INTRODUCTION

The purpose of this study is to evaluate the correlation between kinematic parameters and ball speed during a volleyball spiking maneuver. By accentuating the parameters that have the strongest correlation to ball speed, athletes can enhance their athletic performance. It is our hypothesis that higher rotational velocities of the pelvis and trunk and a greater range of shoulder external rotation will be correlated with faster ball speed after contact. A secondary aim of this study is to begin accumulating injury data over the playing careers of the athletes involved. This data can form a baseline to assess which kinematic parameters might be associated with injury.

METHODS

Cohort
Fourteen healthy collegiate Division I female volleyball athletes served as subjects. All participants played the position of either middle blocker or outside hitter. None of the subjects were injured or recovering from injury at the time of testing. The subjects had a mean mass and height of 75±6.2 kg and 1.85±0.03 m.

Data Collection
After obtaining informed consent, each athlete's spiking mechanics were evaluated in an indoor laboratory (Figure 1). A standard volleyball net was arranged in the lab at regulation height (2.24 m). An experienced volleyball coach set the ball for each trial. Subjects started from a self-selected position about 3-4 m from the net, and approached the net at approximately a 45° angle. The set was timed such that it arrived in the hitting position when the athlete was at the peak of their jump. Subjects each took several warm-up trials to become acclimated to the lab environment and to become familiar with the timing and height of the set. For the recorded trials, the participants were instructed to spike the ball with full effort. Five spikes were recorded for each athlete and the trial with the highest ball velocity was used for this analysis.

Figure 1. Indoor testing conditions and marker set used to evaluate volleyball kinematics.

Marker Set
A total of fifteen reflective markers (12mm diameter) were used to track landmarks used in the kinematics analysis (Figure 1). Markers were attached bilaterally at the lateral superior tip of the acromions, humeral epicondyles, greater femoral trochanters, lateral femoral epicondyles, lateral malleoli, and lateral to the fifth metatarsal. One marker was attached to the non-hitting wrist between radial and ulnar styloids and on the hitting wrist, two markers were placed, one each on the radial and ulnar styloids. One additional marker was attached to the ball to track the trajectory and velocity after contact.
Data Processing
A 14 camera high speed motion analysis system (Motion Analysis Corp, Santa Rosa, CA) was used to track the marker positions during each trial. Images were collected at a rate of 200 Hz and digitized using EvaRT software. A custom designed software package was used to calculate all kinematic parameters. This software has been previously used to analyze the kinematics of baseball pitchers\(^1\).

Rotational speed was measured as the angular velocity of the pelvis, upper torso, shoulder internal rotation, and elbow extension. Timing was evaluated by defining the time of lead foot contact as 0% and the time of ball contact as 100%. The timing of peak velocity measures was calculated using this definition. A linear regression analysis was used to quantify the relationship between the kinematic parameters and ball speed.

RESULTS

Earlier peak pelvic angular velocity (Figure 2, \(p=0.039\)) and greater maximum shoulder external rotation (Figure 3, \(p=0.045\)) are both associated with higher ball speed. Other kinematic parameters were not significantly correlated to ball speed (Table 1).

DISCUSSION

From this study, we have observed two kinematic parameters that are significantly correlated with ball speed. The kinematic sequence of the spiking motion begins with pelvic rotation, then torso rotation followed by shoulder and elbow rotation. The initiation of this sequence has a greater impact on ball speed than the rotational velocities generated.

![Figure 2: Earlier peak pelvic angular velocity was positively correlated with higher ball speed.](image)

![Figure 3: Peak shoulder external rotation was positively correlated with higher ball speed.](image)

REFERENCES


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Table 1: Averaged kinematic measures and timing recorded during volleyball spiking.

<table>
<thead>
<tr>
<th>Parameter (Peak)</th>
<th>Average</th>
<th>STDEV</th>
<th>Range</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball Speed (mph)</td>
<td>45</td>
<td>6.30</td>
<td>24.3</td>
<td>n/a</td>
</tr>
<tr>
<td>Shoulder Ext Rot (deg)</td>
<td>148</td>
<td>15.28</td>
<td>51.80</td>
<td>85.90 ± 3.79</td>
</tr>
<tr>
<td>Pelvis Angular Velocity (deg/s)</td>
<td>424</td>
<td>206.53</td>
<td>685.65</td>
<td>57.17 ± 13.07</td>
</tr>
<tr>
<td>Torso</td>
<td>277</td>
<td>102.72</td>
<td>322.79</td>
<td>86.49 ± 5.24</td>
</tr>
<tr>
<td>Shoulder (internal)</td>
<td>3637</td>
<td>1960.25</td>
<td>6945.62</td>
<td>103.81 ± 2.05</td>
</tr>
<tr>
<td>Elbow</td>
<td>1862</td>
<td>671.41</td>
<td>2293.80</td>
<td>96.26 ± 1.33</td>
</tr>
</tbody>
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