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Short communication

Between-leg differences in challenging single-limb balance performance one year following anterior cruciate ligament reconstruction

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ABSTRACT

Following anterior cruciate ligament (ACL) rupture, reconstructive surgery (ALCR) is often performed to mechanically stabilise the knee, however functional deficits often persist long after surgery. Impaired single-limb standing balance has been observed in the ACLR limb compared to healthy individuals. However, it remains inconclusive as to whether these same balance deficits exist between the injured and contralateral uninjured limbs, during challenging balance tasks, and at a time when patients are permitted to return to sport. 100 adults who had undergone a primary hamstring-tendon ACLR 12 months previously (68 male; median[IQR] age: 28.1[14.1] years) performed tests of single-limb standing with the knee in a functional position of 20–30° flexion, with their eyes closed, over 20 s (Nintendo Wii Balance Board). Two repetitions were performed on the ACLR and uninjured limb. Measures of postural control included centre of pressure (CoP) path velocity, anterior-posterior and mediolateral range and standard deviation, and were averaged across the two trials. Wilcoxon signed-rank tests showed no significant between-leg differences in single-limb balance for any of the CoP measures of interest (all P values > 0.686). Further, multiple linear regression analyses showed no significant associations between concomitant meniscectomy or chondral lesions noted at the time of ACLR and measures of single-limb balance on the ACLR limb one year later (all P values > 0.213). In the context of prior research, these findings suggest bilateral balance deficits may exist prior to ACL injury, or appear post ACL-injury or ACLR. Treatment of balance deficits should therefore consider both limbs after ACLR.

1. Introduction

Anterior cruciate ligament (ACL) rupture disrupts the mechanical stability of the knee, leading to proprioceptive deficits [1]. Whilst an ACL reconstruction (ACLR) restores mechanical stability, persistent proprioceptive impairments may contribute to a failure to achieve optimal functional recovery [2]. Further, concomitant meniscectomy, and chondral lesions identified at the time of ACLR, increase the risk of post-traumatic osteoarthritis [3]; one mechanism for this may be altered neuromuscular control which could manifest as balance deficits.

Impaired single-limb standing balance has been observed in individuals after ACLR during static [4,5] and dynamic [6] tasks, when compared to healthy controls. In comparison, beyond 6 months post-ACLR, single-limb balance ability appears to be equivalent between the injured and uninjured limbs [4,5,7]. However, assessing balance performance with eyes open, where visual input can compensate for altered knee proprioception, may not be sufficiently sensitive to detect between-limb balance deficits in young active adults [4–7]. Indeed, when standing with the eyes closed, balance deficits have been observed in the ACLR

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limb [8]. As patients in that study were tested 15 days post-surgery, when effusion and pain are common, it remains unknown whether between-leg differences exist at a time when return to sport is typically permitted (i.e. 12 months post-operatively). This information is clinically important, as neuromuscular deficits, including single-limb balance control, may precede (and increase the risk of) ACL injury, thus reinforcing their capacity to predict ACL re-rupture and contralateral injury [9].

Therefore, this study investigated between-leg differences in static single-limb balance performance with eyes closed, in patients 12 months post-unilateral ACLR. We hypothesised that measures of centre of pressure (CoP) movement would be greater when standing on the ACLR limb compared to the uninjured limb. We also explored any associations between concomitant injuries at the time of ACLR and balance performance 12 months post-ACLR.

2. Methods

2.1. Participants

Adults (aged 18–50 years) who had undergone primary hamstring-tendon ACLR by one of two orthopaedic surgeons in Melbourne, Australia between July 2010-August 2011 were eligible for inclusion [10]. Patients were invited to participate at their routine 12 month surgical review, and at the time of study assessment needed to be 11–15 months post-ACLR. Exclusion criteria were: i) post-operative injury or follow-up surgery to the ACLR knee; ii) injury or surgery to the ACLR knee prior to ACL rupture; iii) history of bilateral knee injury or surgery; iv) other lower limb musculoskeletal, cardiovascular or neurological condition affecting balance or gait; v) contraindications for MRI or radiography; and vi) inability to read or speak English. The study received ethical approval before commencement and participants provided written, informed consent prior to participation. Ethical approval was granted by The University of Melbourne Human Research Ethics Committee (HREC 0931086). Details of the ACLR procedure (single-bundle, 4-strand semi-tendinosus/gracilis) and indications for concurrent meniscectomy or meniscal repair have been published [11]. Cartilage lesions identified arthroscopically were defined as present if Outerbridge score ≥2 [11]. Rehabilitation commenced from the first post-operative day with immediate weight-bearing, range of movement exercises, and progressed to a graduated program of neuromuscular retraining and return to sport.

2.2. Procedures

Participants stood barefoot on their ACLR limb on the centre of a Nintendo Wii Balance Board (WBB, Nintendo, Japan) with their eyes closed, arms folded across their chest [12], and knee flexed 20–30° [5]. The balance task was performed on both the ACLR and uninjured limb (left leg always tested first). Following a practice trial, two repetitions were performed on each leg for a period of 20 s. Given the difficulty of the task, participants were permitted to briefly touch down on the floor with their non-test leg to re-stabilise themselves, and to return to the test position as quickly as possible. CoP measures were calculated using the average of the two repetitions. The reliability of CoP measures extracted from the WBB during single-limb standing with eyes closed in healthy adults has been established [13].

2.3. Data extraction and analysis

The WBB was connected to a laptop (via Bluetooth) using custom-written software (LabVIEW 8.5, National Instruments), calibrated as detailed previously [13], and interpolated to 100 Hz and low-pass filtered at 12.5 Hz. Measures of balance included CoP total path velocity, range and standard deviation (SD) in anterior-posterior (AP) and mediolateral (ML) directions.

Table 1
Demographic, surgical and patient-reported outcomes of participants (N = 100).

Participant characteristics	Mean ± SD*
Male sex, number (%)	68 (68)
Age at the time of surgery, median (IQR) years	28.1 (14.1)
Height, metres	1.8 ± 0.1
Weight, kilograms	80.6 ± 6.3
Time from injury to ACLR, median (IQR) weeks	13.4 (20.3)
Time from ACLR to test date, median (IQR) months	12.6 (1.0)
Concomitant injuries/surgery at the time of ACLR	
• Medial meniscectomy, number (%)	21 (21)
• Lateral meniscectomy, number (%)	23 (23)
• Tibiofemoral chondral lesion, number (%)[a]	17 (17)
• Patellofemoral chondral lesion, number (%)[a]	10 (10)
Tegner Activity Scale, median (IQR)	6 (3)
Hop for Distance (Limb Symmetry Index)	86.9 (16.9)
Knee injury and Osteoarthritis Outcome Score:	
• Symptoms	82.6 ± 13.3
• Pain	90.4 ± 9.5
• Activities of daily living	96.7 ± 6.0
• Sport and Recreation	81.2 ± 16.8
• Quality of Life	67.4 ± 18.7
Knee Flexion Range of Motion (°)	131.4 ± 6.8
Knee Extension Range of Motion (°)[b]	−1.0 ± 4.2
KT1000 Anterior Knee Translation, number (%):	
• <0 mm	17 (17)
• 0–3 mm	55 (55)
• >3 mm	28 (28)

ACLR, anterior cruciate ligament reconstruction: IQR, inter-quartile range.
*Values are mean ± standard deviation (SD), unless otherwise indicated.
[a] Chondral lesion defined as Outerbridge ≥2.
[b] Negative value indicates degrees of lack of full extension.