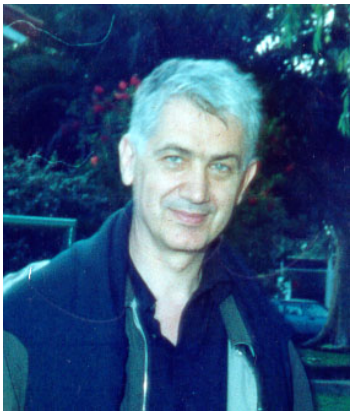
Rotational Instability of the ACL Injured and Reconstructed Knee in Low and High Demanding Activities. A 3-D Motion Analysis Study

Anastasios Georgoulis MD. Associate Professor,
Head of Arthroscopy and Sports Medicine,
Dept. of Orthopaedic Surgery.
Director of Orthopaedic Sports Medicine Center,
University of Ioannina. Greece.

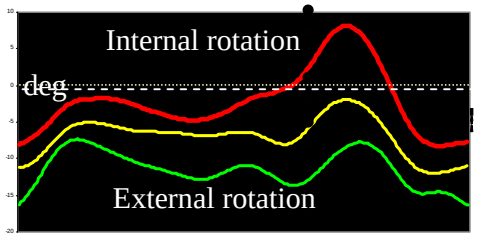


The subject of modified gait patterns after ACL injury and reconstruction is very interesting; an important part of the research society is concentrated on this subject. The ability of the ACL and ACL graft to withstand anterior tibial loads has been investigated extensively. There is limited research however, focusing on the ACL as a stabilisator when a combined rotational load is applied.

There are some clinical questions that need to be answered: What is the gait pattern of a deficient knee? Which movements are abnormal and may cause cartilage damage? Does ACL reconstruction restore every pathological function to normal? These questions can be investigated objectively by using an *in-vivo* method like motion analysis. With a three-dimensional optoelectronic system we can capture the movements of reflective markers placed on selected bony landmarks of the lower limbs and pelvis. The system calculates a lot of parameters, like flexion-extension, abduction-adduction and, finally, internal-external rotation of the knee, which is our research object.

Over the last three years, we examined the internal-external rotation of the ACL-deficient and reconstructed knee in different stressful activities. We examined these subjects during walking, which is an undemanding activity, during descending and pivoting, which is a demanding activity and during subsequent pivoting after landing, an activity considered by many researchers to represent demands that are more comparable to those found during high level sports.

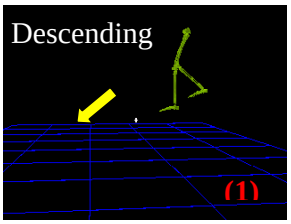
In our first project, we examined ACL-deficient and reconstructed subjects, and we found that the ACL injured knees have an increased internal rotation. This abnormal internal rotation of the tibia may be the cause of cartilage damage of the medial compartment; this is a hypothesis that has to be the subject for further investigation. However, ACL reconstruction partially restored this increased tibial rotation during walking (*Georgoulis et al. (2003) Am J Sports Med 31:75-79*).

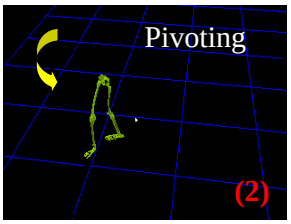


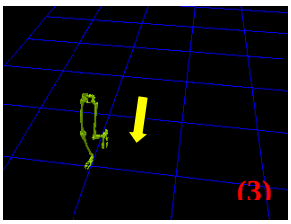
Internal – External Rotation during Walking

Red line: ACL Deficient group
Yellow line: ACL Reconstructed group
Green line: Control Group

In our second project, we investigated a very demanding activity like descending and subsequent pivoting, in order to learn whether these gait adaptations remain the same. We measured the internal-external rotation of the tibia during descending and pivoting in so-called successfully ACL-reconstructed patients which means a) no complaints in daily activities, b) KT-1000 arthrometer difference less than 2mm and c) Lysholm score more than 85 points. We evaluated the maximum range of motion of the tibial internal-external rotation during the pivoting period, and we found a significant difference (p=0.01) within the ACL reconstructed group, between the reconstructed and the contralateral intact leg. (*Ristanis et al. (2003) Knee Surg, Sports Traumatol, Arthrosc 11:360-365*)

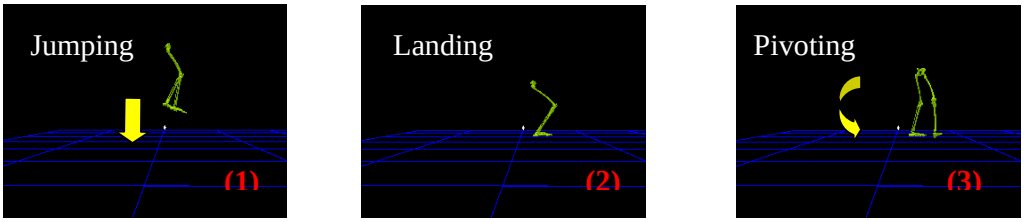






In a third project, we measured the internal-external rotation in ACL deficient and reconstructed knees after landing and subsequent pivoting. We selected landing as the task, because it

represents an activity that places higher demands on the knee than walking, jogging or stair climbing. In addition, we combined this stressful activity with subsequent pivoting to further increase rotational loads on the knee. Such a task is considered by many researchers to represent demands that are more comparable to those found during high-level sports like basketball. Our results revealed significant differences between the reconstructed leg of the ACL group and the healthy control, and between the deficient leg of the ACL deficient group and the healthy control. We also found no significant differences between the deficient leg of the ACL deficient group and the reconstructed leg of the ACL reconstructed group. *("Tibial rotation remains a problem one year after ACL reconstruction during high demanding activities" submitted for publication)*



Our studies show that ACL injury leads to abnormal internal-external rotation of the knee joint, during both, low and high demanding activities. Although ACL reconstruction restores anterior tibial translation, does not seem to fully restore normal movement, especially during loading and extreme rotation conditions. Our findings indicate that current ACL reconstruction procedures improve tibial rotation in low demanding rotational activities like walking, but fail to rotationally stabilize the knee when higher loads are applied.

The results from our study, provides support to other studies, which indicated that ACL reconstruction does not fully restore ACL function. Andriacchi et al. dynamically assessed the functional outcome of patients who had undergone ACL reconstruction and found that successfully ACL reconstructed patients displayed virtually no abnormality during low demanding activities, but noticed however, that with higher demanding activities like pivoting or jogging, persistent gait adaptations were present.

A possible explanation for these findings is that the ACL reconstruction unfortunately does not re-establish the anatomy of the ACL. Unlike the patellar tendon that has a more uniform anatomy, ACL consists of 2 major bundles that exhibit different patterns during motion. The anatomic complexity of the ACL has not been reproduced by current ACL reconstruction procedures. A two-bundle graft is now being used by some surgeons to simulate better the morphology of the original ACL, but this technique has not been investigated extensively. A recent *in-vitro* study by Woo et al. showed that the placement of the tunnel at 10 or 2 o'clock provides better functional stability in terms of internal-external rotation than a placement at 11 or 1 o'clock.

Currently, the success level of an ACL reconstruction is clinically assessed via static measurements of anterior tibial translation (KT 1000 arthrometer). With our study, we emphasized the need to develop an objective measure to assess functional dynamic stability of the knee after surgery, especially in regard to tibial rotation, in order to improve clinical practice.

In conclusion, the ACL reconstruction doesn't fully restore stability of the knee in terms of internal-external rotation of the tibia, even if the pathological anterior translation of the tibia is significantly restored. Improvement of current techniques and development of new surgical procedures or grafts should also contribute in restoring internal-external rotation and not only anterior translation.

ACKNOWLEDGEMENTS

The author gratefully acknowledges Ristanis Stavros MD, Moraiti Tina MD, Tsepis Ilias PhD, Msc, Siarava Elia MS and Giakas Giannis PhD Bioengineering, from the Orthopaedic Sports Medicine Center, University of Ioannina and Nick Stergiou, PhD, Associate Professor from the HPER Biomechanics Laboratory of the University of Nebraska at Omaha, USA, for their invaluable assistance.

REFERENCES

1. Brandsson S, Karlsson J, Sward L, et al. (2002) Kinematics and laxity of the knee joint after anterior cruciate ligament reconstruction. Pre- and postoperative radiostereometric studies. *American Journal of Sports Medicine 30:361-367*
2. Bush-Joseph CA, Hurwitz DE, Andriacchi T, et al. (2001) Dynamic function after anterior cruciate ligament reconstruction with autologous patellar tendon. *American Journal of Sports Medicine 29:36-41*
3. Georgoulis AD, Papadonikolakis A., et al. (2003) Three-dimensional tibiofemoral kinematics of the anterior cruciate deficient and reconstructed knee during walking. *American Journal of Sports Medicine 31:75-79*

4. Kanamori A, Zeminski J, Woo SL, et al. (2002) The effect of axial tibial torque on the function of the anterior cruciate ligament: a biomechanical study of a simulated pivot shift test. *Arthroscopy 18:394-398*
5. Loh J, Fukuda Y, Woo SL, et al. (2003) Knee stability and graft function following anterior cruciate ligament reconstruction: Comparison between 11 o'clock and 10 o'clock femoral tunnel placement. *Arthroscopy 19:297-304*
6. Ristanis S, Giakas G, Georgoulis AD et al. (2003) The effects of anterior cruciate ligament reconstruction on tibial rotation during pivoting after descending stairs. *Knee Surg, Sports Traumatol, Arthrosc 11:360-365*
7. Woo SL, Kanamori A, Zeminski J, et al. (2002) The effectiveness of anterior cruciate ligament reconstruction by hamstrings and patellar tendon: a cadaveric study comparing anterior tibial load vs rotational loads. *Journal of Bone & Joint Surgery - American Volume 84-A:907-914*
8. Yagi M, Wong EK, Kanamori A, et al. (2002) Biomechanical analysis of an anatomic anterior cruciate ligament reconstruction. *American Journal of Sports Medicine 30:660-666*