ALTERATIONS IN LANDING MECHANICS DURING FORWARD JUMP IN INDIVIDUALS WITH CHRONIC ANKLE INSTABILITY

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The purpose of this study was to investigate the effects of different distance forward jump among the healthy control, coper, and CAI groups. Participants were asked to perform a single-leg forward hop and followed with a single-leg landing on the force plate. The forward jump distance was standardized to 50%, 100%, and 150% of leg length from the center of the force platform. Results from the current study indicated two major findings: the CAI group were use greater ankle external rotation to avoid the possibility of ankle sprains during single-leg landings. During descending phase of landing, the CAI group demonstrated a greater medio-lateral GRF compared to healthy group. Our findings indicated that different landing strategy of ankle joints exist among 3 groups.

KEY WORDS: ankle sprain, sport injury, single-leg landing, functional test

INTRODUCTION: Lateral ankle sprain (LAS) is occured from a sudden excessive ankle inversion combined with an extreme internal rotation of calcaneous, with or without ankle plantarflexion (Gehring, Wissler, Lohrer, Nauck, & Gollhofer, 2014). LAS injuries often result in joint effusion, muscle weakness, altered movement, and reduced functional performance. Jump-landing is a common and complicated movement repeatedly used at various sports activities, such as gymnastics, soccer, basketball and volleyball. These types of sports activities could carry higher risk associated with lower extremity injuries. Most LAS often occur during single-leg landing. The inverted ankle sprain may cause excessive stress of the lateral ligament complex, which could lead to an unstable ankle. (Fong, Chan, Mok, Yung, & Chan, 2009). The LAS injuries have a high recurrence rate up to 75% (Hootman, Dick, & Agel, 2007; Yeung, Chan, So, & Yuan, 1994). Chronic ankle instability (CAI) is often a result from repeated LAS. It's estimated that 73% of people who suffer LAS will go on to develop CAI (Yeung et al., 1994). The individuals with CAI complain about ankle "giving away" and loss of function as well as fail to return to the level of previous activity (Delahunt et al., 2010; Konradsen, Bech, Ehrenbjerg, & Nickelsen, 2002). CAI is associated with lower extremity neuromuscular mechanical changes in the performance of motion tasks, such as walking, running gait and jump-landing movement. These are related to the recurrent episodes of ankle instability (Brown, 2011). In addition to CAI, people who have history of ankle sprains but without functional movement limitations have been called "copers". This group not only could provide clinical evidence when compared to CAI, but also could be used as a comparison to healthy people (Wikstrom et al., 2010).
Recently, studies have shown that CAI group does have differences in the ankle kinematics compared to the healthy controls and copers. However, there was still not enough information regarding to the joint kinetics of the CAI group during dynamic tasks (Drewes et al., 2009). Kristianslund, Bahr, and Krosshaug (2011) showed that joint kinetics could provide more detail information about the neuromuscular control of the ankle joint while injuries occurred during dynamic tasks than joint kinematics alone. It has been known that multidirectional jump-landing tasks could be a potential injury risk for the ankle joints (Wikstrom et al., 2010). Single leg landing from a forward jump requires good neuromuscular controls to prevent ankle sprains. Studies have shown that CAI group has difficulty to maintain ankle stability during jump-landing task. When difficulty level of forward jump increased, CAI group could possibly have a greater chance to suffer ankle injuries than the healthy controls and copers (Sinsurin et al., 2013). In order to avoid second ankle injury, correct functional movement assessment should be applied to CAI athletes. Hence, if we can identify differences in lower extremity joint kinematics and kinetic variability between coper and CAI individuals may provide a stronger, more relevant comparison in moving toward prospective studies and development of clinical outcome prediction models to prevent the reinjury risks. Therefore, the purpose of this study was to compare kinematics and kinetics variability between individuals with healthy control, coper and CAI group when performing different distance of forward jump-landings. We hypothesized that ankle joint kinematics and kinetics would differ among those who were CAI, copers and healthy controls.

METHODS: Twelve subjects were recruited to participate in this study. Among these 12 subjects, 4 subjects who had classified as CAI (CAIT score is less than 23 with repetitive ankle sprains and feeling instability and weakness over ankle joint), served as the experimental group; 4 subjects who had classified as coper (CAIT score is ranged between 25 and 28 with an ankle sprain experience at least 12 months ago); 4 subjects who had classified as healthy control (CAIT score is higher than 28 with no ankle injury history. If the CAIT score is less than 24, the participant needed to be test by an experienced athletic trainer to confirm the severity of ankle functional instability (Liu et al., 2013). Detailed demographic information was present in table 1.

Table 1
Detailed demographic data of each group

	CAI	Coper	Healthy control
N	4	4	4
Gender	F: 3, M: 1	F: 3, M: 1	F: 4, M: 0
Height (cm)	172.7 (13.5)	181.7 (7.1)	178.5 (7.9)
Mass (kg)	62.0 (3.5)	79.3 (11.0)	71.2 (13.8)
Age (years)	20.7 (2.1)	21.3 (1.5)	21.3 (4.3)
CAIT score	18.0 (2.0)	28.0 (1.0)	28.0 (0.0)
No. of sprains	>3	1	0

The exclusion criteria included an additional ankle injury (multi-ligament injury); osteoarthritis; severe muscle atrophy; or a recent injury to the spine, hips, ankles, or contralateral lower extremity joints in the previous 6 months. Kinematics and kinetics data were collected in a laboratory setting using 10 Vicon infrared video cameras (200 Hz), and one Kistler force platform (1000 Hz) were synchronized to acquire the ground reaction force and kinematic data during jump landing respectively. The marker were placed utilizing plug-in-gait marker set (Sinsurin, Vachalathiti, Jalayondeja, & Limroongreungrat, 2013).
Before data collection, subjects were allowed to warm-up by running on a treadmill at a self-selected speed for approximately 5 min. For the testing task, participants were asked to perform a single-leg forward hop and followed with a single-leg landing (supporting leg only) on the force plate. The forward jump distance was standardized to 50%, 100%, and 150% of leg length (greater trochanter to lateral malleolus) from the center of the force platform and assigned to subjects randomly. This task was modified from the task described by Liu et al (2013). If the participant could not maintain balance or have extra hops during single leg landing, then that trial was considered a failure; at least 5 successful trials were collected.
The Vicon Nexus software was used to collect data of 3D marker trajectories and ground reaction force, respectively. Kinematics and kinetics data was processed using Visual 3D (C-motion, Rockville, MD, USA). The 3D marker trajectories and GRF data were filtered by a fourth-order zero-lag Butterworth digital filter at cut-off frequencies of 8 Hz and 40 Hz, respectively (Sinsurin et al., 2013). The sagittal and frontal plane lower extremity kinematics and kinetics data during landing phase were used for analysis.
One way ANOVA with Tukey's post-hoc test was used to identify significant differences among the healthy control, coper, and CAI groups. Statistical analyses were performed using SPSS statistical software (SPSS Inc., Chicago, IL). Significance levels were set at $\alpha = .05$.

RESULTS: The CAI group showed significantly greater ankle external rotation angle compared to the healthy group during 150% leg length forward jumps ($p < .05$) (Fig. 1). The CAI group showed greater medio-lateral ground reaction force compared to the healthy group ($p < .05$) (Fig. 2).

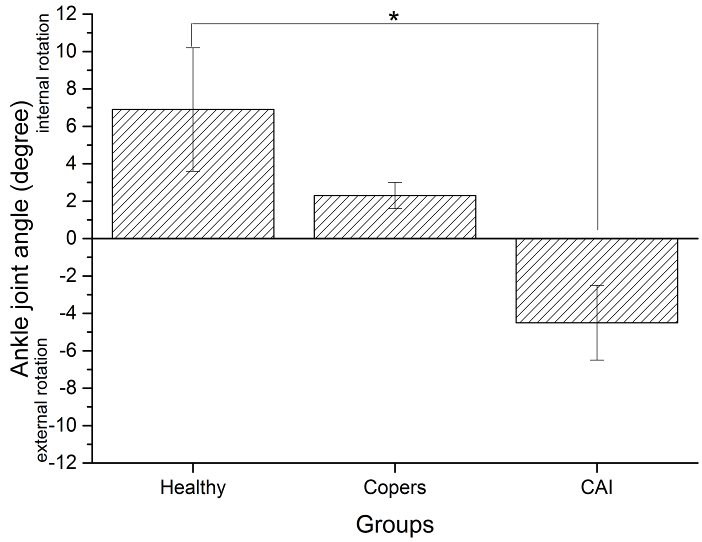

Figure 1: Ankle angle during 150% leg length forward jumps at initial contact.

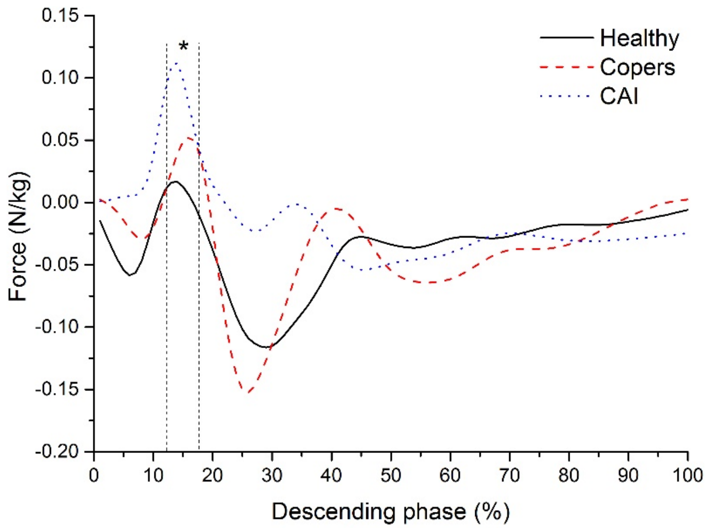

Figure 2: Medio-lateral GRF during 150% leg length forward jumps from intial landing to the lowest center of mass location.

DISCUSSION: The purpose of this study was to investigate the effects of different distance forward jump on sagittal and frontal plane joint kinematics and kinetics among the healthy control, coper, and CAI groups. Results from the current study indicated two major findings: (1) The CAI group were use greater ankle external rotation to avoid the possibility of ankle sprains during single-leg landings, (2) During descending phase of landing, the CAI group demonstrated a greater medio-lateral GRF compared to healthy group.

In this study, there were no significant differences between the groups in terms of sagittal plane range of motion, peak angular velocities and peak extension moments during the descending phase of landing at 3 different forward jump distances. At forward jump of 150% leg length distance, a significant greater ankle external rotation angle and frontal plane GRF were discovered at initial single leg landing of the CAI group. The greater ankle external rotation angle of CAI indicates that CAI group utilized more lateral ankle muscle activations to avoid ankle inversion during initial landing (Kavanagh, Bisset, & Tsao, 2012). In addition, the greater medio-lateral GRF of CAI was also related to the anticipatory lateral ankle muscle activations. As the forward jump challenge level increased, the trend of ankle external rotation and medio-lateral GRF increased, which could resist the effect of ankle inversion during foot initial contact, especially for the CAI group.

CONCLUSION: Our findings indicated that different landing strategy of ankle joints exist among 3 groups. CAI group demonstrated a greater ankle external rotation and greater frontal plane GRF than two other groups. However, the forward jump test could not detect the possible injury risk of the coper group. The coper individual could become CAI from another ankle sprain during functional sports activities. Therefore, it's important to figure out the possible injury risk for CAI and copers. In the current study, small sample size was the major limitation. More subjects need to be recruited and lower extremity muscle activations need to be analyzed for the following study.

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