Evaluation of a smartphone-based markerless motion capture system for assessing the kinematics of gymnasts

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Summary

This study evaluates the ability of a smartphone-based motion capture system to assess the kinematics of gymnasts, by comparing its performance to that of a gold standard marker-based motion capture system. Kinematics were computed for both gymnastics and non-gymnastics movements, with the smartphone-based system showing higher accuracy for the latter. Further development is needed before using this markerless system to monitor gymnastics to the same accuracy as more standard movements.

Introduction

Marker-based motion capture allows kinematics of human movement to be calculated accurately but must be conducted in a laboratory with specialist equipment and personnel. This makes it expensive, and the space limits what movements can be performed. Monitoring gymnasts in their training environments could enhance our understanding of their injuries and facilitate the implementation and evaluation of injury prevention measures. This study compares a smartphone-based markerless motion capture system (OpenCap) [1] to a gold standard marker-based motion capture system (Vicon) to see how well the markerless system can track basic gymnastics movements.

Methods

Ten participants (5M, 5F; height 1.72 m (SD 0.095); mass 65.3 kg (SD 9.2)) gave informed consent to participate in this study. Each participant with full body motion capture markers attached performed three trials of: walking, squatting, sit-to-stand, handstand, cartwheel, handstand walk, and handstand hop. Their movements were recorded simultaneously by a 16-camera Vicon setup (Valkyrie 16 cameras) and a 3-camera OpenCap setup.

Marker trajectories were captured, labeled, filtered, and exported using Vicon Nexus. They were then processed using the OpenSim Inverse Kinematics tool [2] using a full body musculoskeletal model [3] with range of motion constraints removed. OpenCap was used with default settings and kinematics were exported directly from the dashboard.

Of the 210 trials collected, 196 trials from both systems were successfully time synchronized, and kinematics compared.

Results and Discussion

The average root mean square error RMSE for all calculated kinematic variables across gymnastics movements (51.76°) was much larger than that of the non-gymnastics movements (12.33°) (Figure 1).

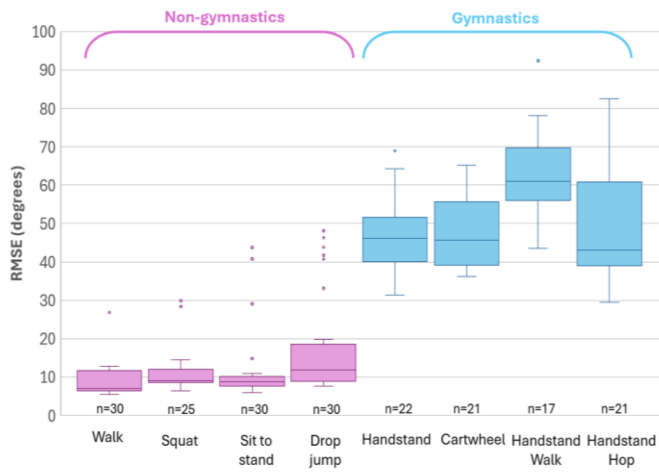

Figure 1: The average root mean square errors (RMSE) for all calculated kinematic variables between the marker-based and markerless system for each trial type. Non-gymnastics movements (pink) and gymnastics movements (blue).

The sections of movements that transitioned between an upright posture and an upside-down position typically struggled to be tracked by OpenCap, resulting in the largest kinematic errors. Pelvis orientation was consistently incorrect throughout the movements, probably due to the range of motion constraints imposed in the OpenCap processing pipeline. Errors in other joint angle estimations varied throughout the movements, with little consistency in estimation.

Conclusions

OpenCap was successful in monitoring movements when the participant was upright, but it could not track all kinematics accurately when they were upside down. Its performance is currently insufficient to be used as an alternative to laboratory-based solutions for tracking gymnastics. Training on specific gymnastics movements would likely improve the performance for estimating kinematics of gymnastics, as would the relaxation of range of motion constraints.

Acknowledgments

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References

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