THE SAGITTAL-PLANE LANDING BIOMECHANICS WITH MOVING FORWARD

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The purpose of this study was to identify the difference of vertical ground reaction force and lower extremity and trunk kinematics in landing with moving forward. Ten healthy female subjects participated in this study. They performed four different single-leg landing tasks with dominant leg. The distances between 30 cm height box and force platform were set 0, 15, 30, 45 cm, respectively. A motion analysis system was used to obtain ground reaction force and the lower extremity and the trunk kinematics. There were significant differences in the only hip joint kinematics, such as the hip flexion angle at initial contact and the peak hip flexion angle during absorption phase of landing. Hip flexion angle showed the increase with the increase of forward moving distance. This result suggested that the landing with moving forward would change only hip joint kinematics.

KEY WORDS: drop landing, trunk, lower extremity, kinematics, ground reaction force.

INTRODUCTON: Athletes perform jumping and landing frequently. According to several previous literatures, it has been reported that the impact attenuation mechanism would related to cause lower extremity injuries, such as anterior cruciate ligament (ACL) injury (Nunley et al., 2003), lateral ankle sprain (Mckay et al., 2001) or stress fracture (Zadpoor et al., 2011). Thus it is important to understand the landing biomechanics in various situations to prevent lower extremity injuries.

Some previous studies have reported that the landing with nearly full extension of the knee was associated with the mechanism of noncontact ACL injuries (Myer et al., 2004) and increased the joint angle of the ankle plantar flexion at touchdown cause increased ankle sprain occurrences (Wright et al., 2000), thus it seems that it is important to clarify the landing kinematic characteristics of the lower extremities especially in sagittal plane.

Among the sports activities, the athletes jump in a variety of heights and land in all directions sometimes with moving. Some previous studies have reported that peak ground reaction force (GRF) increases with landing heights (Yeow et al., 2009; McNitt-Gray, 1993). However few studies have focused on the difference between landing biomechanics in various directions. Therefore the purpose of this study was to indentify GRF and kinematic characteristics of the lower extremity and the trunk in the sagittal plane during landing with moving forward. We hypothesized that the peak GRF during landing would increase and kinematics variables would also change during landing with the increase of forward moving distance.

METHODS: Ten female volunteers (age = 20.2 ± 0.98 years, height = 1.62 ± 0.05 m, mass = 57.0 ± 4.73 kg) were participated in this study. All subjects were belonging to the basketball or volleyball club activities of Ochanomizu University, and generally healthy with no history of ACL injury, neurological disorder, lower extremity surgery or lower extremity injury within the 6 months prior to data collection.

All subjects performed single-leg drop landings on a force plate from a platform of the 30 cm height. The distances between the force platform and the box for the drop landing were 0, 15, 30, 45 cm, respectively. The order of the four different distance conditions was randomized. They were allowed more than three practice jumps and then performed five successful jumps. They were instructed to drop directly down off the box and land with dominant legs on the force plate. After landing, they were instructed to keep their balance more than three seconds. The dominant leg of all subjects was right side.

Three-dimensional lower extremity and trunk kinematic data were collected using an motion capture system at a sampling rate of 250 Hz (Vicon, Vicon Motion Systems). 41 retro reflective markers were placed on the lower limbs and the upper body. The ground reaction force was collected using force plate sampled at 1000 Hz (9286BA, Kistler). Custom computer software (Kwon3D, VISOL) was used to generate the joint angles of the lower extremity and the trunk in sagittal plane at initial contact (IC), the peak hip flexion, knee flexion and ankle dorsiflexion angles during absorption phase of landing. Peak vertical ground reaction force (vGRF) was also analyzed.

The mean values of the five trials for each condition were used for all analysis. The kinematics and ground reaction force of the dependent variables as well as the different levels of independent variables were entered to statistical software package (SPSS 22.0, SPSS inc.). The level of significance was set a priori at 0.05. The repeated measure ANOVA (repANOVA) procedures were used to evaluate the effect of four different distances on all variables. When indicated by significant differences in repANOVA, post-hoc analysis were conducted using the Tukey-Kramer method.

RESULTS: Significant differences were obtained in the peak vGRF, the hip and the trunk flexion angle at IC and the peak joint angle of the hip and the ankle during landing, although no significant difference was found in the knee and the ankle joint angle at IC and the peak joint angle of the knee (Table 1).

There were no interaction effects in the peak vGRF, the trunk and the hip joint angle at IC and the peak ankle dorsiflexion angle (Table 1). By contrast, there were significant differences in the hip flexion angle at initial contact between 0 cm and 45 cm ($p<0.01$), 15 cm and 45 cm ($p<0.05$) (Figure 1). Also there were significant differences in the peak hip flexion angle during landing between 0 cm and 30 cm ($p<0.05$), 0 cm and 45 cm ($p<0.01$), 15 cm and 45 cm ($p<0.01$) (Figure 2).

Table 1
Peak vGRF and joint angle of the ankle, the knee and the trunk in sagittal-plane (mean ± SD)

		The angle at initial contact			Peak angle	
Distance	vGRF	Ankle plantarflexion	Knee flexion	Trunk flexion	Ankle dorsiflexion	Knee flexion
0 cm	3.58±0.71	13.20±6.35	20.98±3.77	4.02±5.63	27.82±5.33	58.41±7.98
15 cm	3.51±0.59	14.09±5.57	20.01±3.72	2.84±4.86	27.01±4.74	58.74±8.46
30 cm	3.71±0.75	13.74±5.80	21.37±2.87	2.67±5.89	26.33±5.61	60.93±7.69
45 cm	3.68±0.67	15.65±5.44	21.05±3.31	-1.21±6.80	24.55±4.95	61.68±3.82

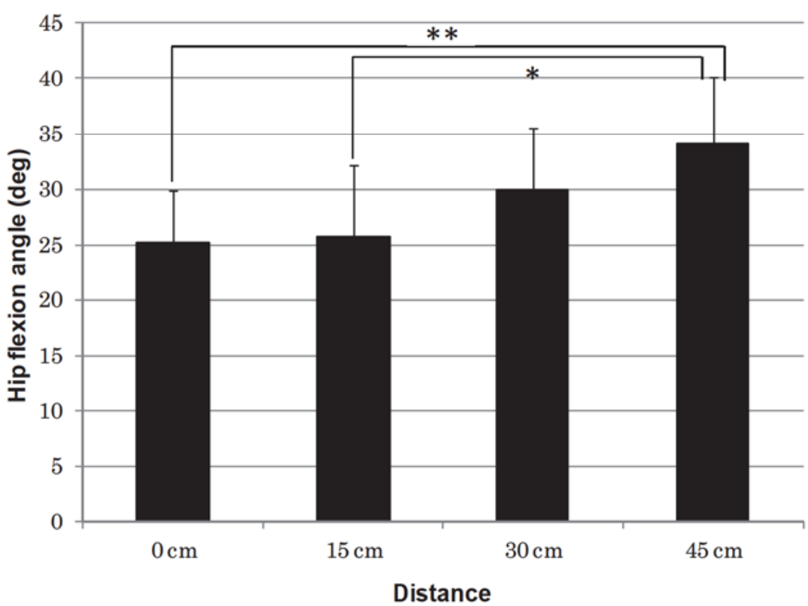

Figure 1: Hip flexion angle at initial contact with different forward moving distances

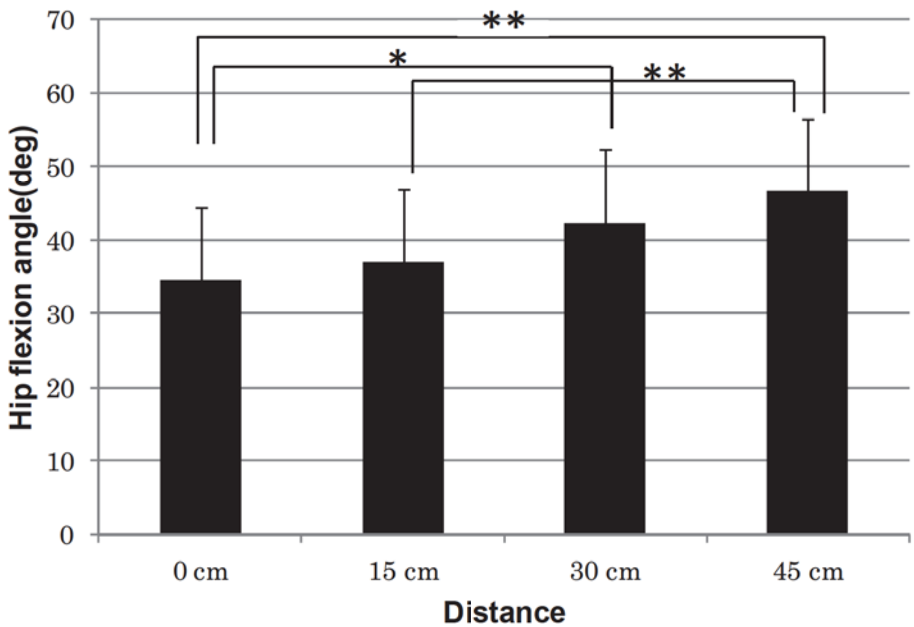

Figure 2: Peak hip flexion angle during landing with different forward moving distances

DISCUSSION: In this study, we found significant difference in only hip kinematics with the increase of forward moving. Therefore it is indicated that the landing with moving forward could influence to the hip movement.

Since the subjects land with greater forward movement, they need to stop their center of gravity moving forward to keep their balance on the landing surface. Therefore we expected that the peak vGRF during landing would increase with the increase of forward moving distance. Previous studies have reported that the greater ankle plantarflexion angle at IC and the peak trunk, hip and knee flexion angle during landing were associated with the decrease in peak vGRF (Rowley et al., 2015; Yeow et al., 2009; DeVita et al., 1992), thus we hypothesized that these kinematic variables in sagittal plane would also change at IC and during the absorption phase of landing with moving forward. Contrary to our hypothesis, there were no significant differences in the peak vGRF and joint kinematics except for the hip. As a result of this study, it was suggested that the hip strategy contributes to the restraint of the increase in vGRF during landing regardless of the forward moving distance.

Hip flexion brings the center of the mass in the trunk segment closer to the center of the knee joint, thus it is speculated that the greater hip flexion during landing would contribute to the decrease of the external knee flexion moment and quadriceps activation. Furthermore, Shultz et al (2009) reported that anterior shear forces were greater in individuals who demonstrated less hip flexion during landing. Accordingly, we suggest that the hip strategy during landing with moving forward may contribute to reduce the mechanical load to the knee.

CONCLUSION: The landing with the increase of forward moving distance showed the greater hip flexion angle at IC and during the absorption phase. From the results of this study, it was suggested that the hip joint strategy could be involved in landing with moving forward.

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