

A NEW METHOD FOR ASSESSMENT OF FUNCTIONAL STABILITY AT THE KNEE JOINT

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INTRODUCTION: Muscle forces are transmitted by the joints to the movement of the body. Sometimes high muscle forces are used, especially in sports practice. To stabilize the arthron, it is necessary to train the musculature in a functional way. Knowledge of the stability of the arthron during its function in athletic use is helpful to prevent the arthron from overuse or injury. The knee joint frequently becomes unstable due to disruption of the cruciate ligaments. Several methods and devices were developed to test the amount of the tibial translation. Among other things, tibial translation depends on the status of the cruciate ligaments. When the cruciate ligaments are examined, the patient usually sits down or lies on the back with the leg unloaded and the knee joint muscles relaxed (DANIEL et al. 1985, ANDERSON/LIBSCOMP 1989). The examination focuses on the passive stability of the knee joint. Measurement of the passive stability of the ankle joint cannot give an exact description of the active stability of the ankle joint during functional situations (GOLLHOFER et al. 1993, LOHRER et al. 1993, SCHEUFFELEN et al. 1993). Measurement of the functional stability of the knee joint gets more and more a subject of interest (LYSHOLM et al. 1994, PFEIFFER et al. 1996). At the same time the examination methods that are used remain the same as those used during examination of passive stability. We have developed a device to measure the tibial translation of the knee joint. The purpose of the study was to test our new device and the corresponding method in a simple functional situation like standing and to measure the functional stability of the knee joint. We measured the size of the tibial translation and the reflex activities of the knee joint muscles in dependence on acl-status, load of the leg and size and dynamic of the applied mechanical stimulus.

METHODS: Functional stability of the knee joint represented by the amount of the tibial translation and the muscle function was measured. In our investigations we induced an anterior drawer while the patients were standing upright with the knees slightly bent. To evoke any reflex-activity at the knee-joint muscles, we induced the anterior drawer with a falling weight. We compared the injured and the uninjured knee of acl-deficient subjects after acl-reconstruction and rehabilitation (N=12) with one knee of normal healthy subjects (N=12). The force, the knee joint angle and the EMGs of hamstrings and quadriceps were recorded. With our new device the anteroposterior shift of the tibia was measured. The load of the leg (loaded/unloaded) and the force applied to evoke the drawer (100N/200N) were varied. To measure the anterior tibial translation, we induced the pulling force slowly, to measure the reflex activity of the knee joint muscles the pulling force was induced rapidly. As the well-known methods and devices were not developed for measurement in functional situations, we developed a new device. The device consists of two linear potentiometers fixed in a frame. The frame is applied to the

shank. One linear potentiometer is connected to the patella, the other is connected to the tibia. The potentiometers are mounted parallel to each other and also parallel to the tibial plateau. The upper potentiometer measures the movement of the thigh in relation to the frame. The lower potentiometer measures the movement of the shank in relation to the frame. Movement of the device in relation to the shank cannot be excluded, when the subject is running or jumping. Especially movement between device and shank in the sagittal plane, which is the measurement plane, could cause mistakes during measurement. Therefore the lower potentiometer is necessary to prevent mistakes. The tibial translation in relation to the femur is calculated as the difference between the movement of the thigh and the shank in relation to the frame. The device was validated in vitro with radiography of a cadaver specimen.

Tibial Translation: To measure the tibial translation, a weight was fixed with a rope guided by a roll at the shank of the standing subject in order to induce an anterior drawer. Lifting and lowering of the weight was performed slowly (4-5s), so that the shank moved slowly in the antero – posterior direction. We used two different weights (10kg and 20kg) to vary the force (approximately 100N and 200N). The force was recorded with a force transducer (Kistler). The subjects were asked to fix their knee joint angle in order to prevent rotatory movement of the joint. The joint angle was recorded with a goniometer (Penny&Giles).

Muscle Function: Corresponding to the experimental design described above, we induced the anterior movement of the shank with a falling weight (2,5kg; 1,5m) pulling at the rope. In order to limit the force (approximately 100N and 200N) pulling at the shank, we fixed a synthetic protection between the rope and the force transducer at the shank. To document the reflex reaction of the musculature depending on the destabilizing stimulus, we recorded the EMGs of Mm gastrocnemius medialis, biceps femoris, semitendinosus, rectus femoris, vastus medialis and vastus lateralis.

RESULTS: Tibial Translation: The recorded tibial translation can be figured as a function of the force pulling at the shank.

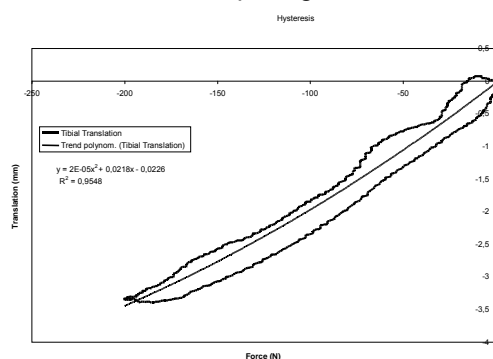


Figure 1: Anterior tibial translation (mm) as a function of force (N)

The drawer reached a maximum of 6.0mm under the condition leg unloaded/heavy weight (Mean = 2.7mm; Std. Dev. = 1.9mm). There was no significant difference in anterior drawer among the subjects with ACL-reconstruction and the healthy

subjects. The tibial translation was more dependent on the force pulling at the shank than on the load of the leg.

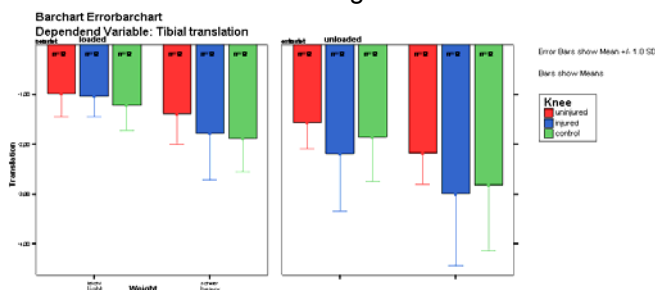


Figure 2:

Maximum anterior tibial translation (mm) depending on load of the leg (loaded/unloaded) and pulling weight (light/heavy)

Muscle Function: Approximately 33ms after initial increase in force, the synthetic protection has torn off and the maximum force was reached. After 60 - 70ms reflex activity was recorded in all muscles. The reflex latency, especially of the knee bending muscles, varied significantly, from the injured knee of the experimental group, on one hand, and the uninjured knee of the experimental group and the control group, on the other hand.

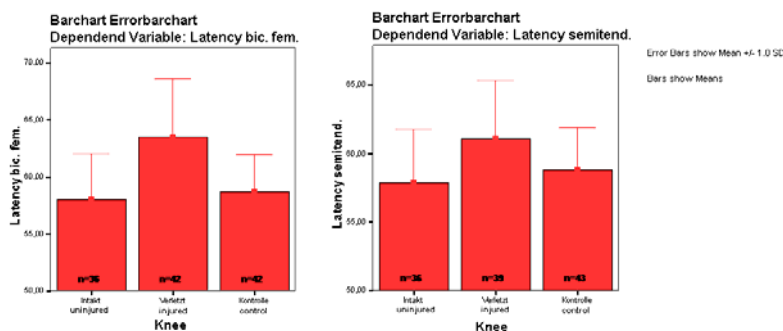


Figure 3: Reflex latencies (ms) of biceps femoris and semitendinosus

The magnitude of the reflex activity represented by the EMG amplitude and the integrated EMG did not vary among the knees and the groups, but had a tendency to vary with the load of the leg. Amplitudes and integrals of the knee bending muscles increased when the leg was unloaded, while the amplitudes and the integrals of the knee extending muscles increased when the leg was loaded.

CONCLUSIONS: Tibial Translation: There was no significant difference among the experimental and the control group concerning the tibial translation in the functional situation of the experiment. The subjects of the experimental group were all successfully reconstructed and rehabilitated. They have all returned to their former sports activities and can be considered mechanically stable in functional situations. The small translations we have measured in comparison to other authors (DANIEL et al. 1985, RIEDERMANN et al. 1991) are the result of the experimental design. Compressive forces in the knee joint as a result of the loaded leg make an additional contribution to stability of the joint. The posture (standing upright with the

knees slightly bent) causes muscle forces which also increase the joint compression and the stability of the knee joint. Several devices and methods for examination of knee joint stability are known (STROBEL et al. 1995). Usually they are designed for examination of passive stability. With our new device and the corresponding method, we are able to measure the tibial translation of the knee-joint exactly under functional conditions.

Muscle Function: To measure the muscle function, we did not record any muscle forces or power output, because muscle function in connection with joint stability seems rather to be a question of reflex activity than of voluntary contraction. For example, in alpine skiing the time period between mechanical impact and destruction of morphological structures in accidents lasts about 40ms (JOHANSSON et al. 1990). Therefore we recorded the EMGs to document the reflex activity of the knee joint muscles in dependence on a mechanical stimulus. Morphological investigations could prove the existence of sensory structures in most of the so called passive structures of the knee joint (JOHANSSON et al. 1991; GRABINER 1993). Their physiological role in connection with the knee stabilizing musculature has been documented (SOLOMONOW et al. 1987; GRABINER et al. 1994). Disruption of the anterior cruciate ligament reduces the passive stability of the knee joint and leads to a loss of sensory functions. Passive stability can be reconstructed by surgery, but this may lead to further destruction of sensory structures and additional decrease in sensory function (SJÖLANDER 1989). The sensory function of the reconstructed knee joint and the reflex activity of the knee joint muscles remain changed over a period of time (PFEIFFER 1996). In our investigation, the reflex latencies of the knee stabilizing muscles were significantly prolonged in the injured legs of the experimental group. The muscular contribution to knee joint stability can be estimated by recording reflexes of these muscles with the EMG. Further investigations are needed to compare different methods of acl-reconstruction, rehabilitation and bracing. The experimental designs should become more and more dynamic to estimate the stability at the knee-joint under functional conditions, which are relevant in sports practice. Future investigation will focus on measurement of the drawer, while the patients are walking, running, jumping or bicycling.

REFERENCES:

- Anderson, A. F., Libscomb, A. B. (1989). Preoperative Instrumented Testing of Anterior and Posterior Knee Laxity. *Am. J. Sports Med.* **17**, 387-392
- Daniel, D. M. et al. (1985). Instrumented Measurement of Anterior Knee Laxity in Patients with Acute ACL Disruption. *Am. J. Sports Med.* **13**, 401-407.
- Gollhofer, A., Scheuffelen, C., Lohrer, H. (1993). Neuromuskuläre Stabilisation im oberen Sprunggelenk nach Immobilisation. *Sportverl. - Sportschad.* **7**, 23 – 28.
- Grabiner M. D. (1993). Ligamentous Mechanoreceptors and Knee Joint Function: The Neurosensory Hypothesis. In M. D. Grabiner, *Current Issues in Biomechanics* (pp. 237 – 254). Champaign, Ill.: Human Kinetics Publishers.
- Grabiner M. D., Koh, T., Draganich L. F. (1994). Neuromechanics of the Patellofemoral Joint. *Med. & Sci. in Sports & Exerc.* **1**, 10 – 21.
- The complete literature list is available from the author. E-Mail: Sven.Bruhn@sport.uni-stuttgart.de*