Synergistic trunk dynamics reduces risk of shoulder injury during volleyball hitting.

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Summary

The follow through phase of volleyball hitting can cause shoulder injuries like rotator cuff tears, which is associated with the high arm angular velocities and the eccentric forces generated by the external rotators to slow the arm after striking the ball. We used musculoskeletal modelling and simulations to optimize the whole-body kinematics during volleyball hitting. We found that trunk motion in the direction of the swing during the follow through reduces the peak shoulder joint moments and arm velocity, which translates to reduced risk of rotator cuff injury.

Introduction

Volleyball swings are characterized by high velocity shoulder extension, adduction and internal rotation. External rotators contract eccentrically during the follow through phase to generate moments about the shoulder to stop the fast-moving arm, which can cause injuries like the rotator cuff tear [1].

Musculoskeletal modelling and simulations have been used to find optimal whole-body movement patterns that enhance sports performance [3] and reduce the risk of injury by reducing joint moments [2,3]. The purpose of this study is to use the same techniques to find the optimal participant specific whole-body kinematics that would reduce shoulder moments, velocity of the humerus and eccentric contraction of external rotators, reducing injury risk.

Methods

We collected experimental volleyball hitting data (10-camera Vicon motion capture system) from three right-handed male participants. We created participant-specific models and generated dynamically-consistent motions in OpenSim using the Upper and Lower Body Model (www.simtk.org) and a two-level optimization framework [3, 4] to significantly reduce pelvis residuals during this dynamic task. We analysed the follow through phase from the instant when the ball leaves the hand until the final peak of any shoulder moment.

We used an optimization framework to find the optimal whole-body movement pattern that would reduce the shoulder moments and velocities (representing the time-varying lengths of external rotator muscles), effectively reducing injury risk. Our optimization framework reduced the shoulder moments by adjusting the whole-body kinematics. The humerus velocity and length of external rotators were reduced by formulating the optimization so that the shoulder coordinates followed a trajectory that linearly deviates from the original trajectory by 15° (less extension, adduction, and internal rotation) at the end of the follow through phase.

Results and Discussion

The peak shoulder moments were significantly reduced ($p < 0.05$) (Figure 1b). All optimized movement simulations moved the trunk segment toward the direction of the arm swing. For the first participant (Figure 1a) who primarily swung in the sagittal plane slightly away from the body pre-optimization, the trunk flexed more (10° ± 2°), with slightly more right lateral flexion (5° ± 1°) post-optimization. For the second participant who primarily swung across the body, the trunk had higher left lateral flexion (6° ± 3°) and higher rotation about the vertical axis (5° ± 3°) post-optimization. For the third participant who primarily hit cross court shots by internally rotating the arm, the trunk had higher rotation (5° ± 4°) about the vertical axis post-optimization. The residuals of the optimized motions remained near zero, and motion of the trunk was balanced by legs to conserve angular momentum.

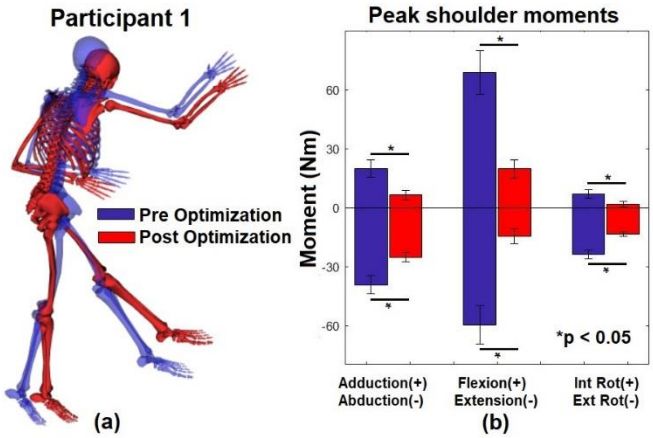

Figure 1: (a) Pre- and post-optimization kinematics of participant 1 and (b) changes in peak shoulder moments for all participants.

The results indicate that trunk motion that precedes the motion of the arm in the kinematic chain, like the motion of a whip, helps reduce the risk of injury at the shoulder. The trunk is also more equipped with larger muscle to handle the increased load compared to the shoulder.

Conclusions

Trunk motion in the direction of the arm swing may reduce risk of injury at the shoulder by reducing peak shoulder moments during follow through phase of volleyball hitting.

References

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