# EFFECTS OF KINEMATIC FEEDBACK ON VERTICAL JUMP PERFORMANCE

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The purpose of this study was to examine the immediate effects of kinematic feedback on vertical jump performance. Twenty recreationally active women were randomly assigned to the treatment or control group. Participants performed five maximal countermovement jumps pre-feedback and five jumps post-feedback. Visual and verbal feedback based on the mover's pre-feedback jumps was provided to the treatment group. All participants were also allowed to view their jump performance on video. Treatment participants made reductions in maximal knee flexion (p=0.003) and depth of descent (p=0.003) but no significant changes in jump height (p=0.07), pre- to post-feedback. These findings suggest kinematic feedback is an effective means of modifying movement, however, the feedback in the present study did not result in improvement in jump height.

**KEYWORDS:** motion analysis, range of motion, video, visual and verbal feedback.

**INTRODUCTION:** To enhance jumping ability and improve opportunities for success in sport and physical activity, researchers have worked to identify important predictors of jump performance such as peak and average mechanical power (e.g., Argón-Vargas & Gross, 1997; Dowling & Vamos, 1993). This knowledge has been successfully used to provide feedback and improve vertical jump performance (Staub, et. al., 2013). But, given the tools required for such measurements, power may not be a practical variable for the purpose of feedback for coaches, teachers, and athletes. Ubiquitous technology, such as video, might offer a more convenient method of providing feedback and improving performance.

Feedback based on movement kinematics has been used to improve performance, among skilled men and women, in tasks such as landing and loaded squat jumps (Chijimatsu et al., 2020; Nagata, et al., 2020). However, similar work with the vertical jump and less skilled women is lacking. Video feedback related to knee range of motion could prove useful in improving vertical jump height if we combine our knowledge of skilled and novice jumpers, the relationship between vertical jump performance and knee range of motion, and how women respond to movement instruction to develop effective feedback (Domire & Challis, 2007; Moran, & Wallace, 2007; Ross & Hudson, 1997, Walsh et al., 2007). At present it is not clear how immediate kinematic feedback, specific to knee range of motion, might influence vertical jump performance among less skilled women.

Therefore, the purpose of this study was to examine the immediate effects of kinematic feedback on vertical jump performance. It was hypothesized that participants who received feedback specific to their performance would modify range of motion in the jump, and that the changes in range of motion would be associated with increases in vertical jump height.

**METHODS:** Twenty women [age: 22.6 ± 3.07 years; height: 1.63 ± 0.07 m; mass: 67.4 ± 12.0 kg] read and signed an informed consent form approved by the University Institutional Review Board prior to participating in this study. Participants were recreationally active (i.e., minimum of 30 minutes of moderate-to-vigorous physical activity at least 2 times per week) and were not required to have any specific jumping experience.

To determine the effects of feedback on vertical jump performance, kinematic and ground reaction force data were collected synchronously during maximal vertical jumps performed with a countermovement without an arm swing (i.e., arms akimbo). Data were collected during pre- and post-feedback conditions. Kinematic data were measured at 120 Hz using a six-camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA, USA). Digital video was also collected, for feedback purposes, at 30 frames per second using an iPad 2 positioned perpendicular to the plane of motion (Apple, Cupertino, CA, USA). Additionally, ground reaction forces were sampled at 1200 Hz from two force plates to identify the instant of take-off (Kistler, Amherst, NY, USA).

Upon arriving to the lab participants were blindly assigned to the treatment or control group and were asked to complete a health history questionnaire. They then proceeded to complete a 5-minute self-pace ride on a stationary bike and a series of dynamic warm-up exercises. After the warm-up, 32 retro-reflective markers were attached to the skin and clothing of the participant, by the same researcher, using a modified version of the Helen Hayes marker set (i.e., lateral pelvis markers were added).

Participants then completed three familiarization trials prior to data collection. They were instructed to begin with one foot on each force plate and complete a countermovement jump with arms akimbo while attempting to jump as high as possible. Participants were required to rest one minute between all jumps.

Five pre-feedback jumps were then recorded using the previously described motion capture system, iPad 2, and force plates. Upon completing the pre-feedback trials one representative jump was chosen to provide feedback to the participant. All participants were given the chance to review their jump in slow motion and real-time as many times as they wished on the iPad 2. For treatment participants a target maximum knee flexion zone, based on previous research, was set between 70° and 85° (Hudson & Owen, 1982; Ross & Hudson, 1997). This zone was used to provide treatment participants specific feedback based on their maximal knee flexion angle. Participants under the target zone were asked to used a larger range of motion, participants within the zone were asked to make small decreases in range of motion, and those over the zone were asked to make larger decreases in range of motion. When treatment participants reviewed their jump video their maximum knee flexion angle in the jump, and the target zone for the knee flexion angle, was displayed using the Hudl Technique app (Agile Sports Technologies Inc., Lincoln, NE, USA).

After watching the video, participants were asked to perform a minimum of three practice jumps to incorporate changes to their jumping technique. After a one minute rest period, control participants were reminded that they could jump higher and treatment participants were reminded that they could jump higher and of the specific feedback they received. Data were then collected during five more maximal countermovement jumps.

Trajectories of the markers were low-pass filtered using a fourth-order, zero-lag Butterworth filter with a cut-off frequency of 12 Hz. The lower extremity and pelvis were modelled as a three-dimensional system of rigid links (Skelton Builder, Motion Analysis, Santa Rosa, CA). Joint centre locations and the orientation of each segment were reconstructed from the filtered marker trajectories using transformations derived from a reference trial of quiet standing. Body segment masses and centre of mass locations were determined using measured anthropometrics and published data (de Leva, 1996). Range of motion was defined as the maximum knee flexion angle and depth of descent (i.e., vertical displacement of the centre of mass) during the countermovement of the jump. Jump height was defined as the vertical distance travelled by the body's centre of mass from take-off (i.e., an ipsilateral ground reaction force less than 10 N) to the peak height of the jump.

For each participant, means and standard deviations were computed for the dependent variables across trials of the same type (i.e., pre-feedback and post-feedback trials, respectively). The breakdown of participants by group (i.e., control and treatment) and feedback group (i.e., target zone group) led to omitting two participants (i.e., treatment participants in the "under target zone") from the statistical analyses as there were no control participants available for comparison. Given that within and over target zone participants were all asked to reduce range of motion, the remaining 18 participants were compared using a 2 x 2 (group x condition) mixed effects, repeated measures analysis of variance (ANOVA). Significant interaction effects were explored with a paired or independent t-test as appropriate. Statistical significance was set at $p < 0.05$ for the initial analyses and $p < 0.025$ for all post-hoc analyses. All statistical analyses were performed using SPSS 23.0 (SPSS, Chicago, IL, USA).

**RESULTS:** A significant group by time interaction was detected for maximum knee flexion angle ($p= 0.017$). Post-hoc analyses showed a significant decrease in knee flexion among treatment group participants from pre- to post-feedback ($p=0.003$). Post-hoc analyses also revealed a significant effect of group in the post-feedback condition (p=0.004); specifically, treatment participants used less knee flexion than the controls in the post-feedback condition (Table 1). The post-hoc analyses revealed no significant effect of time among the control participants (p=0.667) and no differences in knee flexion angle between groups in the pre-feedback condition (p=0.055). A significant main effect of feedback was found for depth of descent (p=0.003). Specifically, depth of descent across groups decreased from 33.4 cm pre-feedback to 27.5 cm post-feedback. There was no significant effect of group for depth of descent (p=0.267). Statistical analyses for jump height revealed no significant effects of feedback (p=0.07) or group (p=0.831), though the treatment group did exhibit a 2 cm decrease in jump height pre- to post-feedback.

**Table 1: Pre- and Post-Feedback Kinematic Data for the Vertical Jump.**

| | Control | | Treatment | |
|---|---|---|---|---|
| Variable | Pre-Feedback | Post-Feedback | Pre-Feedback | Post-Feedback |
| Knee Flexion (°) | 103.2±14.2 | 101.01±10.7 | 107.1±12.5 | 86.3±7.5 |
| Depth of Descent (cm) | 33.0±7.1 | 30.4±6.6 | 33.9±4.5 | 24.3±4.6 |
| Jump Height (cm) | 24.2±3.9 | 23.8±3.8 | 24.4±8.7 | 22.4±6.4 |

**DISCUSSION:** The purpose of this study was to examine the immediate effects of kinematic feedback on vertical jump performance among recreationally active college-aged women. Treatment participants (i.e., those who received kinematic feedback) exhibited an adjustment in maximal knee flexion angle from pre- to post-feedback. However, the observed changes in range of motion to the target zone did not result in the enhancement of the jump height.

Treatment participants were given feedback that was specific to their performance and aimed at modifying lower extremity range of motion, with the intent of improving vertical jump height. Whereas control participants received feedback in the form of watching their performance on video without any specific instruction. As hypothesized treatment participants exhibited a 20.8° decrease in maximal knee flexion from pre- to post-feedback, which was associated with a 9.6 cm decrease in depth of descent. Control participants did not demonstrate any significant differences in maximal knee flexion between conditions; however, they did demonstrate a significant decrease in depth of descent of 2.6 cm. It is not clear why watching their own performance without specific instruction seemed to encourage control participants to use a smaller range of motion post-feedback. However, it is evident, that when provided specific kinematic feedback unskilled participants were able to modify their movement pattern in a manner that aligned with the provided feedback.

Though modifications to range of motion were in accordance with the feedback provided, corresponding improvements in jump height were not observed. There may be a couple of explanations for the lack of increase in vertical jump height in the presence of the desired changes in range of motion. First, despite basing the target knee flexion zone on previous observations of skilled jumpers (Hudson & Owen, 1982; Moran & Wallace, 2007; Ross & Hudson, 1997), perhaps a larger range of motion, rather than a smaller one, is appropriate in the vertical jump. For example, when Domire and Challis (2007) incorporated greater knee flexion in their computer simulation, jump height increased. This notion is further supported by Hsieh and Cheng (2016) who observed skilled women jumpers use a larger range of motion and jump higher than their less skilled counterparts. It is also possible that there is no optimal range of motion for the vertical jump. That is, perhaps the ideal range of motion is specific to characteristics of the jumper such as, sex, skill, and strength.

Another potential explanation for the lack of improvement in vertical jump height is that when changes to range of motion are implemented, a new coordination pattern may need to be established to exhibit improvements in jump height. For example, when Domire and Challis (2007) asked participants in their experimental study to use a larger range of motion they were not able to jump higher with the increase in range of motion. However, the computer simulation model mirroring the larger range of motion used by the participants was able to jump significantly higher after the coordination of the model was modified. Thus, it is possible participants in this study did not have sufficient time to modify their coordination pattern and experience the benefits of the observed changes in range of motion.

The present work is not without limitations. One important limitation was the skill level of the participants. Though, acute changes in performance have been elicited in landing and loaded squat jump tasks using similar methods, participants in those studies were likely more skilled than the present participants. Thus, it is possible that we did not allow sufficient time and practice to develop improvements in jump height in this less skilled population.

Given the ease of use of video, it seems appropriate to continue to work to understand how video and existing biomechanical knowledge can be combined to modify movement in a manner that improves skill and safety. Though, this has been shown to be feasible for some tasks, improvements to the current work are needed if this is to be a successful method for improving vertical jump performance. Future investigations should examine the influence of skill level, the duration and frequency of feedback, and the nature of the feedback (e.g., larger or smaller range of motion). If such investigations are successful, the findings could be used by coaches, athletes, teachers, and recreationally active individuals to enhance the skill and safety of movement in a variety of contexts.

**CONCLUSION:** This work established that kinematic feedback can be used to change jump kinematics in this understudied population (i.e., recreationally active women). Though, the present feedback did not result in improved jump height, the simple methods used for feedback hold promise for future use by coaches and teachers. To make these practical tools effective, we must develop feedback that is sufficient for both modifying movement and improving performance.

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