Original article

Comparison of the Shooting Angles and Shooting Accuracy in Wheelchair Basketball and Basketball Players

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Abstract: Shot accuracy is very important for success in wheelchair basketball (WB) and basketball games. The kinematics of the ball affects the shot accuracy. The main purposes of this study are to compare the kinematics of the ball according to the outcomes of WB and basketball players' shots and compare the shooting accuracy of WB and basketball players. Male senior athletes (17 basketball, 6 WB) voluntarily participated in the research. Participants made static shots from 6 spots (n=1515) and the analyses were made. The shots were separated into 4 groups. The first group contained the "Clean Shot"s (CS) which the ball goes into the hoop with no or 1 hit to the rim. The second contained all the "Success" shots (S) but CS. The third contained "Missed" shots, the ball hit to the rim. Fourth contained the rest of the missed shots (Air Ball). Reliable and valid 94fifty Smart Sensor Basketball was used in this research. For both WB and basketball players, CS angles were significantly higher than other shots and no significant difference was found between S angles and unsuccessful shots. CS angles of WB players were significantly higher than basketball players. This research showed that the entry angle affects CS for both sports. It is thought that it may raise CS and shooting percentage if coaches train their players by taking entry angles into consideration. Another finding of this study was CS angles of WB players are higher than basketball players. The reason for this may be the more active, hence more improved, upper extremity motor skills of the WB players.

Keywords: Shooting angle; Basketball; wheelchair basketball; kinematics; 94fifty; ball trajectory; shooting accuracy

1. Introduction

Basketball and wheelchair basketball (WB) is some of the most popular team sports at the Olympic and Paralympic Games, respectively (Francis, 2019; Ivanković et al., 2010). Thus several studies related to basketball and WB are published previously (Flueck, 2020; Mancha-Triguero et al., 2019; Marszałek et al., 2019; Marszałek & Molik, 2019; Okazaki et al., 2015). Some of these studies focus on shooting since shot accuracy is one of the important technical skills that affect success in these games (Novriansyah et al., 2019; Özkan et al., 2019). In basketball, the jump shot technique consists of 5 phases: preparation, ball elevation, stability, release, and inertia (Okazaki et al., 2015). There are two main dissimilarities between basketball and WB shooting techniques. These dissimilarities are WB athletes being lower and generating propulsive forces mainly from the upper body (Shigematsu et al., 2021; Prvulovic et al. 2022; Malone et al., 2002). As a result of these dissimilarities, the ball trajectory and kinematics of the ball are expected to differentiate. Hence WB players should be trained differently than basketball players. Because of this necessity, the above-mentioned kinematical differences need to be well understood, since it is common that WB coaches are originally basketball players and coaches.

In basketball, shooting performance-related variables were examined under three different titles: segmental movement organization, variables that influence shooting performance, and ball trajectory (Okazaki et al., 2015). The kinematics of the ball during the shooting was previously investigated using various protocols in basketball (Hussain et al., 2017; Okazaki et al., 2015) and WB (Malone et al., 2002). For instance, ball kinematics were studied during free throws in WB by Malone et al. (2002); during jump shots in basketball by Rupčić et al. (2015a), Hussain et al. (2017), and Abdelrasoul et al. (2015); during free throws in basketball by Hamilton and Reinschmidt (1997); and during free throws and jump shots in basketball by Okazaki et al. (2015). Furthermore, in some studies, the factors that affect shooting performance and what the shooting success depends on were examined (Abdelrasoul et al., 2015; Chen et al., 2009; Francis et al., 2016; Hussain et al., 2017; Schwark et al., 2004). However, in these studies, shooting kinematics were specified by using methods such as modeling and video analysis. Unfortunately, despite the success of these methods in the matter of scientific studies, it is almost impossible to use these methods easily and continuously during training. Whereas, a novel method, smart sensor basketball, to examine the ball kinematics exists in the literature (Rupcic et al., 2015). For player development, this method is easy to use in real life during training continuously. Moreover, in the literature, it is difficult to find studies that directly specify the kinematics of the ball.

In basketball and WB games, free throws appear less than shots for a field goal (Francis et al., 2021; Gómez et al., 2014). Nevertheless, most of the shooting performance in WB-related papers focused on kinematics during free throws instead of shots for a field goal (Malone et al., 2002). In addition, while the majority of the kinematic analyses in these studies were done by the video camera method, a very limited number of studies used smart sensor basketball (Rupcic et al., 2015a). Finally, the literature review found no previous studies comparing shooting accuracy and ball kinematics of elite basketball and WB athletes, during shots from several angles and distances in Turkey.

There are two primary purposes of this study: 1) to compare the kinematics of the ball according to the outcomes of WB and basketball players' shots, and 2) to compare the shooting accuracy of WB and basketball players. A secondary aim of this research is to compare the ball kinematics according to the outcomes of three different basketball player groups (guard, forward, center) with different playing positions. Finally, in the light of the data obtained in this article, it is targeted to enlighten the basketball and WB coaches and players to increase shooting success.

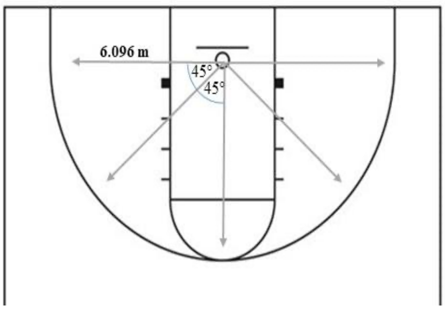
2. Materials and Methods

A total of 23 elite male basketball and WB (respectively 17 and 6) athletes playing in professional leagues (For WB players; who play the highest level league affiliated to the official federation in Turkey and for basketball players; who play the 2nd league affiliated to the official federation in Turkey) voluntarily participated in the research. According to McKay et al., (2022) these participants are considered Tier 4; Elite athletes. Having an injury that may affect the shooting performance or kinematics, and making strenuous physical exercise 24 hours before the test session were determined as exclusion criteria. Then, the height (sitting height for WB athletes) of the participants were measured; and age, sport (basketball or WB), sports experience, and playing position (guard, forward, or center) data were collected (Table 1). Besides these data, functional classification of the WB players (according to the

International Wheelchair Basketball Federation) was recorded. WB players' functional classes were 1.0, 2.5, 3.5, 4.0, 4.5 and 4.5. This study was approved by the Local Ethics Committee of XX University (2019/11-31). This study also confirms the standards set out by the Declaration of Helsinki. All participants were informed about the procedures and have given written consent.

Before the test, a 20 minutes standard warm-up protocol was carried out. During the first 10 minutes of the protocol, participants performed a general warm-up, and during the last 10 minutes of the protocol, participants made shots from the spots that they were going to make shots during the test. Following the warm-up, participants made static shots from six spots. One of the spots was a free throw and the others were set at a distance of 6.096 meters (20 feet) from the vertical projection of the basket's centre on the floor (Figure 1: The shooting spots (except free throw).

Figure 1. The shooting spots (except free throw)



Participants performed static shots from those six spots. During the shots, there was no time limit and participants were instructed to shoot directly through the rim (not to use the backboard). When a participant used the backboard, the shot was repeated. The shots were separated into four groups according to their outcomes. The first group was named as clean shot (CS). A CS was defined as a successful shot without hitting the rim or a shot that passed directly through the rim with hitting the rim once. The second group was named as success shot (S), and it contained all the success shots but CS. The third group contained missed shots that the ball hit the rim, and it was named a missed shot (M). And the last group was named as air ball shot (AB). The AB group contained missed shots without hitting the rim.

The participants were tested in groups of two or three to eliminate the effect of fatigue. The athletes performed at least 10 shots from each spot. If a participant couldn't make a minimum number of three CS during those 10 shots, he was continued to perform new shots from the same spot until he reached a total number of three CS. If the participant still couldn't make at least three CS after the 15th shot, his shooting was stopped and he changed the spot. When a participant changed the spot, the next participant started shooting. While the next participant was shooting, the previous participant was resting until it was his turn to shoot again (minimum 3 minutes of recovery between each spot). With the above-mentioned procedure, it was targeted to prevent shooting performance and shooting mechanics to be affected by fatigue.

The data of a total of 1515 shots were obtained as a result of a total of 23 athletes shooting 10 to 15 shots from each spot. We used sensor embedded ball commercial name is the 94Fifty basketball. This reliable and valid ball has nine individual pressure sensors, a Bluetooth chip, and an eight-hour wirelessly-rechargeable battery. The specific positioning of these sensors provides a 360-degree perspective. Four key aspects of these elements are tracked by the 94Fifty - shooting arc, shot release and speed, shot backspin, and dribbling power and speed. During the shots, the angle of the ball's entry to the rim was recorded by using the android application of the ball (Abdelrasoul et al., 2015; Rupčić et al, 2015b). The obtained data of angles were compared according to the sports of the athletes (basketball, WB), outcome groups of the shots (CS, S, M, AB), and playing positions of the basketball players (guard, forward, center). Besides the entry angle of the ball, shooting (CS+S), S, and CS percentages of the participants were calculated. And these percentages of the basketball players were compared with WB players.

IBM SPSS for Windows (version 22.0; Chicago, IL, USA) program was used for statistical evaluations. The statistical distribution type of the data was evaluated using normality tests (Kolmogorov-Smirnov).

According to these test results, it was observed that the data group did not have a normal distribution. Therefore, the Mann-Whitney U and Kruskal-Wallis test with Bonferroni correction was performed as a post hoc test. The significance level was set at $p < 0.05$.

3. Results

A total of 23 male athletes were included in the research: six WB players and 17 basketball players (5 guards, 8 forwards, and 4 centers). The demographics of the participants are shown in Table 1.

Before starting to analyze the angle comparisons, shooting (CS+S), CS, S, M, and AB percentages of the players compared according to the sports. These analyses showed no significant difference between basketball and WB players according to their CS, S, M, AB, and shooting (CS+S) percentages (respectively U=31, z=-1.401, p=0.161; U=33.5, z=-1.226, p=0.22; U=29, z=-1.541, p=0.123; U=40, z=-1.067, p=0.286; U=24, z=-1.891, p=0.059; Table 2). While the angle data were being analyzed according to the outcomes of the shots, first of all, CS angles were compared with the angles of the remaining shots (S+M+AB). Separate analyses were performed for all participants, basketball players, and WB players. All three analyses indicated that CS angles were significantly higher than the angles of the remaining shots (respectively U=216094.5, z=-7.067, p<0.001; U=115514, z=-6.178, p<0.001; U=14917, z=-3.856, p<0.001; Table 3). Afterward, S angles were compared with angles of unsuccessful shots (M+AB) by the same above-mentioned procedure. And the analyses showed no significant difference between S angles and angles of unsuccessful shots (respectively U=64340, z=-0.075, p=0.94; U=33679.5, z=-0.423, p=0.672; U=4475.5, z=-0.144, p=886; Table 4).

Considering the results of the previously performed analyses, CS angles were compared in the remaining analyses. A comparison of CS angles according to the sports of the participants (basketball, WB) showed that CS angles of WB players were significantly higher than CS angles of basketball players (U=27534, z=-3.077, p=0.002; Table 3). When CS angles of the basketball players were compared according to their playing positions (guard, forward, center), the analyses indicated that CS angles of the guards were significantly higher than forwards and centers (x2(2)=22.607, p<0.001; U(N_{guard}=139, $N_{forward}$=201)=9761, z=-4.739, p<0.001; U(N_{guard}=139, N_{center}=117)=6652, z=-2.517, p=0.038; U(N_{center}=117, $N_{forward}$=201)=10312, z=-1.835, p=0.207; Table 5).

Table 1. Demographic data of the participants

		Minimum	Maximum	Mean	SD
All participants (n = 23)	Age (year)	16	43	23.35	6.520
	Sports experience (year)	2	23	10.74	4.634
Basketball players (n = 17)	Height (cm)	180.5	209.0	192.406	8.1076
	Age (year)	18	33	22.53	5.001
	Sports experience (year)	6	20	10.47	3.727
WB players (n = 6)	Sitting height (cm)	118.0	164.5	142.917	19.6276
	Age (year)	16	43	25.6	9.913
	Sports experience (year)	2	23	11.50	7.007

Table 2. Comparison of the CS, S, M, AB, and shooting (CS+S) percentages according to the sports

	Sport	Mean (%)	SD	Sig. (Mann-Whitney U)
CS	**Basketball players (n = 17)**	42.006	9.7648	0.161
	WB players (n = 6)	36.000	9.3597	
Shooting (CS+S)	**Basketball players (n = 17)**	54.171	9.9441	0.059
	WB players (n = 6)	45.817	9.7559	
S	**Basketball players (n = 17)**	12.165	3.6985	0.22

	WB players (n = 6)	9.800	3.4537	
M	**Basketball players (n = 17)**	45.5824	9.7273	0.123
	WB players (n = 6)	51.300	4.7950	
AB	**Basketball players (n = 17)**	0.2588	0.58101	0.286
	WB players (n = 6)	2.8833	5.27955	

CS: Clean Shot; S: Success; M: Missed, AB: Air Ball, SD: Standard deviation; Sig: Significance; WB: Wheelchair basketball; SD: Standard deviation

Table 3. Comparison of the CS angles and the angles of the remaining shots

Shots	Shot Outcomes	Mean (°)	SD	Sig. (Mann-Whitney U)
All participants (n = 1515)	CS (n = 602)	44.6146	3.93385	< 0.001*
	Remaining (n = 913)	43.1424	4.09207	
Basketball players (n = 1103)	CS (n = 457)	44.2823	3.84531	< 0.001*
	Remaining (n = 646)	42.8328	3.78122	
WB players (n = 412)	CS (n = 145)	45.6621	4.03839	< 0.001*
	Remaining (n = 267)	43.8914	4.68474	
Comparison of the CS angles of basketball players and WB players				
Sport		**Mean (°)**	**SD**	**Sig. (Mann-Whitney U)**
CS of Basketball players (n = 457)		44.2823	3.84531	0.002**
CS of WB players (n = 145)		45.6621	4.03839	

**: CS angles were significantly higher than the angles of the remaining shots; **: CS angles of the WB players were significantly higher than the CS angles of the basketball players; CS: Clean Shot; SD: Standard deviation; Sig: Significance; WB: Wheelchair basketball.*

Table 4. Comparison of the S angles and the angles of the unsuccessful shots

Shots	Shot Outcomes	Mean (°)	SD	Sig. (Mann-Whitney U)
All participants (n = 913)	S (n = 175)	43.2971	3.92058	0.940
	Unsuccessful (n = 738)	43.1057	4.13342	
Basketball players (n = 646)	S (n = 135)	43.0889	3.75453	0.672
	Unsuccessful (n = 511)	42.7652	3.78900	
WB players (n = 267)	S (n = 40)	44.0000	4.41443	0.886
	Unsuccessful (n = 227)	43.8722	4.73982	

S: Success; SD: Standard deviation; Sig: Significance; WB: Wheelchair basketball

Table 5. Comparison of the CS angles of basketball players according to their playing positions

CS of Basketball Players (n = 457)	Mean (°)	SD	Sig. (Kruskal-Wallis)
CS of guards (n = 139)	45.4676	2.96184	< 0.001*
CS of forwards (n = 201)	43.3831	4.05679	
CS of centers (n = 117)	44.4188	4.02629	
Playing Positions	**Forwards - Centers**	**Forwards - Guards**	**Centers - Guards**
Adj. Sig. (Bonferroni Correction Mann-Whitney U)	0.207	<0.001*	0.038*

**: Significant difference between playing positions; CS: Clean Shot; SD: Standard deviation; Sig: Significance; Adj. Sig.: Adjusted significance*

4. Discussion

In the current study, ball kinematics during shots of elite basketball and WB athletes, from various angles and distances, were investigated. The findings showed that shooting success was directly related to the entry angle of the ball, and the CS angles of WB players and guards were higher.

The main finding of this study was that during CS the entry angle of the ball was higher than the rest of the shots in both basketball and WB. In a high-trajectory shot where the ball has a higher angle of entry, the ball is more likely to enter the rim (Mačura, 2013). Similarly, Rupčić et al. (2015) showed that during successful shots the entry angle of the ball is higher in basketball. It is also known that while basketball players are shooting, the release angle of the ball is positively correlated with the entry angle of the ball (Khlifa et al., 2013; Okazaki & Rodacki, 2012). Furthermore, Khlifa et al. (2013) specified that a higher release angle of the ball leads to a higher free throw percentage in basketball. Even though the results of the above-mentioned studies are similar to the results of the current study conducted for basketball players, in the literature review no previous studies were found comparing ball kinematics of successful and unsuccessful shots in WB players. Hence, it is recommended to plan similar studies for WB.

Malone et al. (2002) calculated (via video recordings) entry angles of the ball during 67 successful free throws in the 6th Men's Gold Cup World WB Championship, and they determined the optimum entry angle as between 40-44°. Rupčić et al. (2015a) examined entry angles during 9 successful and 6 unsuccessful 2 point shots, and 5 successful free throws of a Croatian U16 National Basketball Team member by using 94fifty Smart Sensor Basketball. The results of this study showed that the mean entry angle of the ball was 48°, 44.5°, and 41.6° during successful free throws, successful 2 point shots, and unsuccessful 2 point shots, respectively. In these studies (Malone et al., 2002; Rupčić et al., 2015a) the shots were not categorized in the same method as in our research; for instance, CS and S were not categorized in different groups. Nevertheless, it can be said that the findings of the present study and the above-mentioned studies indicate coherent results. In the current research, there was no significant difference between the angles of S and unsuccessful shots (M+AB) for both basketball and WB. In light of these findings, it can be said that the entry angle of the ball affects only CS during a shot, not S. Moreover, the CS percentage of the successful shots (CS+S) was calculated for basketball and WB and were found 77%, and 78%, respectively. Because of these two above-mentioned findings, it may be thought that (I) most of the successful shots are CS, and (II) the entry angles of the ball during unsuccessful shots (M+AB) are lower than the angles during CS, but not lower during S. Hence, it may be more beneficial to practice on increase only CS percentage by ignoring S during basketball and WB training. To increase the CS percentage, it is suggested to coaches and athletes focus on increasing the entry angle of the ball during the training. During the literature search, no study was found separating the successful shots into CS and S categories and comparing them. Therefore similar studies are recommended in the future.

The current study also showed that the entry angles of the ball during CS were higher in WB players than in basketball players. One of the reasons for this difference may be the lower release heights of the WB players compared to basketball players. Shooting from the same distance with a lower release height requires a higher release angle, hence the ball kinematics changes (Malone et al., 2002; Schwark et al., 2004). These kinematical changes may cause changes in the entry angle of the ball (Khlifa et al., 2013; Okazaki & Rodacki, 2012). One of the limitations of this research was that the device used in the study was capable of determining only the entry angle of the ball, not other kinematical parameters such as release angle. Planning similar research to compare more kinematical parameters is suggested. Another reason for the above-mentioned difference can be the more active upper extremity (since the passivity of lower limbs, biomechanical characteristics, and body limitations), hence more improved upper limb motor skills of the WB players (Soylu et al., 2020; Zacharakis, 2020). These advanced motor skills may have differentiated the shooting techniques of WB players from basketball players.

During a shot, lowering the release height results in an altered release velocity (Hamilton & Reinschmidt, 1997; Schwark et al., 2004) and increased propulsive forces (Mačura, 2013). Thus it may be predicted that during a shot the release velocity of WB players is higher than basketball players. It may be thought that while shooting from the same distance, having a higher release velocity may lead the entry angle to increase. Furthermore, Okazaki et al. (2007) showed no linear relationship between release velocity and accuracy in basketball. Since the release velocity of the WB players was predicted as higher than the basketball players, and there was no significant difference between the WB and basketball players' shooting percentages; the finding of the above-mentioned research supports the prediction of the current study (Okazaki et al., 2007). Other limitations of the current research were that the kinematics of the shooting techniques, the release velocity, the propulsive forces, and the ratio of the active muscles during the shooting weren't examined.

Another finding of the present research was that during CS, the entry angle of the ball varied according to the basketball players' playing positions (guards' was higher). In the current study, the height of the guards was lower than the forwards and centers as similarly as previously reported by Sindik and Jukić (2011). In the above-mentioned research, the release height was also determined and it was noted that the release height of the guards was lower than the forwards and the centers. In light of these previous findings, it may be predicted that the release height of the guards (the shortest group) was the lowest in our research. Hence, same as the thought discussed before for WB players, it may be thought that the guards' lower release height causes a higher entry angle during CS. In addition, Sindik and Jukic (2011) reported that the guards are more successful shooters than forwards and centers. And in another approach, this success difference of guards might be related to the above-mentioned kinematics of the ball.

Rupčić et al. (2015a) noted that in basketball shooting practices biomechanical development also needs to be intended and also the entry angle of the ball must be focused on. Beyond that, the lower entry angle than the optimum is related to insufficient shooting techniques (Rupčić et al., 2015a). Besides, Lenik and Lenik (2016) reported that shooting accuracy is related to the entry angle of the ball but not related to the shooting technique. Likewise, the findings of the current research add support to previous studies, and it can be said that the entry angle of the ball has critical importance for a successful shot in basketball.

One of the limitations of the current study was that the 94fifty Smart Sensor Basketball could determine only the entry angle of the ball. Thus other kinematical variables such as release angle, release height, release velocity, shooting techniques, etc weren't investigated. Another limitation of the present study, the CS angles of the WB players were not compared according to their playing positions. The underlying reason is that the number of WB players was not enough (due to COVID-19 pandemics and the WB players' intense training and game schedule) to perform such an analysis. Hence future studies with appropriate numbers of WB players and with the examination of more kinematical parameters are recommended.

5. Practical Applications

In conclusion, it is determined that during CS the entry angle of the ball was higher than other shots (S+M+AB) in both basketball and WB. It is suggested to focus on increasing CS accuracy rather than S in both basketball and WB. And to improve CS, it is recommended to increase the entry angle of the ball to the optimum angle. According to the present study, the optimum entry angle of the ball for a perfect shot is determined 44.3° and 45.7° for basketball and WB, respectively. To reach this angle, using smart sensor basketball-like devices is recommended for the basketball coaches and players. Lastly, planning future studies that compare the biomechanics of two sports during shooting, and compare the biomechanics of CS with other shots are recommended.

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