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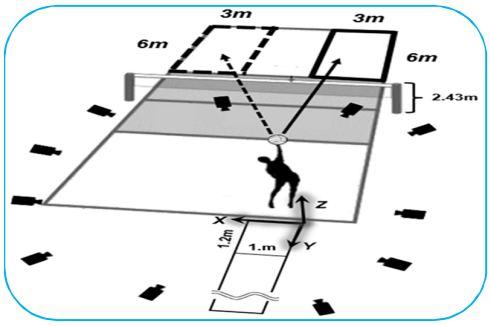
COMPARATIVE BIOMECHANICAL ANALYSIS OF APPROACH PHASE KINEMATICS IN THE JUMP TOPSPIN SERVE, HIGH OUTSIDE SPIKE, AND BACKCOURT SPIKE AMONG ELITE MALE VOLLEYBALL PLAYERS

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ABSTRACT :



The study aimed to investigate the significant differences in selected linear kinematic variables during the approach phases of the volleyball topspin jump serve, spike on a high outside set, and back-row spike among national level male volleyball players. A total of 10 Indian national level male volleyball players, proficient in performing all the three techniques were selected as participants. Eight linear kinematic variables were examined: 1) Distance between the feet at stance (Stance width), 2) Height of the centre of mass (COM) at stance, 3) Distance of approach, 4) Approach phase duration, 5) Approach velocity, 6) Length of the second-last step, 7) Height of the COM at the second-last step, and 8) Height of the COM at the cross step. Data collection was carried out under standardized non-game conditions. Each participant performed the three volleyball techniques while their movements were recorded using two digital cameras positioned in line with the direction of motion. The recorded performances were analyzed using KINOVEA motion analysis software to obtain the kinematic measurements. The collected data were analyzed using Multivariate Analysis of Variance (MANOVA), Univariate Analysis of Variance (ANOVA), and post hoc tests to determine the differences among the three techniques. The findings revealed statistically significant differences in the height of the COM at stance, distance of approach, duration and approach velocity, length of the second-last step, height of the COM at the second-last step, and height of the COM at the cross step among the topspin jump serve, spike on a high outside set, and back-row spike. These results indicate that the approach phase of the three offensive volleyball skills exhibits distinct linear kinematic characteristics in national-level male volleyball players.

KEYWORDS: *Kinematic Analysis, Topspin jump serve, Spike.*

INTRODUCTION

The topspin jump serve is one of the most powerful offensive skills in volleyball, requiring a highly coordinated sequence of movements to generate maximum velocity and spin on the ball. The technique begins with the player positioned deep inside the service zone, followed by an explosive approach run, take-off, and ball contact at the peak of the jump, enabling the ball to cross the net at high velocity with substantial topspin. Similarly, the spike on a high outside set is a dynamic attacking

technique in which the player forcefully strikes the ball downward into the opponent's court at a sharp angle, making it difficult for the defense to respond (Selinger & Ackerman, 1986). The back row spike, performed by players attacking from behind the attack line, is another high-intensity offensive skill that combines speed, power, and precision. Owing to the high velocity and aggressive nature of these three techniques, opponents are provided with very limited time to anticipate, react and successfully play the ball. Biomechanical factors play a crucial role in enhancing the performance of these offensive skills. An optimal toss/set distance and flight of the ball provide the player with sufficient time to develop horizontal velocity during the approach run, thereby contributing to greater momentum before take-off (Tilp, Wagner, & Müller, 2008). Efficient transfer of horizontal momentum into vertical velocity requires athletes to perform a preparatory loading phase, during which the hip, knee, and ankle extensors contract eccentrically while the hips and knees flex, storing elastic energy before take-off (Miyamoto et al., 2011). According to the principle of conservation of momentum (Alexander & Honish, 2009), a longer and more effective approach run contributes to greater jump height and improved attacking performance (Khayambashi, 1977; Maxwell, Bratton et al., 1980). Consequently, elite volleyball players commonly employ a four-step approach to maximize horizontal momentum. The horizontal velocity generated during the approach is subsequently transferred through the kinetic chain during take-off and arm swing, contributing to increased ball velocity. From the ready position, characterized by flexed hips, knees, and trunk, the player initiates take-off by sequentially extending the lower limbs. Owing to the forward momentum developed during the approach, the trailing leg extends first, followed by the lead leg, resulting in an effective vertical lift. Simultaneously, an upward arm swing contributes additional force and vertical momentum, thereby enhancing jump performance (Tang, 2013). Given the biomechanical significance of these offensive volleyball techniques, the present study aimed at investigating the relationship between the selected linear kinematic variables of approach phase of topspin jump serve, spike on a high outside set, and back-row spike.

METHODOLOGY

The present study aimed to examine the significant differences in selected linear kinematic variables during the approach phase of the volleyball topspin jump serve, spike on high outside set, and back-row spike. Ten Indian national-level male volleyball players, proficient in performing all three techniques, were purposively selected as participants. Each participant was instructed to perform the topspin jump serve, spike on high outside set, and back-row spike under standardized, non-game conditions. The performances were recorded using two digital video cameras. Camera 1 (Sony Alpha 7S II, 50 mm lens, 120 frames·s^{-1}, 1080p resolution) was positioned 9 m from the center of the performance area, while Camera 2 (Sony Alpha 7R III, 24–70 mm lens, 120 frames·s^{-1}, 1080p resolution) was positioned 15 m from the center of the performance area. Both cameras were aligned perpendicular to the sagittal plane of motion and mounted at a height of 1.75 m, approximately corresponding to one-half of the average ball contact height of the participants during the execution of the three techniques. Across all trials, the two successful trials recorded the highest ball velocity for each participant and each technique were selected for analysis. KINOVEA motion analysis software (Version 0.8.26; Charmant, 2017) was used to analyze the recorded videos. The following eight linear kinematic variables of the approach phase were measured: distance between the feet at stance, height of the centre of mass (COM) at stance, Distance of Approach, duration of the approach run, approach velocity, length of the second-last step, height of the COM at the second-last step, and height of the COM at the cross step. Statistical analyses were performed using SPSS Statistics Version 20.0 (SPSS Inc., Chicago, IL, USA). Differences among the topspin jump serve, spike on a high outside set, and back-row spike were evaluated using Multivariate Analysis of Variance (MANOVA). When significant multivariate effects were observed, Univariate Analysis of Variance (ANOVA) followed by post hoc multiple comparison tests were conducted to identify specific differences among the three techniques. Statistical significance was established at the 0.05 level.

RESULTS OF THE STUDY

Table 1

MANOVA of all Dependent variables of Topspin jump serve, Spike on high outside set and Back Row Spike

		Value	F	Hypotheses df	Sig.	Partial Eta Squared
Technique	Pillai's trace	1.982	69.632	16.000	.000	.991
	Wilks' lambda	.000	90.343[a]	16.000	.000	.993
	Hotelling's trace	400.796	116.899	16.000	.000	.995
	Roy's largest root	336.080	214.718[b]	8.000	.000	.997

From table No.1 it evident that, statistics of four tests revealed about the group effect on Independent Variables, Gender and Group: ''Pillai's'', ''Wilks'', ''Hotelling's'', and ''Roy's.'' Huberty (1994, pp. 183-189) offers a detailed discussion of these four statistics, and in the independent variable (Topspin jump serve, Spike on high outside set and Back Row Spike). All the tests indicate the multivariate effect is statistically significant for the current data (Wilks' = 0.000, F = 90.343, p <.000). The significant value of F is the indication of significant differences between selected dependent variables and techniques.

Table 2

Univariate ANOVA on effect of Technique with dependent Variables of Topspin jump serve, spike on high outside set and Back court spike among Elite Male Volleyball Players

Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Distance between Feet (Stance)	0.002	2	0.001	0.221	0.803	0.008
	0.319	57	0.006			
Height of COM(Stance)	0.399	2	0.199	52.685	0.000	0.649
	0.216	57	0.004			
Distance of Approach	9.091	2	4.546	40.035	0.000	0.584
	6.472	57	0.114			
Approach Phase Duration	0.490	2	0.245	9.253	0.000	0.245
	1.509	57	0.026			
Approach velocity	7.731	2	3.866	18.181	0.000	0.389
	12.119	57	0.213			
Length of Second-last step	0.441	2	0.220	17.243	0.000	0.377
	0.728	57	0.013			
Height of COM (Second-last step)	0.181	2	0.090	27.887	0.000	0.495
	0.185	57	0.003			
Height of COM (Cross Step)	0.195	2	0.098	37.787	0.000	0.570
	0.147	57	0.003			

Table 2 discusses that there was significant difference in the Height of COM at stance (F = 52.685, p<0.05), distance of approach (F = 40.035, p < 0.05), approach phase duration (F = 9.253, p < 0.05), approach velocity (F = 18.181, p < 0.05), length of second-last step (F = 17.243, p < 0.05), height of COM at second-last step (F = 27.887, p < 0.05), and height of COM at cross step (F = 37.787, p < 0.05). There was no significant difference between stance width (F = 0.221, p > 0.05).

Table 3

Pair-wise Comparisons of means of significant dependent Variables on Group (LSD)

Dependent Variable	Technique		Mean Difference	Std. Error	Sig.
Height of COM(Stance)	Topspin jump serve	Spike on high outside set	0.1905*	0.01945	0.000
		Back Court Spike	0.1470*	0.01945	0.000
	Spike on high outside set	Topspin jump serve	-0.1905*	0.01945	0.000
		Back Court Spike	-0.0435	0.01945	0.088
	Back Court Spike	Topspin jump serve	-0.1470*	0.01945	0.000
		Spike on high outside set	0.0435	0.01945	0.088
Distance of Approach	Topspin jump serve	Spike on high outside set	0.4160*	0.10656	0.001
		Back Court Spike	-0.5350*	0.10656	0.000
	Spike on high outside set	Topspin jump serve	-0.4160*	0.10656	0.001
		Back Court Spike	-0.9510*	0.10656	0.000
	Back Court Spike	Topspin jump serve	0.5350*	0.10656	0.000
		Spike on high outside set	0.9510*	0.10656	0.000
Approach Phase Duration	Topspin Jump Serve	Spike on high outside set	0.2005*	0.05146	0.001
		Back Court Spike	0.1815*	0.05146	0.003
	Spike on high outside set	Topspin jump serve	-0.2005*	0.05146	0.001
		Back Court Spike	-0.0190	0.05146	1.000
	Back Court Spike	Topspin jump serve	-0.1815*	0.05146	0.003
		Spike on high outside set	0.0190	0.05146	1.000
Approach velocity	Topspin jump serve	Spike on high outside set	-0.1805	0.14581	0.663
		Back Court Spike	-0.8355*	0.14581	0.000
	Spike on high outside set	Topspin jump serve	0.1805	0.14581	0.663
		Back Court Spike	-0.6550*	0.14581	0.000
	Back Court Spike	Topspin jump serve	0.8355*	0.14581	0.000
		Spike on high outside set	0.6550*	0.14581	0.000
Length of Second-last step	Topspin jump serve	Spike on high outside set	0.1930*	0.03575	0.000
		Back Court Spike	0.0250	0.03575	1.000
	Spike on high outside set	Topspin jump serve	-0.1930*	0.03575	0.000
		Back Court Spike	-0.1680*	0.03575	0.000
	Back Court Spike	Topspin jump serve	-0.0250	0.03575	1.000
		Spike on high outside set	0.1680*	0.03575	0.000
Height of COM(Second-last step)	Topspin jump serve	Spike on high outside set	0.1310*	0.01800	0.000
		Back Row Spike	0.0915*	0.01800	0.000
	Spike on high outside set	Topspin jump serve	-0.1310*	0.01800	0.000
		Back Court Spike	-0.0395	0.01800	0.097
	Back Court Spike	Topspin jump serve	-0.0915*	0.01800	0.000
		Spike on high outside set	0.0395	0.01800	0.097
Height of COM(Cross Step)	Topspin jump serve	Spike on high outside set	0.1370*	0.01608	0.000
		Back Court Spike	0.0925*	0.01608	0.000
	Spike on high outside set	Topspin jump serve	-0.1370*	0.01608	0.000
		Back Court Spike	-0.0445*	0.01608	0.023
	Back Court Spike	Topspin jump serve	-0.0925*	0.01608	0.000
		Spike on high outside set	0.0445*	0.01608	0.023

Table 3 shows that the Height of COM at stance, there was significant difference between topspin jump serve and Spike on high outside set (Mean difference = 0.1905, $p < 0.05$); there was significant difference between topspin jump serve and back court spike (Mean difference = 0.1470, $p < 0.05$); and there was no significant difference between Spike on high outside set and back court spike ($p > 0.05$). When exploring the analysis of Distance of Approach, the results showed significant difference between topspin jump serve and Spike on high outside set (Mean difference = 0.4160, $p < 0.05$); significant difference between topspin jump serve and back court spike (Mean difference = -0.5350, $p < 0.05$); and significant difference between Spike on high outside set and back court spike (Mean difference = -0.9510, $p < 0.05$). The analysis of approach phase duration showed significant difference between topspin jump serve and Spike on high outside set (Mean difference = 0.2005, $p < 0.05$); significant difference between topspin jump serves and back row spikes (Mean difference = 0.1815, $p < 0.05$); and no significant difference between Spike on high outside set and back court spike ($p > 0.05$). While examining the approach velocity, no significant difference was found between topspin jump serve and Spike on high outside set ($p > 0.05$); significant difference was found between topspin jump serve and back court spike (Mean difference = -0.8355, $p < 0.05$); and significant difference was found between Spike on high outside set and back court spike (Mean difference = -0.6550, $p < 0.05$). Exploration of the length of second-last step showed that there was significant difference between topspin jump serve and Spike on high outside set (Mean difference = 0.1930, $p < 0.05$); there was no significant difference between topspin jump serve and back court spike ($p > 0.05$); and there was significant difference between Spike on high outside set and back court spike (Mean difference = -0.1680, $p < 0.05$). Analysis of Height of COM at second-last step revealed that there was significant difference between topspin jump serve and Spike on high outside set (Mean difference = 0.1310, $p < 0.05$); there was significant difference between topspin jump serve and back court spike (Mean difference = 0.0915, $p < 0.05$); and there was no significant difference between Spike on high outside set and back court spike ($p > 0.05$). While examining the Height of COM at cross step, significant difference was found between topspin jump serve and Spike on high outside set (Mean difference = 0.1370, $p < 0.05$); significant difference was found between topspin jump serve and back court spike (Mean difference = 0.0925, $p < 0.05$); and significant difference was found between Spike on high outside set and back court spike (Mean difference = -0.0445, $p < 0.05$)

Univariate ANOVA on effect of Technique with dependent variables indicates that there are significant differences in Height of COM at stance, Distance of Approach, Approach Phase Duration, approach velocity, length of second-last step, height of CG at second-last step, and Height of COM at cross step as $p < 0.05$ but, there was no significant difference between feet at stance as $p > 0.05$. Pairwise comparison of the topspin jump serve, Spike on high outside set and back court spike also indicates that there are significant differences exist between the Height of COM at stance, distance of approach, approach phase duration, approach velocity, length of second-last step, height of COM at second-last step, height of COM at cross step, among topspin jump serve, spike on high outside set and back court spike of elite male volleyball players.

CONCLUSION

The result showed that height of center of mass (COM) at stance was greater in topspin jump serve when compared to back court spike and spike on high outside set. Distance of approach of back court spike was greater when compared to topspin jump serve and spike on high outside set. Approach phase duration in topspin jump serve shows greater value when compared to back court spike and spike on high outside set. Approach velocity in back court spike was found greater when compared to spike on high outside set and topspin jump serve. Length of second-last step in topspin jump serve was greater when compared to back court spike and spike on high outside set. Height of COM at second-last step was greater in topspin jump serve when compared to back court spike and spike on high outside. Height of COM at cross step is greater in topspin jump serve when compared to back court spike and spike on high outside set of elite male volleyball players.

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