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HOW TO CONTROL ANKLE JOINT IN VARIOUS DIRECTIONS OF ONE LEG JUMP-LANDING: FRONTAL PLANE MOMENT AND EMG STUDY

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The variation of jump-landing directions would challenge muscular control around ankle joint. The purposes of this study were to assess the frontal plane moment of ankle and EMG of tibialis anterior (TA), peroneus longus (PL), and medial head of gastrocnemius (GAS) muscles. Eighteen male athletes participated in the study. Subjects performed the one leg jump-landing test from a 30 cm height platform in four directions; forward (0°), 30° diagonal, 60° diagonal, and lateral (90°) directions. The finding exhibited that peak evertor moment significantly increased from forward to lateral direction. The need for increased muscle activity of PL was highlighted. The landing needed more co-contraction between TA and PL for maintaining balance. It seems that the awareness around ankle during jump-landing in diagonal and lateral direction should be more focused comparing to forward direction.

KEY WORDS: joint moment, joint angle, jump-landing, ankle joint

INTRODUCTION: Lateral ankle sprains are the most common of sport injuries (Fong, Hong et al. 2007). Ten to thirty percent of athletes who had lateral ankle sprain developing chronic ankle instability (CAI) (Peters, Trevino et al. 1991) and then increase the risk of ankle injuries. Previous researches studied to understand the risk and mechanism of ankle sprain during variety of activities such as walking, cutting, and forward landing tasks (Caulfield and Garrett 2002; Monaghan, Delahunt et al. 2006; Gehring, Wissler et al. 2013). Excessive inversion angle and unphysiological inversion moment might be the cause of the ankle injury during landing (Parenteau, Viano et al. 1998; Kristianslund, Bahr et al. 2011). In the real situation of games and practices, athletes perform many directions and different postures of movements. No study has investigated the multi-direction effect during one leg jump-landing. The researchers expected that variation of jump-landing directions would challenge neuromuscular control around ankle joint. Therefore, purposes of this study were to assess the frontal plane moment of ankle and EMG of tibialis anterior muscle (TA), peroneus longus muscle (PL), and medial head of gastrocnemius muscle (GAS). The natural patterns of ankle moment and EMG are essential for understanding the muscular control around ankle joint. Moreover, this would be the fundamental data to compare with the athletes who have the risk of ankle sprain.

METHODS: Eighteen male athletes participated in the study. All participants were members of organized university teams. Participants had no reported musculoskeletal disorders within 3 months prior to data collection. Subjects were excluded if they had history of serious injury or operation of lower extremities (e.g. Ankle sprain, CAI, ACL injury, fracture, patellar dislocation). Each participant read and signed an informed consent which was approved by the Committee on Human Rights Related to Human Experimentation of Mahidol University.
Procedure: All tests were collected in the motion analysis laboratory at the Faculty of Physical Therapy, Mahidol University equipped with a Vicon™ 612 workstation (Oxford Metrics, Oxford, UK). Kinematics and GRFs data were captured by four video cameras (200 Hz) and forceplate (1,000 Hz), respectively. Muscle activation was measured by an electromyography (Noraxon Myosystem) at a frequency of 1000 Hz in order to quantify dynamic muscle function of TA, PL, and GAS. Surface electrodes were placed in pairs over the muscle belly in dominant leg with an interelectrode spacing of 2 cm center to center

according to recommendations of the European Recommendations for Surface Electromyography (SENIAM) (www.seniam.org). The sixteen reflective markers based on lower body model of Plug in Gait were placed bilaterally on the subject's bony prominences at the anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), thigh, lateral condyles of femur, shank, lateral malleolus, heel, and 2nd metatarsals. Subjects practiced jump-landing 3 - 5 times in each direction to become familiar with the testing movements. Subjects performed the one leg jump-landing test in four directions; forward (0°), 30° diagonal, 60° diagonal, and lateral (90°) directions (Figure 1). The order of jump direction was selected randomly. A 30 cm height platform was placed 70 cm from the center of forceplate. The participants stood on the dominant leg on a wooden platform, and flexed the other knee approximately 90° with a neutral hip rotation. Both hands were placed on the waist to eliminate variability in jumping mechanics due to arm-swing. Each subject was instructed to carefully jump-off the wooden platform without an upward jump action. Subjects jumped and landed with the dominant leg while always facing and looking forward during jump-landing tests. If a subject did not maintain unilateral balance, land on the center of forceplate, or maintain hands on the waist, it was considered as an unsuccessful trial and reperformed. Three successful trials in each direction of jump-landing were analyzed. Participants rested five minutes between directions and at least thirty seconds between trials. Only the dominant leg of subjects was assessed.

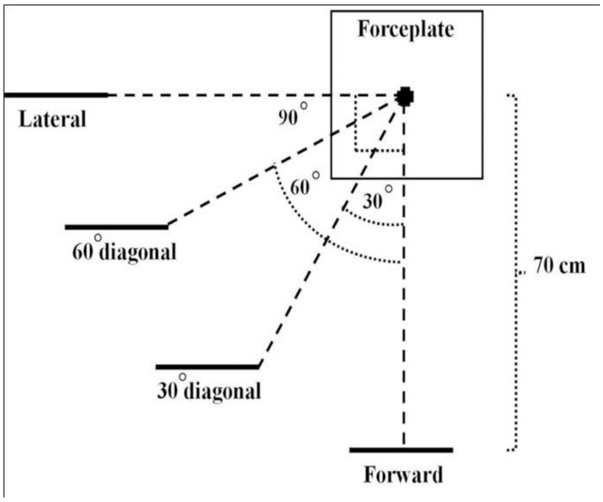

Figure1: Research setting of jump-landing directions.

Data acquisition and analysis: Sixteen marker coordinates were filtered by a fourth order zero-lag Butterworth digital filter at a cut-off frequency of 8 Hz residual analysis technique (Winter 2005). EMG data from each muscle were filtered by second order recursive Butterworth filter at low pass frequency 350 Hz and high pass frequency 30 Hz, respectively, and then full-wave rectified. A three dimensional model of the lower extremity was constructed by Plug in Gait software. The peak ankle moment and averaged EMG 100 ms prior to and 300 ms after landing from three trials were averaged and analyzed. The highest peak EMG of each muscle was selected from a trial of forward jump-landing test and analyzed as maximum EMG amplitude of each trial. This value of each muscle was used to normalize the EMG signals obtained during the jump-landing tests. Repeated measures ANOVA with post-hoc comparison were performed to analyze the data. The statistical comparisons were performed with SPSS statistics 17. The level of statistical significance was set at p-value less than 0.05.

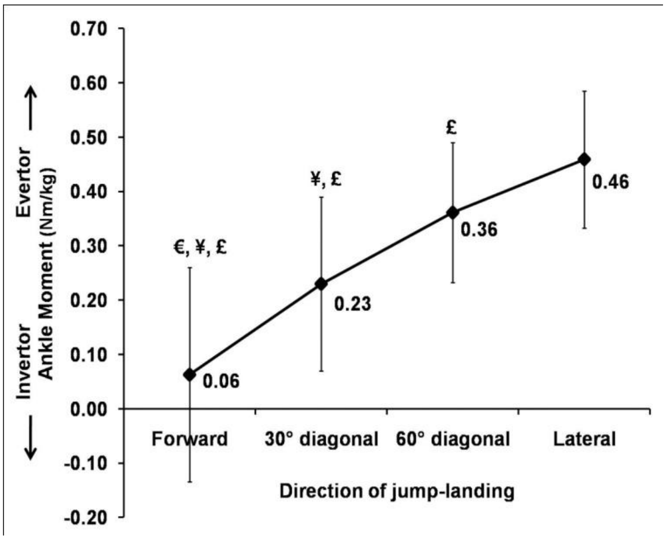

Figure 2: Peak internal net ankle moment during landing in four directions.
€ Sig. compared with 30° diagonal direction
¥ Sig. compared with 60° diagonal direction
£ Sig. compared with lateral direction

RESULTS AND DISCUSSIONS: Peak evertor moment exhibited an increasing trend from forward to lateral direction (Figure 2). Direction significantly influenced to peak evertor moment [$F(1.96, 33.32) = 75.67$, $p < 0.001$]. This study demonstrated that jump-landing without injury needed more mechanical demand of ankle evertor muscles from forward, 30° diagonal, 60° diagonal, and lateral directions, respectively. When observing EMG of TA and PL muscles, after foot contact, significant increase in TA [$F(3,51) = 5.48$, $p = 0.002$] and [PL $F(3,51) = 7.99$, $p < 0.001$] muscle activities from forward to lateral direction of jump-landing were indicated (Figure 3). Even though TA muscle increased muscle activity, PL muscle showed higher EMG. Therefore, an increase of PL muscle activity could be the cause of increasing evertor moments. Neuromuscular response is an important factor to increase joint dynamic stability and prevent injuries (Williams, Chmielewski et al. 2001). PL muscle showed high muscle activity through jump-landing task. Neptune et al stated that TA and PL muscles may help to reduce risk of ankle sprain injury (Neptune, Wright et al. 1999). These muscles prevented excessive rotation and stabilize subtalar joint. High TA muscle activity after foot contact would help to co-contract for maintaining balance during landing.

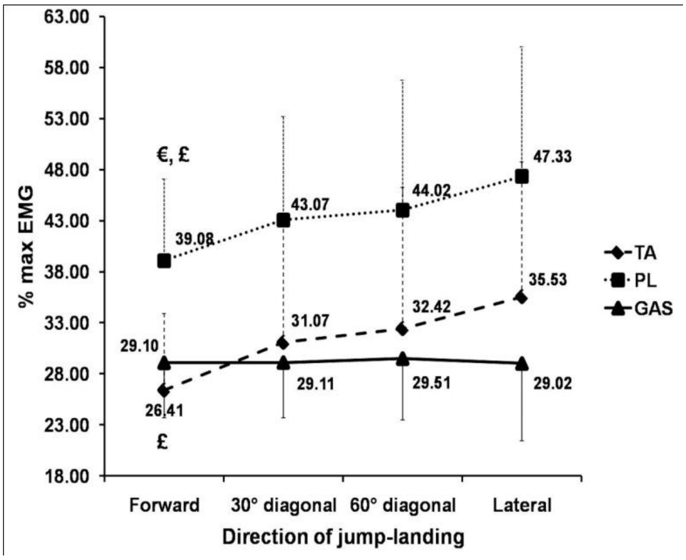

Figure 3: Averaged EMG 300 ms before contact.
€ Sig. compared with 30° diagonal direction
¥ Sig. compared with 60° diagonal direction
£ Sig. compared with lateral direction

Before foot contact phase, direction significantly influenced to PL $F(3,51) = 10.44$, $p < 0.001$ muscle activities of 100 ms before foot contact (Figure 4). Early and high muscle pre-activation helps to reduce the time needed to develop muscle tension and increase muscle forces. This study supported the finding of previous study (McLoda, Hansen et al. 2004). PL muscle showed higher muscle activity than TA muscle before foot contact. Moreover, a trend of decreasing activity of GAS was observed in the current study. Landing with ankle inversion could be a cause of lateral ankle sprain (Fong, Hong et al. 2009). Feedforward neuromuscular control consists of activating the musculature around ankle joint before foot contact (Santello 2005). Gutierrez et al stated that this control may be more important for dynamic joint stability than feedback neuromuscular control (Gutierrez, Kaminski et al. 2009). The preparatory phase is the important period to control ankle in proper posture and then could respond to impact force during landing. When observing the direction effect, there was a trend of increasing PL muscle activity from forward to lateral direction. Impair reflex response, was found in CAI group, especially delayed the reaction time of evertor muscles to unexpected inversion (Konradsen and Ravn 1990). In

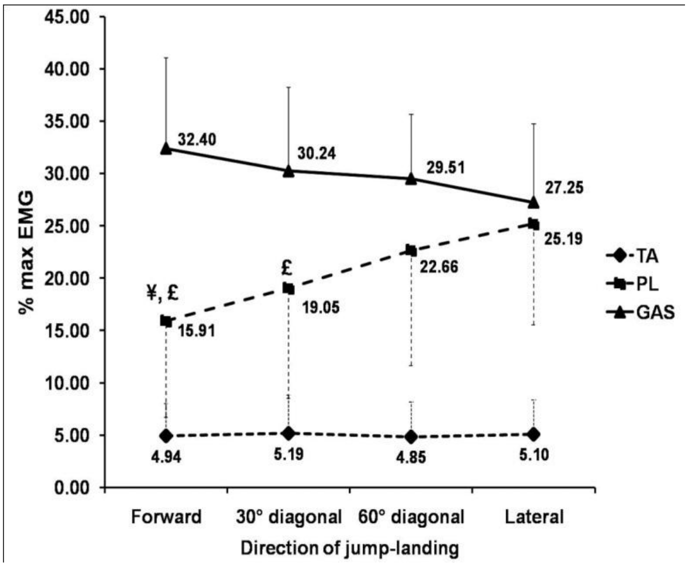

Figure 4: Averaged EMG 100 ms before contact.
€ Sig. compared with 30° diagonal direction
¥ Sig. compared with 60° diagonal direction
£ Sig. compared with lateral direction

case of CAI and muscle fatigue during late practice or game, risk of ankle sprain might be increase because of decreasing PL muscle activity in preparatory phase. Multi-directions of jump-landing in athletes with CAI would be interesting for the further study.

From the finding of this study, the jump-landing from forward to lateral direction would need more PL muscle activity through jump-landing activity. This study indicated the need for increased awareness during jump-landing in diagonal and lateral direction. The current study examined and reported muscle activities of lower extremity in healthy groups. The data represent the natural patterns of lower extremity muscles in various jump-landing directions.

CONCLUSION: Direction significantly influenced the frontal plane moment and muscle activities of TA, PL, and GAS. The need for increased muscle activity of PL was highlighted through jump-landing task. The awareness around ankle joint during jump-landing in diagonal and lateral direction should be focused compare to forward direction.

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