Can the Knee Go Over the Toe?

By

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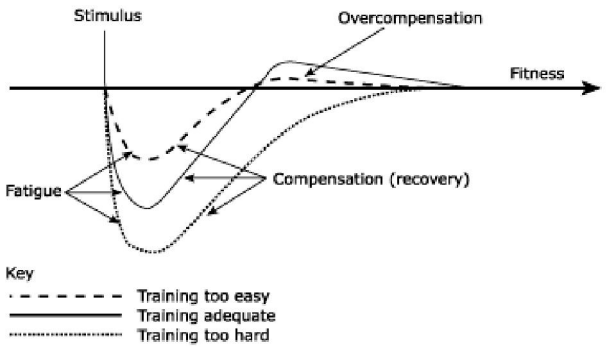
Back in 1926, Canadian endocrinologist Hans Selye began studying the science of stress. Through his years of research, he developed the theory of stress, known as General Adaptation Syndrome, or GAS. Though this research was based on psychological and hormonal responses to stressors, this theory also holds true for human physiology. Basically, the body will adapt to the amount of stress placed on it. Whether it is chronic or acute stressors, the human body is a resilient machine, capable of adapting and super compensating to greater and greater levels of stress.

Supercompensation is when the human body is exposed to physical stress, properly recovers back to baseline fitness from this stress, and compensates by increasing fitness level/physiological capacity in anticipation of greater future stresses. For example, after a hard weight training workout (the mechanical stress), protein degradation (breakdown) occurs, and the body needs to begin the recovery process by rebuilding both the nervous and muscular systems. Upon recovering back to baseline levels, the body will then "supercompensate" to a greater baseline level in an effort to adjust itself to increased future mechanical stress levels. Cellular hypertrophy, muscle fiber recruitment, lactic acid threshold or buffering, hormonal responses, and neuromuscular responses are examples of mechanisms the body may use as methods of supercompensation.

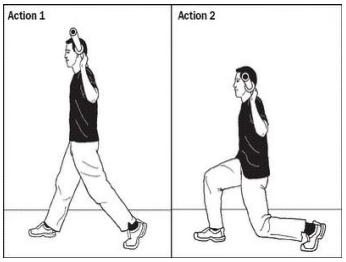


So what does this have to do with the knee going over the toe during exercises? Well, another way the body adapts to mechanical stress is through soft tissue and bone remodeling. The body protects its joints by increasing the soft tissue integrity surrounding the joint, each time they are exposed to and properly recover from stressors. (***Note properly recover***, as this may be a major reason why so many

chronic injury patterns occur in many endurance sports). Muscles, joints, cartilaginous tissue, bone, and ligaments become stronger with greater amounts of properly applied stress and adequate recovery.

Understanding this, it is then clear that the more properly applied stress (along with adequate recovery) you apply to the body, it should adapt by increasing the integrity of the soft tissue surrounding a joint. So when reading the research on deep knee flexion (ala: letting the knee pass over the toe during exercise), why is it all these studies point to the greater amounts of tibiofemoral joint stress as a negative with regards to knee health and ligament injury potential. Didn't' we learn anything from Dr. Kenneth Klein's, unfortunately now disregarded studies on knee stability, that deep squatting may actually be more beneficial to the knees than half squatting.

For example during deep knee flexion full squat studies have shown much greater muscle activation from the glutes, hamstrings and adductors than half squats, which were shown to exhibit greater amounts of quadriceps activation. In other words, with deep knee flexion, there are 3X as much muscle being recruited to pull the body out of the deep position. This activation is based on the way the human machine is designed. With the hamstring muscles coming from the back of the thigh, attached proximally at the ischial tuberosity of the pelvis, wrapping around both sides of the knee and inserting into the front of the tibia, to the adductors attaching at the pelvis and inserting into the medial femur, each of these muscles play a major role in bringing the body out of deep knee flexion.

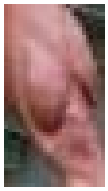


The potential for future knee problems??

Due to their insertion points, during deep knee flexion, the activation of the hamstrings protects the knee by pulling back on the knees, taking some of the anterior shear stress off the quadriceps. The adductors work in similar fashion, but from a more proximal position. Basically these muscles, along with the gluteal musculature, balance out the pulling forces placed on the knee capsule during deep knee flexion angles, disallowing greater amounts of anterior stress from the quadriceps musculature. So in essence, without the pulling forces of the hamstrings and adductors (as well as hip extension assistance from the gluteal musculature) during knee extension exercises, wouldn't there be greater potential for knee injury due to the anterior forces left unchecked by these muscles????

As a matter of fact, research shows that the greatest stress on the ACL actually occurs in open kinetic chain leg exercises (1,2,3,4,5,6), especially when compared with standing closed kinetic chain

exercises. A particularly interesting study by Escamilla et al (2010) compared the forces on the ACL between long step lunges (ala the knee not even crossing the ankle plane) and short step forward lunges (more similar to knee crossing the toe plane split squats). ***The researchers found minimal ACL tension in the short lunge with greater knee flexion as compared with the long lunge. Of equal importance, they also found significantly greater PCL forces with the long stride lunges.*** Ouch!!!



And what about the VMO musculature? The Vastus Medialis Obliques (the medial teardrop muscle above the kneecap) is activated during the top of knee extension and guess what??? The bottom of knee flexion. So in order to train the VMO in both functional ranges, there should be a need for both ranges of motion in a standing position. But how is this possible if much of the research in the strength, conditioning, and training world recommends we stay away from one of those ranges of motion, deep knee flexion, or the knee passing over the toe.

Looking at it from an everyday perspective, try walking up or down a stair case without the knee going over the toe. The natural way to do it is with the knee passing the toe plane. You would think, especially according to the deep knee flexion studies, that those athletes whom are involved in sports with the greatest degrees of knee flexion would have the highest incident of knee injury. One such sport which achieves deep knee flexion with tremendous amounts of force is Olympic Weightlifting.

According to the deep knee flexion studies, these athletes would qualify as those creating the greatest amount of stress in that deep knee flexion position. You would expect all Olympic weightlifters, both active and retired, to be walking around, check that, hobbling around, with knee injuries so great that the Olympics would contemplate banishment of the sport all together. Or could it be the exact opposite? Perhaps the body follows along the lines of Selye's work and adapts to the stresses placed on the knee joint, actually strengthening the ligaments and soft tissue about the knee capsule, thus, decreasing the risk of injury.

A closer look at the injury profiles of Olympic Weightlifters may provide some insight. Studies on Olympic weightlifters show large forces placed on knees in the catch phase, or deep knee flexion. Sometimes weight greater than 2 times the athlete's bodyweight is snatched over head and caught in the deep knee flexion position (the

position we are told to avoid). Yet, injury profile studies out of the United States Olympic Training Center show a rate of 3.3 injuries per 1000 hours of weightlifting exposure, with 85% of the knee injuries being tendonitis (Calhoon and Fry 1999). In other words, an Olympic weightlifter training with heavy weights and great amounts of physical stress roughly 6 days per week, 2X per day on many of those days, may experience knee problems 1 workout roughly every 33 weeks?? Compare that to the injury profiles of endurance athletes whom experience injuries … Makes you wonder!!

So, under healthy knee circumstances, can the knee also pass the toe plane in single leg movements such as lunges and split squats. In my personal experience with hundreds of athletes, one of the best ways to strengthen the knees and surrounding muscles is to incorporate full range of motion deep knee flexion exercises with perfect technique. These exercises not only allow for multiple thigh muscles to activate (i.e.: adductors, hamstrings, glutes, and quads) due to their range of motion, but also allow for recruitment of VMO musculature due to end ranges of motion achieved during these exercises.

As a matter of fact, at APECs we utilize these types of full range exercises when working with athletes in the rehabilitation setting. For instance we will work alongside physical therapists in the rehabilitation of an athlete's knee after an ACL tear. Many physical therapists whom refer patients to APECs comment on the speed of progress these athletes make, especially those whom are able to perform full range of motion, knee going over the toe strength training exercises. A few excellent examples of this are former Tri Valley League MVP and Boston Globe All Scholastic Soccer Player Melissa Menapace, former High School All-American and current Yale Lacrosse Star Luke Aronson, and former High School All-American and current Cornell Lacrosse Player TJ Weil. Each of these athletes came to APECS post ACL surgery and rehabilitation. Upon structural balance testing and realization of weak VMO in standing positions as well as weak hamstrings as flexors of the knee, we put these athletes through specific strengthening protocols, alternating between phases of accumulation and intensification, to strengthen the integrity of the knee structure.

Below is a sample of a beginner post-physical therapy rehabilitation program:

Exercise	Reps	Sets	Tempo	Rest Interval
A1: Poliquin Step Ups (Low Platform)	20-25	3	1010	60s

A2: Kneeling Hamstring Curls (Neutral)	6-8	3	6020	60s
B1: 12" Box FFE Cable Split Squats	12-15	3	3030	60s
B2: Low Box Step Ups	10-12	3	1010	60s
C1: Farmer Carry (Rehab focus)	20-40yds	3	NA	10s
C2: Backward Sled Drag (Rehab focus)	20-40yds	3	NA	60s

******Note**: During 3 of these exercises, A1: Poliquin Step Ups, B1: Cable Split Squats, and C2: Backward sled drag, **the knee crosses past the toe plane. Especially on the split squats in which the athlete is required to bring the knee as far forward over the toe as they can while maintaining proper technique**. For an excellent description on this exercise, read Charles Poliquin's blog tip The Value of Split Squats by Clicking Here ******

So, to answer the question that so many professional in the strength and conditioning and personal training industries receive, can the knee go over the toe? In this strength coach's opinion, yes, as long as the knees are healthy and proper mechanics are a priority. To learn more about the proper mechanics of many lower extremity exercises, it is recommended to learn from the best in the world and enroll in Coach Charles Poliquin's PICP Strength Coach Certification, as the lower extremities are covered in the Level II Internship of this oft-sold out program. Check it out at www.charlespoliquin.com.

Enjoy, work, and ……Succeed!

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1. Escamilla R, Fleisig G, Zheng N, Barrentine S, Wilk K, Andrews J. **Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises.** *Med Sci Sports Exerc.* 30(4); Pp 556-569. 1998.

   "tibiofemoral and patellfemoral compressive forces were greatest in the closed kinetic chain exercises at full flexion. Of interest was the fact that the greatest tension on the ACL was actually found in the open kinetic chain exercises, at or near the full extension position. The stress levels about the tibiofemoral and patellafemoral joints were higher at deep knee flexion of the closed kinetic chain exercises, but the highest ACL strain was in fact not found in these ranges of motion, rather in the end range extension of the open kinetic chain exercises. Hmmmm. Another study by Wilk et al 1996 echoed similar findings, in which the greatest stress on the ACL was seen in the open kinetic chain exercises at near or full extension.

2. Wilk K, Escamilla R, Fleisig G, Barrentine S, Andrews J, Boyd M. **A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises**. *Am J Sports Med*. 24(4); Pp 518-527. 1996.

3. Stuart M, Meglan D, Lutz G, Growney E, An K. **Comparison of intersegmental tibiofemoral joint forces and muscle activity during various closed kinetic chain exercises**. *Am J Sports Med.* 24(6); Pp 792-799. 1996.

4. Escamilla R, Fleisig G, Zheng N, Lander J, Barrentine S, Andrews J, Bergemann B, Moorman C. **Effects of technique variations on knee biomechanics during the squat and leg press**. *Med Sci Sports Exerc. 33*(9); Pp 1552-1566. 2001.

   The researchers found little or no ACL forces at all in both the leg press and squat, even though there were greater tensile and compressive forces in the squat exercise.

5. Zheng N, Fleisig G, Escamilla R, Barrentine S. **An analytical model of the knee for estimation of internal forces during exercise**. *J Biomechan.* 31(10); Pp 963-967. 1998.

   Similar findings with no anterior cruciate ligament tension in the squat and leg press, whereas peak ACL tension was found in the seated extension open kinetic chain exercise.

6. Irish S, Millward A, Wride J, Haas B, Shum G. **The effect of closed kinetic chain exercises and open kinetic chain exercise on the muscle activity of vastus medialis oblique and vastus lateralis.** *Journal of Strength and Conditioning Research.* 24(5); Pp 1256-1262. 2010.

   Of the 3 exercises utilized in this study, the double leg squat with hip adduction, the lunge, and the open kinetic chain knee extension exercise, the lunge was found to have the most balanced recruitment of the VMO and vastus lateralis musculature. Just imagine the ratio if the lunge was done to a greater degree of flexion in the knee.

7. Escamilla R, Zheng N, Macleod T, Imamura R, Edwards W, Hreljac A, Fleisig G, Wilk K, Moorman C, Paulos L, Andrews J. **Cruciate ligament forces between a short and a long step forward lunge.** *Med Sci Sports Exerc.* Feb 2010.

   The researchers took 18 subjects through their 12 rep max long step lunge and short step lunge while recording forces and EMG recruitment patterns. The researchers found minimal ACL tension in the short lunge with greater knee flexion, but this was significantly insignificant. On the flip side, the researchers did find much greater, in fact significantly greater PCL forces in the long stride lunge, you know the one in which the knee barely passes the ankle, never mind deep knee flexion with the knee passing near the toe!!