Figure 5C).

- ***Lunges*****:** Lunges can be beneficial in increasing the co-contraction of the quadriceps and hamstrings, which can increase the strength and stability of the knee joint. To perform the lunge, assume a fully erect standing position with the feet hip-width apart. Take a step forward, with either leg, into a split-stance. Keeping the front foot in complete contact with the ground, flex the forward hip while flexing at the rear knee simultaneously. Continue to descend until both knees reach approximately 90^{o} of flexion. The back knee should be roughly 1-2 inches above the ground and should not make contact with the floor. To complete the movement, extend the front leg and rear knee simultaneously and return to starting position.

- ***Modified single-leg squats*****:** Building ankle and knee stability is essential when attempting to improve a squatting pattern. Previous research has shown increased hamstring and gluteus medius activity during the single-leg squat as compared to the traditional two-legged method (20). This increase in activity of the knee and hip musculature during uni-lateral movements may aid in increased stabilization of the knees during the squat. To begin the movement, take a standing position with a standard weight bench situated behind the individual. Next, place one foot on the bench. Perform a one-legged squat paying close attention to knee placement (i.e., tracking over the foot with no valgus or varus movement). *This is a high-intensity exercise and should only be performed by intermediate or advanced resistance-trained individuals.

Figure 5 (A) Hip Hinge – Starting Position (B) Hip Hinge – End position (C) Squat with dowel

Note: The exercises above are only recommendations made by the authors. It is solely at the discretion of trainer to determine the implementation of any new exercise for the client or athlete.

CONCLUSION

Assessing a squat movement pattern can be crucial in the prevention of injuries, addressing muscular imbalances and weaknesses, as well as properly incorporating advanced progressions into strength and conditioning programs. Not only important in sports performance, squat movement patterns are performed frequently throughout a majority of ADL's. During aging functional movements such as a squat become noticeably more essential for independence. Thus, coaching individuals to perform this complex exercise correctly may have long-lasting health benefits. If done incorrectly, over time, compensations can occur creating muscular imbalances and instability throughout the body which can lead to joint and soft tissue pain, increased risk of injury, and improper mechanics. Adding external resistance to an already incorrect squat may also increase the likelihood of future compensations. Therefore, screening an individual is vital prior to the addition of any type of external resistance.

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