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Clinical Viewpoint

Considerations with Open Kinetic Chain Knee Extension Exercise Following ACL Reconstruction

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The Journal of Orthopaedic and Sports Physical Therapy (*JOSPT*) published a clinical viewpoint article in September 2020 authored by Drs. Noehren and Snyder-Mackler, entitled "Who's Afraid of the Big Bad Wolf? Open-Chain Exercises After Anterior Cruciate Ligament Reconstruction."[1] In this article, they advocate for the use of open-chain exercises post anterior cruciate ligament reconstruction (ACLR), using the fairy-tale of the "Three Little Pigs" as a metaphor to validate their viewpoint. As noted in the *JOSPT* clinical viewpoint of Drs. Noehren and Snyder-Mackler, they favor the use of open kinetic chain (OKC) exercises to strengthen the quadriceps post-surgery. In contrast, we are concerned about our patients performing OKC knee extension exercises with significant resistance in unsuitable range of motion (ROM) and at inappropriate time frames during the rehabilitation process following ACLR surgery. This clinical viewpoint discusses the concerns with using OKC knee extension exercises and strategies to ensure safe, effective quadriceps strengthening post-ACLR.

There is no doubt, as the authors point out, that quadriceps strength and limb symmetry are essential to the restoration of adequate knee function after ACLR, particularly as it relates to the ability to return to sport, incidence of subsequent knee injury, and the long-term development of osteoarthritis.[1–3] OKC knee extension exercises can be used safely following ACLR and must be an integral part of the rehabilitation process. Fleming et al[4] reported similar ACL strain values with OKC knee extension and CKC squats with very load resistance loads. We routinely prescribe this exercise for our patients following ACL surgery. However, being too aggressive (maximum effort or high force exercise) can be deleterious to the integrity of the ACL graft post-operatively and lead to patellofemoral pain complications.[5]

OKC knee extension when used inappropriately can be harmful to the post-operative integrity of the graft because of the unopposed anterior shear forces placed on the graft. Wilk et al[6] reported during isotonic open chain knee extension there is minimal to no hamstring muscle activity, and therefore no co-contraction. Furthermore, near terminal knee extension (40 to 0 degrees of knee flexion), the amount of quadriceps force produced to extend the knee joint is 3-4 times greater, thus resulting in higher ACL strain. Co-contraction of the quadriceps and hamstrings is important in order to reduce anterior tibiofemoral shear forces and ACL strain.

Increased load results in an increased amount of strain placed on the ACL.[7,8] Beynnon et al[7] placed strain gauges into normal subject's ACLs, reporting the highest amount of in vivo ACL strain from 40 to 0 degrees, and found that as resistance increased, so too did the amount of strain placed on the ACL. Grood et al[8] reported that very large quadriceps forces are needed to perform the last 15 degrees of OKC knee extension, and the quadriceps forces increased significantly with added resistance. It has been theorized that as resistance increases, ACL strain incrementally climbs.[4,9,10] These forces can be especially detrimental in reconstructions using hamstring grafts due to soft tissue fixation and with allografts, both of which are more susceptible to creep or graft stretch-out. Beynnon et al[11] reported on serial knee laxity test results utilizing accelerated compared to non-accelerated rehabilitation programs following ACL reconstruction. The investigators reported that subjects had an increase in knee laxity when leg extensions were increased in both groups. Thus, care should be exhibited when increasing loads are applied to the leg during OKC knee extension exercises, especially in the 40 to full extension range of motion.

Another closely associated consideration in the appropriate use of resisted OKC knee extension exercises is the significant reaction force and stress placed on the patellofemoral joint in a population that may be prone to

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developing anterior knee pain. Steinkamp et al[12] and Escamilla et al[13] both found that the patellofemoral joint reaction and compressive forces were significantly greater between 50-0 degrees of knee flexion during the OKC knee extension exercise when compared to CKC exercises. With the patellofemoral contact surface area significantly decreased near full extension, and the quadriceps forces significantly increased in this range, the patellofemoral joint may be more susceptible to injury during heavy resisted OKC knee extension.

A frequently seen complication following ACLR is rehabilitation-induced anterior knee pain. Because this complication is difficult to resolve once it is established and can result in deleterious effects on both continued rehabilitation and functional outcomes, the development of anterior knee pain during rehabilitation must be avoided at all costs. In our opinion the judicial use of OKC knee extension is crucial to ensuring that anterior knee pain does not develop as a primary complication during rehabilitation following ACLR.

Isokinetic OKC knee extension exercise has been shown to be safe at higher angular velocities, due to the mechanical ability of the apparatus to accommodate resistance through motion. Wilk et al[14] reported that at slower speeds, such as 60 degrees per second, there was greater anterior tibial translation than at faster speeds. At higher speeds (180 degrees/second and 300 degrees/second), less torque was produced, thus resulting in less anterior tibial translation during accommodative resistance knee extension. It is important to note that traditional isotonic knee extension is performed at approximately 60 deg/sec.

Our recommendations to the readers are to heed the moral of the three little pigs: Hard work and dedication pay off when resistive exercise is properly applied and controlled. Post-operative rehabilitation of patients who have undergone ACLR should consist of OKC and CKC exercises in combination with a focus on restoring quadriceps symmetry to the recovering limb. Patients should not perform full range OKC knee extensions with significant force for 6 to 9 months following ACLR, until the graft has incorporated into the osseous tunnels and graft maturation has occurred. OKC knee extension exercises performed at low load are safe and are safer to use from 90 to 40 degrees of knee flexion ROM. High loads from 40 to 0 degrees of knee flexion can be harmful to the knee especially for patients following ACLR or with ACL laxity.

In conclusion, our position is that rehabilitation professionals need not be afraid of the big bad wolf or the proper, appropriate use of OKC knee extension. After all, it is a useful and necessary exercise to improve quadriceps strength and a method of performing isolated muscle testing. But, like the little pig that built his house of bricks, make sure you are wise in your selection of the appropriate amount of resistance, arc of motion, time frame from surgery, and the type of patient when incorporating OKC knee extension into exercise programs for your patients following ACLR.

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REFERENCES

1. Noehren B, Snyder-Mackler L. Who's afraid of the Big Bad Wolf? Open-chain exercises after anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther*. 2020;50(9):473-475. doi:10.2519/jospt.2020.0609

2. Lepley LK. Deficits in quadriceps strength and patient-oriented outcomes at return to activity after ACL reconstruction: A review of the current literature. *Sports Health*. 2015;7(3):231-238. doi:10.1177/1941738115578112

3. Toole AR, Ithurburn MP, Rauh MJ, Hewett TE, Paterno MV, Schmitt LC. Young athletes cleared for sports participation after anterior cruciate ligament reconstruction: how many actually meet recommended return-to-sport criterion cutoffs? *J Orthop Sports Phys Ther*. 2017;47:825-833. doi:10.2519/jospt.2017.7227

4. Fleming BC, Oksendahl H, Beynnon BD. Open- or closed-kinetic chain exercises after anterior cruciate ligament reconstruction? *Exerc Sport Sci Rev*. 2005;33(3):134-140. doi:10.1097/00003677-200507000-00006

5. Luque-Seron JA, Medina-Porqueres I. Anterior Cruciate Ligament Strain In Vivo: A Systematic Review. *Sports Health*. 2016;8(5):451-455. doi:10.1177/1941738116658006l0

6. Wilk KE, Escamilla RF, Fleisig GS, Barrentine SW, Andrews JR, Boyd ML. A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *Am J Sports Med*. 1996;24(4):518-527. doi:10.1177/036354659602400418

7. Beynnon BD, Johnson RJ, Fleming BC, Stankewich CJ, Renström PA, Nichols CE. The strain behavior of the anterior cruciate ligament during squatting and active flexion-extension. A comparison of an open and a closed kinetic chain exercise. *Am J Sports Med*. 1997;25(6):823-829. doi:10.1177/036354659702500616

8. Grood ES, Suntay WJ, Noyes FR, Butler DL. Biomechanics of the knee-extension exercise. Effect of cutting the anterior cruciate ligament. *J Bone Joint Surg Am*. 1984;66(5):725-734. doi:10.2106/00004623-198466050-00011

9. Beynnon BD, Fleming BC. Anterior cruciate ligament strain in-vivo: A review of previous work. *J Biomech*. 1998;31(6):519-525. doi:10.1016/s0021-9290(98)00044-x

10. Beynnon BD, Fleming BC, Johnson RJ, Nichols CE, Renström PA, Pope MH. Anterior cruciate ligament strain behavior during rehabilitation exercises in vivo. *Am J Sports Med*. 1995;23(1):24-34. doi:10.1177/036354659502300105

11. Beynnon BD, Johnson RJ, Naud S, et al. Accelerated versus nonaccelerated rehabilitation after anterior cruciate ligament reconstruction: A prospective, randomized, double-blind investigation evaluating knee joint laxity using roentgen stereophotogrammetric analysis. *Am J Sports Med*. 2011;39(12):2536-2548. doi:10.1177/0363546511422349

12. Steinkamp LA, Dillingham MF, Markel MD, Hill JA, Kaufman KR. Biomechanical considerations in patellofemoral joint rehabilitation. *Am J Sports Med*. 1993;21(3):438-444. doi:10.1177/036354659302100319

13. Escamilla RF, Fleisig GS, Zheng N, Barrentine SW, Wilk KE, Andrews JR. Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. *Med Sci Sports Exerc*. 1998;30(4):556-569. doi:10.1097/00005768-199804000-00014

14. Wilk KE, Andrews JR. The effects of pad placement and angular velocity on tibial displacement during isokinetic exercise. *J Orthop Sports Phys Ther*. 1993;17(1):24-30. doi:10.2519/jospt.1993.17.1.24