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Tibial rotation in anterior cruciate ligament reconstructed knees during single limb hop and drop landings

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ABSTRACT

Background: Alterations in knee joint kinematics have been suggested as a potential mechanism that influences the development of osteoarthritis of the knee after anterior cruciate ligament reconstruction. Whilst previous work has shown changes in internal–external tibial rotation during level walking, many patients aim to return to high impact activities following surgery. This study examined tibial rotation during single limb hop and drop landings in anterior cruciate ligament reconstructed knees compared to a control group, and also evaluated the influence of graft type (hamstring or patellar tendon).

Methods: In 48 participants (17 patellar tendon graft, 18 hamstring graft and 13 controls) internal–external rotation was measured during single limb hop and drop landings in a gait laboratory at mean of 10 months after surgery.

Findings: There was no difference between the two graft types and both patient groups had less internal rotation when compared to the control group. For 60% of patients, internal rotation values were at least 5° less than the control group mean.

Interpretation: Anterior cruciate ligament reconstructed knees with both hamstring tendon and patellar tendon grafts show altered rotational kinematic patterns during high impact dynamic load activities.

1. Introduction

The anterior cruciate ligament (ACL) plays a key role in the kinematics of the tibiofemoral joint. It controls anterior–posterior tibial translation as well as internal–external rotation (Andersen and Dyhre-Poulsen, 1997; Fu et al., 2000). Rupture of the ACL can therefore significantly affect tibiofemoral joint motion and numerous studies have noted abnormal knee movement patterns in patients following ACL rupture (Andriacchi and Dyrby, 2005; Gao and Zheng, 2010; Georgoulis et al., 2003; Hurd and Snyder-Mackler, 2007; Li et al., 2006).

It has been suggested that abnormal knee kinematics may play a role in the initiation and progression of knee osteoarthritis by changing cartilage load distribution (Andriacchi and Mündermann, 2006; Andriacchi et al., 2006; Stergiou et al., 2007). Specifically, kinematic shifts are proposed to cause increased loading to areas not conditioned to frequent load bearing. If the tissue cannot adapt to the new loading pattern, degenerative metabolic changes may occur. In this model, changes in the mechanical environment precede biological changes and emphasise the importance of restoring knee biomechanical patterns to avoid premature osteoarthritis after ACL injury (Chaudhari et al., 2008).

ACL reconstruction is a common procedure and generally allows a return to sporting activities. Biomechanical studies have nonetheless shown that this surgery does not necessarily restore normal tibial rotation (Gao and Zheng, 2010; Papannagari et al., 2006; Ristanis et al., 2005; Scanlan et al., 2010; Tashman et al., 2004, 2006; Webster and Feller, 2011). For instance, with regard to level walking, recent studies have shown that the ACL reconstructed knee is less internally rotated (offset towards external tibial rotation) during stance with respect to the uninjured contralateral knee and control groups (Scanlan et al., 2010; Webster and Feller, 2011).

This may also be the case for more strenuous, high impact activities, which is significant because it is usually these types of activities to which patients aim to return. Tashman et al. (2004; 2006) have identified alterations during downhill treadmill running whereby ACL reconstructed knees were shown to be more externally rotated. Other studies have also shown the inability of ACL reconstruction to restore tibial rotation during pivoting activities (Chouliaras et al., 2007; Georgoulis et al., 2007; Ristanis et al., 2005, 2009).

Single limb hop and vertical drop landings have previously been investigated as they simulate sport components and induce relatively large vertical ground reaction forces. Whilst there have been a number of studies which have shown kinematic alternations during single limb landing in the sagittal plane following ACL reconstruction (Gokeler et al., 2010; Vairo et al., 2008; Webster et al., 2004), there is only one study to date to have investigated rotational kinematics

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during a hop landing activity (Deneweth et al., 2010). Deneweth et al. (2010) used high speed radiography to assess knee joint kinematics during single limb hop landings in 9 ACL reconstruction patients at a mean 4 months following surgery. Similar to previous studies, they found the reconstructed knee to be less flexed during the landing phase; they also found the reconstructed knee to be less internally rotated than the contralateral knee. The authors concluded that after ACL reconstruction, knee joint kinematics were significantly different from the uninjured knee during the hop landing task and that such alterations may impact on knee joint degeneration. The potential importance of these findings highlights the need for further research in this area.

The patient group in the Deneweth et al. (2010) study was mixed with respect to graft type and the surgical technique used for the reconstruction procedure. Whilst all patients had hamstring grafts, two had an allograft and both single bundle and double bundle reconstruction techniques were performed. Although this may enhance the generalizability of the findings, it is unclear what impact these variations might have on the kinematic data. There is some evidence that variation in surgical technique, such as the placement of the femoral and tibial bone tunnels, affects gait biomechanics (Ristanis et al., 2009; Scanlan et al., 2009). Graft specific changes in knee kinematics and kinetics have also been reported in the sagittal plane during single limb hop landings between hamstring and patellar tendon grafts (Webster et al., 2005). Whilst rotational kinematics have been shown to be similar between graft types for level walking (Webster and Feller, 2011), it is unclear whether the same applies for more high impact activities.

The overall goal of this study was to examine tibial rotation during single limb hop and vertical drop landings in ACL reconstructed knees for which the surgery had been performed using a hamstring tendon or patellar tendon graft. The aim was to evaluate the influence of graft type as well as to compare both grafts to a control group. The hypothesis tested was that the tibial rotation would be similar between the two graft types and that both ACL grafts would differ from a healthy control group.

2. Methods

2.1. Participants

Thirty-five subjects who had undergone uncomplicated single bundle primary ACL reconstruction with either a central third bone patellar tendon bone autograft (n = 17) or a four strand (doubled semitendinosus/doubled gracilis) hamstring autograft (n = 18) participated. This patient group (except for one patellar tendon patient) also participated in a level walking study and have therefore been previously described (Webster and Feller, 2011).

A group of 13 control subjects with no history of lower limb pathology also participated. For control subjects to be included they had to be between 18 and 40 years and be currently participating in Category I (involving jumping, hard pivoting, cutting) or II (involving running, twisting, turning) (Noyes et al., 1989) sports on a weekly basis. The control subjects were of comparable age and current type of sport activity to the patient groups. The demographic characteristics of all the participants are shown in Table 1.

For all ACL-reconstructed subjects an arthroscopic procedure had been performed by the same experienced knee surgeon at least 6 months (mean 10 months) prior to participation. Apart from the graft type and site of harvest, the surgical technique, including graft fixation, was identical in both groups. Proximal fixation was by means of an EndoButton attached to the graft with a doubled 3 mm polyester tape and an absorbable interference screw was used for tibial fixation. Postoperatively all subjects underwent the same rehabilitation protocol as previously described (Webster and Feller, 2011). Running was allowed from 10 weeks and the commencement of sports specific drills from 3 months.

Table 1
Subject characteristics.

	Hamstring tendon graft	Patellar tendon graft	Control
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	26.6 (6)	24.0 (5)	23.1 (4)
Males:females	16:2	16:1	11:2
Height (cm)	177.7 (8.7)	178.5 (6.5)	176.5 (7.8)
Weight (kg)	79.3 (7.2)	78.2 (6.1)	72.3 (10.3)
Time injury to surgery (weeks)	11 (8.2)	13.1 (11.8)	
Range	3–32	4–29	
Time since surgery (months)	9.0 (2.4)	10.9 (2)	
Range	6–12	9–15	
Sports activity (0–100) [a]			
Pre Injury	91.6 (7.2)	92.5 (8.5)	
At time of testing	82.5 (14.6)	83.9 (17.6)	88.5 (7.7)
IKDC subjective knee score at time of testing(0–100%) [b]	82.2 (12.1)	79.7 (9.7)	98.8 (3.8)

[a] Noyes et al. (1989).
[b] Irrgang et al. (2001).

Subjects underwent physical examination and were to be excluded from the laboratory analysis if objective signs of laxity were found, as determined by either a KT-1000 arthrometer-measured side to side difference greater than 3 mm at 132 N or a positive pivot shift test. None of the 48 participants were excluded based on this testing. Subjects also completed the International Knee Document Committee (IKDC) Subjective Knee Evaluation Form (Irrgang et al., 2001) on the test day.

2.2. Procedures

Subjects were informed of the nature of the experiment and gave written consent which was approved by University Ethics Committee. Measurements of each subject's pelvis and lower limbs were obtained and reflective markers were attached to the lower limb using the standard Plug-in-Gait marker set (Davis et al., 1991; Kadaba et al., 1990).

Data were captured in the central portion of a 10-metre linoleum covered walkway using a three-dimensional motion analysis system (Vicon, Oxford Metrics Ltd., UK). Ground reaction forces were recorded from a force plate (Kistler, Winterthur, Switzerland) set in the floor of the laboratory. To obtain a reference point for the markers, a static trial was obtained with the subject in quiet standing. For this trial, a knee alignment device was used to determine the centre of the knee joint as previously described (Webster and Feller, 2011; Webster et al., 2005).

Each subject then performed two functional landing tasks which included a one legged horizontal hop and a one legged vertical drop landing. The horizontal hop consisted of a single one-legged hop from a distance equal to the subject's leg length. Leg length was defined as the distance from the tip of the greater trochanter to the tip of the lateral malleolus. For the vertical drop test the subject stood 5 cm from the edge of a 15 cm high wooden platform and performed a single one legged drop to the ground. For both activities, subjects were instructed to place their hands on their hips, hop forward and land on the same leg. They were further instructed that on landing they were to look straight ahead and stabilise as quickly as possible. Once the experimenter had judged that the subject was stable, a cue was given to notify the subject of completion of the activity. Three practice trials were performed on each leg for both tasks. During testing, six trials on both the affected and contralateral limb were performed for both the hop and vertical drop tasks.

2.3. Data analysis

Lower limb segment trajectories were filtered by fitting Woltring's quintic spline with a mean squared setting of 20 to the data prior to