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Research article

LOWER-LIMB DYNAMICS AND ENERGY ABSORPTION DURING THREE DIFFERENCE TYPES OF SINGLE LEG LANDINGS

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Abstract
Journal of Sports Science and Physical Education 3(1): 9–16, 2015 - This research aimed to determine ACL injury risk from the jump landings by observing peak joint moments and energy absorptions. Single leg landings from 3 different jumps which were 1) drop jump (SDL) 2) counter movement jump (SCL), and 3) stop jump (SJL)) were investigated. Sixteen national hockey players of Australia participated in the study and performed all jump tasks, 5 trials each. Twelve high speed cameras, placed around the participants, captured 3D motion at 250 Hz and the force plate recorded the ground reaction at 2000 Hz synchronously. 3-D orientation of reflective markers attached on the athlete's skin and the recorded ground reaction force were used for computation of moment and energy absorption of the lower limb. One way MANOVA with repeated measure was employed for statistical analysis. Results showed that the greatest peak knee valgus moment ($p<0.001$) was occurred during SJL. Hence, athletes are likely to get their ACL injured by performing the stop jump landing. In addition, SJL also led to the greatest peak hip abduction and internal rotation moments ($p<0.01$). The majority of energy absorption was occurred at the ankle joint (54-56%) while muscles around the knee (30% - 41%) and the hip (5-14%) joint contributed to a lesser energy absorption. Energy absorption implied that muscles contracted eccentrically. Since SJL induced the greatest amount of energy absorption at the ankle joint, then muscles around the ankle joint should be stronger in order to prevent injury from SJL.

Keywords: *Joint moment, energy absorptions, ACL.*

Introduction

ACL injury is common in athletes while single leg landing increased athlete's risk for ACL injury (Koga et al., 2010). At an initial ground contact of landing, the lower extremity muscles such as hip and knee extensors, and ankle plantar flexors are recruited to decelerate the whole body movement (Kellis & Kouvelioti, 2009; Shultz et al., 2009) which results in the increasing of joint stress of lower extremity. Hence, athletes are likely to sustain ACL injury during deceleration phase (Dufek & Bates, 1990; Briner & Kacmar, 1997). Among them the greater incident of ACL injury is found in female athletes (Renstrom et al., 2008).

The differences in gender, jump height and the direction of the landing from the jump effect on both kinematics and kinetics of the lower limb (Ford et al., 2006; Ali, Robertson & Rouhi, 2014) which may result in the susceptible to ACL tears. Drop landing from a 60 cm box height have been observed in both female and male athletes. Kernozek et al., (2005) reported that female athletes generated a smaller knee varus moment at the time of peak knee valgus angulation than male. Russell et al., (2006) also demonstrated that female athlete tend to land with a greater knee valgus than male at initial contact. However, a greater total knee valgus has also been found in female athlete compared to male athletes while they performed a 31 cm drop jump (Ford, Myer, & Hewett, 2003). In addition, female athletes performed greater lower extremity frontal plane kinematics than male (Ford et al., 2006).

Energy absorption at the joint has been reported as a contributor for reducing ACL injury (Norcross et al., 2010) however, the controversial results regarding the role of the joint as the energy absorber have been reported. Some studies reported that the ankle joint played a major role in energy absorption while the knee and hip extensors were minor absorbers during both stiff and soft landings (Devita & Skelly, 1992; Zhang, Bates & Dufek, 2000). In contrast, the knee joint was reported as a primary energy absorber during drop landing from a 60 cm box height and the minor absorbers were the ankle and hip joints, respectively (Decker, 2003).

Single leg landing from various jump styles such as a drop jump (SDL), counter movement jump (SCL) and the stop jump (SJL) may induce ACL injury risk differently. Since joints moment and energy absorption have related to the ACL injury, then this study aimed to compare peak joint moment and energy absorption from these 3 difference jump styles.

Methods

Subjects

Sixteen elite female field hockey players participated in this study (Age = 22.2±2.9 years, height = 1.7±0.1 m, weight = 62.9±7.1 kg). All participants provided their informed consent prior to data collections. Ethics approval was obtained from the Human Research Ethics Office at the University of Western Australia (RA/4/1/5713).

Instrumentation

The three-dimensional orientations of full-body were recorded at 250 Hz using 12 high speed cameras (Vicon MX system, Oxford, UK) placed around the athletes. The ground reaction force was also recorded synchronously at 2,000 Hz using a 1.2 m x 1.2 m force plate (AMTI, Watertown, MA). Both the 3-dimensional orientation of segments and the ground reaction force data were low pass filtered with a zero-lag fourth order Butterworth filter at the cut off frequency of 14 Hz. This cut off frequency was determined from the residual analysis [Winter, 2005]. The functional hip joint center and knee joint axes were computed from a custom lower body kinematic model [Besier, Sturnieks, Alderson & Lloyd, 2003] using Bodybuilder. Thereafter, kinematics and kinetics of the lower limb were determined via inverse dynamics (Vicon Peak, Oxford Metrics Ltd., UK).

Experimental

All subjects were asked to wear their spandex short, socks and shoes. The participants were required to warm up and stretching and this would take 15 minutes. They then instructed to perform three difference single leg landing tasks in natural style. Reflective markers were placed at bilateral lower extremity skin based on UWA marker set (Alderson, 2005). According to calibration model, the anthropometric data of each subject was required by the software.

After the practice, subjects performed drop landing from a 30 cm box height, countermovement jump, and stop jump with their dominant leg place on the force plate. The recovery periods between trials and tasks had been given which were 30 seconds and three minutes, respectively The 5 successful trials of each jump lading were used for kinematics and kinetics analyses.

Data and Statistical Analyses

Energy absorption was determined from the integration of negative joint power over time (Winter, 2005). It represented the eccentric muscular contraction at the hip, knee and ankle joints. Joint moment and energy absorption were normalized to body mass. Thereafter, mean and standard deviation of peak joint moment and energy absorption obtained from the weight acceptance phase (first 40 percent of landing phase) were reported. The landing phase started from initial contact to maximum knee flexion. One way MANOVA with repeated measure was used to investigate the different among those variables. When the statistical significant different was found the multiple comparison was employed using Tukey HSD. Significance for all tests was set at $p < 0.05$ (SPSS version 17.0, Statistical software, Chicago, IL, USA)

Results and Discussion

Peak joint moment was reported in table 1. The results showed that peak hip flexion moment of SCL was significantly greater than that of SDL and SJL ($p<0.01$). However, peak hip abduction and internal rotation moments of SJL was greatest ($p<0.001$). In addition peak knee vagus moment of SJL was also greater than that of SDL and SCL ($p<0.001$)

Energy absorption, during weight acceptance phase, observed from three styles of single leg landing was showed in figure 1. The result revealed that energy absorption at the ankle joint was greatest when performing SJL and it was greater than that occurring from SDL ($p<0.05$). Energy absorptions at the knee and the hip joints of all jump landing were insignificant different. Muscles of the ankle joint played a major role in energy absorption. The percentage of energy absorption at the ankle joint occurred from SDL, SCL, and SJL equalled 56%, 54% and 54% respectively. The knee extensor muscles were the second largest contributor to energy absorption during landing (30%, 34%, and 41% respectively) and the last was supported by hip muscles during SDL (14%), SCL (12%), and SJL (5%) respectively through the weight acceptance phase as figure 2.

ACL tear is likely during single leg landing from the stop jump (SJL) because the factors relating to ACL injury were found in this jump. SJL induced the greatest peak knee vagus moment, the peak hip abduction and internal rotation moments compared to other jumps. Peak knee extension, valgus and internal rotation moments are identified as the mechanical ACL injury risks factors (Jindrich, Besier & Lloyd, 2006; Bendjaballah, Shirazi & Zukor, 1997) and likely to be an important factor affecting to ACL strain (McLean, Huang & Bogert, 2008). Our result also showed that peak knee extension moment from stop jump was greater than previous reported (Brown, McLean & Palmieri, 2014; Pollard, Sigward & Powers, 2010). The discrepancy in our finding and those previously reports moments might be resulted from the difference in participant experience (Sigward & Powers, 2006). Our participants were elite hockey players which their team was in the top of world ranking. Whereas the participants in the previous studies (Brown et al., 2014; Pollard et al., 2010) were amateur female athletes.

The greatest percentage of energy absorption was found at the ankle joint, therefore ankle joint was the main energy absorber compared to the hip and the knee joint. This finding supported the previously reported (Devita & Skelly, 1992; Zhang et al., 2000). The greatest amount of the energy absorption at the ankle joint also implied that muscle around the ankle joint contracted eccentrically. Since plantar flexion moment was found during drop landing then the energy absorption at the ankle joint was a consequence of eccentric contraction of plantar flexors. The eccentric contraction of plantar flexors helps decelerate the lowering of the body onto the ground after dropping from the jump. Moreover, the gastrocnemius, a plantar flexor, is a bi-articular muscle which passes through the ankle and the knee joints, therefore its eccentric contraction would also help stabilize the knee during landing. In addition, the greatest energy absorption was found from the stop jump landing (SJL) which implied that the plantar flexors have to be activated more than other jumps. Hence, athletes, whose plantar flexors are not sufficiently strong, may get injured from jump landing, especially stop jump landing.

Table 1: The comparison of peak joint moment between SDL, SCL, and SJL.

Peak joint moment (Nm/kg)	**SDL** $\bar{X}$±S.D.	**SCL** $\bar{X}$±S.D.	**SJL** $\bar{X}$±S.D.	***p*-value**
Hip				
– **Flexion**	**1.46±0.66**	**2.24±0.55**	**1.31±0.50**	**0.01[a]**
– **Abduction**	**-0.31±0.16**	**-0.28±0.27**	**-0.80±0.23**	**0.00[b]**
– **Internal rotation**	**0.63±0.20**	**0.64±0.25**	**0.97±0.40**	**0.02[b]**
Knee				
– Extension	3.26±0.51	3.64±0.72	3.76±0.56	0.13
– **vagus**	**-0.15±0.07**	**-0.12±0.10**	**-0.45±0.27**	**0.00[b]**
– Internal rotation	0.24±0.13	0.21±0.11	0.21±0.11	0.47
Ankle				
– Plantar flexion	1.92±0.32	1.90±0.56	1.92±0.48	0.72

Note: [a] SCL>SDL&SJL, [b] SJL>SCL&SDL

Figure 1: The comparison energy absorption between SCL, SDL, and SJL at hip, knee, and ankle joint.

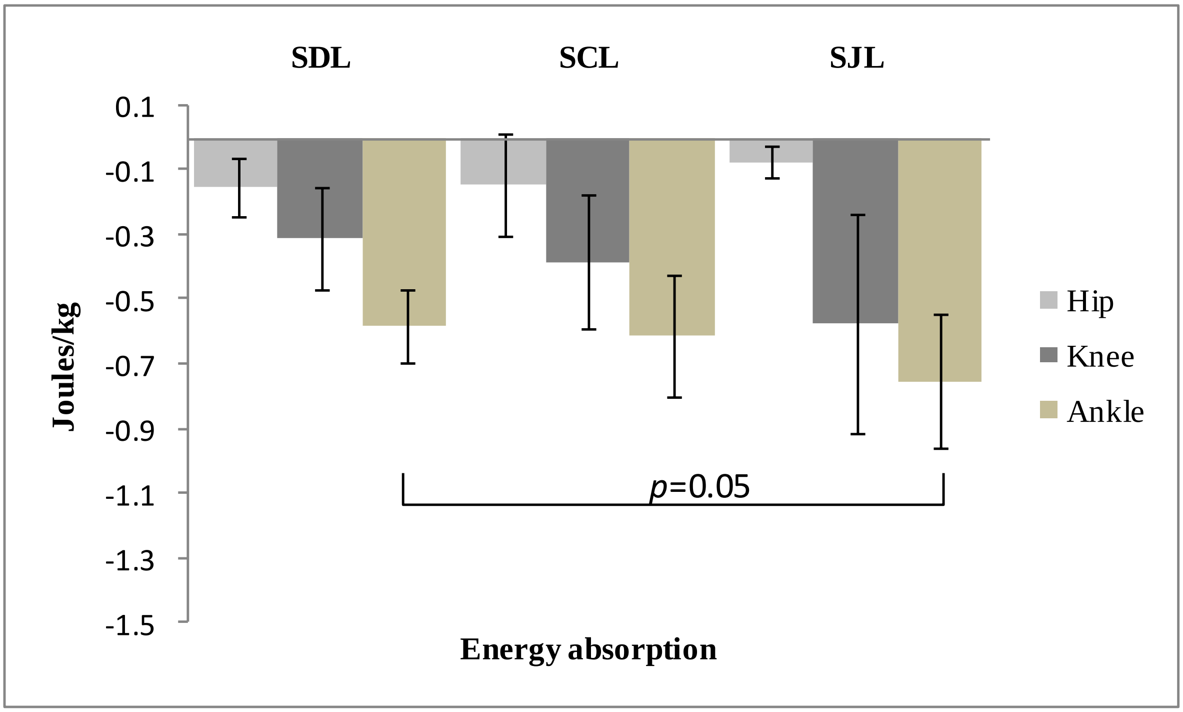
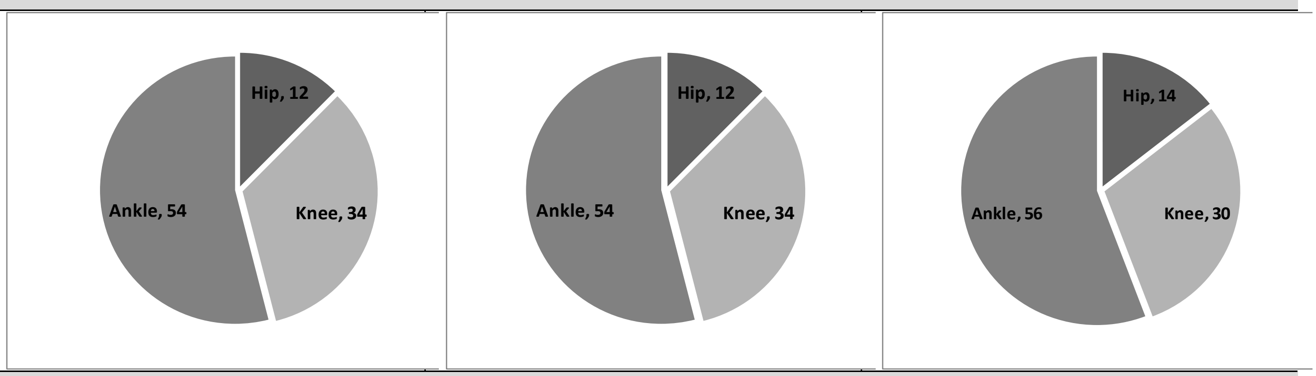


Figure 2: The percentage of energy absorption at the ankle, knee, and hip joints during SDL, SCL, and SJL.

Energy absorption

(Percent)



SDL	SCL	SJL

Conclusion

Landing from stop jump (SJL) may contribute to a greater ACL injury risk compared with landing from the drop jump (SDL) and counter movement jump (SCL). It is because a greatest peak knee vagus moment which was the risk factor for ACL injury was found in the SJL. In addition, the eccentric contraction of plantar flexor at the ankle joint may contribute to the stability of the knee and the ankle joint during landing onto the ground.

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