EFFECTS OF VISION AND MULTIPLE COGNITIVE TASKS ON PRE-LANDING AND EARLY LANDING MECHANICS ASSOCIATED WITH ACL LOADING

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The aim of the study was to assess the effect of vision and 1 or 2 cognitive tasks on lower extremity biomechanics associated with ACL loading variables (knee flexion angles, increased impact forces, and knee extension moments) during single-leg drop landing tasks. Thirty-four participants performed landing tasks with or without vision and with or without 1-2 cognitive tasks. The cognitive tasks included counting backward and/or recalling the number of beeping tones. The results indicated counting backward significantly decreased knee angles, and a lack of vision could increase impact forces. However, the combination of two cognitive tasks did not result in the greatest ACL loading variables. Further research is needed to better understand the implications of cognitive distractions on ACL injury risk during more complex athletic movements.

KEYWORDS: ACL injury, biomechanics, motor control, dual task

INTRODUCTION: Anterior cruciate ligament (ACL) injuries are common and serious knee injuries in sports, often occurring during dynamic actions like jump-landings, cutting motions, and sudden deceleration maneuvers (Boden et al., 2022). ACL injuries often occur in single-leg landings, which require greater strength and typically result in limited knee flexion angles at initial contact, increasing the risk of ACL injuries compared to double-leg landings (Li et al., 2020). The main loading mechanisms for ACL injuries involve anterior shear and compressive forces on the tibia at small knee flexion angles (Li et al., 2022). Knee flexion angles, which generally increase just before ground contact, play a crucial role in ACL strain during pre-landing in non-injury scenarios (Englander et al., 2019). Knee motion patterns prior to landing are suggested to contribute to ACL injuries in jump-landing tasks (Li et al., 2023). Studies have shown that single-leg landings are characterized by decreased pre-landing knee flexion angles and velocities compared to double-leg landings, highlighting the increased risk in single-leg scenarios (Li et al., 2023).

In sports, ACL injuries are also frequently observed when athletes' attention is divided (Krosshaug et al., 2007). Visual input plays a vital role in performing precise movements, with research underscoring its importance in landing stability and lower extremity injury risk (Ren et al., 2022). Moreover, divided attention has been shown to affect knee biomechanics related to ACL injury risk (Hughes & Dai, 2023). High cognitive loads during athletic performance, involving the distribution of attention across multiple tasks and environmental stimuli, can reduce focus on movement execution and increase injury risk during landing and cutting maneuvers. Inadequate preparation for landing mid-flight may compromise athletes' ability to anticipate ground contact and adequately increase knee flexion to reduce injury risk. The decision-making process and divided attention in multitasking scenarios can elevate cognitive loads, potentially impairing motor actions (Hughes & Dai, 2023). Previous research has shown that cognitive loads from tasks like counting and recalling numbers, mental arithmetic, or responding to stimuli consistently affect lower extremity mechanics in ways that increase ACL loading variables, such as reduced knee flexion and increased impact forces (Dai et al., 2018). However, most studies have only examined the impact of a single cognitive task, overlooking the complex, multi-stimuli environment in competitive sports.

Therefore, the aim of the study was to assess the effect of vision and one or two cognitive tasks on lower extremity biomechanics associated with ACL loading during single-leg drop landings. It was hypothesized that the condition without vision and with two cognitive tasks would demonstrate the greatest ACL loading during pre-landing and early landing, while conditions with one cognitive task would demonstrate greater ACL loading compared to those without any cognitive tasks.

METHODS: Based on an effect size of 0.50 in peak vertical ground reaction force (GRF) between no counting and counting by 1s during early landing of jump-landing tasks in a previous study (Dai et al., 2018), a sample size of 34 was needed to achieve a power of 0.8 at a type I error rate of 0.05. Thirty-four recreational athletes participated in this study (17 males and 17 females, age: 22.41 ± 2.91 years, height: 1.74 ± 0.08 m, and mass: 73.75 ± 11.73 kg). This study was approved by XXX institutional review board.
Participants performed three practice trials for each condition. There were eight landing conditions: having vision and no cognitive task (VN), no vision and no cognitive task (NN), having vision and counting backward by 1 (VB), no vision and counting backward by 1 (NB), having vision and recalling tones (VT), no vision and recalling tones (NT), having vision and two cognitive tasks (VC), no vision and the two cognitive tasks (NC). During the counting backward by 1s condition, participants initiated the drop landing task immediately upon hearing a random number (ranging from 80 to 199) and continued to keep counting out loud backward by 1 s until completing the landing task (Dai et al., 2018). In the recalling tone task, an Apple iPhone 12 randomly played 1 to 3 beeps. Each beep lasts 50ms with a 200ms gap, totaling 550ms for three beeps. Participants, wearing AirPods, started the task upon leaving the box and were simply required to report the total number of beeps after completing the drop task without counting them aloud (Blakely et al., 2016). Participants stood on a box (30 cm) and started by stepping a non-test leg out first and then dropped down on a force platform (Bertec, Columbus, OH, USA, 1600 Hz) with the test leg (Figure 1). The order of eight conditions was randomized, and the testing leg was counterbalanced among participants. Sixteen retro-reflective markers were placed (Li et al., 2023). The markers were captured by eight opto-reflective cameras (Vicon, Oxford, UK, 160 Hz). Dependent variables included the minimal knee flexion angles during pre-landing, knee flexion angles at initial contact, maximal knee flexion angles, peak vertical GRF, peak posterior GRF, and peak knee extension moment during early-landing. The pre-landing and early-landing phases were defined as 100 ms before and after initial contact. MATLAB 2022a was used for data reduction (MathWorks, Inc., Natick, MA, USA). Two by four repeated-measures analyses of variance (ANOVAs) were conducted. Paired t-tests were applied after a significant interaction effect (p-value ≤ 0.05) was found by ANOVAs. The Benjamini-Hochberg procedure was performed to control the study-wide false discovery rate at 0.05 (Benjamini & Hochberg, 1995). The largest p-value for statistical significance was 0.018 after the adjustment. SPSS Statistics 22 (IBM Corporation, Armonk, New York) was used for statistical comparisons.

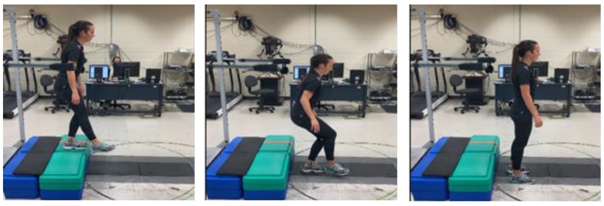

Figure 1. Single-leg drop landing task

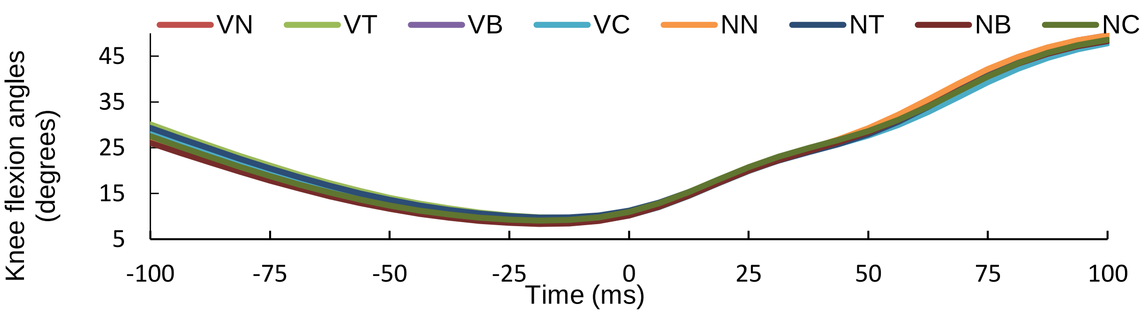

Figure 2. Knee flexion angles 100 ms before and after landing.

RESULTS: Results showed the significant effect of cognitive tasks on knee flexion angles during landing (Figure 2). Specifically, the task of counting backward resulted in lower knee flexion angles both during pre-landing and at initial contact compared to the task of recalling tones. Furthermore, any condition that involved a cognitive task led to smaller maximal knee flexion angles during early landing, in contrast to conditions without a cognitive task. In terms of GRF, vision was found to affect the peak vertical GRF, which was higher in conditions lacking vision across all conditions. However, the peak posterior GRF remained similar across different conditions. In addition, the task of recalling tones resulted in the greatest peak knee extension moment when compared to other cognitive tasks, including counting backward and engaging in a combination of two cognitive tasks. The combination of two cognitive tasks did not lead to significantly greater ACL loading variables.

Table 1: Means ± standard deviations of dependent variables for different landing conditions.

		No Cognitive Task	Recalling Tones	Counting Backward	Two Cognitive Tasks
Minimal Knee Flexion Angles during Pre-Landing (°)	Vision	8.48±4.94	8.54±5.21 **A**	7.50±5.26 **B**	7.69±4.52
	No Vision	7.99±4.70	8.46±4.92 **A**	7.35±4.76 **B**	8.09±4.91
Knee Flexion Angles at Initial Contact (°)	Vision	11.04±4.45 **A**	11.05±4.17 **A**	10.23±4.42 **B**	10.17±4.00
	No Vision	11.05±3.93 **A**	11.26±4.04 **A**	10.17±4.07 **B**	10.94±4.15
Maximal Knee Flexion Angles during Early Landing (°)	Vision	49.53±5.95 **A**	48.34±6.78 **B**	48.35±5.98 **B**	47.81±6.82 **B**
	No Vision	49.49±5.68 **A**	48.28±5.79 **B**	48.33±6.44 **B**	48.57±5.87 **B**
Peak Vertical GRF during Early Landing (BW)	Vision	3.9±0.6 **AⅡ**	3.9±0.5 **ABⅡ**	3.8±0.4 **BⅡ**	3.8±0.4 **CⅡ**
	No Vision	4.0±0.5 **A Ⅰ**	3.9±0.5 **AB Ⅰ**	3.9±0.5 **B Ⅰ**	3.8±0.4 **C Ⅰ**
Peak Posterior GRF during Early Landing (BW)	Vision	0.65±0.13	0.63±0.12	0.64±0.13	0.64±0.14
	No Vision	0.65±0.14	0.63±0.13	0.64±0.11	0.63±0.12
Peak Knee Extension Moment (-) during Early Landing (BW*BH)	Vision	-0.146±0.019	-0.149±0.017 **A**	-0.147±0.018 **B**	-0.144±0.016 **B**
	No Vision	-0.146±0.017	-0.151±0.020 **A**	-0.146±0.020 **B**	-0.148±0.019 **B**

Note: The effect of landing conditions for each vision condition was grouped by A>B>C. The effect of vision for each landing condition was grouped by Ⅰ>Ⅱ. Indicated group differences are statistically significant at $p < 0.05$ false discovery rate-adjusted Type I error.

DISCUSSION: The results did not align with our hypothesis that the absence of vision combined with two cognitive tasks would lead to the greatest ACL loading variables during pre-landing and early landing phases. Contrary to expectations, the combination of two cognitive tasks did not result in significantly smaller knee flexion angles, nor did it lead to greater impact forces and moments, regardless of the presence of vision. This was not consistent with previous studies that the dual task that required allocation of attention negatively impacted knee flexion, abduction, internal rotation, and peak vertical GRF during single-leg landing and cutting tasks (Dai et al., 2018). The lack of increased ACL loading variables in the absence of vision and with two cognitive tasks suggests a possible adaptive response in motor control under the current cognitive demand. When faced with multiple tasks, participants might instinctively adopt more conservative movement strategies to maintain balance and prevent injury, leading to less dynamic and potentially less harmful landing mechanics. The lack of significant differences in knee flexion angles and impact forces with the combination of two cognitive tasks also helps our understanding of cognitive load and its biomechanical consequences. The findings indicated that the body's response to cognitive tasks was not linear and that beyond a certain point, additional cognitive load did not necessarily translate to increased biomechanical variables. It was possible that one cognitive task was already challenging enough to occupy all the attention resources so additional tasks could not further increase the task difficulty and change movement patterns. However, it was noted that in the absence of vision, the vertical GRF was consistently higher across all conditions compared to scenarios where vision was present. This was consistent with a previous study that without vision, drop landings were characterised by 10 % larger GRF, indicating proprioceptive and vestibular information could not fully compensate (Santello et al., 2001).

The findings also partially supported our hypothesis that conditions involving a single cognitive task would demonstrate greater ACL loading compared to those without any cognitive tasks.

While it was observed that conditions involving a cognitive task led to smaller maximal knee flexion angles during early landing, this trend did not extend to the pre-landing and initial contact phases. Notably, the exception was found in the condition of counting backward, which demonstrated significantly smaller knee flexion angles at initial contact compared to conditions without a cognitive task, regardless of the presence of vision. This highlights a specific impact of the counting backward task on knee biomechanics during landing. This was consistent with a previous study that when participants performed a jump-landing task with counting backward by 1 s, they had smaller knee flexion angles at initial contact compared to without cognitive task (Dai et al., 2018). Their results also showed significantly greater peak impact forces. The differences between their study and ours could be because of the complexity of the motor task. In our study, the task involved a single-leg drop landing, which inherently requires a different set of motor controls and balance strategies compared to the previous jump landing task requiring participants to jump from a 30 cm high box forward to a distance of 50% of their standing height away from the box. Jump landing tasks, especially those involving jumping from a height and moving forward, typically demand more from the body in terms of absorption of force, balance, and stability. The kinetic and kinematic demands of such tasks are likely to be greater, potentially leading to different ACL loading patterns compared to a single-leg drop landing.

CONCLUSION: Conditions without vision led to increased vertical ground reaction forces, underscoring the importance of visual cues in modulating impact forces during landing. Counting backward had an impact on reducing knee flexion angles during the early landing phase, highlighting the influence of different cognitive tasks on knee mechanics. Future studies should explore the non-linear relationship between cognitive load and biomechanical responses in landings with varied task complexities.

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