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The Effect of a Secondary Cognitive Task on Lower Extremity Biomechanics During Landing

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Abstract

Background: The purpose of this study was to examine the effect of a cognitive task on jump-landing biomechanics and performance. **Methods:** 26 recreational athletes participated in the study. Participants jumped forward off of a 30cm box a distance equal to one half of their body height, then immediately performed a countermovement jump. This movement was performed in a control condition, while counting backwards by intervals of 1, and by intervals of 7. Initial knee flexion, knee range of motion, peak vertical ground reaction force (PVGRF), stance time, and jump height were calculated. **Results:** There were statistically significant differences in initial knee flexion ($p = 0.0004$), PVGRF ($p = 0.031$), and stance time (0.038) between the control and counting by 1 condition. There were also significant differences in knee range of motion ($p = 0.049$, $p = 0.012$) and jump height ($p = 0.001$, $p = 0.0002$) between the control and both the 1 and 7 conditions. **Conclusion:** This study demonstrated that the addition of a cognitive task did alter both landing biomechanics and performance. These results have implications for developing new ACL injury screening procedures to more realistically imitate a sport environment.

Introduction

Non-contact anterior cruciate ligament (ACL) injuries are common among individuals who perform jump-landing tasks (Boden et al., 2000). Even with the expanding body of literature surrounding these injuries, they continue to be prevalent. It is predicted that over 200,000 ACL injuries occur annually in the United States (Dai, et al., 2012). Prevention is a growing area of research as surgical interventions are not resulting in complete recovery. Research suggests that only 44% of athletes sustaining ACL injuries return to competitive sport, and only 63% return to pre-injury functioning (Ardern et al., 2011).

ACL injuries occur when excessive forces are placed on the knee (Krosshaug et al., 2007). ACL loading and injury risk have been associated with lower extremity biomechanics such as knee flexion angle, knee valgus angle, and peak vertical ground reaction force (Hewett et al., 2005; Yu and Garrett, 2007). Previous literature suggests that many ACL injuries occur when athletes are reacting to a sudden perturbation and land in an unbalanced posture (Krosshaug et al., 2007). Sports settings are open environments and athletes are required to perform jump-landing tasks simultaneously with cognitive tasks such as tracking a ball. The allocation of attention to secondary cognitive tasks may alter an athlete's landing patterns, resulting in increased knee loading and ACL injury risk.

One previous study examined the effect of a choice reaction task on a single-leg landing (Shinya et al., 2011). Researchers concluded that individuals landed with greater vertical ground reaction force (VGRF) in the dual-task condition. A similar study demonstrated that available time of reaction also could have an impact on lower extremity biomechanics during landing (Stephenson, 2015). However, there are currently gaps in the literature regarding the effect of attention allocation alone on jump-landing mechanics.

The purpose of the current study was to examine the effect of a secondary cognitive task on lower extremity biomechanics and performance during a landing task. It was hypothesized that individuals would land with decreased knee flexion angle and jump height as well as increased stance time and peak VGRF with the addition of the cognitive task.

Methods

17 male and 9 female participants athletes (age: 21.6 ± 1.3 yr.; height: 1.78 ± 8.7 m; mass: 75.6 ± 13.0 kg) with experience in a jumping sport were recruited for the current research. Participants were free of injury, had experience playing a sport that involves jump-landing tasks (e.g.: basketball, volleyball, soccer) and were physically active at least 2 times per week. Participants were given an informed consent and a questionnaire which was be reviewed by the investigator.

After participants were determined to be fit to participate, they were given tight fitting clothing and standardized shoes. The participants performed a standardized dynamic warm up. The warm up involved running on a treadmill, toe touches, quadriceps stretches, lunges, and shuffles. After the warm up, the investigator placed retroreflective markers bilaterally on the subject's spinous process of acromioclavicular joints, anterior superior iliac spines, posterior superior iliac spines, iliac crests, and greater trochanters using double-sided adhesive tapes. The investigators also placed retroreflective markers on the lateral thigh, anterior thigh, medial and lateral femoral condyles, superior and inferior tibia, lateral tibia, medial and lateral malleolus, toes, heel, and first and fifth metatarsal head of the dominant side (Figure 1). The three-dimensional location of the markers were tracked using 8 cameras positioned around the testing facility.

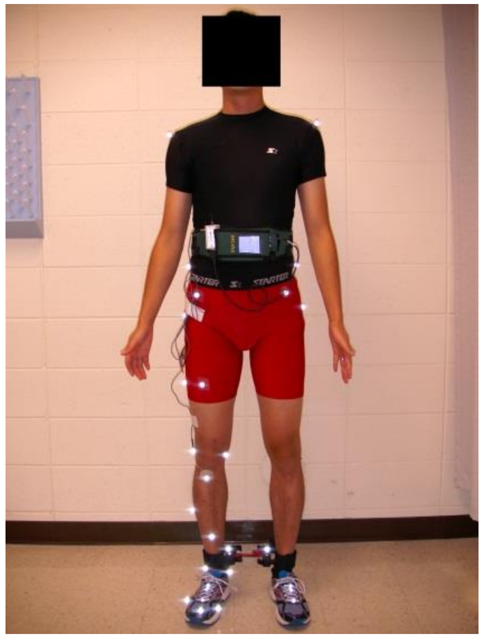
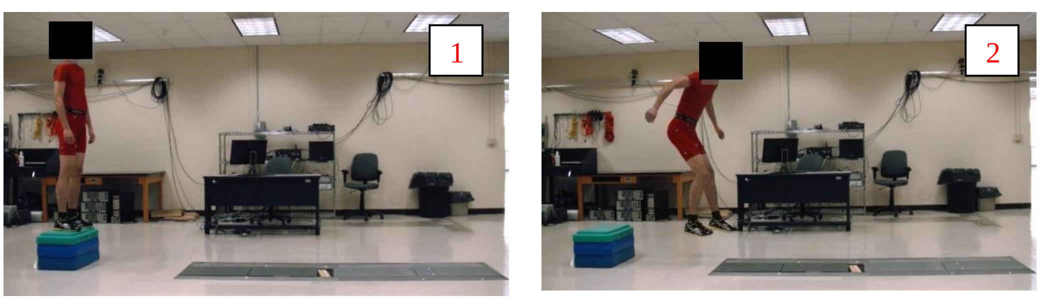


Figure 1: Marker Placement

Participants performed three successful trials of a jump-landing task in each of three conditions: l. no cognitive task, 2. counting aloud backwards by intervals of one, and 3. counting aloud backwards by intervals of seven. In each condition, participants jumped forward off of a 30-cm box a distance equal to one half of their height. They landed with the foot of their dominant leg on a force plate and then immediately jumped vertically for maximum height (Figure 2).



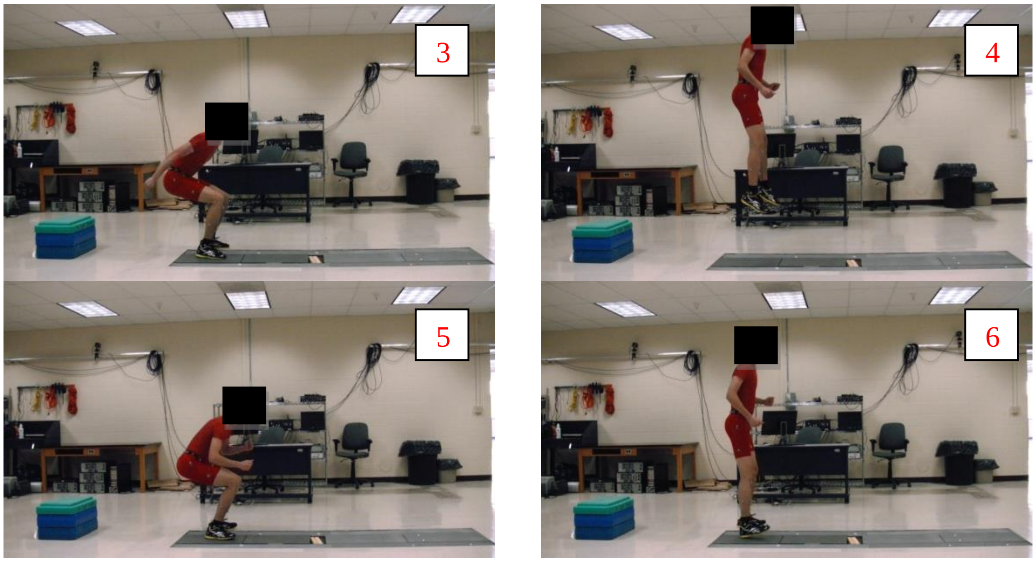


Figure 3: Jump Landing Task

In the conditions with a secondary cognitive task, participants were told a randomly generated number between 80 and 199. They were instructed to immediately start the jump-landing motion after they hear the number and count aloud for the entire duration of the jump-landing task by intervals of either one or seven. Participants were required to count at least one correct number by intervals of seven, and two correct numbers by intervals of one. The order of three testing conditions was randomized. Participants' landing kinematics and VGRF of the dominant leg were captured using eight Vicon cameras and a Bertec force plate.

Participants' knee flexion angles at initial contact, knee flexion range of motion during the stance phase, peak VGRF during the first 100 ms of landing, jump height, and stance time were extracted for analysis. Repeated-measure ANOVAs were performed for each dependent variable with the landing condition as a within-participant factor. A significant ANOVA test was followed by pairwise comparisons using 95% confidence interval. A type I error rate was established at 0.05 for statistical significance.

Results

Statistically significant differences ($P < 0.05$) were observed between all variables. Pairwise comparisons (Table 1) showed that counting backwards by intervals of one resulted in decreased knee flexion angles at initial contact, increased knee flexion range of motion, increased peak VGRF, decreased jump height, and increased stance time compared with the no cognitive task condition. Counting backwards by intervals of seven resulted in increased knee flexion range of motion, decreased jump height, and increased stance time compared with the no cognitive task condition.

Table 1: Descriptive Data (Means ± Standard Deviations) of Biomechanical and Performance Variables.

	Initial Knee Flex (deg)	Knee Flexion ROM (deg)	Peak VGRF (BW)	Jump Height (m)	Stance Time (ms)
No Cognitive Task	26.9 ± 6.5 *	79.9 ± 18.1 * ^	2.53 ± 0.52 *	0.47 ± 0.11 * ^	567.1 ± 152.3 * ^
Counting by One	24.5 ± 6.1 *	82.6 ± 17.1 *	2.79 ± 0.87 *	0.44 ± 0.11 *	593.3 ±141.6 *
Counting by Seven	25.7 ± 7.6	83.7 ± 16.8 ^	2.66 ± 0.79	0.43 ± 0.11 ^	590.5 ± 140.1 ^

ROM: range of motion; VGRF: vertical ground reaction force; BW: body weight; * and ^: Significant differences between two conditions with the same symbol.

Conclusion

The findings suggest that the addition of a cognitive task could alter landing mechanics and also decrease jump performance. The decreased knee flexion angle at initial contact and increased VGRF during the condition of counting backwards by intervals of one have been shown to be associated with increased ACL loading (Dai, 2012). Both cognitive tasks resulted in significantly increased knee flexion range of motion, decreased jump height, and increased stance time. These changes suggest that the allocation of attention to the secondary task results in a perturbation to the preferred jump-landing control patterns. This deviation from the preferred control patterns may be associated with decreased mechanical efficiency of muscles and utilization of the stretch-shorting cycle, leading to a decrease in jump performance.

Interestingly, counting backwards by one and counting backwards by seven did not appear to lead to the same changes in landing mechanics. This may be attributed to the perceived difficulty of the task and the corresponding allocation of attention. Participants were able to count continuously backwards by one from the initial contact to take-off. On the other hand, participants typically counted the first number during the stance phase of landing when counting backwards by seven. The task difficulty may have contributed to some small differences in landing mechanics between the two cognitive conditions. While the cognitive task in the current study could be easily implemented, future studies may develop sports specific cognitive tasks.

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