The effect of range-of-motion constraints on the ability of a musculoskeletal model to calculate the kinematics of gymnasts

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Summary

Range of motion (ROM) constraints are used in musculoskeletal models to restrict motions to those that are anatomically feasible. Gymnastics movements can require ROMs outside those used for typical musculoskeletal models. This study investigates the use of ROM constraints when estimating the kinematics of gymnasts and concludes that pelvis constraints should be removed to improve kinematic estimates. Relaxation of other constraints may also be necessary to calculate the correct joint angles.

Introduction

Musculoskeletal models are used to simulate and analyse human movements. Kinematics can be calculated using 3D marker trajectories to estimate body positions and orientations. Constraining the range of motion (ROM) of segments and joints can ensure that the resulting poses are realistic. These constraints are especially necessary when there is less confidence in the accuracy of marker positions, e.g. when they suffer from skin-movement artefact or are estimated from 2D videos. Gymnastics movements can require ROMs outside those used for typical musculoskeletal models. This study investigates the effects of imposing ROM constraints when using motion capture data to estimate the kinematics of gymnastics.

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: handstand, cartwheel, handstand walk, and handstand hop. Their movements were recorded by a 16-camera Vicon setup (Valkyrie 16 cameras). 93 of these trials were successfully processed for analysis.

Marker trajectories were captured, labeled, filtered, and exported using Vicon Nexus. Processing was conducted in OpenSim [1] using a full body musculoskeletal model [2]. For each participant the model was scaled, then the Inverse Kinematics tool was used to compute joint angles for different ROM constraint conditions: default model constraints; pelvis unconstrained; pelvis and hips unconstrained; all affected variables unconstrained; and completely unconstrained. Marker errors and joint angles for each condition were compared.

Results and Discussion

Marker error was largest for the default constraint condition (RMSE = 0.0898 m) and smallest for the completely unconstrained condition (RMSE = 0.0245 m). Removing pelvis constraints accounted for 99.1% of the difference in RMSE between the default constraints and completely unconstrained. The impact of releasing further constraints on segments and joints was minimal. In addition to the pelvis and hip angles, the affected angles were knee, ankle and elbow flexion, and subtalar angle. The effect of the default pelvis constraints was most obvious during the upside-down phases of gymnastics movements (Figure 1).

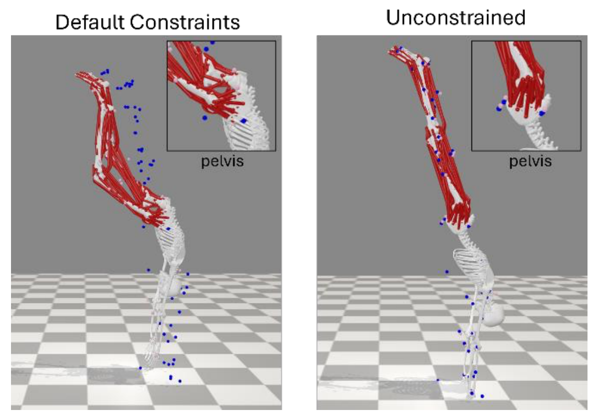

Figure 1: Snapshot of a handstand trial processed using the IK tool in OpenSim for default ROM constraints and unconstrained. Blue markers are experimental, and pink markers are from the model.

There were no anatomically impossible movements for any of the constraint conditions. However, this could potentially occur when processing less accurate marker positions with minimal constraints. In such instances, imposing those constraints that had the smallest impacts on model accuracy may be necessary to ensure realistic motion.

Conclusions

Typical ROM constraints used in some musculoskeletal models may be too limiting for gymnastics movements. Removing pelvis constraints was necessary to allow upside down movements and improve all kinematic estimates. Other joint constraints affected individual kinematic measurements to a lesser degree but may still be necessary when processing marker positions measured with less accuracy to ensure anatomically possible poses.

Acknowledgments

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References

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