LANDING TRAINING WITH CONCURRENT TACTILE FEEDBACK INCREASED MAXIMUM KNEE FLEXION ANGLE AND DECREASED IMPACT FORCES

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The current study evaluated the effects of landing training with a tactile feedback device on knee flexion angles and impact ground reaction forces (GRF). Twenty-two recreational athletes performed 3 landing trials without the device (baseline), 6 landing trials with the device (training), and 3 landing trials without the device (retention). The maximum knee flexion angle during landing was greater for the training and retention conditions compared to the baseline condition. The vertical GRF at peak posterior ground reaction force (PPGRF) was smaller for the training condition compared to the baseline condition. The sagittal plane resultant force at PPGRF was smaller for the training and retention conditions compared to the baseline condition. The tactile feedback device might be used in landing training to modify movement patterns and decrease the risk of ACL injury.

KEY WORDS: ACL, Kinematics, Kinetics, biomechanics.

INTRODUCTION: Non-contact anterior cruciate ligament (ACL) injuries commonly occur during jump-landing tasks (Boden, Dean, Feagin, & Garrett, 2000). Knee flexion angle has been identified as an important ACL loading mechanism and ACL injury risk factor (Yu & Garrett, 2007). With a constant anterior shear force applied at the proximal tibia, ACL loading increases as the knee flexion angles decreases (Yu & Garrett, 2007). The ACL reaches its peak strain when the knee flexion angle is minimal during landing (Taylor et al., 2011). Because ACL injuries typically occur at the early phase during landing, increasing the knee flexion angle at initial contact of landing has been suggested to decrease the risks of ACL injury (Brown et al., 2012). Additionally, a prospective study found that a decreased maximum knee flexion angle during landing was a risk factor for ACL injury (Hewett et al., 2005). Although peak ACL strain was not like to occur at the maximum knee flexion during landing, an increased maximum knee flexion was likely to increase joint range of motion and decrease impact ground reaction forces (GRF) (Devita & Skelly, 1992).
Training individuals to land with increased knee flexion angles therefore might decrease the risks of ACL injury. Feedback, which is important to facilitate learning during early phases of new skill acquisition, plays an important role in jump-landing training (Ericksen, Gribble, Pfile, & Pietrosimone, 2013). Previous investigators have employed verbal, visual, and audible feedback to increase knee flexion angles and decrease impact GRF in jump-landing training (Ericksen et al., 2013; Steele, Munro, & Wallace, 2004). However, these feedback methods usually had one or several limitations including the need of extra personnel, the need of relatively expensive equipment, time-delay in receiving feedback, and a lack of accuracy. Therefore, the purpose of the current study was to evaluate the effects of landing training with tactile feedback on knee flexion angles and impact GRF during a jump-landing-jump task. It was hypothesized that participants would demonstrate increased maximum knee flexion angles and decreased impact GRF during and after training.

METHODS: Twenty-two recreational athletes (gender: 11 males, 11 females; age: 19.9 ± 2.3 years; height: 1.76 ± 0.1 m; mass: 71.3 ± 9.7 kg) participated in the current study. Participants were physically active and had experience in sports that involved jump-landing tasks. Participants had no history of ACL injuries or other major lower extremity injuries. The current study was approved by University of Wyoming Institutional Review Board.
The testing side (left or right) was randomly selected. Retroreflective markers were placed on participants' bony landmarks to define trunk, pelvis, thigh, shank, and foot segments. Marker positions were captured using 8 Vicon Bonita cameras (Oxford, UK) at a sampling frequency of 160 Hz. GRF and center of pressure data were collected using a Bertec force plate (Columbus, OH) at 1600 Hz. A wearable feedback device (Figure 1) was developed. The

device included three components: a synthetic leather belt with adjustable length, a horizontal component, and a vertical component. The placement of the belt on the shank and the length of the vertical component were adjustable so that the tip of the vertical component would firmly touch the posterior thigh at a certain knee flexion angle. By asking participants to touch the tip of the vertical component during landing, a concurrent tactile feedback regarding whether participants reached a predefined maximum knee flexion angle was provided.

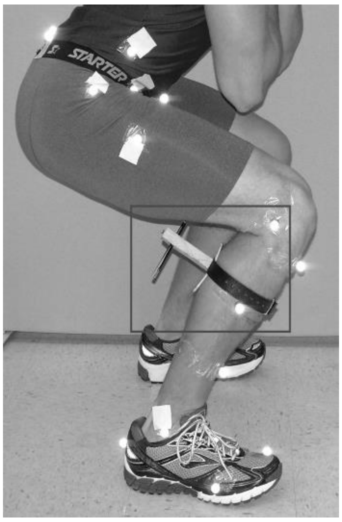

Figure 1. Feedback Device

Participants performed a static trial and jump-landing-jump trials with 30 seconds rest between trials. In the jump-landing-jump task, participants jumped from a 30-cm high box to a distance of 50% of their height forward of the box. Participants landed on both feet with the foot of testing side on the force plate, and rebounded for a maximal vertical jump. Participants performed 3 trials of the landing task without any feedback as baseline trials. Maximum knee flexion during the baseline trials was calculated. The tactile feedback device was then attached to participants' shank. The device was configured in a way that the tip of the vertical component would touch the posterior thigh when the knee flexion angle was either at 100 degrees or 16 degrees greater than the participant's maximum knee flexion during the baseline testing, whichever was larger. One hundred degrees of knee flexion was considered as high knee flexion (Pollard, Sigward, & Powers, 2010) and previous inverstigators have shown that participants were able to increase their maximum knee flexion angle by 16 degrees (Dowling, Favre, & Andriacchi, 2012). Participants performed 6 training trials (first 3 trials as Training I and last 3 trials as Training II) of the landing task with tactile feedback. Participants were instructed to touch the device during landing before they rebounded for a maximum vertical jump. The device was removed from the participant after the training trials. Participants then performed 3 retention trials of the landing task. During the retention trials, participants were instructed to maintain the movement patterns they performed in the training trials.

The marker coordinates and force plate data were filtered at low-pass cut-off frequencies of 15 Hz and 100 Hz, respectively. Knee joint angles were calculated as the Cardan angles between thigh and shank reference frames. The peak posterior ground reaction forces (PPGRF) during the landing phase was used as a critical time point for ACL loading (Yu, Lin, & Garrett, 2006). The initial knee flexion angle, knee flexion angle at PPGRF, maximum knee flexion angle, PPGRF, vertical GRF at PPGRF, and sagittal plane resultant GRF at PPGRF were extracted for analysis. The landing trials were separated into 4 landing conditions: baseline, training I, training II, and retention. Repeated measure ANOVAs with landing condition as a within-participant factor were used to quantify the differences in knee flexion angle and impact GRF. The testing side (right or left) effect was not tested. A significant ANOVA test was followed by paired-wise comparisons using 95% confidence interval. A type I error rate was established at 0.05 for statistical significance.

RESULTS: ANOVAs demonstrated significant condition effects for the maximum knee flexion angle ($p<0.001$, Figure 4), vertical GRF at PPGRF ($p= 0.01$, Figure 6), and sagittal plane resultant force at PPGRF ($p=0.006$, Figure 7). No significant effect was found for the initial knee flexion angle ($p = 0.46$, Figure 2), knee flexion angle at PPGRF ($p=0.28$, Figure 3), and PPGRF ($p=0.08$, Figure 5). The maximum knee flexion angle was greater for the training I ($p < 0.001$), training II ($p < 0.001$), and retention conditions ($p < 0.001$) compared to the baseline condition. The vertical GRF at PPGRF was smaller for the training I ($p<0.001$) and training II ($p=0.024$) conditions compared to the baseline condition. The resultant force at PPGRF was smaller for the training I ($p < 0.001$), training II ($p=0.013$), and retention conditions ($p=0.046$) compared to the baseline condition.

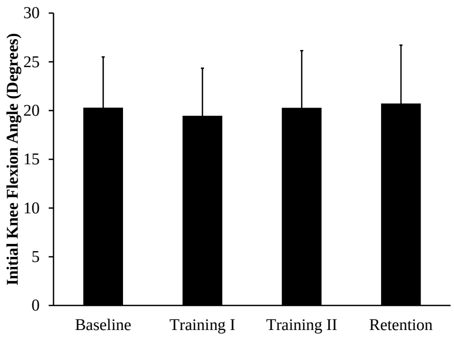

Figure 2. Initial knee flexion angle

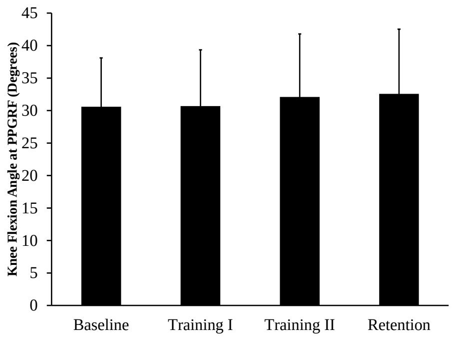

Figure 3. Knee flexion angle at peak posterior ground reaction force

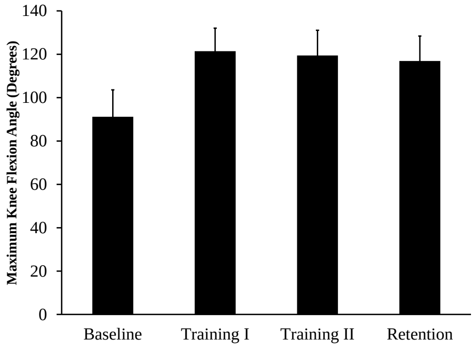

Figure 4. Maximum knee flexion angle

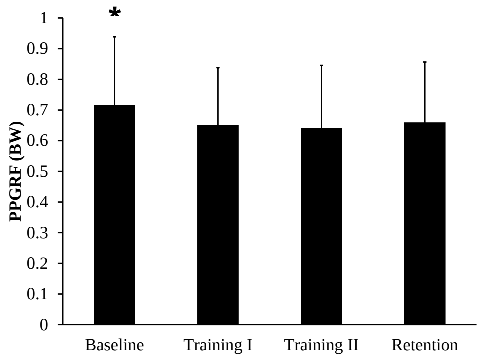

Figure 5. Peak posterior ground reaction force

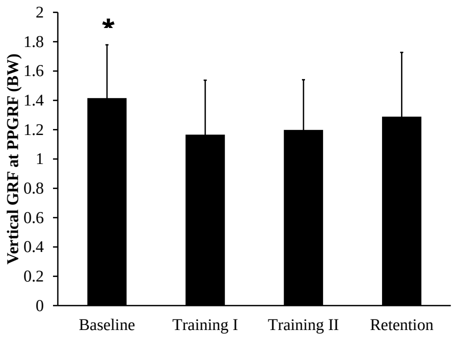

Figure 6. Vertical ground reaction force at peak posterior ground reaction force

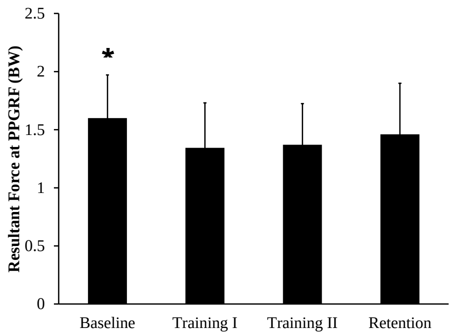

Figure 7. Sagittal plane resultant force at peak posterior ground reaction force

DISCUSSION: The purpose of the current study was to evaluate the effects of training with tactile feedback on knee flexion angle and impact GRF during a jump-landing-jump task. A simple device was developed to provide tactile feedback regarding whether participants reached a predefined maximum knee flexion angle. The findings supported the hypothesis that participants would demonstrate increased maximum knee flexion angles and decreased impact GRF during and after training. Previous investigators have studied the effects of soft landing techniques on lower extremity kinematics and kinetics (Devita & Skelly, 1992; Zhang, Bates, & Dufek, 2000). A soft landing was characterized by increased joint range of motion and decreased impact GRF (Devita & Skelly, 1992; Zhang et al., 2000). With regard to the relationships between impact GRF and ACL loading, GRF transmitted through the tibia to the tibiofemoral joint and a tibiofemoral compressive force could load the ACL through a posterior tibial plateau slope (Meyer & Haut, 2005). In addition, an increased posterior GRF was associated with an increased anterior shear force applied to proximal tibia to load the ACL (Yu & Garrett, 2007). In the current study, the increased knee range of motion dissipated impact GRF through a longer period of time. The decreases in vertical GRF at PPGRF and resultant GRF at PPGRF were significant during the training and retention

conditions. The decreased impact GRF has been previously demonstrated to be associated with decreased ACL loading (Meyer & Haut, 2005; Yu & Garrett, 2007).
The significant increases in maximum knee flexion angle in training and retention conditions were expected because of the specific feedback provided by the device. It should be noted that participants tended to excessively flex thee knee to make sure that they could receive the tactile feedback. Therefore, participants usually reached a maximum knee flexion greater than the predefined maximum knee flexion angle. On the other hand, the increases in maximum knee flexion did not result in increases in initial knee flexion and knee flexion at PPGRF which would be desirable to reduce ACL loading (Brown et al., 2012). Individuals modified their movement patterns specific to the tactile feedback they received. Other feedback or training methods are needed to increase knee flexion angles during early landing phase. The tactile feedback device had several advantages in applications. The device can be implemented to training by an individual independently. The device is easy to use and has a low cost. The device can provide accurate and real-time feedback without time-delay.

CONCLUSION: Jump-landing training with concurrent tactile feedback increased individual's maximum knee flexion angles and decreased impact GRF. The tactile feedback device might be used in landing training to modify movement patterns and decrease the risk of ACL injury. The tactile feedback device has advantages in applications because it can provide independent, accurate, and real-time feedback at a low cost.

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