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JOINT KINEMATICS OF LANDING IN ACL REHABILITATED VOLUNTEERS

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The purpose of the present study was to compare the variability of movement and force production in ACL rehabilitated volunteers during landing from a maximal drop jump. Male (n=6) and female (n=7) volunteers with previous ACL reconstruction and rehabilitation performed a maximal drop jump diagonal side cut task (x20 trials). Knee and hip joint kinematics in all three planes were calculated during the landing component of the task. The range of motion (ROM) of the hip and knee joint, showed differences between the legs. The previously injured leg showed smaller ROM in hip and knee ab-adduction and knee flexion extension. The decreased range of motion in the previously injured leg may be indicative of a less variable landing movement repertoire, which may increase injury risk.

KEY WORDS: Anterior Cruciate Ligament, hip, joint angles, knee, maximal drop jump.

INTRODUCTION: Anterior cruciate ligament (ACL) injuries are recognised as one of the most common and serious sports injuries with upwards of 250,000 ACL injuries occurring in the United States each year (Boden et al. 2000). Reconstructive surgery is typically recommended to restore the knee joint stability and function after ACL injury. Almost 80% of athletes undergoing surgery are unable to successfully return to preinjury-level sport participation and therefore quit their sports (Chong et al., 2004, Lilley et al., 2002, Soderman et al., 2002). Athletes who are successful in returning to their sport have been shown to be at an increased risk of repeated ACL injury and knee osteoarthritis. Previous research has suggested this could be a consequence of the knee joint kinematics that have not been fully restored by the reconstructive surgery and the rehabilitation that follows (Papannagari et al., 2006 and Brandsson et al., 2002). Movements most commonly associated with ACL injury include, landing and rapid movements involving changes of direction (Myklebust et al. 1997 and Olsen et al. 2004). Landing from a jump is regarded as a multi-segmental coordinated activity which places high demand on the lower extremity to absorb ground reaction forces (Decker et al., 2003, McNitt 2003, Paterno et al., 2007). Compensations can occur between joints and legs to maintain performance where a single joint such as the knee has been compromised by injury (Gauffin and Tropp 1992, Risberg et al., 2009, Gokeler et al., 2009). Previous research assessing the landing technique of ACL rehabiltated athletes has used the first landing period of the drop jump i.e. the land from the drop. The second landing phase i.e. landing from the drop-jump, has not been previously investigated in this population is thought it may more accurately replicate match situations especially when the jump is performed maximally to an overhead target. The current study aimed to determine whether rehabilitated ACL individuals (ACLr) were left with residual deficits in landing performance in their previously injured leg after their rehabilitation programs. Knee and hip joint kinematics in all 3 planes were compared between the previously injured and non-injured leg. It was hypothesised that the previously injured leg would display different landing technique to the non-injured control leg.

METHOD: Subjects included six males and seven females (age 23 ± 2 yrs; height 1.74 ± 0.09 m; mass 75.4 ± 19 kg). All subjects were deemed successfully rehabilitated as they all had returned to full competitive participation in their chosen sport. To further ensure full rehabilitation, all subjects underwent a screening process which included completion of 3 different hopping tests, IKDC Knee injury evaluation questionairre, and also a custom designed form assessing details of previous knee injury and current playing experience. Following screening and maximum drop jump reach height assessment, subjects completed 20 trials of a dynamic task. This involved dropping from a 0.30 m bench, and performing an immediate drop and jump to reach and touch a target suspended at their maximum drop jump reach height. The suspended target triggered a directional cueing system which randomly indicated which direction the subject had to run diagonally to on landing. The subjects completed 10 trials running diagonally to the left 10 trials to the right.

Data Collection: Kinematic and kinetic data were acquired using a six-camera high-speed motion analysis system (Eagle; Motion Analysis Corp., Santa Rosa, CA) sampling at 500Hz and synchronised with an AMTI dual force platform system sampling at 1000 Hz. Reflective markers (43) were secured on the asis, psis, sacrum, iliac crest, greater trochanter, medial and lateral epicondoyle and malleolus, upper and lower calcaneous, 2nd and 5th metatarsal of both legs. Marker clusters consisting of four markers were also placed on the thigh and shank (Pollard et al., 2005). Each subject stood in relaxed stance with knees fully extended for a static trial prior to full data collection. All kinematic data was filtered using a Butterworth 4^{th} order, zero lag filter with a 15 Hz frequency cut-off (Winter, 2009).

Data Analysis: The landing period was defined separately for both legs bilaterally by the vertical ground reaction force >10N indicating touch down (Cowley et al., 2006) and the end weight acceptance period defined the end of the landing. As in many previous publications, knee and hip joint kinematics were calculated in Visual 3d (Pollard et al., 2005). Knee and hip angles of flexion-extension, abduction-adduction and rotation were calculated for both legs. The following discrete measures were reported for both legs, maximum, minimum, range of motion and values at ground contact.The differences between the mean scores of the previously injured and control leg were assessed by a repeated measures ANOVA (with α = 0.05). Cohen's d_z was used to evaluate effect sizes.

RESULTS: Average maximum and minimum hip and knee joint angles for both legs are shown in Figure 1. (a & b). There were no significant differences between legs for maximum and minimum hip and knee angles. A moderate effect size did show however, that the control leg had a greater minimum knee flexion angle (d_z = 0.594); (i.e. increased knee flexion) this with a p-value of 0.06 shows a notable difference. Average values for joint angles at ground contact for both legs are shown in Figure 1 (b). No significant differences or moderate-large effects (d_z>0.5) were shown between legs for the measured joint angles at ground contact (Figure 2 (a)). Average values for joint angle ROM for both legs are in Figure 2 (b). Greater ROM is reported in the control leg for a number of joint angles; hip flexion-extension (p= 0.017, d_z= 0.54, average difference between legs = 3.8°), hip rotation (p>0.1, d_z = 0.62, average difference between legs = 2.2°), knee flexion-extension (p= 0.02, d_z=0.902, average difference between legs = 2.8°) and knee abduction-adduction (p= 0.09, d_z= 0.53, average difference between legs = 1.4°).

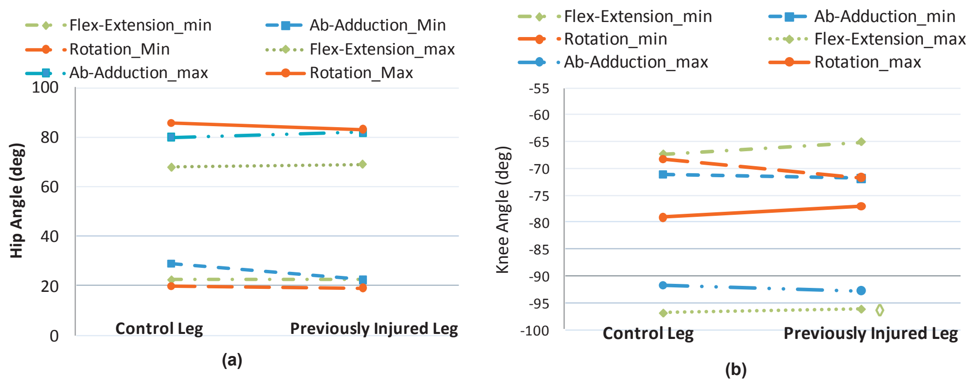

Figure 1: Maximum and minimum joint angles, of hip and knee.

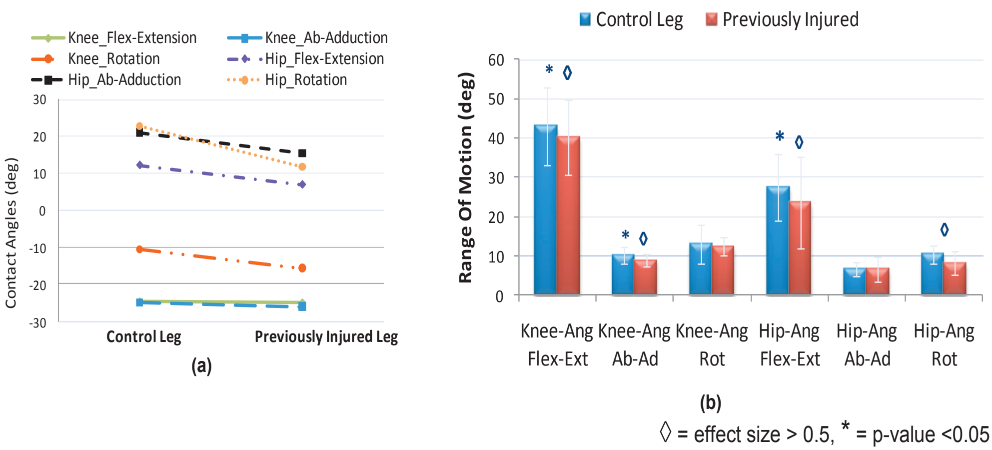

Figure 2: Hip and knee, joint angles at ground contact and range of motion.

DISCUSSION: This study aimed to determine whether rehabilitated ACL individuals (ACLr) were left with residual deficits in landing performance in their previously injured leg. Knee and hip joint kinematics in all 3 planes were compared between the previously injured and non-injured leg. It was hypothesised that the previously injured leg would display different landing technique to the non-injured control leg. Apart from knee flexion-extension, there were no differences between the control and previously injured legs for the maxima and minima of hip and knee joint angles. This is interesting, as previous work has found inter-limb compensations with hip and ankle joints compensating for the decreased work at the knee (Decker et al., 2003). The one notable difference between legs for joint angle maxima and minima showed the knee on the control leg had increased flexion angle. This increased knee flexion may indicate that the control leg was required to absorb more of the landing and therefore required increased flexion at the knee. The lower levels of knee flexion on the previously injured leg may also be of concern, as low knee flexion is a risk factor for ACL injury (Boden et al. 2000). The joint angles values including knee flex-extension did not show any differences between legs at ground contact, which indicates no increased injury risk due to increased knee extension in the previously injured leg at that point in time. Differences in ROM between legs showed that the hip and knee joints of the control leg moved through a greater range of motion than the previously injured leg, with significant differences and medium-large effects shown in hip and knee ab-adduction and knee flex-extension. The increased ROM at hip and knee of the control leg may indicate a intra-limb compensation where the control leg is required to control the landing to a greater extent than the previously injured leg using a different landing movement pattern. Whether or not the previously injured leg has a different landing movement pattern needs to be investigated to a deeper level, investigation of the joint angles time series' and joint coupling patterns may provide more information to shed further light on this finding. The inherent differences that exist between healthy dominant and non-dominant legs also needs to be examined as this may be masking or causing differences between the control and previously injured leg.

CONCLUSION: The principal differences between the legs were shown in the ROM of hip and knee joint angles between legs. The hip and knee joints of the control leg moved through a larger range of motion than the previously injured leg, especially hip and knee ab-adduction and knee flexion extension. The increased range of motion in the control leg in combination with the finding of increased knee flexion may be indicative of an altered landing movement pattern needed to compensate for the previously injured leg. The role of leg dominance and further measures of movement patterns and joint coupling/coordination need to be investigated before any concrete recommendations can be made on this finding.

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