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Jump–landing biomechanics following a 4-week real-time feedback intervention and retention

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ABSTRACT

Background: Poor neuromuscular control can increase the risk of anterior cruciate ligament (ACL) injury. Landing with decreased knee and hip flexion may increase the risk of lower extremity injury. Feedback interventions have demonstrated changes in jump–landing biomechanics. Traditional feedback (TF), provided after task completion, includes critical factors to focus on during jump–landing. Real-time feedback (RTF), provided while completing the task, may be superior for improving jump–landing biomechanics. This investigation evaluated the effect of RTF + TF compared to TF and a control group in changing lower extremity jump–landing biomechanics following a 4-week feedback intervention and a 1-week no feedback retention.

Methods: Participants completed 12 feedback sessions over 4 weeks. At each session, participants performed 6 sets of 6 jumps off a 30 cm box. Participants were provided TF or RTF + TF following each set of jumps. Participants were tested at baseline, immediately following the 4-week intervention and following a 1-week retention. The control group was tested at two time points 4 weeks apart.

Findings: Acquisition analysis: RTF + TF and TF groups demonstrated greater change in peak hip flexion angles and peak knee flexion angles compared to the control group following the intervention. TF and RTF + TF groups demonstrated a greater decrease in peak vertical ground reaction force compared to the control group. No significant differences were observed between groups in the retention analysis.

Interpretation: This study provides evidence of acquisition of biomechanical changes following a 4-week feedback intervention. Future research should further investigate the retention of biomechanical changes, the optimal length of feedback interventions and transfer of learned biomechanics to similar athletic tasks.

1. Introduction

Proper neuromuscular control of the lower extremity and trunk may play a critical role in decreasing the risk of sustaining an anterior cruciate ligament (ACL) injury (Grindstaff et al., 2006). Specific movement characteristics (Hewett et al., 2005) that can be identified during a jump–landing (Norcross et al., 2013; Padua et al., 2011) may predict ACL injury risk. Those who land from a jump with decreased knee and hip flexion (Hewett et al., 2005; Norcross et al., 2013) and high knee abduction moments (Myer et al., 2015) have been found to have a higher likelihood of sustaining a non-contact ACL injury. Interventions that include some form of feedback have been especially beneficial in changing jump–landing mechanics in a way that may help reduce ACL injury risk (Hewett et al., 2006). Feedback is a fundamental motor learning technique that has demonstrated the ability to enhance the acquisition and retention of learning motor skills (Wulf et al., 2002). Feedback can be generally defined as information made available to the participant in an attempt to alter a movement (Winstein, 1991). Varying modes of feedback have been provided at time points before or after a task is complete in an effort to improve acquisition and retention of landing biomechanics (Ericksen et al., 2015; Etnoyer et al., 2013; Ford et al., 2015; Herman et al., 2009; Onate et al., 2001; Onate et al., 2005).

Traditional jump–landing feedback (TF) can be described as a checklist of critical biomechanical factors (Herman et al., 2009; Onate et al., 2005) inherent to proper jump–landing mechanics which may decrease the risk of knee injury, such as bending at the hips and knees and landing softly. Traditional feedback is provided after the completion of a jump–landing, and has previously been referred to as post-response feedback (Ericksen et al., 2015). The two major goals of jump–landing

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feedback interventions are to decrease landing forces and increase sagittal plane knee and hip kinematics while completing an athletic task. Increased dynamic knee valgus has prospectively been demonstrated to be present in females who sustained a non-contact ACL injury (Hewett et al., 2005). Onate et al. (2005) and Herman et al. (2009) successfully implemented traditional augmented video feedback protocols to decrease vertical ground reaction force (vGRF) and increased knee flexion angles following a 1-time intervention; however, no changes were demonstrated in frontal plane biomechanics at the knee.

Real-time feedback (RTF) provides feedback during completion of an athletic task compared to TF, in which feedback is given following completion of the athletic task. RTF has been utilized successfully with slower, more repetitive movements such as gait (Barrios et al., 2010; Crowell and Davis, 2011; Willy et al., 2012) and is being explored with dynamic movements such as jump–landing (Beaulieu and Palmieri-Smith, 2014; Ericksen et al., 2015; Ford et al., 2015). Beaulieu and Palmieri-Smith (2014) demonstrated a decrease in vGRF during jump–landing immediately following RTF on knee abduction moment visualized during a double limb landing. A single session RTF jump–landing intervention (Ericksen et al., 2015) focused on decreasing knee frontal plane motion demonstrated increased knee and hip flexion angles and decreased peak vGRF during a jump–landing. Determining the efficacy of RTF interventions in changing jump–landing biomechanics has important implications for reducing injury risk; yet, there has been no previous investigation of RTF interventions following a long-term acquisition period over multiple consecutive weeks or a short-term retention. Retention of biomechanical changes may suggest durability of altered motor patterns, which may translate to changes outside of a laboratory setting and a potential reduction in injury risk (Onate et al., 2005). It is important for participants who are trained with feedback to be able to retain and apply the motor strategies that they have previously learned at a later date. In order for any type of feedback intervention to have lasting effects on lowering injury risk, participants must be able retain the newly acquired motor patterns following a period of time without feedback.

The purpose of this investigation was to determine the effect of a 4-week RTF + TF intervention on rebound jump–landing biomechanics immediately following a 4-week intervention (acquisition) and one week following completion of the intervention (retention). Our primary hypothesis was that following the four-week intervention, participants in the RTF + TF and TF groups would demonstrate: (1) decreased peak vertical ground reaction force (vGRF), peak knee abduction angle, peak external knee abduction moment, and peak external knee extension moment; and (2) increased peak knee and hip flexion angles and peak external hip extension moment during a rebound jump–landing task compared to the control group that received no feedback. Our secondary hypothesis was that compared to the TF group, the RTF + TF group would demonstrate greater retention of the biomechanical changes one week following the end of the intervention.

2. Methods

2.1. Study design

We utilized a randomized controlled trial design with a block randomization with concealed allocation to assign participants into 1 of 3 groups: TF, RTF + TF, or a control group. Participants were unaware that there were two feedback groups and therefore were unaware of the group to which they were assigned (TF or RTF + TF). Outcome measures were collected at 3 separate time points during a rebound jump–landing task (baseline, following the four-week acquisition period, and at the one-week retention time point). All 3 groups were tested at the acquisition time point and only participants in the intervention groups were tested at the retention time point, which was scheduled one week following the acquisition testing.

2.2. Participants

All participants were healthy females, between the ages of 18 and 30 years, recruited from a university student population (RTF + TF: $n = 16$, 20.00 ± 1.63 years, 1.63 ± 0.07 cm, 59.76 ± 8.46 kg; TF: $n = 16$, 19.25 ± 1.39 years, 1.65 ± 0.08 cm, 56.49 ± 7.04 kg; control: $n = 16$, 19.75 ± 1.73 years, 1.64 ± 0.05 cm, 59.23 ± 8.83 kg). We excluded any individuals with a history of lower extremity fracture, surgery, major knee or hip ligamentous injury (such as knee sprains or chronic knee pain), chronic ankle instability (<90% on the Foot and Ankle Ability Measure), or a body mass index of greater than 30. Potential participants were screened by a single investigator using the Landing Error Scoring System (LESS) (Padua et al., 2011) and included if they presented with dynamic knee valgus upon landing from a jump. All participants were provided written informed consent approved by the university institutional review board prior to performing any of the experiments.

An *a priori* sample size estimate was performed using knee abduction pre-test means and standard deviations from a previous investigation performed in our laboratory (Ericksen et al., 2015). We estimated that 15 participants were required per group to detect a statistical difference between groups with 80% statistical power and an alpha level of 0.05.

2.3. Instrumentation

Kinematics were collected with a 12 camera, digital Eagle motion analysis system (Motion Analysis Corporation, Santa Rosa, CA) and associated Cortex software (Motion Analysis Corporation, Santa Rosa, CA, version 3.6.1) at a sampling rate of 100 Hz. Ground reaction forces were collected with two 18 in. by 20 in. AMTI OR6-5 force platforms (Advanced Motion Technology, Inc., Watertown, MA) at a sampling rate of 1000 Hz. A 107 cm monitor (Sony Bravia, New York, NY), which was interfaced with the motion capture system, was used for administration of the RTF.

2.4. Three dimensional biomechanical analysis

A rebound jump–landing task was used to assess lower extremity biomechanics and consisted of a jump–landing from a 30 cm box, placed at a distance of 50% of the participants' height away from the edge of the force platform, with an immediate rebound jump for maximum height (Padua et al., 2011). The following kinematics and kinetics were chosen for inclusion in the final analysis because of the previous association with the risk of non-contact ACL injury: (Hewett et al., 2005; Norcross et al., 2013; Padua et al., 2011) peak knee flexion angle, peak knee abduction angle, peak external knee extension moment, peak external knee abduction moment, peak hip flexion angle, peak hip adduction angle, peak external hip extension moment, peak external hip adduction moment, and peak vertical ground reaction force (vGRF). All outcome measures were collected at the peak value at the first 25% of the stance phase (initial contact to toe off). The first 25% of the stance phase was selected for analysis as peak ACL loading has been estimated to occur within the first 60 ms upon landing from a jump (Kernozek and Ragan, 2008). Initial contact and toe off were defined as the point at which the vGRF exceeded and fell below 10 N (McLean et al., 2007), respectively, upon landing from a jump and rebounding for maximum height. The outcome measures of interest were averaged over 3 trials. Prior to baseline testing, the participants performed practice trials until the investigator was satisfied that the participants were comfortable with the task.

Prior to each data collection session, the motion analysis system was calibrated, and participants were outfitted with forty retro-reflective markers to collect all kinematic variables. The full marker set included bilateral landmarks of acromioclavicular joint, posterior superior iliac spine, iliac crest, anterior superior iliac spine, greater trochanter, anterior femur, patella, lateral femoral condyle, medial femoral condyle, tibial