Quadriceps Moment Arm with Migration of Tibiofemoral Contact Point to Evaluate ACL Reconstruction during Rehabilitation

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Abstract- Anterior Cruciate Ligament injury is usually reconstructed in young patients who undergo rehabilitation. We have applied a novel intrument based on videofluoroscopy and Baltzopoulos´ method to estimate the Center of Rotation and secondarily to calculate the instanteneous Moment Arm as extension progresses. Data from 6 patients show that the normal knee behaviour in terms of Moment Arm length is restored by reconstruction to a great extent, except for an apparent tighter situation towards full extension.

Keywords-ACL; Kinematics of the Knee; Moment Arm; Quadriceps

INTRODUCTION

After reconstructive surgery of the Anterior Cruciate Ligament (ACL) and during rehabilitation, clinicians need a quantitative evaluation of the knee joint. Presently only qualitative and approximate maneuvers are commonplace throughout the world. Static imaging such as X rays, CT or MR are also used in clinical settings. Anatomical structures are precisely described but there is no possible dynamic functional evaluation, which is the core problem of ACL lesions [1] [2]. To study the kinematics of the knee, sophisticated clinical research environments can sometimes count on video fluoroscopic analysis (VFA) [10].

Diagnostic tests to confirm ACL tears include the Lachman test, the pivot shift test and the use of the KT 1000/2000 arthrometer [5]. An ACL injury results in functional impairment of the knee [7] and of the overall lower limb function [8], which may lead to the indication of reconstructive surgery. There is a need to put numbers to both the pre surgical and reconstructed conditions, since the clinician feels a looser knee joint when ACL is not operational and then perceives a "tied up" joint after surgery, sometimes beyond expectations. This lack of certainty and of an objetctive measurement led us to develop and compare existing methods, such as the TFCP, the instantaneous rotation point (Rouleaux) and now the moment arm.

The Quadriceps Moment Arm (QMA) is a kinematics parametre which quantifies the geometry of action of muscles and is directly related to movement efficiency of the knee. This is so because a short Arm requires a greater force for the same work done than with a longer Arm. The rupture of the ACL, by altering the relative distance between articular surfaces, inevitably alters the QMA, a condition quickly compensated by muscle adaptation. Normal physiology describes moreover that the QMA varies during flexo-extension movements, There is a number of published methods to determine the QMA during knee joint extensiónr [3] [4] [5] [6] [7].

Several papers refer to QMA in a variety of conditions, but none are used as clinical routine practice. [8] [9] . We are developing a method to study and follow up knee joint rehabilitation, starting with TFCP and now including QMA [2].

MATERIAL AND METHODS

Specifications of an Evaluation Instrument: CINARTRO

In order to obtain a proof of concept and to validate the method, an experimental set up was built and used to analyze results on real data. A C-arm X-ray equipment with video data acquisition hardware was used with software to describe the migration of CoR on the tibia (CINARTRO specifications in given in Santos[10]).

Description of Patients

Six male patients were studied (25 ± 3.6 years, range 18-35 years), all had an isolated tear of the ACL three to six months earlier (no ligament nor meniscal injury); closed knee injury; Score of the International Knee Documentation Committee -IKDC- equal to A; healthy contralateral knee. "*Bone-patellar tendon-bone*"

surgical technique was performed on all of them. The first X-ray exploration was done three months after injury (Injured and contralateral knees) and the second X-ray exploration six months after reconstruction (only reconstructed knee). Approval of the Ethics Committee of the Universidad de la República was obtained for this study.

Data Acquisition and processing by CINARTRO

The 30 videofluoroscopic images were analised one by one, by the same person (DS) in order to give the software the anatomical points necessary for geometrical calculations. CINARTRO software uses both lines -straight line for tibial plateau and three points on the femoral condyle projection- to determine the CoR following the method described by Baltzopoulos [3]. Additionally the tendon outline was indicated for CINATRO to draw its direction, which allows to calculat geometrically the Moment Arm with respect to CoR.

To better enhance differences and reduce eventual inaccuracies which can be taken as similar to "noise" in the distribution of data, we grouped the measurements in three positions during the last portion of hanging leg extension from 45 º to full extension. With respect to the hanging leg position angle defined as 90 º, we determined 135 º, 150 º, 165 º and full extension 180 º. The Moment Arm at these angles are mean values of the neighbouring values taken from the series of 30 VFC images.

Statistics

We used Friedman´s Test to assess significant differences and compared injured and intact knees further using Wilcoxon-Nemenyi-McDonald-Thomson`s Multiple Comparisons. A p of < 0.05 was considered significant.

RESULTS

The Moment Arm varies as the knee joint rotates towards full extension, as shown in Table 1. The magnitude of this modification also varies froma normal contralateral knee to either an injured knee or the same knee after surgical reconstruction.

Table 1. CINEARTHROGRAPHIC EVALUATION OF 6 PATIENTS IN TERMS OF QUADRICEPS MOMENT ARM

Table Head	**Position of leg**			
	135 º	***150 º***	***165 º***	***180 º Full extension***
Healthy	**39 ±3.0**	**45 ±5.4**	**43 ±4.8**	**44 ±3.2**
Injured	**47 ±5.1**	**51 ±7.6**	**62 ±4.8**	**53 ± 4.5**
Reconstructed	**38 ±2.9**	**41 ±3.8**	**40 ±2.2**	**37 ±1.7**

a. *Moment Arm given in mm from patellar tendon to center of rotation. Mean ± SD.*

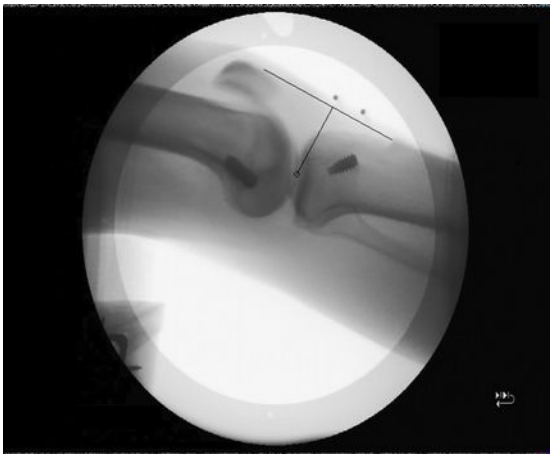

Figure 1. One image of the Cineartrography by Video fluoroscopy. Note the tendon line and the center of rotation, by CINARTRO software besed on points defined by the user on screen.

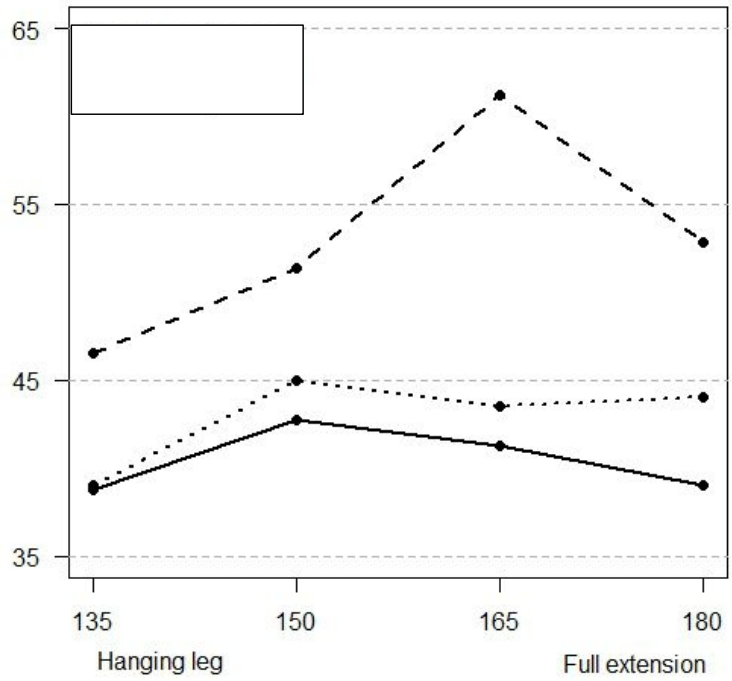

Figure 2. Moment Arm Length (mm) as a function of leg position (degrees) towards full extension. CINARTRO software allows to distinguish the normal knee (dotted line) from loose (dashed line - injured ACL) or tight (solid line - reconstructed) knees.

Discussion

We have calculated the moment arm of six patients, in different knee joint conditions. The normal contralateral knee of these otherwise healthy young men, has a behaviour described in figure 2, where at the end of the extension, an extra freedom is granted to the tibia, enabling a "kick to the moon" effect as full extension approaches. This is due to the rotula, which keeps the tendons away from the condyles as extension increases. An injured knee on the other hand appears to have a different behaviour, as the moment arm is increased throughout the rotation, which is somehow expected due to the fact that the ACL retention os lost. When surgical repair is performed, the same knee behaves differently, in quite a similar way to the normal knee, except that the last portion of the extension is constrained by a shorter arm (37 mm in lieu of 44 mm), giving probably a different character to the movement and the muscular effect on it. This finding has to be confirmed in future studies, applied to a greater numer of patients, either in active rehabilitation follow up or "surgical repair-only" patients.

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