A THREE-DIMENSIONAL KINEMATIC ANALYSIS OF THE VOLLEYBALL JUMP SERVE

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INTRODUCTION

The serve is the first attacking weapon in the modem game of volleyball. Since the late 1980's (although pioneered by the Brazilians a decade earlier), the most powerful form of service has been the 'jump,' or attack, serve.

As its name suggests, this serve consists of the player throwing the ball into the air from the baseline, and then jumping into court to smash it towards the opponents. The potency of this serve is mainly due to its speed, giving the receivers only 0.5s to react. In addition, it is hit with heavy topspin (and often sidespin) which also makes it more difficult for the opponents to direct the ball accurately to the setter.

There has been a considerable amount of biomechanical literature concerning the volleyball smash (or 'spike'), both in training (Samson and Roy, 1975; Oka et al., 1976; Samson et al., 1978) and competitive matches (Coleman et al., 1993). However, there has been little information comparing these techniques with those required for the attack serve. There has been one previous study examining this type of serve, but this has been concerned solely with its tactical uses (Katsikadelli, 1996).

Therefore, it was the aim of this study to provide descriptive kinematics of some of the biomechanical factors involved in the 'jump' serve. Furthermore, these data could then be compared with results from studies examining the attack smash (spike).

METHODS

Eleven International players (Great Britain) of 193.1 ± 4.8 cm height (mean ± S.D.) and 83.3 ± 4.5kg mass were filmed in competition and training using two gen-locked video cameras filming at 50Hz. Successful serves were recorded, and their approximate impact (or reception) point on court was noted. One successful attempt for each subject was then chosen for analysis. As two players were left-handed, dominant and non-dominant sides were used rather than left and right.

Three-dimensional object space coordinates of digitized image coordinates were obtained using a DLT algorithm and an array of 28 calibration points in the filmed volume, using software written by Bartlett (1990). A 14-segment model was used for subject digitisation, with standardised anthropometric measurements obtained from Plagenhoef (1971). The object space coordinates and computed angles were then smoothed and differentiated using the generalized cross-validated quintic splines algorithm reported by Woltring (1986). Data were tabulated and kinetograms and graphical output plotted.

Relationships between lower limb angular kinematics, centre of mass velocities and vertical displacement were then analysed. Associations between upper limb kinematics, trunk angular movements and post-impact ball speeds were also examined using Pearson Product Moment Correlations.

RESULTS

LOWER LIMB KINEMATICS

Data for the lower limb are provided in Table 1. Centre of mass horizontal and vertical velocities at take-off were 2.76 ± 0.35 $m.s^{-1}$ and 2.77 ± 0.35 $m.s^{-1}$, respectively. No significant correlations were found between maximum pre-take-off lower limb angular velocities and the centre of mass vertical velocity. When these angular velocities were related to centre of mass horizontal velocity, there were also no significant correlations, but the left hip, left knee and right knee angular velocity were found to correlate significantly with the centre of mass resultant velocity (r=-0.77 P=0.005, r=-0.75, P=0.008, r=-0.63, P=0.04).

Table 1.
Lower limb maximum angular velocities and timing (prior to take-off)

		Hip		Knee		Ankle	
		Dorn	Non-Dom	Dorn	Non-Dom	Dorn	Non-Dom
Maximum Angular Velocity ($^{\circ}.s^{-1}$)	Mean	441	637	565	612	770	625
	S.D.	153	148	161	188	232	200
Time prior to take-off at which Angular Velocity occurs (s)	Mean	0.15	0.07	0.11	0.07	0.09	0.05
	S.D.	0.04	0.03	0.02	0.03	0.04	0.02

CENTRE OF MASS VERTICAL DISPLACEMENT AND VELOCITY

Centre of mass velocities at the take-off times for the first and second foot were 2.67 ± 0.30 $m.s^{-1}$ and 2.77 ± 0.35 $m.s^{-1}$. The square of these velocities were correlated with jump height (defined as the difference in the height of the centre of mass at the end of the take-off phase and the maximum vertical centre of mass height when the subject was airborne). Significant correlations of 0.74 ($P=0.004$) and 0.75 ($P=0.004$) were found between the two velocities and height jumped. The centre of mass velocity values at impact were -0.33 ± 0.40 $m.s^{-1}$, ranging from -0.99 $m.s^{-1}$ to 2.76 $m.s^{-1}$.

TRUNK ROTATION

Trunk angular displacements and velocities prior and at impact are shown in table 2. These were correlated with the post-impact ball speed, but again no significant relationships were found.

Table 2.
Shoulder-hip angles and angular velocities (horizontal projection)

		Peak Trunk Rotation	Value at Impact
Shoulder-Hip (deg)	Mean	-33.9	1.6
	S.D.	12.3	10.2
		Maximum	
Shoulder-Hip Angular Velocity ($deg.s^{-1}$)	Mean	515.6	325.8
	S.D.	223.6	254.7

UPPER LIMB KINEMATICS

Mean elbow angular velocity prior to impact was 1362 ± 496 $deg.s^{-1}$, with maximum humerus velocity being 875 ± 172 $deg.s^{-1}$. Hand speed at impact was 16.3 ± 1.5 $m.s^{-1}$ and post-impact ball speed was 23.7 ± 2.1 $m.s^{-1}$. It was found that pre-impact maximum elbow angular velocity, humerus angular velocity and impact hand speed all correlated significantly with post-impact ball speed ($r=0.63$, $P=0.020$, $r=0.77$, $P=0.003$ and $r=0.76$, $P=0.03$ respectively) but centre of mass horizontal velocity did not.

DISCUSSION

It was the aim of this study to examine the mechanical factors underpinning the 'jump' or attack serve. The results showed similarities to other studies on the spiking action, but there were also differences.

Lower limb angular kinematics prior to take-off did not correlate the centre of mass vertical or horizontal velocities. This is in agreement with Coleman et al. (1993), who found the same result for the spike action. This was attributed to the fact that centre of mass velocity depends on the sequential combination of the angular velocities of the lower limb (hip, knee and ankle) and not on the peak value of any of them. However, the homogeneity of the sample may also have been a factor in the non-significance of these relationships.

Jump height was significantly correlated to the square of the centre of mass vertical velocity at take-off of both left and right feet. This was as expected by basic mechanics, but the reason why the relationships were not unity was due to possible errors in digitisation and smoothing, or the incorrect identification of the take-off frame, as noted by Coleman et al., (1993).

Trunk rotation did not seem to play a significant role in generating ball speed. This also was similar to the study of Coleman et al., (1993), but they attributed this to the variation in the direction of the spikes analysed. The present study used serves which were projected straight (parallel to the court sidelines), and so this source of error should not have played a part in the non-significant relationship between trunk rotation and post-impact ball speed. The conclusions are that either the variables identified in trunk rotation may be unrepresentative or erroneous, or that trunk rotation is not important in the 'jump' serve.

Finally, upper limb data showed that elbow and humerus angular velocities were related to ball speed. The latter relationship was also found by Coleman et al. (1993), but the former was not. This may be explained by the fact that a spiker may be trying to achieve maximum contact height in attack (thus promoting premature elbow extension), whereas this is not the case in the serve. Thus the player may concentrate purely on maximising post-impact ball speed, resulting in a high elbow extension velocity. Hand speed at impact was highly related to ball speed, as expected by the law of conservation of momentum.

CONCLUSION

In summary, the 'jump' or attack serve demonstrated many of the same features as the spiking action. This was unsurprising, given the similarities between the two actions. The main differences were the time difference between the dominant and non-dominant leg extensions and the centre of mass horizontal velocity at take-off. These factors reflected the greater amount of linear translation required in the serve. Trunk rotations again seemed to be unimportant in generating ball speed, whereas elbow and humerus extension were significant factors in this respect.

It is intended that the results obtained from this study will be used in a mathematical model (such as those which have been developed for the spike) to examine tactical effectiveness.

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