STRENGTH TRAINING

Uncertainty exists about the optimal squat depth in strength training. It is often assumed that squatting till parallel (thighs parallel with the ground) lead to more performance improvement that squatting deeper. It is also thought that deeper squats bring a higher risk of injury. Is this truly the case? What does the literature tell us about this subject?

The optimal squat depth Till parallel or below parallel?

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In strength training the back squat, flexion and extension of the hips, knees and ankles, is seen as one of the most fundamental exercises.[1,2] Two often used variants (see figure 1) are the parallel squat and the deep squat.[2,3] It is generally assumed that parallel squats lead to more improvement in sports performance compared to deep squats. But is this truly the case? Several studies have compared parallel squats and deep squats regarding different aspects. The findings are conflicting, both with regard to functionality and injury risk. More clarity is needed to reach consensus among coaches about the optimal squat depth.[4] The focus of this article will be on general strength, since this is seen as a desirable adaptation in many different sports.

Figure 1. *Parallel squat (A) and deep squat (B).*[3]

Muscle activity

Muscle activity is among others a useful parameter to look at to get more insight into the functionality of the squat. [1] Caterisano and colleagues[5] found an increase in gluteus maximus activity when the squatting depth increased This suggests that deep squats improve general strength in this muscle more compared to parallel squats. Other studies however did not find any notabel differences between deep squats versus parallel squats for the same muscle.[6,7] A possible reason for these different findings is the participation of female subjects. Females create more knee dominant movement patterns which leads to more quadriceps activity.[6] In this study the quadriceps activity did not change however during deep squats compared to parallel squats. No significant differences in activity were found in upper gluteus maximus, lower gluteus maximus, m. biceps femoris, m. rectus femoris and m. vastus lateralis.[6,7]

RME (Relative muscular effort)

The studies mentioned above suggest little to no change in muscle activity during deep squats compared to parallel squats. Both variants therefore seem equally suitable for improving lower body general strength. When looking at the so-called 'relative muscular effort' (RME), which is an indication of muscle tension related to the maximum muscle force, Bryanton and colleagues[3] found a increase for both knee- and hip extensors in their female subjects when squatting depth increased (see figure 2). The weight on the bar, building up from 50% to 90% of 1RM, only effected the RME of the hip extensors, not the RME of the knee extensors (see figure 3). This means the knee extensors are best trained with deep squats and adding more weight to the bar has no added value.[3]

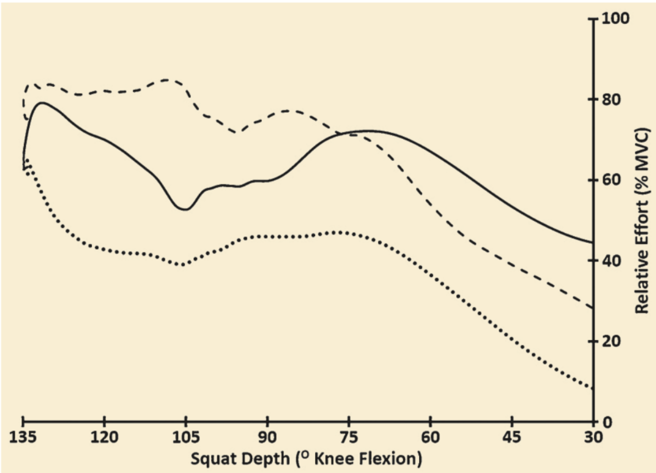

Figure 2 *The correlation between squat depth/ knee flexion (°, x-axis) and RME (%MVC, y-axis) for plantar flexors (continuous line), knee extensors (dotted line) and hip extensors (dashed line).*

To optimally train the hip extensors however, the best choice would be to go for relatively high weights and deeper squats.[3,7] If we combine these findings we can conclude that to optimally train both the knee- and hip extensors a deeper squat is recommended. Similar results were found for male subjects.[8] They followed a twelve week progressive training program with deep squats and higher squats (60° knee flexion). A large increase in quadriceps hypertrophy, isometric knee extension strength and squat jump performance was found after squatting with a greater range of motion.[8] All this suggests that overall lower body strength is more likely to improve when squats are performed deeper.

Other factos

In addition to muscle activity, there are some other factors that can play a role in improving overall strength by performing squats. For example, a relationship has been shown between maximal strength and a larger cross-section of different muscles in the lower body.[9] These results suggest that overall strength is best improved by increasing the diameter of the vastus lateralis, which is more likely in squats with a greater range of motion.[8] Other factors that can affect overall strength are time under tension and eccentric strength. Both factors appear to be greater in deep squats compared to parallel squats, due to the greater absolute distance traveled by the barbell and the time it takes to complete a repetition. However, these are largely assumptions, there is no convincing evidence yet proving that deep squats are better than parallel squats for improving general strength.

Squat depth and injury risk

In addition to all the factors mentioned above, the risk of injury could also say something about the possibility to improve general lower body strength through squats. A low injury risk equals a safe exercise which can only have a positive influence on adaptations. It is believed that deep squats are associated with an increased risk of injury to the knees and lower back.[2] The deep knee flexion would produce enormous forces, especially on the knee joint. The parallel squat is therefore often recommended, even for athletes with healthy knees.[10] Hartmann & Klusemann[1] argue however, that several relevant mechanisms have not been considered in this recommendation. Like the highest compressive forces that occur in the knees at 90° flexion. With further flexion, the weight distribution and force transfer are only improved by the so-called 'wrapping effect'.[1] This is a contact moment between the quadriceps tendon and the inter-condylar fossa that provides a supporting surface. Due to this contact, the compressive forces are reduced and a lower risk of injury can be expected.[1] Secondly, the actual weight that can be lifted is lower in deep squats than in parallel squats, so the forces will also be smaller. Finally, they indicate that opting for parallel squats to avoid degenerative bone processes could work counterproductive.[1] Due to the nourishing nature of movement, the tissues in the knee joint may be nourished insufficiently when only partial movements, such as parallel squats, are performed.

Cruciate ligaments

The tension on the ligaments in the knee joint can increase with greater squat depth. The forces on both the anterior (ACL) and the posterior cruciate ligament (PCL) and the meniscus seem to increase with increasing knee flexion.[4,10,11] This might lead to the conclusion that parallel squats are safer than deep squats in this respect, but a counter argument is provided by Comfort & Kasim.[4] They have shown that an increase in hamstring co-contractions during squatting can decrease ACL tension and thereby reduce the injury risk.[12,13] The effect of these hamstring co-contractions on PCL tension and forces on the patellofemoral joint remains unknown. For that reason, athletes with complaints or an injury history in one of these areas seem to be better off with parallel squats.[3] However, a counter-argument is presented by Hartmann & Klusemann[1], who indicate that the acting forces are not large enough to cause any kind of damage to the ACL and/or PCL. In addition, the load can cause adaptations in the ligaments which in turn reduce the risk of injury. The greater range of motion

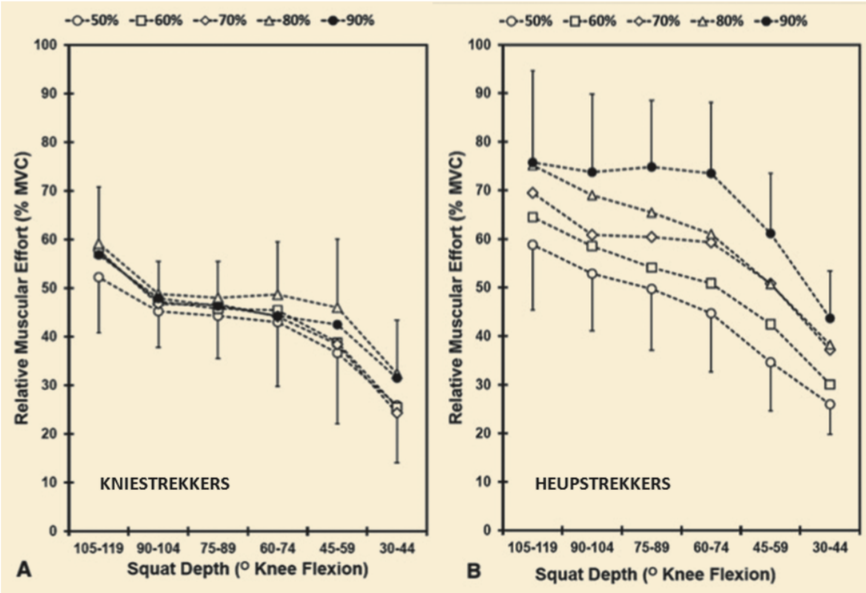

Figure 3 *The effect of barbell weight (50% to 90% 1RM) and squat depth (° knee flexion, x-axis) on the RME (%MVC, y-axis) of the knee extensors (A) and hip extensors (B).*[8]

in deep squats increases the cross-sectional area of the ACL and PCL, allowing them to withstand more forces and tension.[1,14] Although some evidence has been found for a higher injury risk with deep squats, the amount and content of the counterarguments are convincing enough to assume that deep squats are just as safe as parallel squats.

Conclusion

Conflicting evidence has been found comparing the functionality and safety of deep squats
with parallel squats. Some studies found little or no increase in muscle activity when squat depth increased, while others found an increase in muscle activity, relative muscle strength, and sport-specific physical adaptations. Contrary to popular beliefs there is no increased injury risk due to increased forces on the knee joint and spine in deep squats compared to parallel squats. Both from a functional and safety perspective it seems
therefore, that deep squats are certainly no worse and may even be better suited for improving overall lower body strength. Coaches may therefore consider incorporating deep squats into the strength training of athletes, provided proper technique is maintained.

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