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The Loaded Squat

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Statement of Purpose

Although torque on the knee joints and it's various supporting structures has been shown to increase when an individual allows for their knees to track farther over their toes, this action alone should not stop an individual from performing a squat, because of a possible fear of "damaging" their knees. Instead, the individual should take three main aspects of proper squat technique into consideration, in order to maximize their squat potential using a barbell. These include: the force being placed upon their lumbar spine and the stability of the trunk, proper ankle dorsiflexion, and adequate knee flexion.

This thesis will first analyze the supposed origins of the negative connotations towards allowing knee traction over the toes, and why some may in fact believe it to be detrimental towards knee health. Once doing this, the more recent research will be discussed explaining the three aspects named above and why the first point is in fact flawed when taking athletes with healthy bone structures into consideration.

Anatomical and Biomechanical analysis of the Ankle, Knee, Hip and Spinal joints

Before arbitrating between these two opposing groups of thought, it is important to first analyze the anatomy and proper movement patterns of all of the joints involved in the barbell back squat. As the lifter is descending, or the eccentric part of the exercise, they are simultaneously performing hip flexion (bringing your hips to your chest), knee flexion (kicking your knee back towards your bottom), and ankle dorsiflexion (pointing your toes towards you).

During the concentric, or upward motion of the squat, the individual is then extending his/her hips (kicking leg backwards) and knees (straightening your leg) whilst plantar flexing his/her ankles (pointing your toes away from your body). Knowing these primary actions done by larger lower extremity muscle groups is critical before examining the kinematics of each particular joint.

The discussion shall begin at the anatomically lowest of the major joint structures in the human anatomy, the ankle complex. According to Dr.Brad Schoenfeld's meta-analysis, "Squatting Kinematics and Kinetics and their application to exercise performance," the tibia, fibula and talus form to make up the talocrural and subtalar joints that form the overall ankle complex. These joints perform dorsiflexion, plantarflexion, eversion and inversion of the foot (Schoenfeld, 3498). The actions of eversion and inversion, or shifting the foot outward and inward are not directly beneficial to perform during a squatting motion since it is critical to keep your foot placement ideally in one place. On the other hand, as noted above, both dorsiflexion and plantarflexion are done during a squat by the concurring leg movement relative to the fixed foot (Figure 1). Regarding open-chained dorsiflexion, the superior trochlear surface of the talus joint will slide backwards towards the tibia and fibula whilst the inferior surface will roll forwards away from the two leg bones, bringing the foot towards the body. Normal dorsiflexion range of motion is about 20 degrees for most individuals. Also, the gastrocnemius and the soleus muscles that insert on the calcaneus by the Achilles tendon are involved in contracting eccentrically during dorsiflexion. To clarify, imagine an individual who is performing a squat. As they are descending, their tibia and fibula both translate forward and decrease the angle of the ankle joint relative to the knee joint, this is the action of dorsiflexion in a close chained exercise such as the squat. Plantarflexion, the other and opposite saggital plane movement occurs when the talus bone simultaneously slides forward on the tibia and fibula and rolls back towards the posterior portion of the foot. Unlike dorsiflexion, normal plantarflexion range of motion is much higher, showing a degree range of up to 50 degrees. For the two major calf muscles, they concentrically contract, allowing for plantar flexion to occur. The subtalar joint, or the joint underneath the talus is not as vital as the larger talocrural joint, but it still has a critical role during every-day movements. Its main goal is to “maintain postural stability and to limit eversion and or inversion of the foot” (Schoenfeld, 3498). Analyzing the ankle joint complex is the first step of understanding proper squat mechanics. We will now move upwards and discuss the knee joint complex.

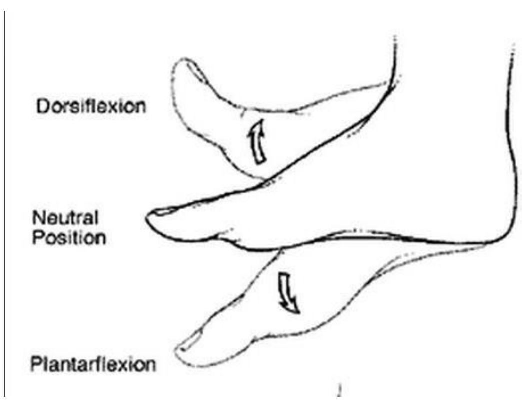

Figure 1

There are four main bones that form this synovial hinge joint; these include the fibula, tibia, femur and patella (knee cap). All together, these bones, along with the musculature, flex and extend the knee. During flexion of the knee joint, which again occurs during the squat eccentric, the patella will glide downwards toward the tibia through a groove formed by the two femoral condyles called the patellofemoral groove. As the squatter then rises out of the squat, by performing knee extension, the patella will then glide back up through the patellofemoral groove back to its normal resting position (Figure 2). The sliding of the patella along the articular cartilage provides additional mechanical leverage in extension, which can reduce wear on the quadriceps and patellar tendons from friction against the intercondylar groove (Schoenfeld, 3499).

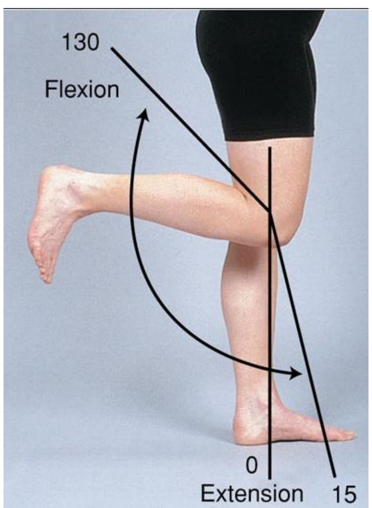

Figure 2

The four bones in this area also form two important hinge joints: the patellofemoral joint and the tibiofemoral joint. Simply put, the patellofemoral joint is where the patella and the femur join. Also, the tibiofemoral joint forms together the structures connecting the tibia to the femur. Knowing these two structures is critical to understand how force is applied to the overall knee joint.

Unlike the ankle joint, the muscles involved in performing flexion and extension of the knee joint during a squat are much larger and have a higher strength output and threshold than the smaller calf and foot muscles that insert around the ankle joint. The vastus lateralis, vastus medialis, vastus intermedius and rectus femoris all show extremely high electromyography activity by concentrically contracting to perform knee extension, but also eccentrically contract during knee flexion. The three major hamstring muscles are the biceps femoris, semitendinosus, and the semimembanosus. These muscle bellies normally perform knee flexion, but during a squat, when the forces of the barbell and gravity are pushing the athlete's feet into the ground, they contract along with the quadriceps to exert a pulling force on the tibia, which helps to reduce the shear forces placed onto the anterior cruciate ligament.

Since one of the sides in this paper argues that the shear forces being placed upon the ligaments of the knee by allowing forward knee traction is detrimental to knee joint health, it is critical to first look at what these ligaments actually do. The ligaments located outside and on the sides of each knee joint are the medial collateral ligament (MCL) and the lateral collateral ligament (LCL). These ligaments are responsible for mediolateral stability of the knee and restrain knee abduction and adduction respectively (Forde, 12). The anterior cruciate ligament, or ACL, runs from the posterior position inside the knee joint to a more anterior position within the knee. Its primary role is to stabilize the knee in both forward and backwards translation and will stop the tibia from translating too far forward. Stopping the excessive backwards motion of the tibia is the role of the posterior cruciate ligament (PCL), which simply runs from the medial aspect of the medial femoral condyle to the posterolateral aspect of the proximal tibia. Keeping the functions of these four main knee ligaments is vital to understand the differing sides that are proposed in this thesis.

The hip joint, which is a ball and socket joint, is formed by the coming together of the femur and the pelvis. The femoral head of the femur (the ball) fits and moves around in the acetabulum (socket) of the pelvis. Resulting from this highly moving joint, the hip is able to perform flexion, extension, abduction, adduction, internal rotation, external rotation, horizontal abduction and horizontal adduction (Figure 3). During the downward eccentric portion of the squat, the individual is actively performing hip flexion which moves the leg forward and away from the body as the torso descends. The hamstrings and gluteus maximus eccentrically contract as a lengthening force is placed upon them. Research shows that the gluteus maximus critically contracts this way to effectively stabilize the knee joint (Schoenfeld, 3500). As the lifter reaches a parallel squat position, the anterior muscles; the rectus femoris, iliacus, and psoas have been shown to concentrically contract to allow the individual to descend even further. Once the individual presses up from the ground, and the hip extends and comes back to its normal position, the hamstrings, along with the gluteus maximus, concentrically contract to propel the athlete upwards.

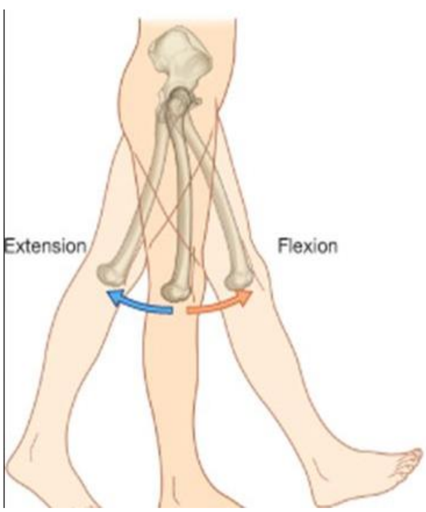

Figure 3

Analyzing the movement of the joints and muscles of the spine is the final area we will examine. Each of the 24 intervertebral symphysis joints of the spine is capable of performing spinal flexion, extension, lateral flexion and rotation. Moving inferiorly along the spine, each vertebral segment becomes “progressively larger and thicker from cervical to lumbar regions (Schoenfeld, 3501). It is critical for the lumbar vertebrae to be denser compared to the thoracic and cervical vertebrae because they must be able to withstand the weight of the body being placed upon them. This particular point is important to remember and will be looked at more in depth later on in this thesis. Between each vertebra lies an intervertebral disc which consists of the nucleus pulposus and annulus fibrosus. These connective tissues are vital because of their role in shock and force absorption, which protects the integrity of the spine during our daily actions. During the squat, the individual should focus on maintaining a neutral spine and upright posture throughout the entire range of motion. This should be done so that the forces being placed upon the spine (especially the lumbar spine) is not as severe as if the spine was excessively flexed or extended.

Dr. Karl Klein and the Deep Squat

Although this thesis arbitrates on the point of knee travel over an athlete’s toes, when one squats well below 90 degrees (parallel), for most individuals, their knees will ultimately track over their toes. Knowing this correlation, it is important to try and find where the negative opinion on excessive patellar travel originated from.

The first person that began to look at the implications of the deep squat and its effects on athletes was a University of Texas exercise science researcher named Dr. Karl Klein. His initial reason for conducting this study in 1961 was to “understand the reason behind the rise in number of college football players that were sustaining serious knee injuries" (Horschig, 91). The study had two sample groups. The first was a group of 128 competitive weightlifters who had been performing full range of motion squats for a long period of time. The second sample group consisted of 360 college students who had no experience at competitive weightlifting, or weight training in general. For the actual conduction of the study, "Dr. Klein used an aluminum gadget for his test which covered the upper and lower leg much like a leg cast" (Shea, 3). A force was applied in all four directions upon the knee joint and was read by a gauge similar to one used to take blood pressure. Doing so measured the laxity of the medial and later collateral ligaments of the knee. After observing the amount of pressure on the knee, Dr. Klein came to the ending decision that "full squats loosened the knee joint and was harmful to the knees" (Shea, 3). Also, he came to the conclusion that the group that had previously weightlifted had unstable collateral and anterior cruciate ligaments from squatting to such a depth.

As Dr. Klein's research became more well known, certain national associations and groups went on to agree with his findings. One such group was the American Medical Association, which publicly stated that full squats had the "potential for severe injury (medical cartilage deterioration) to the internal and supporting structures of the knee joint" (Shea, 4). The public and common sports magazine, Sports Illustrated wrote an article on Dr. Klein's research, which greatly added to the growing negative opinions on deep squatting and its effect on supporting knee structures. Even the Marine Corps went on to "eliminate the squat jumper exercise from their physical conditioning programs" (Horschig, 91).

The manner at which this study was conducted, especially the aluminum gadget device, was highly subjective; especially far too subjective for today's research conducting criteria. More specifically, during the experiment, Dr. Klein did not have a standard device that applied the pressure on the various individuals. Instead, forces and pressure was applied by the researchers themselves. After the study was concluded, subjects later stated that many times, the pressure varied from different applications. They went on to comment that sometimes, the pressure applied was so large; it hurt the knees of the subjects. Also, the question of whether or not the subject had previous squatting experience was asked before the experiment was conducted, not after. According to one article, "this gave the tester the opportunity to have a built in prejudice and eliminate the testing procedure from the pure, controlled category" (Shea, 3).

The bold statements and conclusions of Dr. Klein were also naturally met by contention from other researchers at that time. Dr. John Pulskamp, an author for the column "Strength and Health," wrote a piece that vigorously disagreed with Dr. Klein's findings. In 1964, Dr. Pulskamp wrote, "full squats are not bad for the knees and they should certainly not be omitted out of fear of knee injury" (Horschig, 92). Unfortunately, the negative opinion of below parallel squats had already become wide-spread enough and was already being implemented by major associations, resulting from this; Dr. Pulskamp's message was not taken seriously.

Although Dr. Klein's work did introduce a more critical angle towards a specific aspect of lower extremity biomechanics, he did not delve far into the actual forces that are placed upon the knee when performing these certain movements. Andrew Fry was one researcher who studied and calculated the torques placed upon the hip and knee joints. His subjects performed two types of squats: an unrestricted squat and a restricted squat (Figure 1). The unrestricted squat group was allowed to have their knees move anteriorly over their toes, and their results showed a total average of 150.1 N of force, with a standard deviation of 50.8 N. On the other hand, the restricted squat group, whose knees were prevented from moving forward by a wooden barrier, displayed only 117.3 N of force, with a standard deviation of 34.2 N (Fry, 631).

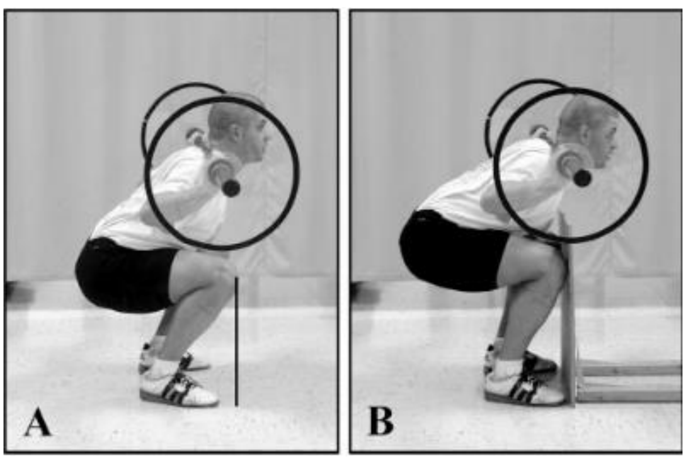

Figure 4

Various types of forces were also studied by Fry and his group of researchers. These forces included: shear force (forces pushing a structure in two opposite directions) and compressive force (exertion of pressure upon an object). During the descent of the squat, and as an athlete's knees translated forward, overall shear forces upon the patellofemoral and tibiofemoral joints were shown to increase. The compressive forces upon these two same joints were shown to increase as knee angle increased. Dr. Brad Schoenfeld's meta-analysis also investigates these compressive forces. First, the maximum values of tibiofemoral compression had the possibility of reaching up to 8000 N at 130 degrees of knee flexion, and decreased to

5500 N at just 60 degrees of knee flexion. For the patellofemoral joint, it was found that compressive values were around 6000 N at 130 degrees and only 2000 N at 30 degrees of knee flexion. It should also be noted, these values are all dependent on the amount of resistance being applied by an external force, and it is not simply gravity producing these high values.

When the knees are allowed to come forward, and a high knee flexion angle is produced, there are some structures of the knee joint that bear the brunt of the force more so than others. The medial and lateral menisci, which are the fibrous cartilages between the femur and the tibia, are at the greatest risk, especially when the individual has had menisci injuries before.

Continually, for individuals with poor knee stability due to injury or skeletal muscle weakness, "there also may be a susceptibility to patellofemoral degeneration given the high amount of patellofemoral stress that arises from contact of underside of the patella with articulating aspect of femur during high flexion. This can lead to chondromalacia, osteoarthritis, and osteochondritis" (Schoenfeld, 3499). Other reasons that can lead to knee arthritis and overall knee tissue degeneration are age, weight, genetics, and sports that repeatedly load the knee joint (Miller, 1).

Although many medical professionals have found negative implications to excessive knee flexion and or forward knee traction, many times, this is usually due to an individual's poor mechanical patterns and musculature weakness. The final part of this thesis will refute the negative outlook on forward patellar movement, and will analyze the necessary proper squat technique required for an athlete.

Forward patellar travel is necessary for a stable and safe squat

As stated above, this last section will analyze the implications of a squat technique that athlete's should strive for. The aspects of a squat that will not compromise knee health include the allowance of: ankle dorsiflexion, adequate knee flexion, and proper trunk stability and lean.

Ankle Dorsiflexion

Whilst descending during a barbell squat, your shin will go from a vertical position with the ankle to an angle less than 90 degrees. This action of reducing the angle between the shin and the ankle is known as dorsiflexion. Also, as the lower limb moves forward, the knee also tracks forward as well. Depending on the flexibility and mobility of the individual, this movement of the ankle and the lower limb will differ, and if there are any restrictions, it can possibly compromise the integrity of the surrounding musculature and structural components of the knee.

A research study done by Elisabeth Macrum and David Robert Bell in 2012 analyzed the kinematics of the ankle joint by either limiting or allowing the ankle joint to move freely. Their results showed that if ankle dorsiflexion range of motion was limited during a squat, the quadriceps musculature were much less active than if ankle dorsiflexion was not limited. Since we know that having adequate anterior lower extremity muscle strength is important for knee structure stability, it is critical for ankle dorsiflexion to occur, so that proper strengthening can occur to stabilize the knee joint (Macrum 149). The study also showed this limiting of the ankle joint increased soleus activity and activation. Even though excessive activation, breakdown, and then rebuilding of the soleus muscle fibers does provide a slight benefit for knee stability, this can also lead to the tightening of the muscle and surrounding tissues as well. According to Macrum,

> “limited ankle-dorsiflexion range of motion due to gastrocnemius and soleus tightness is known to exist in individuals with patellar-femoral pain (PFP)…Specifically, decreased dorsiflexion during weight-bearing tasks limits the ability to lower the body’s center of mass, encouraging increased subtalar-joint pronation and tibial internal rotation to gain additional motion” (Macrum, 145).

If the individual does not address this tightness, it can lead to potential anterior to posterior imbalances, which may increase the risk of an injury for an athlete.

In relation to injury risk factors during a squat, studies have found that if ankle dorsiflexion is limited, there is a higher risk of an anterior cruciate ligament injury occurring. Fong et.al states, “dorsiflexion range of motion restrictions may be associated with a greater risk of anterior cruciate ligament injury” (Fong, 1). The researchers also noted a correlation between dorsiflexion and ground reaction forces during a landing type motion or a squat. More specifically, they found that when jumping and then landing on a surface, if dorsiflexion was limited (by not allowing the knees to come forward), a much lower knee-flexion displacement and larger ground reaction force was observed. The ACL and other knee joint structures were shown to absorb 42% more newton’s of force when the subject used this specific landing posture (Fong, 4). Upon the completion of the study, the researchers recommended “clinical techniques to increase plantar-flexor extensibility and dorsiflexion ROM, which may be important additions to ACL-injury prevention programs” (Fong, 5).

Another research study shows a positive correlation between limiting dorsiflexion range and increased symptoms of patellar tendinopathy. The research article, “Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players,” analyzed measurements of pain in 113 male and female volleyball athletes when asked to land with their knees directly above their toes, instead of allowing forward knee traction upon landing. This study followed these athletes for four weeks whilst they performed their normal volleyball activities. One of the three sample groups in particular had to perform specific exercises which optimally loaded the patellar tendon. At the end of the four week long period, the researchers used a pain rating scale along with ultrasound imaging to analyze the forces being loaded upon the patellar tendon. When taking age, height, weight, weekly activity levels and years of volleyball experience into consideration, the researchers discovered that “the only potential risk factor that appeared to be associated with tendinopathy (patellar) was ankle dorsiflexion range” (Malliaras, 306). Also, the volleyball athletes who performed the extra patellar loading throughout the period, and rated a higher pain level in their knees, were not able to dorsiflex their lower extremity as well as the other two groups. Based on the data provided by this research, it seems that “improving dorsiflexion range among players with reduced range may have implications for the prevention of patellar tendon injury” (Malliaras, 309).

In summary, if ankle dorsiflexion is limited during a squat, by an external device, or by not allowing the knees to come forward, not only is can it lead to patellar tendinopathy, it can also lead to increased forces on the ACL, and decreased activation of the quadriceps musculature.

Adequate Knee Flexion

Although there still is negative bias towards excessive knee flexion and forward knee motion, there are too many positive factors associated with allowing the knees to move forward during a squat.

Newer research has emerged that explains that allowing ones knees to actively move forward during any type of squatting motion is beneficial towards knee structure stability. The researchers also advocate safe squatting mechanics by emphasizing and prioritizing proper mobility and flexibility for the athletes. One particular study studied the effects of implementing the barbell squat exercise into a group of 32 football players training programs. Researcher Robert Panariello had the athletes perform strict squats twice a week for 21 weeks, and also had them exert themselves at a rating of perceived exertion (RPE) value of 8. The athlete's passive displacements were "recorded at 67, 89 and 133 N with the knee at 30 degrees and 90 degrees of flexion (Panariello, 5). Using a knee ligament arthrometer at the 12th and 21st week mark, Panariello observed that there were no significant differences between pre and post exercise results for active and passive tests (5). After analyzing the exercise measures, and taking the 130% to 200% barbell loads into consideration, he stated, "this study demonstrates no significant increases in anterior-posterior tibiofemoral translation in the subject group" (Panariello, 6). This study supports the notion of allowing adequate knee flexion because it shows that during the squat, the structural components of the knee are able to remain stable during the entire range of motion of the exercise.

As discussed earlier in this paper, the literature that arose in the 1960's, authored by Dr. Karl Klein, and analyzed the potential dangers of the squat on the ligamentous structures of the knee joint. Since the mid-20th century, these accusations and hypotheses have been refuted by many exercise scientists. The latest literature tells us "that ligaments inside our knees are actually placed under very little stress in the bottom of a deep squat" (Horschig, 99). The deep squat refers to an athlete's hip going at least parallel to the ground. By doing this, the knee will automatically have a high degree of flexion, and they will be forced to move forward. Although this is true, it does not mean that excessive forces are placed upon the ligaments as the athlete descends deeper into the squat. Using more advanced and better technology has allowed researchers to study these structures. Pertaining to the ACL, the science has found that stress on this ligament is at its highest during the first four inches of the squat, when the knee has not yet passed over the toes, and there is only around 15 degrees of knee flexion. As the squatter descends farther, the forces placed upon the ACL decrease. Continually, the maximal forces on the ACL (at the top of the squat) have been found to only be 25% of the ultimate stress the ACL is able to withstand (Horschig, 99). Unlike the ACL, the PCl sustains its maximum forces just above a parallel squat position, and is never really put under much stress during a squat. The general consensus seems to be that as you squat deeper, and your knees flex and track forward, the safer it is upon the ligamentous structures of the knee.

Performance of a proper squat, with adequate mobility, seems to lead to the strengthening and stabilizing of the knee joint, which is the final point I will touch upon pertaining to knee flexion. The quadriceps and hamstrings musculature that insert in and around the patellar joint antagonistically work to stabilize the knee. These muscles limit excessive movement, and allow a co-contraction and balance to occur as the eccentric, isometric and concentric is performed. TJ Chandler, the author of “The effect of the squat exercise on knee stability,” observed and discovered enlightening and interesting information on this topic. After having an experienced group of powerlifters and weightlifters perform a rigorous eight week training program consisting primarily of squats, he then went on to compare these two groups to the studies control group, a large sample of male and female college students, who were not experienced in either of these sports. The results showed that both the powerlifters and weightlifters had “significantly tighter than the controls on the anterior drawer at 90 degrees of knee flexion” (Chandler, 8). The knee ligament arthrometer was used again for this study to measure the knee stability. The researchers also measured higher quadriceps muscular activation during the squat for the weightlifters group, compared to the control group. The ability to effectively contract and fire one’s musculature, especially the lower extremity muscles that surround the knee, supports the reason why the experienced weightlifting groups showed more tendon and musculature stability at the end of the experiment.

Today, research is continually being done analyzing how effective the barbell squat is for overall knee structure health. Much of the science seems to state that allowing your knee to flex more than 90 degrees activates the correct muscles, decreases the shear forces, stabilizes the knee joint, and decreases the stress upon the lumbar spine, which is the final point of this thesis.

Trunk stability and safety

A large amount of spinal loading from the deep squat is another common fear many have when attempting to execute a loaded squat. Although the vertebral joints are the most vulnerable during the squat (Schoenfeld, 3501), especially when not accompanied by proper intraabdominal pressure, this fear is still unwarranted and not backed by science because much of the literature suggests that deep squats are beneficial for spinal stability, whereas quarter and half squats are detrimental for spinal integrity.

As discussed in the anatomical section of this thesis, the spine should maintain a natural lordotic curve as the individual descends and ascends during the squat. Schoenfeld states, “no lateral movement of the spine should take place at any time” (3501). This includes spinal flexion as well. The maintenance of a rigid spine also eliminates any planar motion, and allows for an upright posture to be consistent throughout the movement.

Authors Hagen Hartmann, Klaus Wirth and Markus Klusemann wrote a meta-analysis comparing different squat depths and their resulting loads on the knees and vertebrae. One particular area of the spine they analyzed was the L3-L4 segment. Multiple individuals were asked to perform quarter and half squats for a longer duration of time. After doing so, the researchers returned, and measured a 0.8 to 1.6 fold bodyweight load “resulted in compression loads of 6-10 fold on that particular spinal segment” (Hartmann, 6). They then compared the deep squat group, which allowed forward knee traction. Hartmann and his colleagues discovered there was only a 3.89 fold increase of vertebral pressure when doing a squat with a larger range of motion. They also found that when the deep squat was performed consistently, with proper technique, the vertebral bodies became "enhanced," and were more tolerant towards loading because of their adaptation and increased bone mineral density.

Actively bracing your core, or creating intraabdominal pressure, before the eccentric part of a squat allows a safer technique to be had. Doctor Brad Schoenfeld describes this technique effectively. In his loaded squat meta-analysis, he states,

> "Increasing intraabdominal pressure may serve to alleviate vertebral forces. An increased IAP creates a "balloon" anterior to the spine that resists compression. It also provides an antiflexion movement in the lumbar region that reduces active contraction of the erector spinae, diminishing spinal compression generated by associated muscle tension. Also, increased IAP raises intramuscular pressure of the erector spinae muscles and stiffens the trunk, contributing to greater spinal stabilization during dynamic lifts"(3501).

Common injuries such as low back pain occur at a low percentage for athletes who perform bracing. The primary reason for this deals again with the muscles surrounding the spinal column. When intra-abdominal pressure is performed, researchers found electromyogram activity of 12 trunk muscles to be significantly increased (Cholewicki, 2). The concentration on one's breathing into the stomach, which effectively contracts and stabilizes the trunk musculature, can also be used during one's rehabilitation. Researchers also found when this action is performed in any activity, not necessarily just the squat, overall trunk stiffness increased by 21-42% (Cholewicki, 2). This supporting data emphasizes the importance of this technique when it comes to squatting. In summary, an athlete should concentrate on their spinal posture compared to their forward knee traction because any lumbar or spinal injury that one may sustain under heavier loads is far more important than any knee injury.

To conclude

Although some research has shown an increase in compressive forces as the athlete descends in a squat and the knees translate forward, these forces are not large enough to cause damage to the knees supporting structures. Instead, it is more important to focus on spinal stability because of the much more serious vertebral injuries that may occur if proper squat technique is not emphasized.

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