Comparing Biomechanical Outcomes of Standard vs. Sport-Specific Jumps in Mixed Reality

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Summary

This study examined how externally focused, soccer-specific tasks in mixed reality (MR) affect jumping and landing biomechanics. MR headers induced stiffer hip and knee sagittal movements and increased knee valgus and hip adduction moments compared to standard countermovement jumps (sCMJ), patterns linked to higher anterior cruciate ligament (ACL) injury risk. These findings highlight the need to integrate externally focused, sport-specific tasks into return-to-sport (RTS) assessments for more ecologically valid evaluations.

Introduction

Injury risk screenings and RTS assessments often lack ecological validity, relying on controlled, internally focused movements that do not reflect real-world sports demands [1]. Extended reality, including virtual reality (VR) and MR, offers a way to simulate externally focused, sport-specific scenarios, valuable for RTS assessments after ACL injuries. External focus tasks in VR lead to stiffer landing patterns[2,3], suggesting that incorporating realistic stimuli can improve clinical decision-making. However, VR's exclusion of real-world stimuli limits its RTS application. MR integrates both, making it potentially more suitable for RTS assessments. This study compared sCMJ to two MR-based jumping tasks to assess MR's impact on landing biomechanics.

Methods

Thirty-three healthy male participants (mean age: 26.5 ± 4.3 years, height: 180.9 ± 6.4 cm, mass: 78.45 ± 9.3 kg) with backgrounds in change-of-direction sports completed 3 trials of three jump tasks: (1) sCMJ, (2) MR-based CMJ (MRCMJ), where they pushed a virtual bar upwards, and (3) MR-based header (MRHead), where a virtual ball was headed into a goal. A soccer-specific application (MotumXR) was used for creating the MR-scenarios. Data collection was done via 3D motion capture system (Qualisys, 14 cameras) and two force plates (AMTI Inc.). Trials were processed using Visual3D (HAS-Motion), and analyzed via rANOVA with Benjamini-Hochberg correction ($p < 0.05$).

Results and Discussion

Flight time and jump height did not differ significantly among the three tasks ($p > 0.31$). The MRHead showed shorter contact time ($p < 0.001$), shorter concentric duration ($p = 0.008$), and a higher modified reactive strength index ($p < 0.001$), with stiffer sagittal plane movements (~33° lower hip and ~26° lower knee range of motion, $p < 0.001$) compared to the two other jump tasks. During the jump, hip extension moment decreased while knee extension moment increased ($p < 0.001$), and the hip showed greater internal rotation ($p < 0.001$) and adduction moments ($p \leq 0.022$). The MRHead also exhibited a higher maximum knee valgus moment ($p < 0.001$) and shorter landing duration compared to sCMJ ($p = 0.01$). During landing, peak hip flexion angles decreased by ~13° ($p < 0.019$) for MRCMJ and ~25° for MRHead ($p < 0.001$) compared sCMJ, while knee flexion angles were ~8° lower for the MRHead only ($p \leq 0.022$). Frontal plane analyses revealed higher hip adduction angles ($p < 0.026$) and moments ($p \leq 0.05$) for the MRHead, alongside a higher external knee rotation moment on the left leg compared to sCMJ ($p = 0.003$).

The MRHead task demonstrated distinct biomechanical patterns that align with soccer-specific demands, such as maintaining an upright posture and focusing on the ball during aerial interactions. The jump phase involved stiffer sagittal plane movements, shorter ground contact time and concentric duration, and a higher modified reactive strength index, reflecting the need for precise timing and raised environmental awareness. Landing mechanics in the MRHead and MRCMJ showed reduced hip and knee flexion, consistent with previous findings in VR settings[1,2]. However, the MRHead also exhibited increased hip adduction, knee valgus and extension moments during take-off, as well as greater hip adduction and knee external rotation moments during landing, highlighting increased knee joint loading and potential contribution to ACL injury risk factors.

Conclusions

While the sCMJ remains a valuable tool for assessing general athletic performance, it does not capture the biomechanical demands of soccer-specific tasks like heading. These findings highlight the importance of incorporating externally focused, sport-specific tasks into RTS assessments to provide ecological validity and improve injury risk screening.

References

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