BIOMECHANICS OF STOP-JUMP LANDING AND IN-LINE SKATING JUMP LANDING

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The purpose of this study was to identify the movement characteristics of lower extremities during stop-jump landing and in-line skating jump landing. Two subjects were asked to perform three jump landing tasks: stop-jump with barefoot (BF), stop-jump with ankle constrain (AC) and jump with in-line skating boots (IS). Landing movements in sagittal plane were recorded by one high speed camera. The activation of four muscles during landing was measured by EMG system. The kinematic results showed that most variables were significantly different between the three jump landing tasks, except for knee angle at ground contact. More activated rectus femoris and smaller knee flexion acceleration found in IS have been considered to be related the ACL injury. It can be concluded that in-line skating jump landing might have higher lower limbs injury risk.

KEY WORDS: in-line skating, jump landing, ankle constrain.

INTRODUCTION:

Previous studies (Houshian & Andersen, 2000; Osberg & Stiles, 2000) about in-line skating have most focussed on the investigation of injury and the effect of using a guard. These studies indicated that about 66-80% in-line skaters had injuries, and these injuries were about 80% occurring in lower limbs. However, there were no researches to study the mechanics of injury.

Stop-jump consists of a 2-3 steps approach run and a two-footed landing followed by two-footed takeoff to maximum height (Chappell, Yu, Kirkendall & Garrett, 2002; Yu, Lin & Garrett, 2006). However, no study has been involved to investigate the second two-footed landing after the takeoff. The studies of drop landing indicated that knee, ankle joints and plantarflexor played important roles in landing cushioning (Decker, Torry, Wyland, Sterett & Steadman, 2003; Self & Paine, 2001). In-line skating boots will constrain the motion of plantar-flexion, however, their influence on kinematics and muscle activation of lower limbs during landing was unknown. Therefore, the purpose of this study was to describe the movement characteristics of lower limbs during landing with stop-jump and in-line skating jump.

METHOD:

Data Collection: The subjects were two male college students of in-line skating club (age: 25 & 23; height: 171 & 172 cm; weight: 65.5 & 54.7 kg). One high speed camera (Mega Speed MS1000, sampling rate: 120Hz) was used to record the movement of the subjects' dominant leg in the sagittal plane. The reflective markers were placed on greater trochanter, lateral condyle of tibia, lateral malleolus and 5^{th} metararso-phalangeal joint. Surface EMG electrodes (MA-300, sampling rate: 960 Hz for each sensor) were attached to the skin on the muscle bellies of rectus femoris, long head of biceps femoris, tibialis anterior and medial head of gastrocnemius of dominant leg. The in-line skating boots is composed of polyurethane (PU) shell, aluminium frame and PU wheels. The hardness of wheels is 78A.

The subjects were asked to jump over a 17cm height obstacle, positioned one meter in front of a forceplate under three conditions: 1) stop-jump with barefoot (BF): the subjects performed stop-jump and two-footed landing on the forceplate followed by moving off immediately. 2) stop-jump with ankle-constrained barefoot (AC): the same with the BF task, but the subject's ankle was taped using standard prophylactic taping technique by a trained experimenter. 3) jump with in-line skating boots (IS): the subject performed two-footed takeoff with in-line skating boots after a run-up, and two-footed landing on the forceplate.

Data Analysis: The two dimensional spatial coordinates of the selected point was calculated using a direct linear transformation procedure by Kwon 3D motion analysis software. The raw data were smoothed using 4th-order butterworth low-pass filter at a cut frequency of 6Hz. The EMG raw data were filtered by 4th-order butterworth 10-400Hz band pass filter and normalized by maximum voluntary contractions (MVC). Average integrated EMG (IEMG) data were computed after full wave rectify.

This study focused on the kinematic and muscle activaction of lower limbs. The ground reaction force were not analyzed in present study. Seventeen variables: joint angle and angular velocity at the instant of ground contact, angular displacement (ROM) from ground contact to 200ms after ground contact, maximum joint flexion velocity and acceleration of knee and ankle joints were measured for each jump landing. Average IEMG during each of following time interval: 1) for the pre-landing phase (100ms before foot contact with ground), and 2) for the impct phase (defined as the first 100ms after initial ground contact) were also analyzed.

One-way ANOVA was used to compare these variables among the three experimental conditions, and LSD method was used to identify the difference between conditions. The statistical significance level was set at $p < 0.05$.

RESULTS:

From the video films, the landing style of BF and AC was toe-heel, but IS was heel-toe for the two subjects. The landing technique of three conditions was similar in hip and knee joint. The pattern of ankle angular velocity was different between IS and BF and AC (Figure1). Kinematic variables shown in Table 1 shows that most kinematic variables were different between the three conditions, except for knee angle at ground contact. In pre-landing and contact phase, IEMG of rectus femoris and tibialis anterior in IS were larger than in BF and AC (Figure 2).

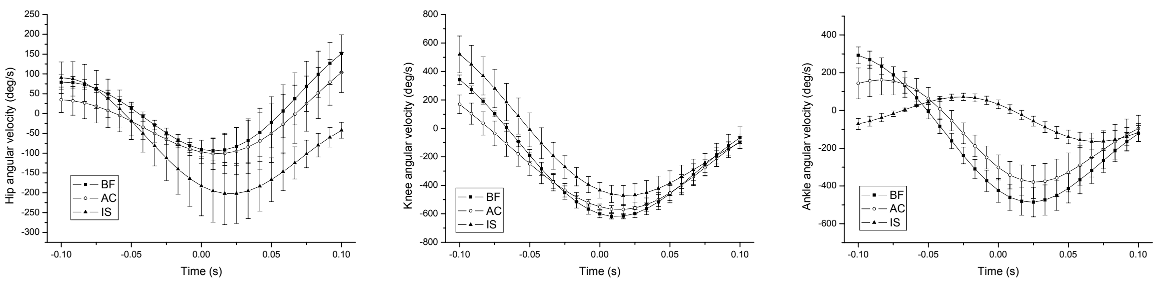


Figure 1: Hip, knee and ankle angular velocity. Positive means extension and negative means flexion. The time is zero at ground contact.

DISCUSSION:

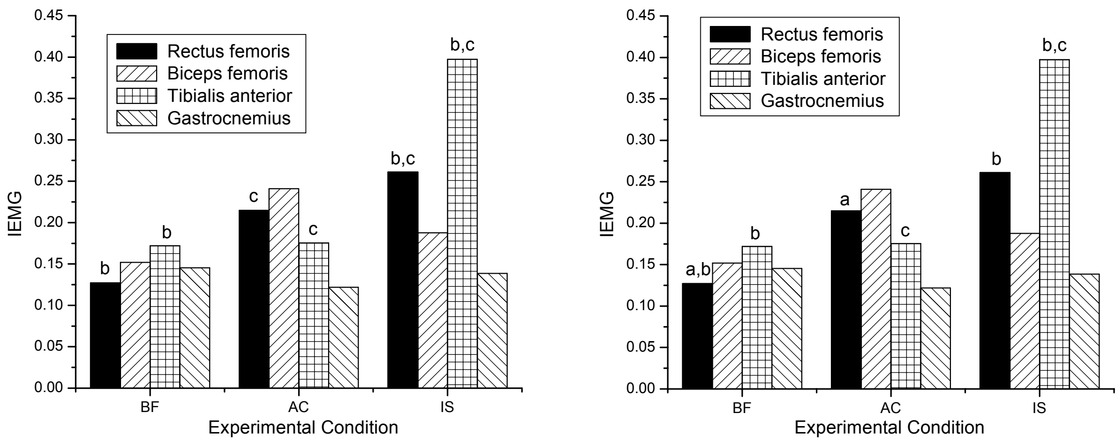
The purpose of this study was to describe the movement pattern of lower limbs during landing under stop-jump and in-line skating jump. The more constrain of ankle joint motion, example for the AC and IS conditions, the smaller ankle angle at ground contact. Larger joints flexion was considered to be the softer landing (Kovacs et al., 1999). The smallest angular velocity and ROM of knee and ankle joints occurred under IS condition is because the in-line skating boots could absorb impact energy through the PU wheels and the metal frame deformation. Therefore, the subjects were not necessarily able to attenuate the impact force by larger joint flexion velocity and larger joint flexion. In-line skating landing technique needs more stability at ground contact. Therefore, the subjects decrease the joint angular velocity and ROM to keep the correct posture to avoid falling.

The study of Kovacs et al. (1999) showed that the knee angle at touch-down was no difference between forefoot drop landing (FFL) and heel-toe drop landing (HTL) style. They were about 148°. The result of the present study was similar to the results of Kovacs et al. (1999). The results of maximum knee and ankle joint flexion velocity in BF were similar to the results of drop landing from 60cm height (Decker et al., 2003).

Table 1 Results of kinematical variables. (suffix k: knee joint; a: ankle joint; θ: joint angle at ground contact; $\dot{\theta}$: angular velocity at ground contact; ROM: angular displacement during landing; Max. $\dot{\theta}$: maximum angular flexion velocity during landing; max $\ddot{\theta}$: max angular acceleration during landing)

Variable	BF	AC	IS
θ_k (deg)	150 ± 7	146 ± 4	148 ± 4
θ_a (deg)	121 ± 4 a,b	115 ± 5 a,c	96 ± 6 b,c
$\dot{\theta}_k$ (deg/s)	579 ± 35 b	561 ± 37 c	405 ± 60 b,c
$\dot{\theta}_a$ (deg/s)	406 ± 52 a,b	253 ± 123 a,c	17 ± 69 b,c
ROM_k (deg)	42 ± 4 b	40 ± 5 c	34 ± 7 b,c
ROM_a (deg)	38 ± 5 a,b	28 ± 8 a,c	11 ± 4 b,c
Max. $\dot{\theta}_k$ (deg/s)	615 ± 25 b	583 ± 46 c	467 ± 69 b,c
Max. $\dot{\theta}_a$ (deg/s)	469 ± 57 a,b	341 ± 92 a,c	151 ± 44 b,c
Max. $\ddot{\theta}_k$ (deg/s^2)	8931 ± 1821 b	8335 ± 1140 c	6730 ± 1292 b,c

a: Statistically significant difference between BF and AC (p<.05).
b: Statistically significant difference between BF and IS (p<.05).
c: Statistically significant difference between AC and IS (p<.05).



a: Statistically significant difference between BF and AC (p<.05).
b: Statistically significant difference between BF and IS (p<.05).
c: Statistically significant difference between AC and IS (p<.05).

Figure 2: IEMG of four muscles in three conditions during pre-landing phase (left) and impact phase (from ground contact to 100ms after, right).

The IEMG results were similar to a previous study (Fagenbaum & Darling, 2003). In the pre-landing phase, the IEMG of rectus femoris in IS was largest, it was which resulted from the need of stability at ground contact. To keep landing posture and decrease the range of flexion and flexion velocity of knee joint, the rectus femoris was more activated in the pre-landing phase. On the other hand, because the weight of the skating boots, the subjects had

to activate their tibialis anterior in order to flat-foot landing. Therefore, the activation of tibialis anterior in IS was larger than in BF and AC.
The study indicated that (Fagenbaum & Darling, 2003) the knee joint accelerated quickly into flexion was beneficial to prevent anterior cruciate ligament (ACL) injury as long as the hamstring muscles were active, but it didn't discuss this more detail. Li et al. (1999) demonstrated that hamstring co-contraction may protect the ACL when the knee flexion angle was greater than 30°. In present study, the knee acceleration in IS was smallest, but the activation of biceps femoris was not different between three conditions. Moreover, increasing quadriceps activation resulted in increased quadriceps force during pre-landing phase may increase ACL loading during landing (Chappell et al., 2007). In this study, the activation of rectus femoris was largest. These might result in higher ACL injury rate under in-line skating landing. The study of Yi et al. (2003) indicated that reducing ankle range of motion during landing would result in less energy being absorbed by the eccentric action of calf muscles and it would increase the risk of ankle injury. In this study, the in-line skating boots restricted the ankle motion, especially the plantar-flexion. Therefore, it is possible that in-line skating landing lead to higher lower limbs injury rate.

CONCLUSION:
This study identified the characteristic of the landing of stop-jump and in-line skating jump landing. To keep stable posture during landing, the subjects performed smaller changes in the kinematics of lower limbs and the skating boots played the role in energy absorbing under in-line skating jump condition. However, the smaller knee flexion acceleration as the hamstring activation was similar and higher activation of quadriceps might result in higher ACL injury risk. Furthermore, the ankle motion was limited by the skating boots, and it is possible to increase the lower limbs injury risk.

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