

# ENDPOINT INSTANTANEOUS RADIUS OF ROTATION MAGNITUDES IN SOCCER AND VOLLEYBALL PLAYERS

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## INTRODUCTION

Subjects with greater and lesser skills are often compared to identify components of expert performance. Those gross features found only in the experts are usually concluded to be vital to successful skill execution. It is also apparent, however, that fine differences exist within experts. Although two athletes may seem to perform a task in an almost identical manner, the outcomes may be different. In sport, slight differences in performance may separate success and failure. It is sometimes difficult to determine what causes those differences in an expert population due to similar methods of execution. A novel approach may identify intersubject differences within a homogenous group.

Soccer and volleyball players attempt to develop large foot/hand velocities to obtain large ball velocity magnitudes (BV). The kicking and striking tasks are similar in that many muscle groups act to coordinate multiple segments to achieve optimal contact surface velocity at impact. Although maximal endpoint velocity is desirable, it is only useful if achieved at the instant of impact. Therefore, these skills require muscular strength and fine motor control.

A particle's linear velocity ( $\mathbf{v}$ ) is determined by its angular velocity ( $\mathbf{A}\mathbf{V}$ ) and radius of rotation. If the foot/hand center of mass (CM) is modeled as a single point in space, regardless of the segments involved in the action, it possesses an instantaneous ? and

instantaneous radius of rotation (IRR) at any given time. The IRR is an imaginary segment that connects the endpoint CM to some location in space about which it rotates. An examination of the IRR may offer insight about something that greater skilled athletes do to maximize their performance. Since segment  $\mathbf{A}\mathbf{V}$  occurs due to muscular action, coordinating segmental motion to increase the IRR will result in a greater endpoint  $\mathbf{v}$  for a given muscular force. It is possible that experts manipulate their segments to increase the overall IRR to optimize the endpoint CM velocity at impact.

The purpose of this investigation was to determine if those experienced athletes who obtain greater BV than other experts also have different peak magnitudes of the IRR (pIRR). Separate but identical analyses were performed with soccer kicking and volleyball spiking. It was hypothesized that those athletes with higher BVs will have greater pIRR magnitudes than their counterparts.

## METHODS

Two separate data collections were conducted. 16 experienced soccer players (SP) kicked a soccer ball as hard as possible, and 8 experienced volleyball players (VP) spiked a volleyball as hard as possible. Multiple trials of each task were videotaped at 60 Hz. Video data were digitized to identify the 3-D location of the CM of the striking endpoint and ball during each

picture. Digitizing occurred from the beginning of hip flexion/shoulder flexion until impact. The trial for each subject that resulted in the greatest BV was chosen for further analysis. The trials were arranged in sequential order of BV, and divided into two equal groups of F (fast) and S (slow). An initial dependent t-test ensured that the BVs differed between each group ( $p < .05$ ).

For each trial, the CM  $v$  and  $AV$  magnitudes were computed for each picture. The IRR magnitude was found as

$$|IRR| = |v| / |AV|$$

The trial was then examined to find peak  $|IRR|$  (pIRR), peak  $|v|$  and peak  $|AV|$ . Dependent t-tests were used to compare the F and S groups for the three dependent variables. Alpha was set at  $p < .05$  to determine significance.

## RESULTS AND DISCUSSION

It was unexpected to find that for the pIRR, S and F group trends were different for each sport. Experienced SP tended to have a lower pIRR while VP tended to have greater pIRR values (Table 1, Figure 1). Although statistical significance was not reached, trends indicate that there may be differences within each group. The peak values for each variable did not necessarily occur at the same picture.

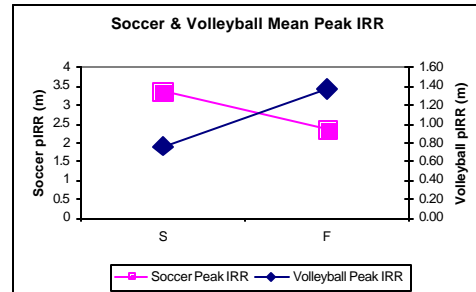
The large pIRR in SK in each group may occur because the  $v$  is affected by rotation and translation. The whole body translation during approach may increase the pIRR.

**Table 1. Mean (SD) Magnitude of SP and VP BV, pIRR, Angular and Linear Velocity**

	BV  (m/s)		Peak  IRR  (m)		Peak  AV  (rad/s)		Peak  v  (m/s)	
	S	F	S	F	S	F	S	F
SP (n=16)	24.91 (1.34)*	28.48 (1.35)	3.39 (1.31)**	2.37 (0.72)	17.99 (2.77)	19.29 (2.26)	14.37 (1.39)*	15.91 (0.75)
VP (n=8)	20.01 (0.70)*	22.66 (0.58)	0.76 (0.17)**	1.38 (0.68)	61.68 (9.77)	50.38 (14.46)	11.66 (1.14)	12.79 (0.92)

\* $p < .05$ , \*\* $p < .13$

It is possible that SP attempt to minimize the pIRR to reduce the moment of inertia of the moving segments, thereby increasing  $AV$  for a given amount of muscular force. They sacrifice rotational radius for increased rotational velocity. In contrast, VP may not need to reduce their pIRR because of the smaller relative mass to move. They can afford to increase their pIRR to increase  $v$ .



**Figure 1:** SP and VP pIRR means.

It might also be that because SP were kicking a resting ball, while VP struck an airborne ball, the task environment resulted in different control strategies. SP freely chose their speed and direction of approach, while VP were required to react to the flight of the ball. These constraints may have resulted in different control strategies.

## SUMMARY

We found that SP may tend to decrease their foot CM IRR, while VP may increase their hand CM pIRR to obtain higher ball velocities. Further study should be conducted with greater subject sizes to increase statistical power.