EFFECTS OF TRUNK POSTURE ON LOWER LIMB JOINTS: IMPLICATIONS FOR NON-CONTACT ANTERIOR CRUCIATE LIGAMENT INJURY

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Non-contact anterior cruciate ligament (ACL) injuries are common and trunk posture may be an important determinant of landing injury management. Seven university female athletes (age 19.57±0.79 y) volunteered and completed countermovement jumps (CMJ) using both single and double leg landings across three different trunk landing positions (lean forward, self-selected and upright). Lower limb joint angles and torques were calculated at peak vertical ground reaction force (vGRF). Repeated measure ANOVA 2-Way ($p \leq 0.05$) was used to test the within-subject differences of landing biomechanical characteristics. Results indicated that trunk posture can influence joint displacement angles and reduce knee joint load in landing, potentially reducing the prevalence of non-contact ACL injury during the CMJ.

KEYWORDS: Sagittal plane, Landing, Trunk position, ACL injuries, Non-contact, CMJ.

INTRODUCTION: ACL injuries typically occur during single and double-leg landing actions, often seen in sports such as Basketball and Handball (Yu et al., 2007). In those sports, landing manoeuvres, such as single-leg and double-leg landings are usually performed with large landing impacts being primarily attenuated in the lower extremity joints (Prodromos et al., 2007). Therefore, inadequate shock attenuation capability of the lower extremity joints during landing can easily lead to injuries. Excessive landing impact is one of the primary risk factors associated with ACL injury. The minimisation of vertical ground reaction force (vGRF) and associated knee joint moments are important strategies to help reduce load and prevent knee injuries (McLean et al., 2005; Yu et al., 2007; Kulas et al., 2012).

Optimum trunk posture and lower limb strength have also been identified as two key adaptations to control landing impact and possibly reduce anterior cruciate ligament injury (ACL) (Kulas et al., 2012). The control of the sagittal plane trunk position may play a key role in ACL injury, as it is central to balance control (McLean et al., 2005).
Flexion of the trunk is often accompanied by anterior pelvic tilt, a movement that lengthens the gluteus maximus and hamstring muscle group (Harmon & Ireland, 2000). This movement influences the force-length relationship of these muscles, placing them in a position that increases their ability to exert a force (Kulas et al., 2012). This occurs due to the centre of mass of the trunk moving forward with increased trunk flexion, moving it closer to the knee and further away from the hip in the horizontal plane. Thus, this study aims to determine what influence trunk positions have on these known lower body biomechanical ACL injury mechanisms (Prodromos et al., 2007; Kiapour et al., 2016).

METHODS: Seven university female Basketball and Handball athletes (age 19.57±0.79 y, height 164.21±8.11 m, body mass 60.43±5.99 kg) with ≥ 2 years of training volunteered to participate in this study. Testing was conducted using two 0.6 × 0.6 m force plates (Ex-Jumper, DKH, Tokyo, Japan) sampling at 1000 Hz. A total of 47 retro-reflective markers were attached bilaterally to capture whole-body motion (Blackburn et al., 2009), utilising a 10-camera motion analysis system (Vicon motion analyser MX, type of T20 and T20S) collecting at 250 Hz.
Participants were instructed to keep their arms akimbo throughout CMJ test to remove the effects of arm swing. During the CMJ, participants dipped down to their self-selected starting position and then accelerated upward in an attempt to gain a maximum jumping height before landing back on the force plates. All participants had to complete two variations of jumping tasks; both double-leg jump and a single right-leg jump. Each task was repeated three times

with one minutes break between each trial to eliminate the fatigue effects. For standardisation, participants were instructed to keep their legs as straight as possible after their landing from the CMJ (Figure 1). The calculation of the jump height was based on flight time and gravitational acceleration (9.81m). The following equation was used to calculate the jump height: Jump height = $g \cdot t^2 \cdot 8^{-1}$ (Correlation between GRF and tibial acceleration in vertical jump), where g; 9.81 (m/s^2 gravity), t; flight time in jump (sec).

Figure 1. CMJ procedure; A) Double-leg jump, B & C Single right leg jump

The CMJ test was conducted for three trunk postures, leaning forward (LF), self-selected (SS) and upright (UR). LF was maintained by emphasising the participant to have their weight concentrated on the foot metatarsal; SS was the participant's preferred posture, while UR, was maintained by emphasising having their weight concentrated on the heels.
Sagittal plane joint angles and torques for the ankle, knee and hip were calculated when the peak vGRF values were observed. Conventional inverse dynamics techniques were used when computing joint kinetics (Kawamori et al., 2006). All kinetic values were body weight normalised (Myklebust et al., 2003).
Landing biomechanics were assessed during a double-leg/single-leg stop-landing maneuver, using a video-based motion analysis system. Repeated measure ANOVA 2-Way ($p \leq 0.05$) was used to test the within-subject differences of landing biomechanical characteristics between conditions (LFL, SSL, URL) and task (double and single leg).

RESULTS: Results of sagittal plane joint kinematics are seen in table 1. Significant correlation main effects were observed for jump height (60-70 cm) between double leg and single-leg landing conditions ($p \leq 0.05$). Knee (47.5± 5.8) and ankle (56± 7.7) joint angle during the double-leg landings were significant while holding the LFL trunk position compared with other trunk positions. Moreover, hip joint angle also displayed a significant point during double-leg landing when SS trunk position was selected ($p \leq 0.05$). Also, the CMJ during single leg landing showed a significant effect to the right dorsiflexion during SSL ($p \leq 0.05$).

Table 1. Mean and ± SD (N.m) of hip, knee and ankle joint angles at the maximum GRF (*Significant difference p≤ .05), LF = leaning forward, SS = self-selected, UR = upright.

	Double Leg			Single leg (Right leg)		
	Hip	knee	Ankle	Hip	Knee	Ankle
SSL	42.2 ± 5.7*	48.3 ± 5.3	78.1 ± 6.6	27.5 ± 10.0	42.7 ± 6.8*	77.7 ± 5.5*
LFL	40.6± 5.9	47.5± 5.8*	56± 7.7*	34± 8.7	37.9±10.0	38.4±4.7
UPRL	24.3±9.7	28.9±11.4	40±6	26.7±10.5	26.5±11.3	58±30

No correlations were observed between landing joint torque and CMJ test. Overall, Significant positive of hip joint angle was, further, obtained in double-leg SS, suggesting that hip angle should be reduced to achieve greater force in the self-selected posture.

Table 2. Mean and ± SD (N.m) indicate hip, knee and ankle joint torque in degrees at the maximum GRF (*Significant difference p≤ .05), LF = leaning forward, SS = self-selected, UR = upright.

	Double-Leg			Single-leg (Right leg)		
	Hip	knee	Ankle	Hip	Knee	Ankle
SSL	40.3 ± 5.4	45.4 ± 6.4	79.2 ± 7.5	31.4 ± 11.2	44.5 ± 4.5	82.5 ± 5.8
LFL	42.4± 5.3	57.8± 8.7	77.54±7.2	44± 10.9	66.2±11.7	69.5±4.7
UPRL	28.7±11.3	33.4±11.7	58±3	33.8±13.4	37.5±12.2	59±34.1

DICUSSION: It was hypothesized that active trunk flexion during landing (flexed landing strategy) from a CMJ will decrease landing forces. This technique has been shown to positively influence ACL injury risk reduction in professional Basketball and Handball female players. This study also highlighted that hip, knee and ankle joint torques were not influenced by trunk positions during landing. Hip joint angle was significant during double leg SS landing (42.2 ±5.7), While, knee and ankle were significant during single leg SS landing. The knee and ankle dorsi flexion joint angle were also significant during double leg LF landing (47.5± 5.8 and 56± 7.7 respectively). The joint angle during landing showed that the URL was perhaps the harmful position during landing ($p > 0.05$). The results showed the largest vertical peak GRF in URL and the smallest vertical peak GRF in LFL. Therefore, the shock-attenuating strategy adopted during URL was less effective and ACL harmful, while the LFL may be more ACL protective. However, findings show the SSL and LFL trunk positions produced lower plantar flexor moments and may consequently reduce ACL injury risk during landings . The findings of the current study indicate that LFL increases the lower extremity shock-attenuating capacity and stabilises the knee by preventing excessive quadriceps contraction while maintaining hamstring muscle contraction and increasing knee flexion angles during the post-impact phase of landing. Conversely, URL decreases lower extremity shock-attenuating capacity and knee flexion angle while increasing quadriceps contraction. LFL maybe more ACL protective.

CONCLUSION: Current results suggested that adaptations of joint angles were more correlated with landing from CMJ compared to joint kinetics (hip, ankle and knee $p \leq 0.05$). Individuals should therefore avoid URL as it may be ACL harmful. Sustaining a large GRF during landing has been thought to be harmful to the ACL as it increases knee joint compressive force (Cormie et al., 2012). The risk of ACL injuries may be further increased if the larger GRF is associated with a GRF vector that passes through or in front of the centre of the knee joint (Boden et al., 2000; Yu et al., 2007). Thus, the larger GRF and greater quadriceps activation immediately after foot contact at shallower knee flexion angles observed in URL as compared with in LFL indicate that URL is more ACL harmful (Myklebust et al., 2003; Blackburn at al., 2009). Contrary to URL, LFL may be considered to be more ACL protective as it showed opposite tendencies to that of the URL condition.

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