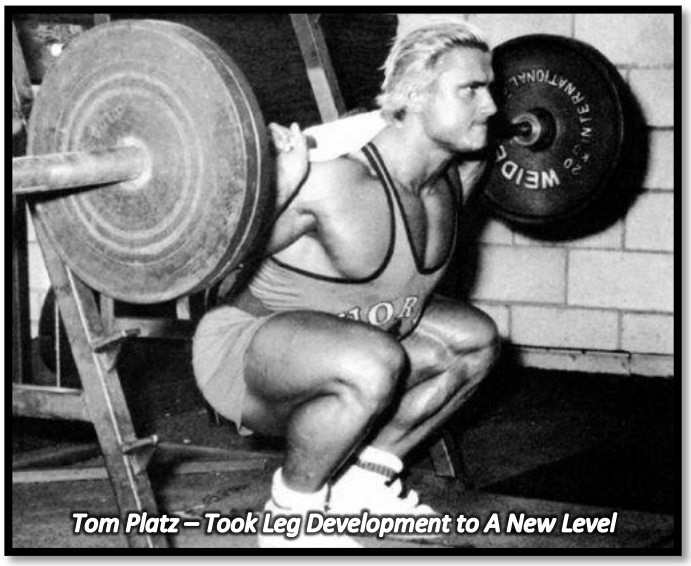
The Science of Health, Nutrition and Fitness

The Full Squat: The Science Behind the Debate **Author: Carl Conroy**

The barbell squat is one of the most accepted and yet maligned exercises in the sphere of resistance training. Criticised for its injurious potential and yet exulted as being one of the greatest mass and strength builders available to the aspiring bodybuilder or sports participant. Debates about the effectiveness of the movement and how it should be performed are still at the forefront of gym discussion and scientific scrutiny. So in order to make a knowledgeable judgment as to how and where to use this movement you must have some understanding of the 'assertions' that are made regarding the exercise; and what is scientifically demonstrable; or indeed, what is just gym myth. Herein, we shall now look at the barbell squat and attempt to answer some of these complex but pertinent questions.



The article will cover several areas of significance to the barbell squat and will endeavour to provide a qualified overview of these factors. The factors that will be discussed are:

- Should you 'full squat' or not?
- Barbell squat – Anabolic stimulation

Karl Klein (1961) influenced the current trends and thinking regarding the full squat; which still exist today

Should You Do Full Squats?

In 1961, a researcher named Dr. Karl Klein, who already had an inherent predisposition to criticize full squats, carried out a piece of research that involved testing Olympic lifters for knee ligament stability. When compared against a control group and with subsequent cadaver research; he surmised that the Olympic lifters had an increase in the slackness of the collateral and ACL ligaments of the knee. With this in mind he recommended that individuals should not go below parallel when performing the barbell squat. The fallout of this recommendation was that the United States military, the New York School Board and the American Medical Association all took this research so seriously that the demise of the full squat began. The ripple effect of this research has carried through to modern times despite the fact that many studies have contradicted these original findings and further,

'Dr. Karl Klein's study at the University of Texas in 1961 was a poorly designed and badly conducted mess that has never been replicated and has been successfully rebutted many times. Klein concluded

that below parallel squats produced "loose" knees, although no other training protocol was evaluated for comparison, no other tester administered the measurements, and all the data was biased by pre-test questioning of the subjects' (Rippetoe, 2007)

So with that in mind what would be the recommendations for squat and knee flexion angle if knee damage is to be avoided. Let us first look at the supporting structures of the knee joint i.e. the knee ligaments and stability. Many research endeavours have addressed the premise that full squats are a risk factor in respect of knee stability. Research of course usually always has an element of contradiction but let us first look at studies that have shown positive result in terms of knee stability and employment of the squat exercise movement.

Chandler T.J., Wilson G.D. and Stone M.H. (1989) carried out a large study which involved 100 male and female college students. They carried out 9 tests regarding knee stability after an 8 week squat training program and determined that '*no effect of squat training on knee stability was demonstrated in any of the groups tested*'. Their study looked at full and half squats.

Panariello R.A., Backus S.I. and Parker J.W. (1994) studied the effect of the squat exercise on the anterior-posterior knee translation of professional football players. Thirty-two subjects with normal knees participated in a 21-week off-season training program. The subjects performed power squat exercises with barbell loads of 130% to 200% body weight two times per week. The knees of each subject were tested by a single examiner with a knee ligament arthrometer before the training program and at 12 and 21 weeks. As a result of this study the researchers arrived at the conclusion that there were '*no significant increases in anterior-posterior tibio-femoral translation in athletes using the squat exercise as part of their off-season training program'*.

The other main argument in terms of knee damage suggest that the compressive forces observed in the full squat technique might have degrading effects to structures such as the articular cartilages and the menisci which are heavily involved in the weight bearing process.

However, Hartmann H, Wirth K, and Klusemann M. (2013) asserted that the opposite could be the case and that full squats might positively benefit these compressive structures, stating that,

'Concerns about degenerative changes of the tendofemoral complex and the apparent higher risk for chondromalacia, osteoarthritis, and osteochondritis in deep squats are unfounded. With the same load configuration as in the deep squat, half and quarter squat training with comparatively supra-maximal loads will favour degenerative changes in the knee joints and spinal joints in the long term' Hartmann *et al (2013).*

Many studies have illustrated that full squats do not cause significant instability in the knees and might even be beneficial in stopping injuries occurring.

Hartmann *et al (2013).* Chandler T.J. et al (1989) and Panariello R.A. *et al* (1994)

They further and more importantly proceeded to state that,

'The deep squat presents an effective training exercise for protection against injuries and strengthening of the lower extremity. Contrary to commonly voiced concern, deep squats do not contribute to increased risk of injury to passive tissues'. Hartmann et al (2013).

Gullett J.C, Tillman M.D, Gutierrez G.M. and Chow J.W. (2009) after their study on front and back squats; stated that '*the back squat resulted in significantly higher compressive forces and knee extensor moments than the front squat*'. But that statement does not inherently suggest these are damaging compressive or moment forces. They further go onto state that '*Shear forces at the knee were small in magnitude, posteriorly directed, and did not vary between the squat variations*'. Their recommendations from this were that '*results suggest that front squats may be advantageous compared with back squats for individuals with knee problems such as meniscus tears, and for long-*

term joint health'. But this study does not 'clearly' conclude that below parallel back squats are a significant issue where knee damage is a consideration.

Sahli S. *et al* (2008), suggested that '*the half squat may be safe to use for quadriceps strengthening with very low potential loading on the anterior cruciate ligament (ACL)'.* But once again this is a very open ended statement that does not offer clear constructive advice on other squat variations; or their potential benefits.

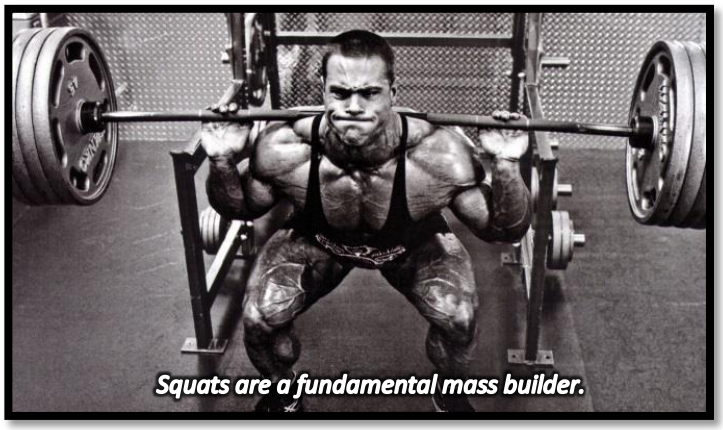
Escamilla R.F. (2001) stated that, '*the parallel squat was not injurious to the healthy knee*'. And further goes onto assert that, '*For athletes with healthy knees, performing the parallel squat is recommended over the deep squat, because injury potential to the menisci and cruciate and collateral ligaments may increase with the deep squat. The squat does not compromise knee stability, and can enhance stability if performed correctly*'. The term 'may' in this statement is a little subjective and perhaps requires a little more clarification.

So should an individual full squat or carry out partial squats with respect to considerations of injury. The consensus with regards to research is that full squats are a useful tool in the bodybuilding and sports specific training arsenal (Hartmann H, Wirth K, and Klusemann M. 2013; Panariello R.A., Backus S.I. and Parker J.W. 1994). However, should a pre-existing injury already exist i.e. anterior cruciate ligament tears, then a partial or half squat might be advisable to strengthen the structures and muscles around the knee after recovery (Sahli S, Rebai H, Elleuch MH, Tabka Z, Poumarat G., 2008). But, be aware that some studies have shown negative potential injurious aspects to squat performance, especially if technique is not precise. (Fleck, S.J. and Falkel, J.E, 1986, Klein, K. 1961).

As summary to this section on squats and the injurious implications let us consider the stance of the National Strength and Conditioning Association (NCSA). That being; *'Some reports of high injury rate may be based on biased samples. Others have attributed injuries to weight training, including squat, which could have been caused by other factors. Injuries attributed to squat may result not from the exercise itself, but from improper technique, pre-existing structural abnormalities, other physical activities, fatigue or excessive training.'* NCSA (2012). They further state that, '*Squats, when performed correctly and with appropriate supervision, are not only safe, but may be a significant deterrent to knee injuries*.'

In conclusion it is our stance, based on all the information contained in this article that squats have been given a bad reputation and the majority of the scientific consensus seems to be this reputation is unfounded. So employ the full squat into your routine but ensure that technique is clean and precise and that science not ego, dictates the poundage's you employ.

The other aspect of whether you should full or partial squat will now be discussed. That being, which squat is most effective for strength and muscular development? The partial squat involves angles of knee flexion short of full flexion; with parallel or 90° squats being the most used format in most mainstream gymnasiums. Full flexion angles at the knee can vary from person to person due to factors such as muscle and tendon stiffness, size of muscular structures and the skeletal construction of that specific individual; but the 'purist' full squat would involve the gluteal muscles almost resting on the heel of the planted feet and the knees moving past the toes of the feet. The question that must arise from this is which technique would lend itself best to muscular development and which would be best applicable to sport specific performance. We have already established that the



full squat is generally a safe exercise so surely it would be sound to theorise that the full range of motion would be the most beneficial technique to use. After all, isn't it the premise behind the Arnold Press that increased range of motion is more beneficial to the deltoids? Why wouldn't the same logic be applied to the squat. Outside of the now disproven dangers of full squat mythology why would an athlete choose to only half squat when full range of motion can stimulate far more of the muscles involved?

A study by Bloomquist, K. *et al* (2013) in which 17 male students were randomly assigned squat training with varying ranges of motion came to the conclusion that;

'*The deep squat training resulted in superior increases in front thigh muscle compared to shallow squat training. In parallel with the larger increase in front thigh muscle cross sectional area, a superior increase in isometric knee extension strength and squat-jump performance were observed in the deep squat group compared to the shallow squat group. Training deep squats elicited favourable adaptations on knee extensor muscle size and function compared to training shallow squats*'. Bloomquist, K. *et al* (2013)

So in the case of this study both bodybuilders and sports individuals would certainly benefit from the employment of full squats.

Bryanton M.A. *et al* (2012) carried out a research study on both depth and barbell loading in the squat and ascertained how these factors would affect the relative muscular efforts of the hip extensors, knee extensors, and ankle plantar flexors. Their research indicated that

> The full depth squat results in significant increases in quadriceps muscle hypertrophy compared to partial squats.
>
> Bloomquist, K. *et al* (2013)

'*Both greater squat depth and barbell load increased hip extensor relative muscular effort. These data suggest that training for the knee extensors can be performed with low relative intensities but require a deep squat depth. Heavier barbell loads are required to train the hip extensors and ankle plantar flexors*.' Bryanton M.A *et al* (2012)

These results suggest that the '*heavy*' full squat is a viable method for extensive stimulation of the gluteal muscles; specifically the gluteus maximus, and is also a very good exercise for the biceps femoris, semitendinosus and semimembranosus; more commonly known as the hamstrings. The research also concluded that the knee extensors which are predominately encompassed by the quadriceps muscle group can be stimulated by lighter resistance loads but do require squat depth to be maximal for increased stimulation.

Gorsuch J. *et al* (2013) measured muscle activity with surface electromyography during partial and parallel squats in 20 Division I collegiate cross-country runners . Males and females were tested. The research arrived at the conclusion that, '*parallel squats may help runners to train muscles vital for uphill running and correct posture, while preventing injury by using lighter weights through a larger range of motion*'. So depth of squat does have sports specific implications with the recommendations here being that runners should use lighter weights but deeper squats to strengthen their leg muscles and avoid injuries.

So it seems that not only are full squats a safe and viable exercise to include in your training regimen but also their employment will result in greater muscular and sports specific adaptations. (Bloomquist, K, Langberg, H, Karlsen, S, Madsgaard, S, Boesen, M, & Raastad, T. (2013), Bryanton M.A, Kennedy M.D, Carey J.P, Chiu L.Z. (2012) and Gorsuch J, Long J, Miller K, Primeau K, Rutledge S, Sossong A, Durocher J.J. (2013). Partial squats or half squats still have their place. For example in periodization they can be used to allow an athlete to become accustomed to increased weights before attempting the full squat or for a beginner trainee the less complex half squat may be a

prudent initial exercise choice. But progression to the 'full squat' should be the goal if full development is the purpose.

Barbell squat – Anabolic stimulation

Another theory in relation to the employment of the barbell squat is that due to the number of muscle groups involved and the intensity of the exercise stimulation, there is a potential for growth inducing chemicals such as testosterone and growth hormone to be released above 'normal' levels. Thus creating a more significant anabolic environment. The following discussion will now look at this theory and determine what research has been establishing in relation to the premise of anabolic hormone release due to resistance exercise?

There is undeniably a link between heavy resistance exercise and increased anabolic hormone production. Craig, B.W. *et al* (1989) determined that, '*strength training can induce growth hormone and testosterone release, regardless of age, but that the elderly response does not equal that of the young*'. Fleck, S.J. *et al* (1998) concurred with this when there research reached the conclusion that, '*age-related differences occur in the endocrine response to heavy resistance exercise, and the most striking changes appear evident in the free testosterone response to heavy resistance exercise in physically active young and older men.*'

Squats can cause increases in anabolic hormones such as testosterone and human growth hormone.

Craig, B.W. *et al* (1989), S.J. *et al* (1998) and Gotshalk, L.A. et al (1997)

Gotshalk, L.A. et al (1997) asserted that this anabolic stimulation was also related to the 'volume' of work carried out. They stated that, '*higher volumes of total work produce significantly greater increases in circulating anabolic hormones during the recovery phase following exercise'*. This higher volume relationship was also indicated in research by Hakkinen, K., and Pakarinen, A. (1993) who found that when ten male strength athletes carried out *'two fatiguing but different types of sessions on separate days*' the higher volume training produced '*increases in the concentrations of serum total and free testosterone, cortisol , and growth hormone'* whereas the corresponding changes seen on the lower volume work '*were statistically insignificant except for relatively slight increase in serum GH level*'.

Volume, resistance, rest periods and modes of training all have an effect on anabolic stimulus.

Gotshalk, L.A. et al (1997), Robbins D.W. (2012) and Pyka, G. *et al* (1992).

Robbins D.W. (2012) determined that '*high volumes (>4 sets) are associated with enhanced strength development but that "moderate" volumes offer no advantage. Practitioners should be aware that strength development may be dependent on appropriate volume doses and training duration*.'

Now we have ascertained that volume and resistance are modifying factors behind anabolic hormone release and strength increases; how does this relate to the squat itself? Pyka, G. *et al* (1992) established that '*resistance exercise promptly elevates circulating GH concentrations in healthy young adults*' and that this was '*related to the intensity of the resistance stimulus*'. Therefore with squats, heavier weights, full range of movement and less rest between sets would facilitate a good anabolic environment. This is concurred with by research carried out by Vanhelder, W.P. (1984) who determined that '*in intermittent weight lifting exercises of equal total external work output and duration as well as identical work-rest intervals, the load and/or frequency of an exercise are determinant factors in the regulation of plasma GH levels*'. So the resistances used, are a major factor in consideration of the squat.

The concept of '*failure*' is another consideration. Izquierdo M. *et al* (1985), carried out a study to '*examine the efficacy of 11 weeks of resistance training to failure vs. non-failure, followed by an*

identical 5-week peaking period of maximal strength and power training for both groups'. They found that, '*Strength training leading to failure resulted in reductions in resting concentrations of IGF-1 (Insulin like growth factor-1) (helps promote normal bone and tissue growth and development)*'. Whereas, non-failure training '*resulted in reduced resting cortisol concentrations and an elevation in resting serum total testosterone concentration*.' The conclusion was that '*there was a potential beneficial stimulus of non-failure training for improving strength and power*'. From this research it can be subjectively asserted that squats to non-failure might be more effective than squats taken to failure for development of strength and power. This would also make the squats 'safer'.

Mode also seems to be influential in respect of the stimulation of anabolic hormone release. Shaner A.A. *et al* (2014) carried out a study regarding mode of exercise; free weight squat and machine leg press. They concluded that, '*free weight exercises seem to induce greater hormonal responses to resistance exercise than machine weight exercises using similar lower-body multi-joint movements and primary movers*'. This was further validated in a study by Schwanbeck S. *et al* (2009) who carried out an experiment where the '*purpose of this experiment was to determine whether free weight or Smith machine squats were optimal for activating the prime movers of the legs and the stabilizers of the legs and the trunk'.* They concluded that '*The free weight squat may be more beneficial than the Smith machine squat for individuals who are looking to strengthen plantar flexors, knee flexors, and knee extensors*'. So once again free weight squats are represented in a positive manner with reference to anabolic stimulation and strength development.

The research regarding the squat goes on and many questions probably still require answering. However, how does what we have learned herein transfers to the use of the squat in any training programme where strength or size are required. Here are our recommendations:

- If you are devoid of injury use the 'full squat' as your main leg exercise.
- Use the partial or parallel squat as an interim exercise where knee injury is present.
- Use four sets or more in your squat routine to gain full anabolic potential.
- Employ free weight squats as opposed to any machine based protocol.
- Keep rest periods to a realistic minimum between squat sets
- Employ weights that allow the performance of between 8 – 12 repetitions per set

Look out for further article on the squat as we will be providing routines and techniques to further push the boundaries of this amazing exercise.

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