Classification of Countermovement Jumps using a Sacral-Mounted Inertial Measurement Unit

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Summary

Metrics from countermovement jumps are important in physical fitness assessments; however, force plates (and inertial measurement units) yield inflated or unreliable jump height values when jump technique is poorly executed. This study aimed to develop algorithms to auto-classify countermovement jumps captured with inertial measurement units as proper or improper based on common mistakes and poor technique. The algorithms achieved an accuracy greater than 90%. This represents a significant development in monitoring and encouraging consistent jumping technique for improved clinical and/or human performance assessments.

Introduction

The countermovement jump (CMJ) is a common test for assessing an individual's lower body neuromuscular function with the use of force plates (FPs) [1]. Recently, inertial measurement units (IMUs) have been shown to accurately measure CMJ height [2], offering a more cost-effective and portable alternative to FPs. However, for both FPs and IMUs, the CMJ height estimation methods are sensitive to improper CMJ techniques [3], leading to compromised clinical and/or human performance decision making. Therefore, we aim to develop IMU-based algorithms to classify proper vs improper CMJs to encourage consistent jumping technique.

Methods

Ten participants (5F/5M) of varying physical abilities performed proper and improper CMJs on a pair of FPs (VALD, Brisbane, Queensland, Australia) while wearing a sacral-mounted IMU (Xsens DOT, Movella, Enschede, Netherlands) recording at 100 Hz and 60 Hz, respectively. The jump variations performed included: 3 proper CMJs, and 4 improper CMJs (squat-like jump (SJ), knees up in flight, feet out in flight (combined as flight movement (FM)), and deep squat landing (SL)). CMJ executions were verified by Strength and Conditioning Coaches.

IMU acceleration and orientation were filtered with a 4th order low-pass Butterworth filter with cutoff frequencies of 6.5 and 10 Hz, respectively [2] and used to calculate global vertical acceleration. The following criteria were used to define improper CMJs: no unloading phase measured as vertical acceleration not below 4.5 m/s^2 before the start of the concentric phase (SJ), sagittal sacrum orientation data (pelvic tilt) greater than 10º during flight (FM), and pelvis orientation greater than 30º after peak landing acceleration (SL) (Figure 1). All phasing and detection were automated for the IMUs. The FPs were set to 'Auto Detect' to allow the platform to classify CMJs vs SJs for comparison.

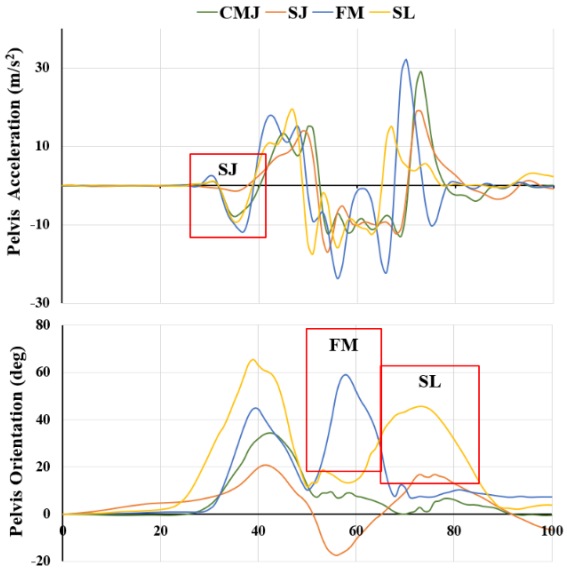

Figure 1: Pelvis vertical acceleration (top) and sagittal orientation (bottom) profiles for proper/improper jump techniques.

Results and Discussion

The IMUs and FPs were able to detect 10/10 and 4/10 SJs, respectively. The IMUs were able to track 18/20 FM and 9/10 SL, while the FPs are not able to detect these techniques. Additionally, the binary proper/improper IMU classifications were successful (precision = 0.90; recall = 0.90; accuracy = 0.94). Overall, IMUs provide better classifications vs. FPs.

This research provides a good start to monitoring technique and future work can focus on integrating more subtle and subjective real-world mistakes to improve classifications.

Conclusions

A sacral-mounted IMU can accurately classify improper CMJs that FPs are unable to detect, which may prevent inflated or unreliable jump height values being produced. This may enhance or replace FP testing to help in monitoring and encouraging consistent jumping technique for improved clinical and/or human performance assessments.

Acknowledgements

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References

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