INFLUENCE OF MOTOR-COGNITIVE PERFORMANCE ON LANDING BIOMECHANICS IN DIFFERENT CONDITIONS: PRELIMINARY RESULTS

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This pilot study examines the impact of varied cognitive loads on lower limb biomechanics during landing tasks. Ten male athletes performed a novel motor-cognitive assessment and then a landing task in three conditions with different cognitive loads. Findings suggest cognitive conditions may affect GRF, joint kinematics, and kinetics. Specifically, unanticipated tasks may elevate GRF, while altered hip abduction indicates adjustments in base support. Hip and knee moments vary based on cognitive conditions, emphasizing their influence on load absorption. Additionally, divided attention correlates with increased knee abduction moment, underscoring its relevance in managing potentially harmful sports movements. These results reinforce prior research, emphasizing the pivotal role of cognitive factors in screening and mitigating injury risks during athletic performances.

KEYWORDS: cognition, ACL, sports injuries, unplanned movements, dual-task.

INTRODUCTION: ACL lesions are among the most common and severe musculoskeletal injuries across sports, frequently occurring in non-contact situations (Kaeding et al., 2017). Non-contact ACL injuries are unlikely to be triggered by a single cause independently eliciting the injury mechanism but rather from concurrent risk determinants (Smith et al., 2012). Among risk factors, athletes' neurocognition has recently gained increased attention due to its pivotal role in organizing movement patterns while handling evolving environmental information (Gokeler et al., 2021). Cognitive performance in sports has been characterized as an athlete's proficiency in executing actions associated with essential functional domains, including visual attention, processing speed, reaction time, and dual-tasking (Harvey, 2019). Deficits in specific cognitive subsets like sensory integration or attentional processing might result in errors in postural coordination and compromised lower limb patterns, elevating the risk of injury (Avedesian et al., 2022; Bertozzi, Fischer, Hutchison, et al., 2023). Assessing baseline motor-cognitive function may be effective for screening athletes injury risk during hazardous sports tasks, such as unanticipated/dual-tasking landing or cutting actions. However, current evaluations of cognitive performance in athletes have primarily relied on clinical tools involving stationary pen-and-paper or computerized methodologies, while these individuals are usually engaged in highly dynamic environments where whole-body movements and peripheral vision significantly contribute to performance (Bertozzi, Fischer, Hutchison, et al., 2023). Therefore, this study aims to assess the relationship between a newly developed motor-cognitive test battery and the biomechanical factors related to ACL injury risk during three different conditions of a landing task.

METHODS: Subjects with a history of prior surgery on lower limbs, previous concussion, musculoskeletal injuries within six months, or color blindness were not considered eligible for the study. Ten male athletes (basketball, volleyball, and soccer players) were recruited in this pilot study (23.5 ± 2.6 years, 177.7 ± 4.0 cm, 72.8 ± 6.1 kg, Tegner Activity Scale: 7.7 ± 0.9). They participated in 3.5 ± 1.4 practice sessions per week and had a total sport experience of

14.9 ± 3.1 years. Participants performed the motor-cognitive test battery using a customizable motor-cognitive training system (WittySEM, Microgate Srl, Italy) (Figure 1), including eight wireless smart indicators. The protocol included five randomized tests developed to evaluate sport-related domains: specifically simple and complex reaction time (RT), processing speed, divided attention, and peripheral vision. Each test exhibited good-to-excellent reliability (ICC = 0.55 – 0.94, paper in review). Cognitive scores were averaged among trials for each test and expressed in ms for RT tests (simple and complex scores were averaged) and accuracy percentage for the remaining ones. Afterward, 57 reflective markers were attached to the participants' anatomic landmarks. Then, participants performed a jump-land-jump task from a 30-cm box (Bertozzi, Fischer, Aflatounian, et al., 2023) onto two force plates (Kistler, Switzerland) in three randomized conditions, while marker positions were collected at 100 Hz using a 6-camera motion capture system (BTS Bioengineering, Italy). The secondary jump direction was defined by the activation of two smart indicators positioned approximately 45° and 2 m away in the secondary directions to stimulate peripheral vision (Figure 1). In the anticipated condition (ANT), they were asked to jump off the box and then jump toward a secondary direction based on a visual cue, one light green already active before the start of the jump. In the unanticipated condition (UNA), the visual cue was triggered by a photocell during the flight phase, 300 ms before landing (Borotikar et al., 2008). The last condition with additional cognitive load (COG) presented three different combinations of light activations triggered by the photocell: 1) one light green and one deactivated where they had to jump toward the green cue, 2) one light green and one blue where they had to jump toward the blue cue, 3) one light green and one red where they had to stop on the plates upon landing maintaining the balance.

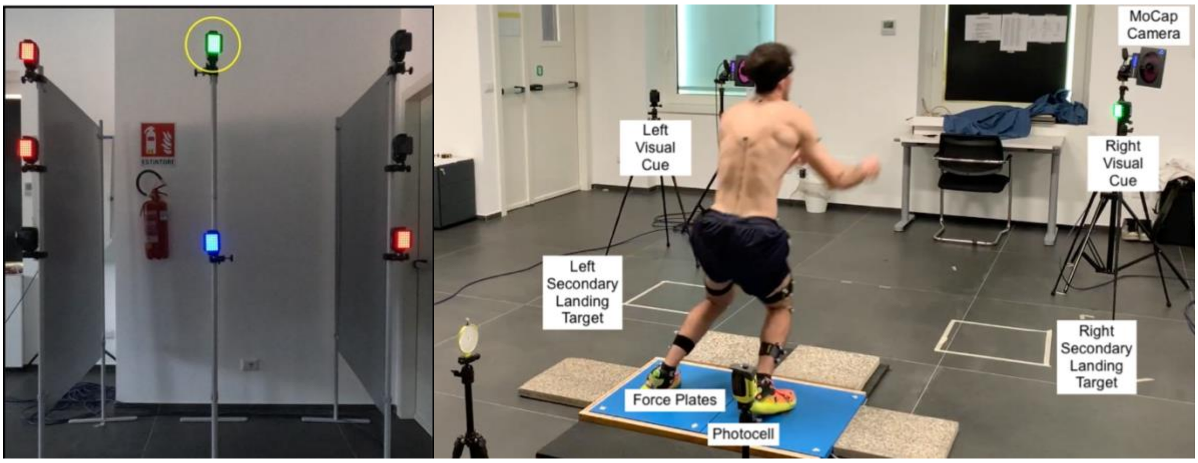

Figure 1: Setup for the complex RT test and execution of the jump-land-jump task.

Three valid trials (i.e., landing with one foot per plate, secondary jump direction correctly identified, secondary jump performed upon first landing without double stepping or sliding on the plates) were recorded and averaged for each condition and direction combination. We analyzed only the dominant lower limb (right for all participants) in the trials jumping toward the dominant secondary direction (i.e., right green light activated for ANT and UNA, right blue light activated for COG). Kinematic and kinetic (externally defined moment) data were processed using Visual3D (C-Motion, USA) software. The peak of the following variables was extracted within a 100-ms window after ground contact, as most non-contact ACL injuries occur within this time frame (Koga et al., 2018): vertical ground reaction force (VGRF), hip abduction angle and moment (HAbA, HAbM), hip flexion angle and moment (HFA, HFM), knee abduction angle and moment (KAbA, KAbM), knee flexion angle and moment (KFA, KFM). Mixed-effect models were implemented for each dependent variable: "participant'' was entered as a random effect and ''condition'' (ANT, UNA, COG) as a fixed effect to study differences among task conditions, with Tukey correction for pairwise comparison if a significant effect was found. The scores from the four cognitive domains were entered as covariates to study the relationship between the biomechanical variables and the baseline cognitive performance. Minitab software (Minitab LLC, USA) was used for statistical analysis with α = 0.05.

RESULTS: Table 1 summarizes descriptive statistics of dependent variables, while Table 2 illustrates the results of the mixed-effect models.

Table 1: Descriptive statistics (mean ± SD) of the biomechanical variables and cognitive scores

Biomechanical Variable	ANT	UNA	COG	Cognitive Score	
VGRF [N/kg]	1.6 ± 0.5	1.3 ± 0.3	1.8 ± 0.5	RT [ms]	806 ± 73
HAbA [°]	0.2 ± 5.6	7.5 ± 5.3	8.6 ± 4.9	Processing speed [%]	84.8 ± 9.9
HAbM [Nm/kg]	0.4 ± 0.5	0.3 ± 0.2	0.4 ± 0.3	Divided attention [%]	60.2 ± 11.7
HFA [°]	71.6 ± 14.1	72.9 ± 12.8	73.8 ± 8.2	Peripheral vision [%]	77.9 ± 8.9
HFM [Nm/kg]	0.6 ± 0.5	1.1 ± 0.6	1.4 ± 0.4		
KAbA [°]	1.7 ± 6.1	3.5 ± 5.7	4.0 ± 5.8		
KAbM [Nm/kg]	0.3 ± 0.3	0.4 ± 0.2	0.3 ± 0.2		
KFA [°]	79.7 ± 6.9	82.5 ± 3.5	81.1 ± 5.7		
KFM [Nm/kg]	2.5 ± 0.8	2.1 ± 0.4	2.3 ± 0.5		

Table 2: Mixed-effect models results

Biomechanical Variable	Condition (p-value)	Post-hoc (adjusted p-value)	Cognitive Covariate (p-value)
VGRF	0.016	COG > UNA (p = 0.013)	-
HAbA	< 0.001	ANT > UNA (p < 0.001) ANT > COG (p < 0.001)	-
HAbM	0.637	-	-
HFA	0.680	-	-
HFM	< 0.001	COG > ANT (p < 0.001) UNA > ANT (p = 0.002)	-
KAbA	0.081	-	-
KAbM	0.228	-	Divided attention (p = 0.042)
KFA	0.318	-	-
KFM	0.046	ANT > UNA (p = 0.045)	-

Being a significant covariate, the individual linear regression between KAbM and divided attention scores is depicted in Figure 2.

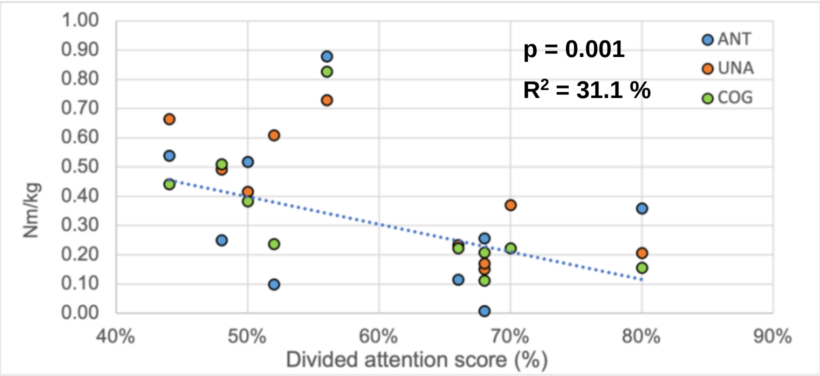

Figure 2: Individual linear regression between KAbM and divided attention

DISCUSSION: The findings of this pilot study highlight that performing landing tasks with different levels of applied cognitive load may influence lower limb biomechanics. Specifically, VGRF increased in COG with respect to UNA, suggesting that the additional cognitive load in an unanticipated task may induce stiffer ground contact and potentially higher loads to be handled by the lower limb joints. However, VGRF in ANT was higher than in UNA. Concerning kinematics, the hip was significantly less abducted in ANT than in the other two conditions, reflecting the need to widen the base of support in a bilateral landing when a cognitive load is added. Finally, regarding joint kinetics, hip and knee moments were affected, demonstrating that joint load in the sagittal plane may change depending on the cognitive condition and, thus, influencing the absorption of the load experienced at the instant of the ground contact. Therefore, integrating neurocognitive challenges during testing may highlight motor-cognitive deficits in athletes potentially more prone to injury risk (Grooms et al., 2023). In addition, when inspecting the effects of the included covariates, one cognitive subdomain (i.e., divided attention) may share a relationship with a critical risk factor, such as knee abduction moment. In this preliminary analyzed athletic sample, the KAbM values increased when divided attention scores worsened, proposing that the attentional focus/control may be a fundamental cognitive subdomain to handle when performing potentially harmful sports movements while coping with concurrent cognitive stimuli, partially confirming previous research on the topic (Bertozzi, Fischer, Aflatounian, et al., 2023; Bonnette et al., 2020).

CONCLUSION: This preliminary analysis reveals that varying cognitive loads during landing tasks may significantly impact lower limb biomechanics. Cognitive factors, particularly divided attention, appear to be related to potentially harmful sports movements while dealing with concurrent cognitive stimuli, reinforcing prior research and highlighting the significance of assessing cognitive domains for mitigating injury risks during athletic performances.

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