Clinical Biomechanics 31 (2016) 113–116

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Brief report

Identification of preferred landing leg in athletes previously injured and uninjured: A brief report

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ARTICLE INFO

Article history:
Received 13 May 2015
Accepted 30 September 2015

Keywords:
Preferred landing leg
Dominant limb
Landing biomechanics
Limb asymmetries
Anterior cruciate ligament reconstruction
Drop vertical jump

ABSTRACT

Background: The preferred or dominant limb is often subjectively defined by self-report. The purpose was to objectively classify preferred landing leg during landing in athletes previously injured and uninjured.
Methods: Subjects with a history of anterior cruciate ligament reconstruction ($n = 101$) and uninjured controls ($n = 57$) participated. Three trials of a drop vertical jump were collected. Leg dominance was defined as the leg used to kick a ball while landing leg preference was calculated as the leg which landed first during landing trials. Limb symmetry index was also calculated during a single leg hop battery. The distribution of subjects that landed first on their uninvolved or dominant leg, respectively, was statistically compared. Limb symmetry from the single leg hop tests were compared within each subgroup.
Findings: The distribution of preferred landing leg to uninvolved limb for injured (71%) and dominant limb for controls (63%) was not statistically different between groups ($P = 0.29$). Limb symmetry was decreased in injured subjects that preferred to land on their uninvolved limb compared to their involved limb during single leg ($P < 0.001$), triple ($P < 0.001$), cross-over ($P < 0.001$), and timed hops ($P = 0.007$). Differences in limb symmetry were not statistically different in controls ($P > 0.05$).
Interpretation: The leg that first contacts the ground during landing may be a useful strategy to classify preferred landing leg. Among the injured subjects, 29% preferred to land on their involved leg, which may relate to improved confidence and readiness to return to sport, as improved limb symmetry was present during hop tests.

1. Introduction

Identification of dominant limb with athletic activity is often subjectively defined by self-report. For example, several research groups determine leg dominance by asking the subject which leg they would prefer to use to kick a ball as far as possible (Ford et al., 2003; Harrison et al., 1994; Ireland et al., 2003; Lephart et al., 2002; Shultz et al., 2001). However, the operational definition of 'dominant' may vary within this question as either the stance leg or the kicking leg (Colby et al., 1999; Ford et al., 2003). Another approach may involve individually matching an injured side to a specific control's same side (Ireland et al., 2003). However, in larger prospective studies with multiple investigative groups involved in injury surveillance, group allocation may change and result in unbalanced cohorts. Therefore, it is often difficult to match injured and uninjured cohorts across multiple sports when examining side-to-side asymmetries.

Lower extremity biomechanics have been examined on the preferred landing leg during a variety of tasks (Howard et al., 2011). Direct comparisons with a preferred leg (leg chosen to land on the majority of the trials) may be used to determine side-to-side asymmetries. Asymmetries in injured athletes are typically observed early in the rehabilitation process and may persist following return to sport. For example, in young, active individuals following primary anterior cruciate ligament (ACL) reconstruction (ACLR), greater quadriceps femoris muscle strength side-to-side asymmetries at the time of return to sport are associated with worse performance on measures of function and performance, and asymmetrical landing strategies during a bilateral landing task (Schmitt et al., 2012; Schmitt et al., 2014). Importantly,

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http://dx.doi.org/10.1016/j.clinbiomech.2015.09.020
0268-0033/

side-to-side asymmetries during landing may relate to increased risk of re-injury after primary, unilateral ACLR (Paterno et al., 2010). A common task used to identify altered biomechanics involves a bilateral drop vertical jump (DVJ) maneuver (Hewett et al., 2005). Subjects are instructed to drop off a box simultaneously with both limbs, land bipedally, and immediately perform a maximum vertical jump. Subtle side-to-side timing differences in landing have been previously utilized to identify a preferred landing side in uninjured and injured athletes (Paterno et al., 2011). Specifically, patients following unilateral ACLR tend to lead with their uninvolved limb, which may offer a unique methodology to identify and match a control subject's preferred limb (Paterno et al., 2011). Therefore, the purpose of this study was to objectively classify the preferred landing leg during a bipedal landing task in athletes previously injured and uninjured. We hypothesized that a similar distribution would be observed among an injured cohort landing first on their uninvolved limb compared to the preferred leg in an uninjured cohort. Furthermore, a secondary purpose was to determine if limb asymmetries during single leg hops would be observed within ACLR and control groups based on group allocation.

2. Methods

2.1. Subjects

One hundred fifty-eight subjects were included in this study from an ongoing prospective study that has been previously described (Paterno et al., 2010). Subjects following unilateral ACLR and return to sport (ACLR $n = 101$, female = 63.4%) and uninjured control subjects (CTRL $n = 57$, female = 73.7) participated. Subject demographics (Table 1) were not statistically different between groups. ACLR subjects did not follow a standardized rehabilitation and was not controlled in this study. Informed written consent was obtained from each subject/parent in accordance with the protocol approved by the Institutional Review Board. Dominant leg was defined in the current study as the leg the subject would use to kick a ball as far as possible. The uninvolved leg was defined in the ACLR group as the side that was not surgically repaired.

2.2. Procedures

Subjects performed three DVJ trials (Fig. 1) from a 31 cm box and landed on two force platforms (1200 Hz, AMTI, Watertown, MA). Each subject dropped down from the box with the standardized instructions to leave the box with both feet at the same time, immediately when hitting the ground, jump up as high as possible towards a suspended target positioned overhead. Subjects also completed a single leg hop battery (Noyes et al., 1991). Four single-leg hop tests were performed, including three hop tests for distance, single hop, triple hop, and triple crossover hop; and a 6-m timed hop. For each test, a practice trial and two measurement trials were performed on each limb, tested in a random order. The averages of two measurement trials for each limb were used to calculate limb symmetry index (involved or non-dominant score divided by uninvolved or dominant score × 100% for the distance measures and uninvolved or dominant time divided by the involved or non-dominant time × 100% for the timed hop). A limb symmetry index of less than 100 indicates deficits in the involved or non-dominant limb.

Table 1
Subject demographics.

	ACLR ($n = 101$)	CTRL ($n = 57$)	P value
Height (cm)	167.3 (11.2)	166.5 (8.8)	0.7
Mass (kg)	65.6 (15.1)	61.4 (11.9)	0.1
Age (years)	16.7 (3.0)	17.2 (2.5)	0.4
Post-surgery (months)	8.3 (2.5)	–	–

Mean (SD) demographics for ACLR and CTRL groups.

2.3. Data analysis

Initial ground contact for both limbs during the DVJ was calculated (Matlab, MathWorks, Natick, MA) as the time that the unfiltered vertical ground reaction force first exceeded 10 N. The side that made initial contact first, during the majority of the trials, was operationally defined as the preferred leg. When timing was equal (exact same frame number identified when vertical ground reaction force first exceeded 10 N), the side that had the larger magnitude of vertical ground reaction force at initial contact was defined as preferred. The absolute time difference between the initial contacts for each leg was calculated and compared between ACLR and CTRL groups.

The distribution of ACLR and CTRL that landed first on their uninvolved or dominant leg, respectively, was statistically compared with chi-square analysis. One-way ANOVA ($P < 0.05$) was used to determine if differences existed in initial contact timing between ACLR and CTRL. Within the ACLR group, subjects were dichotomized into those that preferred to land on their uninvolved limb first compared to those that preferred to land on their involved limb first. Likewise, CTRL subjects were dichotomized into groups based on their preference to land first on dominant leg compared to non-dominant leg. Limb symmetry indices from the single leg hop tests were statistically compared within the ACLR and CTRL subgroups (ANOVA $P < 0.05$).

3. Results

Absolute initial contact timing differences between landing sides were not statistically different between groups ($P = 0.19$). Specifically, ACLR had a difference of 7.4 (SD 5.1) ms compared to 6.3 (SD 4.9) ms in the CTRL group. A total of 71.3% of ACLR subjects preferred to land with initial contact on their uninvolved limb during a DVJ task (Fig. 2). In comparison, 63.2% of CTRL subjects preferred to land on their dominant limb first. The distribution of preferred landing leg to uninvolved limb for ACLR and dominant limb for CTRL was not statistically different between groups ($P = 0.29$).

Within the ACLR cohort, limb symmetry indices during all four single leg hop tests were significantly different between ACLR subjects that preferred to initially land on their uninvolved limb compared to their involved limb during the DVJ trials. Specifically, limb symmetry was decreased in ACLR subjects that preferred to land on their uninvolved limb (UN, $n = 72$) compared to their involved limb (IN, $n = 29$), respectively, during the single leg hop (IN: 102.5 (7.4), UN: 93.7 (6.5), $P < 0.001$), triple hop (IN: 101.7 (6.3), UN: 94.1 (6.8), $P < 0.001$), cross-over hop (IN: 102.5 (10.6), UN: 94.0 (6.6), $P < 0.001$), and timed hop (IN: 100.6 (10.2), UN: 95.6 (7.3), $P = 0.007$) tests. The time post-surgery was not different between the ACLR groups that preferred to land with initial contact on their uninvolved limb (8.3 months) compared to involved limb (8.2 months, $P = 0.87$). A total of 52.5% of the ACLR subjects injured their previously determined dominant limb (based on which side they would use to kick a ball). The distribution of dominant compared to non-dominant injured side was not statistically different ($P = 0.66$) between the ACLR groups that preferred to land with initial contact on their uninvolved limb compared to involved limb. Additionally, there were no differences ($P =$ whether the injured side was classified as dominant compared to non-dominant based on which leg they would kick a ball with.

In the CTRL group, limb symmetry indices on the single leg hop tests were not statistically different between those that preferred to land on their dominant (D, $n = 36$) versus non-dominant (ND, $n = 21$) limb, respectively (single leg hop, D: 98.9 (5.6), ND: 100.5 (4.6), $P = 0.27$; triple hop, D: 98.1 (5.0), ND: 100.3 ± 4.2, $P = 0.09$; cross-over hop, D: 99.7 (4.9), ND: 99.0 (6.8), $P = 0.66$; timed hop, D: 98.4 (6.3), ND: 99.1 (5.6), $P = 0.73$).