



Case report

Anterior cruciate ligament (ACL) loading in a collegiate athlete during sidestep cutting after ACL reconstruction: A case study

Michael A. Samaan^{a,b,*}, Stacie I. Ringleb^a, Sebastian Y. Bawab^a, Eric K. Greska^c, Joshua T. Weinhandl^d^a Department of Mechanical and Aerospace Engineering, Old Dominion University, 238 Kaufman Hall, Norfolk, VA 23529, USA^b Department of Radiology and Biomedical Imaging, University of California, San Francisco, 185 Berry Street, Lobby 6, Suite 350, San Francisco, CA 94107, USA^c Department of Exercise Science and Community Health, University of West Florida, 11000 University Pkwy., Bldg. 72, Rm. 216, Pensacola, FL 32514, USA^d Department of Kinesiology, Recreation and Sports Studies, The University of Tennessee, 333 HPER Building, 1914 Andy Holt Avenue, Knoxville, TN 37996, USA

ARTICLE INFO

Article history:

Received 13 February 2016

Received in revised form 22 March 2016

Accepted 26 March 2016

Keywords:

Anterior cruciate ligament

Sidestep cutting

ACL loading

ACL reconstruction

OpenSim

Musculoskeletal modeling

ABSTRACT

Background: Athletes with anterior cruciate ligament (ACL) injuries usually undergo ACL-reconstruction (ACLR) in order to restore joint stability, so that dynamic maneuvers such as the sidestep cut can be performed. Despite restoration of joint stability after ACLR, many athletes do not return to pre-injury levels and may be at a high risk of a second ACL injury. The purpose of this study was to determine whether or not ACL loading, would increase after ACLR.

Methods: One female Division I collegiate athlete performed bilateral unanticipated sidestep cuts both before ACL injury and 27 months after ACLR. Musculoskeletal simulations were used to calculate ACL loading during the deceleration phase of the sidestep cuts.

Results: Twenty-seven months after ACLR, the athlete demonstrated higher total ACL loading in the ipsilateral limb as well as altered joint kinematics, moments, and quadriceps muscle force production. In the contralateral limb, there were no increases in total ACL loading or muscle force production yet altered lower extremity joint kinematics and moments were present after ACLR.

Conclusions: Higher total ACL loading in the ipsilateral limb of this athlete may suggest an increased risk of second ACL injury. The results of this study provide an initial step in understanding the effects of ACLR on the risk of second ACL injury in an elite athlete and suggest that it is important to develop a better understanding of this surgical intervention on knee joint loading, in order to reduce the risk of second ACL injury while performing dynamic maneuvers.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

The anterior cruciate ligament (ACL) is a mechanical stabilizer of the knee joint, as it prevents anterior tibial translation and provides mediolateral and rotational stability [1–3]. ACL reconstruction (ACLR) is commonly performed in active individuals that participate in sports requiring performance of multidirectional maneuvers [4] (i.e. sidestep cutting) in order to restore functional and anatomical joint stability [5]. Although surgical reconstruction reestablishes joint stability, it may not allow the athlete to return to pre-injury or moderate activity levels due to the possible altered neurosensory function of the ligament [6]. Rates of second ACL injury for both ipsilateral and contralateral ACL ruptures, over a five year period after ACLR, range from 12 to 17.2% [7,8]. In addition, athletes between the ages of 10 and 25 years that returned

to sport within one year of ACLR were 15 times more likely to sustain a second ACL injury of either lower extremity, compared to previously uninjured athletes [9].

Potential mechanisms of second ACL injury in athletes may be multifactorial and include altered joint kinematics [10–12], moments [12] and muscle force production [13–15] as an effect of ACLR. ACLR athletes demonstrated altered coordination variability during a sidestep cut, when compared to healthy controls [10]. Also, ACLR athletes demonstrated increased knee abduction angles and knee adductor moments during the deceleration phase of the sidestep cut [12]. On the contrary, athletes that underwent ACLR did not demonstrate any differences in hip frontal and transverse plane kinematics, during running, when compared to healthy controls [11]. Hip abduction and external rotation strength were similar between ACLR athletes and healthy controls [11] yet reduced quadriceps strength was exhibited as an effect of ACLR when compared to healthy controls [13] and the contralateral limb [14]. In contrast, quadriceps strength returned to approximately 90% within 24 months when compared to the contralateral limb [15]. It is important to understand the effects of ACL reconstruction on risk

* Corresponding author at: Department of Radiology and Biomedical Imaging, University of California, San Francisco, 185 Berry Street, Lobby 6, Suite 350, San Francisco, CA 94107, USA. Tel.: +415 514 8266.

E-mail address: michael.samaan@ucsf.edu (M.A. Samaan).

of second ACL injury, yet analysis of mechanical and physiological measures such as ACL loading and muscle forces during performance of dynamic maneuvers are difficult to assess *in vivo*.

Musculoskeletal modeling allows for the determination of physiological parameters that are difficult to measure *in vivo* during performance of dynamic maneuvers such as single leg landings [16–18], sidestep cuts [19–22] and stop-jumps [23,24]. In particular, musculoskeletal modeling was used to calculate ACL loading, using muscle and joint contact forces estimated from musculoskeletal simulations, on risk of ACL injury during a sidestep cut [19,20]. It is important that a similar approach is used to assess risk of second ACL injury as an effect of ACLR during performance of a sidestep cut. Therefore, the purpose of this study was to assess the functional performance and risk of second ACL injury of an elite athlete that underwent ACLR. It was hypothesized that the athlete will exhibit increased ACL loading, during the deceleration phase (first 50 ms) of the sidestep cut, in both the ipsilateral and contralateral limbs.

2. Methods

2.1. Study participant

In this single case study design, a female Division I collegiate soccer player (mass: 59.2 kg, height: 1.62 m, age: 20 years old) ruptured the ACL of the non-dominant limb, via a contact mechanism during a soccer match. Surgical reconstruction was performed within three weeks of the injury using a patellar tendon allograft. The athlete underwent rehabilitation by the University Athletic Training staff and was cleared by the treating physician to return to play approximately 10 months post-ACLR. The participant provided written informed consent prior to participation in this study. This study was approved by the University Institutional Review Board.

2.2. Experimental data collection

The participant performed unanticipated sidestep cuts using both limbs prior to injury, and these data were used to assess the effects of ACL reconstruction on lower extremity function. The participant was free from lower extremity injuries during the six months prior to testing at the pre-injury time point. The protocol used to perform the unanticipated sidestep cuts (described below) at the pre-injury time point, was used at the post-surgery time point as well.

In this study, the participant returned to the laboratory 27 months post-ACL reconstruction to perform unanticipated sidestep cuts. Segment tracking was performed using 50 light-reflecting skin mounted markers placed bilaterally. Individual markers, used for static calibration, were placed at the acromion processes, iliac crests, greater trochanters, medial and lateral femoral epicondyles, medial and lateral malleoli, the first and fifth metatarsal heads and were removed prior to performing the unanticipated sidestep cuts. Rigid marker plates, consisting of four markers each were placed on the thoracic spine and pelvis, and bilaterally on the femurs, shanks and heel shoe counters. Marker trajectories were collected at 200 Hz using an eight camera motion capture system (Vicon Motion Capture Systems Inc., Oxford, UK). Ground reaction force data were collected simultaneously at 2000 Hz using two Bertec force plates (Bertec Corp., Columbus, OH).

A visualization software, representing soccer-based situations in a laboratory setting [25], was used to trigger the direction in which the participant performed the unanticipated sidestep cuts. A light beam was placed two meters prior to the force plate. Upon breaking the light beam, a stimulus was displayed which indicated the direction in which the participant should perform the sidestep cut. The stimulus was presented 50 ms after breaking the light beam. The participant performed three successful unanticipated sidestep cuts using both limbs. A one minute recovery interval was provided in between each sidestep cut in order to reduce the effects of fatigue. The participant was

instructed to strike the force plate with the appropriate foot and then cut to the contralateral side at an angle of $45 \pm 5^\circ$. Markings on the floor provided the participant with a one meter wide path to ensure an exit trajectory of $45 \pm 5^\circ$ upon cutting to the contralateral side. The approach speed of the participant was controlled to be within 3.5 to $4.5 \text{ m} \cdot \text{s}^{-1}$ using a Brower timing gate system (Brower Timing Systems, Draper, UT). A sidestep cut was defined as successful if the participant maintained the approach speed, the participant's entire foot made contact with the force plate and the participant maintained a $45 \pm 5^\circ$ angle upon propulsion from the force plate. If the sidestep cut was deemed unsuccessful, the participant was asked to perform another trial of the sidestep cut.

2.3. Data reduction

All marker coordinates were filtered using a fourth order, zero lag, low-pass Butterworth filter with a cutoff frequency of six hertz while the ground reaction force data were filtered using a similar filter with a cutoff frequency of 50 Hz [22,26]. An eight segment kinematic model composed of the torso, pelvis and bilateral thighs, shanks and feet was created using Visual3D (v5.00.31, C-Motion Inc., Rockville, MD). The hip joint centers were defined as one-quarter of the distance from the ipsilateral to contralateral greater trochanters [27]. The knee joint center was defined as the midpoint of the medial and lateral femoral epicondyles, while the ankle joint center was defined as the midpoint of the medial and lateral malleoli. Segment coordinate systems were defined using an unweighted least squares method [28]. Joint kinematics were defined using an inverse kinematics algorithm, in order to reduce joint motion artifact [29]. The stance phase was defined as initial contact to toe-off. Initial contact was defined as the time point where the foot made contact with the force plate and the vertical ground reaction force exceeded 20 N.

2.4. Musculoskeletal modeling

An eight segment, 23 degree of freedom (DOF) musculoskeletal model was developed using a modified version of a previous musculoskeletal model [30]. Musculoskeletal simulations of the unanticipated sidestep cuts were created using OpenSim (v3.1) [31]. The torso segment consisted of three DOFs and was modeled as a ball and socket joint [32]. The pelvis consisted of three rotational and three translational DOFs. Both hip joints were modeled as ball and socket joints with three DOFs, while both knee joints [33] were modified to include three DOFs (i.e. flexion/extension, abduction/adduction, rotation) [19,20,34]. Tibiofemoral translations were described as a function of knee flexion angle [35]. The ankle joints were modeled using one DOF. Both lower extremities were each modeled using 43 musculotendon actuators [31,36,37]. Musculotendon actuators consisted of an active contractile element connected in series to a passive elastic element with a damper connected in parallel to the contractile element and eliminated singularities in normalized muscle velocity [38].

Differences in model and experimental marker tracking were minimized through use of the residual reduction algorithm (RRA). RRA applies a set of non-physical forces and moments to a particular body in the model, in order to ensure that the model's motion and joint moments are consistent with ground reaction forces [39]. An external numerical optimization routine [20] was used to determine optimal tracking weights for use in RRA, to ensure that model and experimental differences, as well as residual forces and moments applied to the musculoskeletal model, during the simulations of the unanticipated sidestep cut were minimized. Average RMS differences of the pelvic translations, pelvic and lower extremity rotations as well as the lumbar rotations were below 2.6 cm, 2° and 4.1° , respectively. Average RMS of the residual forces and moments were below 15 N and 49 Nm. These RMS differences fall within the acceptable threshold values for RRA as suggested by OpenSim.

Once optimal marker tracking was achieved through the external optimization routine and RRA, muscle forces that accurately reproduced

Download English Version:

<https://daneshyari.com/en/article/4077174>

Download Persian Version:

<https://daneshyari.com/article/4077174>

[Daneshyari.com](https://daneshyari.com)