How Shoulder Elevation During Wind-up Affects Shoulder Torques During Volleyball Spikes

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Summary

Spiking is a key movement in volleyball with an increased risk for shoulder injuries. We analyzed how a lower shoulder elevation angle during wind-up affects spiking biomechanics using predictive simulations. We find that a lower shoulder elevation during wind-up increases the peak shoulder horizontal adduction torque and reduces the peak shoulder internal rotation torque. The presented analysis is a first step towards defining safer spiking biomechanics.

Introduction

About half of adult volleyball players report shoulder pain during their career, but the link between motions during volleyball spiking and shoulder pain remains unclear [1]. Spiking biomechanics differ between players mostly in the wind-up phase [2, 3]. To date, no analysis has isolated the effect of lower shoulder elevation angles during wind-up, a common adjustment suggested by coaches, on the shoulder torques during spiking.

Methods

We performed a study with three female and three male volleyball hitters that each performed 10 straight volleyball spikes in a laboratory with a stationary ball. A marker-based motion capture system (Motion Analysis Corporation, Santa Rosa, CA, USA) recorded their motion. We used a biomechanical model of the upper body with personalized shoulder rhythm dependencies and independent clavicle elevation actuated by coordinate actuators with activation dynamics [4]. OpenSim Moco simulations reproduced the participants' spiking motion [5]. We performed two simulations in which we tracked the states of these initial simulations: a baseline simulation without any changes, and a simulation that enforced lowered shoulder elevation angles of the hitting arm (Fig. 1 left). In the latter, we lowered the tracked shoulder elevation angle below 90 degrees during the wind-up phase until maximum horizontal abduction (black vertical lines in Fig. 1 right). We evaluated changes in the joint kinetics of the shoulder based on the prescribed change in shoulder elevation angle.

Results and Discussion

With lower shoulder elevation during wind-up, we observe an increased shoulder elevation torque at the beginning of the wind-up phase, and the peak shoulder elevation torque occurs at an earlier time point (Fig. 1 right, middle plot). The peak shoulder horizontal adduction torque increases on average by 20 ± 8 Nm (Fig. 1 right, top plot) while the peak shoulder internal rotation torque decreases on average by 15 ± 12 Nm (Fig. 1 right, bottom plot). The decreased peak shoulder internal rotation torque may offload the rotator cuff muscles responsible for rotating the shoulder. Our methods can be extended to perform muscle-driven simulations during volleyball spiking to further investigate relationships between coaching strategies and injury risk.

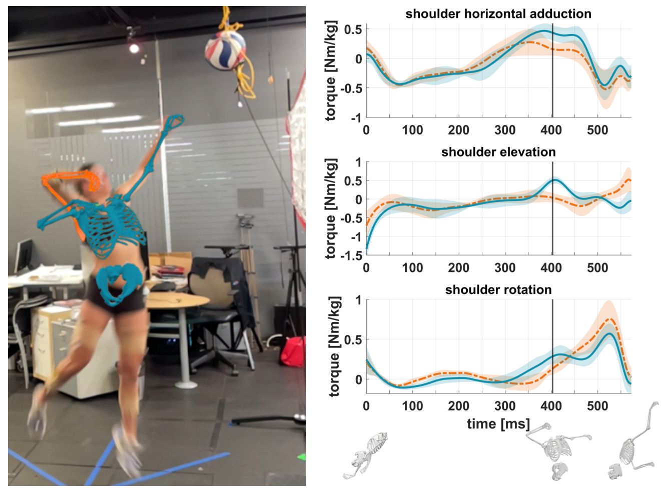

Figure 1: Left: study participant during wind-up; orange and blue models: simulation results w/o and w/ changed shoulder elevation angle. Right: shoulder torques w/o (orange dashed) and w/ (blue solid) changed shoulder elevation angle. Vertical black lines mark the end of the wind-up phase at maximum horizontal abduction. The torques are normalized by body weight and resampled to the average length of wind-up phase and acceleration phase.

Conclusions

Our results suggest that predictive simulations can systematically assess shoulder loading during volleyball spiking towards reducing injury risks.

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