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# Optimizing Squat Technique

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## summary

There are many variations of the squat technique, including stance width, foot positioning, and squat depth. However, research indicates that the optimal squat technique is a wide stance (≥ shoulder width) with natural foot positioning, unrestricted movement of the knees, and full depth while the lordotic curve of the lumbar spine is maintained with a forward or upward gaze.

## Introduction

It has previously been stated that the squat is one of the most popular and important exercises in developing strength and power and is commonly incorporated into strength and conditioning and rehabilitation programs (2, 11, 29). Individuals performing the squat use a variety of techniques that are of personal preference and believed to reduce the risk of injury or be more beneficial for development of specific muscles (13). It is therefore the purpose of this article to identify an optimal technique for the squat based on the selected literature.

## Forces Exerted on the Knee

Contrary to popular belief, research has demonstrated that the squat does not place excessive strain on the anterior cruciate ligament (ACL) (6, 11, 12, 17, 22, 24), even though compressive and shear forces to the knee have been shown to increase as knee flexion increases, reaching peak values near maximum knee flexion (11). Research has shown that the squat exercise produces significantly less anterior displacement when compared to the open kinetic chain (OKC) exercise of the leg extension, thus reducing the amount of strain placed on the ACL (6, 12, 17). Similar results regarding peak posterior cruciate ligament (PCL) forces have also been found, with forces >4.5 times body mass during isokinetic and isometric leg extension, compared with 3.5 times body mass during the squat (12, 29), indicating that the squat may result in a lower risk of injury than the leg extension. It is worth noting that PCL forces increase with increased knee flexion (28, 33) and therefore with the depth of squat. Other research has found that during the squat the ACL was subject to small forces when the knee was less than 50° flexion and that at greater angles the PCL rather than the ACL receive greater loads (13, 29). ACL forces were also much lower when the squat was performed with heals on the ground compared with when the squat was performed with heels elevated during both the descent (26 ± 31 Nm, 95 ± 40 Nm) and the ascent (49 ± 57 Nm) (29).

"Off-season" strengthening programs of professional soccer players demonstrated no significant increases in anterior-posterior tibiofemoral translation in athletes using the squat exercise as part of their off-season training program (24). Therefore, it would appear that not only is the squat a safer leg strengthening exercise than OKC exercises (6, 12, 17), but used consistently in training, it does not increase ACL strain (24) and therefore may reduce the risk of injury comparatively speaking. Other research into OKC and CKC exercises demonstrated performance benefits of CKC exercise, which resulted in a greater increase in strength and power compared with OKC exercise (5).

A deeper squat tends to lead to anterior displacement of the knees and may increase strain on the ACL and meniscus (11). However, research has demonstrated that restricting anterior movement so that the knees do not pass beyond the toes results in a decreased knee torque from 150.1 ±_50.8 Nm (unrestricted) to 117.3 ± 34.2 Nm (restricted). Unfortunately, restricting anterior movement of the knees resulted in an increase in hip torque from 28.2 ± 65.0 Nm (unrestricted) to 302.7 ± 71.2 Nm (restricted) (14). The restricted squat also increased forward lean, which was shown to increase lumbar shear forces (14). Therefore, restricting anterior movement of the knee in an attempt to reduce the forces exerted on the knee may disproportionately increase forces exerted on the hips and lumbar spine. A study investigating head positioning found that in a downward gaze, results in hip and trunk flexion are comparable to a forward or upward gaze (9); therefore, it is recommended that the athlete maintain a forward or upward gaze to prevent an increase in lumbar shear forces.

## Muscle Recruitment

There is continued debate among strength and conditioning experts regarding the most appropriate foot placement and squat depth, not only in terms of stresses on the knee but also in terms of recruitment of muscles.

### Squat Depth and Muscle Activation

Electromyographic studies have found that increased squat depth (half squat 45°, parallel squat 90°, full-depth squat 125°) resulted in a greater percentage contribution of the gluteus maximus during the full-depth squat (7, 23). Vastus medialus oblique data suggest a trend in which the contribution of the vastus medialus oblique increases, in terms of electrical activity, in the partial squat depth but less so during a full squat (7). During the eccentric phase of the weighted-back squat, the relative contributions of 4 muscle groups (vastus medialis, vastus lateralis, biceps femoris, gluteus maximus) at the 3 depths tested were not statistically different for both average and 80-peak integrated electromyographic data (7). Therefore, muscle activation did not differ based on squat depth. However, it is worth noting that the loads used were submaximal (25% body weight and 100–125% body weight) and that recruitment patterns may alter at near-maximal loads.

### Squat Depth and Patello-femoral Joint Forces

A study calculating forces during the squat movement found similar patello-femoral joint (PFJ) forces during the ascent phase of a deep squat when both rapid and slow ascents were utilized (4.73 and 5.99 × body mass, respectively). PFJ forces were also similar during the descent phase of a deep squat utilizing a rapid and slow ascent (7.62 and 7.41 × body mass, respectively) (8). Speed of movement does not dramatically alter PFJ forces during deep squatting. Another study found that PFJ forces increase with increasing knee flexion during squatting. However, knee flexion did not exceed 90° (30); therefore, it is not possible to determine if squatting deeper, where the angle exceeds 90°, would result in a further increase in PFJ forces. Research into biomechanics of the squat and leg press demonstrated that PFJ forces increase with an increase in knee flexion (13). Therefore, individuals with PFJ pain may be better suited to limiting range of motion to a more "functional" range of 50° of knee flexion (13, 31) if specific to their sport.

### Squat Depth and Tibio-femoral Joint Forces

Research (30) has also demonstrated little difference between tibio-femoral joint (TFJ) forces during fast ascent compared with a slow ascent (5.01 and 4.72 × body mass, respectively) and during a fast descent compared with a slow descent (7.62 and 7.41 × body mass, respectively). Speed of movement does not dramatically alter TFJ forces during deep squatting. Therefore, speed of movement can be determined by the speed of movement in the individual's sport, because it does not appear to affect TFJ forces. Further research found that TFJ forces were significantly greater in open kinetic chain compared with closed kinetic chain exercises (20). Research into biomechanics of the squat and leg press demonstrated that TFJ forces increase with an increase in knee flexion (13). Therefore, individuals with TFJ pain may be better suited to limiting their range of motion to a more "functional" range of 50° of knee flexion (13) if specific to their sport.

It is worth noting, however, that for subjects who regularly incorporate the clean and snatch into their training, it is essential that they are appropriately conditioned to squat below 90° because the "catch/receive" phase of both lifts as knee flexion can reach 117.78° (27) as long as injury status permits.

### Feet Width Placement and Muscle Activation

Rotating the feet (neutral, 30–40° medial, 80° lateral rotation) while performing the squat, regardless of depth and stance width (75–140% shoulder width), has been shown to have no noticeable effect on muscle activity of the lower leg (rectus femoris, vastus medialis, vastus lateralis, adductor longus, semimembranosus, semitendinosus, and biceps femoris) (12, 13, 21, 23, 26). Two studies indicate stance width variation does alter muscle recruitment patterns increasing activity of the adductor longus when a wide stance is used (> shoulder width) (21, 23). It is worth noting that this increase in activation of muscles may increase force production and therefore performance during the execution of the lift.

### Hamstring Activation

Research suggests that the squat, regardless of technique variation, produces minimal activity in hamstring muscles (4, 5, 12, 13, 16, 21, 23–25). To ensure balanced leg training, it would be prudent to include hamstring-specific exercises, such as the leg curl and stiff-leg dead lift, because they showed greater hamstring activity than the squat (4, 32). Ideally, both exercises should be incorporated into the training regime to ensure that the hamstrings are worked across both the knee and the hip joints. It is also important to ensure adequate conditioning of the hamstring muscles in comparison to the quadriceps to ensure adequate force generation during cocontraction to minimize both anterior and lateral tibial translation (10, 19), decrease shear forces (18), and increase knee stability (1). Increasing the force of cocontraction of the hamstrings has also been shown to reduce ACL forces during knee flexion (19) and therefore may reduce risk of injury (3). More recent research has demonstrated that a hamstring (eccentric) to quadriceps (concentric ratio) of ≥1.0 or a conventional (concentric) hamstring (concentric) quadriceps ratio of >0.6 may reduce the risk of hamstring and ACL injuries (15).

## Conclusion/Recommendations

Based on the literature reviewed, the optimal squat technique to minimize the risk of injury and ensure maximal activation of the leg muscles should be a wide stance (feet ≥ shoulder width) with a natural foot positioning (12, 13, 21, 23, 26) (ideally closely related to foot position common to the sport); unrestricted movement of the knees (heels remain in contact with the floor, although ideally no further forward than the toes [14, 24]); gaze forwards or upwards (9); and full depth (115–125°) (7, 23, 27), as long as the lordotic curve is maintained.

It has previously been recommended that squat be performed in a more "functional" range of 0–50° of knee flexion (13, 22, 31) because forces on the PCL, PFJ, and TFJ increase with increased flexion (13, 28). However, for any athletes using or planning to use the clean or snatch within their training, it is essential that they incorporate the full-depth squat into their training regime because it is an essential component of the "catch/receive" phase of the clean and the snatch, where knee flexion can reach 117.78° (27). ♦

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