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Research article

KINEMATIC PARAMETERS OF THE JUMP SHOT IN ELITE MALE BASKETBALL PLAYERS

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Abstract. *The primary aim of this study was to determine the kinematic parameters of the jump shot in elite male basketball players, by analyzing the release time for shooting, the angle of entry, and ball spin. The secondary aim of this study was to examine possible differences in these kinematic parameters among the players associated with their playing position. Eighteen male basketball players (7 guards, 8 forwards, 3 centers) from six Serbian senior teams were tested. The 94Fifty basketball sensor was used to obtain the kinematic parameters of the jump shot. The highest average measured values of shot release time were found in centres (1.23±0.23 s) and the lowest in guards (1.07±0.28 s), although these differences were not statistically significant. Furthermore, centres had a lower angle of entry (36.6±2.08°) than guards (40.54±4.76°) and forwards (42.05±3.77°). The highest value of the backspin was obtained by forwards (130±11.91 rotations/min). There were no significant differences between guards, forwards and centers in any of the kinematic variables (p>.01). The relationship between body height and angle of entry was not significant (p>0.05). In conclusion, compared to centers, guards and forwards showed similar results for the examined variables. This evidence seems to support the theory that compared to guards and forwards centres have the weaker shooting techniques. Coaches should encourage all players, especially centers, to shoot from all positions.*

Key words: *Jump Shot, Basketball, Analysis, Playing Positions, Biomechanics*

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INTRODUCTION

The ability to properly execute the jump shot in basketball is an important skill which determines shooting accuracy. The accuracy of shooting at the basket depends on a number of factors, such as anthropological dimensions, pressure, technique, situational constraints, physiological load imposed on basketball players during the game, etc. (Kocić, Berić, Radovanović, & Simović, 2012; Lam, Maxwell, & Masters, 2009; Fontanella, 2008; Button, Macleod, Sanders, & Coleman, 2003; McInnes, Carlson, Jones, & McKenna, 1995; Millslagle, 2002; Rojas, Cepero, Oña, & Gutierrez, 2000). The investigated factors of a successful jump shot can be grouped into 3 categories of performance (Okazaki, Rodacki, & Satern, 2015): 1) ball trajectory; 2) segmental movement organization; 3) variables that influence shooting performance.

A high ball trajectory in basketball, shooting directly through the basket ring produces the best angle of entry. The angle of entry is directly related to the angle of release of the ball through the ring of the basket (Brancazio, 1981). The release angle may be influenced by many factors, including the shooter's height (Satern, 1993), presence of an opponent (Rojas et al., 2000), shoulder angle (Satern, 1988), as well as the distance from the hoop (Miller & Bartlett, 1996; Satern, 1993). Rojas et al. (2000) analyzed the release angle in the presence of an opponent and reported values of 45°. In addition, Miller and Bartlett (1996) found that the release angle of the ball for a shorter distance ranges from 52-55°, and for the longest distance 48-50°, where the release angle of 55-60° produces an optimal entry angle into the basket of around 45-50° (Krause, Meyer, & Meyer, 2008). In a free throw, the angle of entry ranged from 37.8° to 42.0° (Satti, 2004).

Mathematically, the ball shot with a greater angle has a better chance of passing through the basket (Knudson, 1993). The angle of entry can be increased with the spin of the ball as a consequence of Magnus force (Hung, Johnson, & Coppa, 2004). Furthermore, a biomechanical study has focused on joint actions and confirmed that the backspin or back rotation of the ball was associated with more accurate jump shooting performed by experienced basketball shooters (Yates, Holt, & Terauds, 1982). The main movement patterns intended to create a backspin in a jump shot are wrist flexion and radio-ulnar pronation (Martin, 1981). In the theoretical study by Knudson (1993) for a 1-second flight of ball on the way to the basket, the ball should complete approximately 2 to 3 rotations. In contrast, Dobovičnik, Jakovljević, Zovko, & Erčulj (2015) quantitatively analyzed the backspin and reported 1.66 rotations per second (100.94 rotations per minute) for male guards under the age of 20.

In modern basketball playing conditions, besides the backspin and angle of entry into the basket, the time to release of the jump shot is also an important parameter. The total time required to release the jump shot has been reported to be about 0.62 s, but this study could not be the judging criterion due to a very small sample size (only 2 participants) (Fontanella, 2008). In contrast, Dobovičnik et al. (2015) showed that the times required to perform a jump shot were 0.76, 0.83, and 0.83 s for guards, forwards and centers, respectively. Despite these important results, the aforementioned study included 7 youth Serbian basketball teams as well as a Serbian national team of players under 20 (54 participants in total), which represented a large inter-subject variability as well as the variability between the observed results, since the authors presented their results as average values. According to this author's knowledge, there have been no studies performed to examine similar topics in elite senior

basketball players. Further analysis is therefore necessary to determine the release time and backspin of the jump shot in elite male basketball players.

Numerous biomechanical studies (Elliott, 1992; Miller & Bartlett, 1996; Miller & Bartlett, 1993; Okazaki & Rodacki, 2012; Rojas et al., 2000) have examined the release angle of the jump shot, in contrast to only a few studies (Dobovičnik et al., 2015; Satti, 2004) dealing with the angle of ball entry into the basket. The objectives of this study were therefore to determine the kinematic parameters of the basketball jump shot in elite male basketball players, by analyzing the angle of entry, ball spin and release time for shooting; to examine possible differences between kinematic parameters among the players according to their team positions (guards, forwards and centers). We hypothesized that players' positions determined the kinematic parameters of the jump shot.

METHODS

Participants

The study was carried out during the final tournament of the Serbian cup "Radivoje Korać". Eighteen elite male basketball players (mean±SD; age: 22.6±3.24 years; body height: 2.01±.08 m) from six Serbian clubs (three teams competed in the first Serbian Basketball League and three teams in the Adriatic Basketball Association [ABA] League) were analyzed in this study. Three players from each team were randomly selected by the team coaches. The participants were tested during their morning training (10 am), before the game that took place in the evening (after 7 pm). All the basketball players, during the current season, trained 15-20h per week and played in at least one official match according to the data derived from self-reported questionnaires. The participants were divided into 3 groups according to their playing positions: 7 guards (mean±SD; age: 23.6±4.23 years; body height: 1.94±.06 m); 8 forwards (mean ± SD; age: 22.5±2.78 years; body height: 2.02 ± .03 m); and 3 centers (mean±SD; age: 21.0±1.00 years; body height: 2.12±.05 m). All the participants were informed of the purpose of the investigation, and gave their informed consent for the testing.

Procedures

The kinematic parameters of the jump shot were detected with a 94Fifty basketball sensor (InfoMotion Sports Technologies, Ohio, Dublin), the reliability and validity of which was confirmed in previous studies (Abdelrasoul, Mahmoud, Stergiou, & Katz, 2015; Rupčić, Antekolović, Knjaz, Matković, & Cigrovski, 2015). The sensors were connected by Bluetooth to an Android-operating device. The following jump shot kinematic parameters in elite male Serbian basketball players were detected on the Android device: shot release time, angle of entry, and backspin. The estimated kinematic parameters have calibrated an optimal range. According to the company, for shot release less than 0.7 seconds (fast shot), for angle of entry, optimal range is estimated between 42 and 48 degrees (45 is considered perfect), and for a backspin between 130 and 150 rotations per minute (ideally). Optimal values were obtained after the measurements in elite basketball players.

The actual testing, as part of the shooting training, was performed after a warm-up period. The warm-up was performed using generalized and specific exercises in which the participants practiced a number of jump shots. After the completion of a 10 min warm-up, the participants

were instructed to shoot directly through the hoop. All the players were right-handed. The player shot at the basket in his most natural position by a jump shot and received the ball from his co-players who were standing below the basket. The shots were performed in controlled stable conditions, without opponents, without any physical load imposed on the players. The distance from the basket to the shooting spot was 21 ft (6.4 m). This distance was established and applied in previous studies (Miller & Bartlett, 1994; Miller & Bartlett, 1996). Each player performed 11 shots, i.e., one try and 5 shots for the measurement of release time and angle of entry, and 5 shots for ball spin measurements. The position of the player was directly in front of the basket. The arithmetic means of the obtained results were used for statistical analysis. After each shot the android connected to the ball showed the values of adequately measured parameters.

Data analysis

Statistical analyses were performed using the SPSS (v19.0, SPSS Inc., Chicago, IL). Descriptive statistics for kinematic parameters of the jump shot were calculated. The Shapiro Wilk test was used to assess if the data were normally distributed. The differences in kinematic parameters between guards, forwards and centers were determined using a one-way univariate analysis of variance (ANOVA). A Bonferroni correction was applied to adjust P-values for multiple comparisons. Correlation between body height of the players and angle of entry was determined using the Spearman correlation coefficient. The α level was set at $p < .05$ for statistical significance.

RESULTS

The results of the Shapiro Wilk test showed that body height and shot release time were not normally distributed, while the remaining variables were normally distributed. Descriptive statistics data were presented in Table 1. There were no significant differences between guards, forwards and centers in any kinematic variables ($p>0.01$).

Table 1 Kinematic parameters of jump shot according to playing position

Variables	Guards			Forwards			Centers			All participants		
	Mean±SD	Min	Max	Mean± SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max
Shot release time (s)	1.07 ± 0.28	0.81	1.56	1.08± 0.19	0.9	1.5	1.23±0.23	0.98	1.41	1.10±0.23	0.81	1.56
Angle of entry (deg)	40.54±4.76	32.2	45	42.05±3.77	33.4	45.4	36.6±2.08	35.4	39	40.56±4.26	32.2	45.4
Backspin (rot. per min)	127.37±12.49	106.8	145.8	130±11.91	107.2	143.6	121.13±34.96	80.8	142.8	127.5±16.35	80.8	145.8

The relationship between body height and angle of entry was not significant ($p>0.05$). The highest average measured values of shot release time were found in centres (mean ± SD: 1.23±0.23 s) and the lowest in guards (mean±SD: 1.07±0.28 s), although the difference was

not statistically significant. Further, centres showed a lower angle of entry (mean±SD: 36.6±2.08°) than guards (mean±SD: 40.54±4.76°) and forwards (mean±SD: 42.05±3.77°). The highest value of the backspin was obtained by forwards (mean±SD: 130±11.91 rotations/min). All the participants in standard conditions (without an opponent) had a release time of the jump shot above 0.7 seconds (Figure 1). Ten players (55.56%) had an angle of entry and backspin within the optimal range (Figure 2; Figure 3).

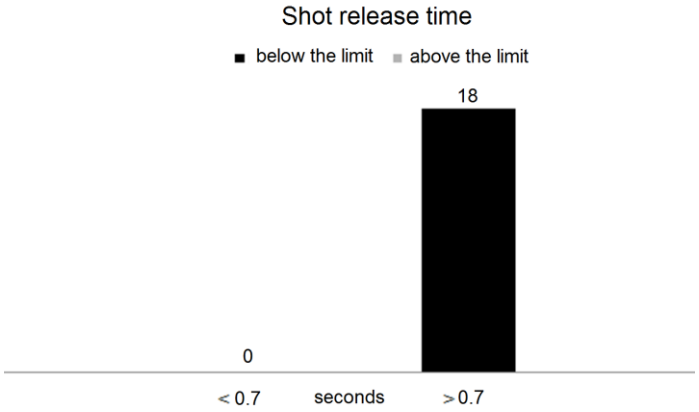

Fig. 1 The number of players which have a shot release time below 0.7 seconds and above 0.7 seconds

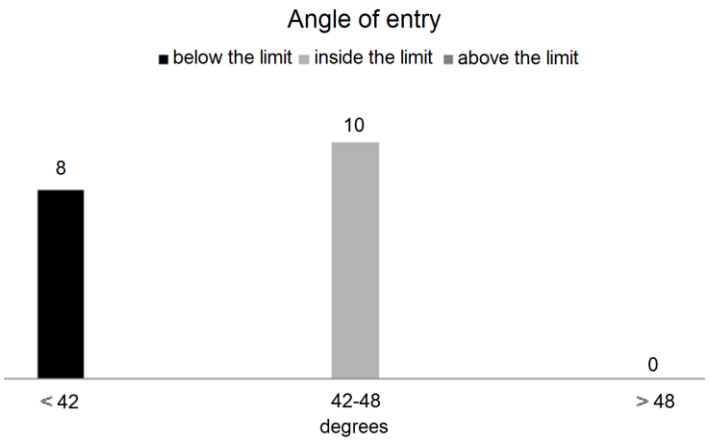

Fig. 2 The number of players which have an angle of entry below 42°, inside 42-48°, and above 48°

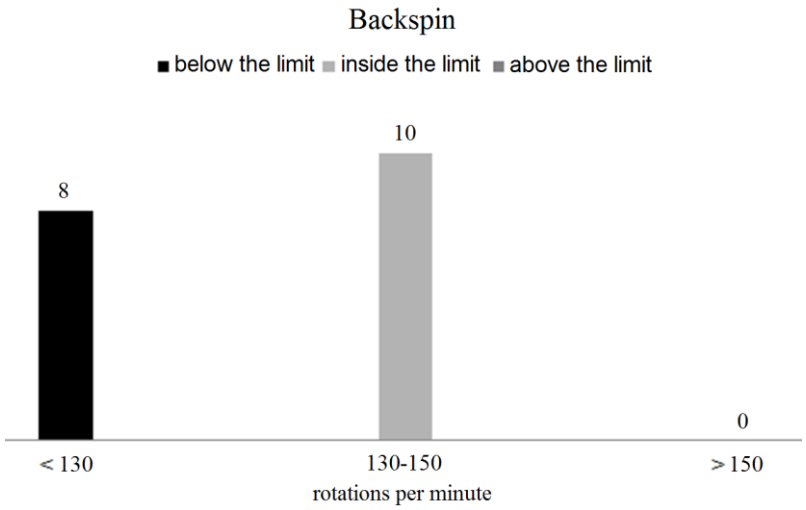

Fig. 3 The number of players which have a backspin below 130, inside 130-150 and above 150 rotations per minute

DISCUSSION

The aim of this study was to determine the values of kinematic parameters (shot release time, angle of entry, backspin) of jump shot in elite male basketball players.

The mean shot release time is 1.10±0.23. This result was not similar to the previously reported data. The time to release shot was greater than that reported for male participants by Fontanella (2008) (0.62 s, respectively) and Dobovičnik et al. (2015) (0.76, 0.83 and 0.83 s for guards, forwards and centers, respectively). The discrepancy can be attributed to different conditions in which the players were tested. In previous studies, the players were asked to receive and release a shot as soon as possible, as in competitive conditions.

It was hypothesized that there was a possible difference in jump shot kinematic parameters among basketball players related to their playing positions. Surprisingly, no significant differences were found among guards, forwards and centers in all measured and calculated jump shot kinematic parameters. Although no significant differences were found when taking all the groups into account, guards and forwards showed similar results for the estimated variables in contrast to centers. This could perhaps be explained by their unfamiliarity with 6.4 m distance shots.

A greater number of backspins introduced an elevation of the trajectory and extended the ball path by approximately 0.1 m (Hung et al., 2004). As a consequence, the angle of entry was larger, improving thus the chance of success. Theoretically, an ideal angle of entry into the hoop is 90°, allowing a player to use the maximum area (target size) of the basket. In contrast, the critical angle is 32.43° (Hay, 1985). However, the use of the real width of the hoop would impose specific mechanical demands on the player, especially if the distance from the basket is increased (Miller & Bartlett, 1993). For that reason, the optimal angle of entry ranged from 42 to 48° (according to the company). The mean angle of entry in this

study was 40.56±4.26°. These results are similar to the previous study (37.8° to 42.0°) (Satti, 2004), but lower than the optimal angle. The players' standing height value (mean ± SD: 2.01 ± .08 m) may be an explanation for the lower angle of entry. Rojas et al. (2000) also assumed that the lower release angle of 42° than 48° can be attributed to a greater height of the ball release, caused by the greater height of the participants in the study, 1.95 m against the mean of 1.83 reported by Miller and Bartlett (1996). On the other hand, we did not find a statistically significant correlation between body height and angle of entry. However, the angle of entry is determined by 3 factors: release height, release angle and release velocity (Okazaki et al., 2015). The players' standing height and vertical jump height are directly related to the ball release height (Okazaki et al., 2015). Therefore, we might speculate that an angle of entry (mean ± SD: 40.56±4.26) lower than the optimum value according to the company was associated in part with a greater vertical jump height, and partly with the players' standing height and a lower release angle. In addition, an increase in release velocity decreased movement consistency (Darling & Cooke, 1987a; Darling & Cooke, 1987b), causing a lower angle of release. However, we excluded this factor as non-influential, since players were not required to perform their shot quickly.

The mean values of the backspin on the way to the basket (127.5 rotations per minute, with 2.13 rotations per second) are in agreement with the earlier theoretical study by Knudson (1993), which reported 2 to 3 rotations per second. On the other hand, this result was in contrast with the quantitative analysis performed by Dobovičnik et al. (2015), where most of the shots performed were not in the recommended range (guards: 1.68 rotations per second; forwards and centers: 1.95 rotations per seconds, respectively). This might be related to the fact that the aforementioned study had involved greater inter-subject variability.

A limitation of the study was the relatively small sample size when centers were concerned (3 centers versus 7 guards and 8 forwards). For this reason, we could not be certain that there were no differences in kinematic parameters among the players according to their position (guards, forwards and centers). Moreover, future studies are needed to determine the extent of the impact of players' standing height, their jump height and release angle on the angles of entry. In addition, the impact of the presence of an opponent on the time to release shot should be analyzed, as well as the impact of release velocity on the angle of entry and backspin.

CONCLUSION

The present study, despite its limitations, revealed that there were no differences in the selected kinematic parameters among elite male basketball players related to their playing positions (guards, forwards and centers). However, this evidence seemed to support the theory that centers had weaker shooting techniques compared to guards and forwards. Coaches should encourage all players, and especially centers, to shoot from all positions. The kinematic parameters of the jump shot in elite male basketball players should further be improved and refined, particularly with respect to the factors of angle of entry and time to release shot.

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KINEMATIČKI PARAMETRI SKOK ŠUTA VRHUNSKIH KOŠARKAŠA

Osnovni cilj ove studije bio je da se utvrde kinematički parametri skok šuta vrhunskih košarkaša, analizirajući vreme potrebno za šut, upadni ugao i broj rotacija lopte unazad. Sekundarni cilj bio je ispitivanje mogućih razlika ovih kinematičkih parametara između igrača u odnosu na poziciju u igri. Testirano je osamnaest košarkaša seniora (7 bekova, 8 krila, 3 centra) iz 6 srpskih timova. 94Fifty senzor je korišćen za dobijanje navedenih kinematičkih parametara. Najveća prosečna vrednost vremena potrebnog za šut utvrđena je kod centara (1.23±0.23 s), a najniža kod bekova (1.07±0.28 s), iako ova razlika nije statistički značajna. Pored toga, centri imaju najniži upadni ugao (36.6±2.08°) u odnosu na bekove (40.54±4.76°) i krilne igrače (42.05±3.77°). Najveća vrednost rotacija unazad dobijena je kod krilnih igrača (130±11.91 rotacija/min). Nije bilo statistički značajne razlike između bekova, krilnih igrača i centara ni u jednoj kinematičkoj varijabli (p>0.01). Rezultati pokazuju da u poređenju sa bekovima i krilnim igračima, centri imaju slabiju šutersku tehniku. Treneri treba da ohrabre sve igrače, a posebno centre da šutiraju sa svih pozicija.

Ključne reči: *skok šut, košarka, analiza, igračke pozicije, biomehanika*