Dominant and non-dominant single-leg landings at different heights: which one is safer among females? Implications for ACL injuries

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INTRODUCTION:

Landing is a common manoeuvre in sporting activities that can often lead to anterior cruciate ligament (ACL) injury with greater risk found in females [1]. Single-leg landing increases the risk of injury compared to double-leg landing because it is performed with less knee flexion and provides less stability. Although there has been significant differences in maximum valgus angle between landing with the dominant and non-dominant leg [2], there is a dearth of information with regards to muscle forces at high risk instances such as when peak GRF occurs during landing. A lack of muscle coordination or delay in their activation due to for example, fatigue at the time of peak ground reaction force (GRF), is believed to be a possible cause of ACL injury. The quadriceps (Q) and hamstring (H) muscles are the main lower body decellerator and knee joint stabilizer during landing, respectively. At peak GRF, the Q/H force ratio, unlike the Q/H strength ratio measured isokinetically, can provide insight into the loading condition at the knee joint during landing. Greater Q/H ratios represent higher anterior knee muscle force and thus increase the risk of the ACL injury.

The aim of this study was to compare dominant versus non-dominant single-leg landings at two heights in females to better understand the effects of muscle coordination with respect to GRFs on ACL injury. Because we propose that dominant leg landing will be better coordinated than non-dominant leg landings, we hypothesized that the Q/H ratio peak will be lower during dominant leg landings compared to non-dominant leg landings. We also hypothesized that the peak Q/H ratio will occur closer to peak GRF at higher landing tasks as well as during non-dominant landing since, we assume that such landing manoeuvres need quicker muscle coordination response (i.e. peak Q/H) to peak GRF to avoid ACL injury.

METHODS:

Eight healthy female participants, with a mean(SD) age of 23.8(3.7) years, height of 167.7(5.7) cm, and mass of 61.8(6.6) kg, were enrolled in this study, which was conducted at the Australian Institute of Sport (Canberra, ACT). All participants signed an informed consent in accordance with the relevant human ethics research committees.

A total of 54 retro-reflective markers (14 mm diameter) were attached to specific locations on the participant’s lower limbs, trunk, and arms. Each participant stepped off a platform and landed barefoot onto the force plates with her dominant (defined as the preferred limb for kicking a ball) or non-dominant limb at heights of 30 cm and 60 cm, respectively. Ten motion capture cameras (250 Hz; VICON Mx, Oxford Metrics, UK) collected three-dimensional kinematic data and two force plates (1000 Hz; Kistler Instrument Corporation, USA) measured ground reaction forces (GRFs). Marker positions were filtered using a Woltring (1986) filter (MSE 15) while GRF data was filtered using a Butterworth filter with a 30 Hz cut-off frequency.

Subject-specific models were developed for each participant. This model consisted of 23 joints and 92 muscle tendon units and was scaled to match each participant’s anthropometry. OpenSim, an open-source 3D musculoskeletal modelling software developed at Simbios [3], was used to perform inverse kinematics and a reduced residual algorithm (RRA) to obtain a dynamically consistent model. Then, a static optimization method was used to predict lower limb muscle forces for each subject. Matlab (The Mathworks Inc., Natick, MA) functions were utilized to obtain results from OpenSim. Muscle forces and their ratios were compared at peak GRF and were reported during landing phase from foot strike to maximum flexion angle. A Paired t-test analysis was used to compare the mean Q/H ratio for different heights and single-leg landing techniques (i.e. dominant vs. non-dominant). All significant levels were set at p<0.05.

RESULTS SECTION:

Significant increases in peak GRF were observed from 60 cm compared to 30 cm (p<0.05) for both dominant and non-dominant leg landings. At peak GRF, the Q/H ratio at a landing height of 30 cm was greater than that at 60 cm for the dominant limb, although this difference was not significant for non-dominant landing (p=0.04 and p=0.24) respectively. Also, the mean Q/H ratio at peak GRF was not significantly different between dominant and non-dominant leg landing for both 30 cm and 60 cm (p=0.61 and p=0.93).

Figure 1. Representative profiles of one subject for Q/H vs. GRF for single-leg dominant (A) and non-dominant (B) landing from 30, 60 cm.

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DISCUSSION:

The mean Q/H ratio was greater at 30 cm than at 60 cm in both dominant and non-dominant landings. This suggests that at 60 cm, when the participant has a greater risk of injury, higher muscle co-contraction (i.e. lower Q/H ratio) was required such that the hamstrings protect the ACL. However, contrary to our hypothesis, the mean Q/H ratio at peak GRF was not significantly different between dominant and non-dominant leg landing for both 30 cm and 60 cm. A possible explanation is that the participants recruited their hamstring muscles to achieve a safe landing for both landing techniques. Thus, the non-dominant leg is not necessarily at greater risk of injury at these heights.

A larger time delay between peak Q/H and peak GRF indicates that Q and H may not be able to stabilize the knee joint in a timely manner to avoid ACL injury. As we hypothesized, there was a smaller shift between peak Q/H and peak GRF at greater heights and for non-dominant landing, suggesting that the participants better coordinate their muscles to protect the knee joint from injury in these situations. However, higher risk situations, such as landings from greater heights, may result in poor muscle coordination, as evident by high Q/H ratio and large delay between peaks. The study was conducted in a controlled laboratory environment and the effect of other external factors, such as type of landing surface and shoe, have not been considered. As a result, the drop landing tasks of this study may not reflect the unpredictable landing maneuvers performed in a game-like situation. Further research is needed to address muscle coordination and timing differences between GRF and Q/H peaks for dominant and non-dominant leg landing.

SIGNIFICANCE:

Safe landing requires coordination of both hamstring and quadriceps muscles. Prediction of such coordination (e.g. Q/H ratio) through biomechanical modelling can lead us to prevent ACL injuries.

REFERENCES: