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A Biomechanical Analysis of the Free Throw Shooting Technique in Wheelchair Basketball: A Pilot Study

Nikola Prvulovic[1], Miljan Hadzovic[1], Ana Lilic[1]

[1]University of Nis, Faculty of Sports and Physical Education, Nis, Serbia

Abstract

The aim of this pilot study is to determine the kinematic elements of the free throw shooting technique among wheelchair basketball players from various classes. Three wheelchair basketball players from the wheelchair basketball club "Nais" took part in the study. The players were classified from IWBF classification 1, 3 and 4.5. All of the participants were right-handed. Free throw shooting recording were made with a fixed camera with a 1920 x 1080p resolution, 30 frames per s, positioned at a height of 1.20 m on the right side of the players facing the basket, at a distance of 7.5 m and 25 cm behind the free throw line. The "Kinovea" video program was used to process the results and the kinematic data for the free throw shooting technique of wheelchair basketball players. The kinematic parameters indicate differences in the performance of the free throw shooting technique among wheelchair basketball players from class 1, 3 and 4.5. A difference in successful throws between the participants from class 1, 3 and 4.5: the angle of ball release 50°, 52° and 47°, velocity of ball release 7.58 m/s, 6.25 m/s and 7.27 m/s, and height of ball release 164.49 cm, 180.71 cm and 190.86 cm, while the temporal parameters and angles of the elbow had the same values. We can conclude that for the successful performance of the free throw shooting technique a basketball player needs to achieve greater height of ball release in the final position.

Keywords: *Wheelchair Basketball, Free Throw Technique, Biomechanical Analysis*

Introduction

Wheelchair basketball is the most popular sport among individuals with disability. In addition, this sport allows athletes with different degrees of injury or disability to compete together (Brasile & Hedrick, 1996; Goosey-Tolfrey, Butterworth, & Morriss, 2002). Players are classified based on degree of disability (www.iwbf.org) (class 1.0, 2.0, 3.0, 4.0 and 4.5) while there are four more subclasses for borderline cases (classes 1.5, 2.5 and 3.5) (Paulson & Goosey-Tolfrey, 2017). Basketball players from class 1 have the highest level of disability and the lowest seated position balance, while players from class 4.5 have minimal disability (Malone, Gervais, Baudin, & Steadward, 1995; Malone, Gervais, & Steadward, 2002). The classes are defined based on the movements of the torso and seated position balance (International Wheelchair Basketball Federation, 2019). The total number of players together on the court cannot exceed 14 during a game (Malone, Nielsen, & Steadward, 2000).

For wheelchair basketball players, as in the case of a standup basketball players, throwing precision is one of the most important factors of success. The throw which is considered the easiest and which gives an individual the opportunity to unimpededly perform the shooting technique is the free throw (Brancazio, 1981; Malone et al., 2000). World championships were won in critical times of tied scores by successful free throws. Up to 70% of free throws were noted in the NBA league of the US, while the average for wheelchair basketball players ranges between 45-55% (Malone, Gervais, & Steadward, 1999; Malone et al., 2000). Of the overall percentage of points scored during a game 20 to 30%

Correspondence:

N. Prvulovic
University of Nis, Faculty of Sports and Physical Education, Carnojevica 10a, 18000 Nis, Serbia
E-mail: nikolaprvulovic87@gmail.com

originate from the free throw (Malone et al., 2000). As a result, knowing the kinematic parameters of the proper shooting technique for individuals with various levels of disability can help to improve the success rate of the basketball team (Malone et al., 1999; Malone et al., 2000).

In wheelchair basketball, when it comes to the height of ball release, even during a free throw the initial height is much lower than that of stand up basketball (Thiboutot, 1999). If the elbow is not fully extended when performing the shooting technique, then it is more difficult for the wheelchair player to achieve the necessary force for the ball to reach the rim of the basket and achieve the ideal shot trajectory (Thiboutot, 1999). Success in wheelchair basketball depends to a great extent on numerous factors, including the mechanics of the players, their morphology, the position of the wheelchair, arm strength and stability of the torso, all of which can lead to player mistakes when performing a successful throw (Malone et al., 2000). Players from class 1, according to the international wheelchair basketball classification, have the least favorable seated position in their wheelchair. In addition, players in this class have a lower initial height of ball release during the throw. They also have different kinematic parameters compared to other wheelchair basketball players from other classes. There are also inter-class kinematic parameter differences among the remaining classes. Depending on their level of disability, players are impeded from prolonged musculature activation when performing the shooting technique to a greater and lesser extent, which in turn affects the precision of the throw (Malone et al., 1995; Malone et al., 1999).

The aim of this pilot study is to determine the kinematic elements of the free throw shooting technique among wheelchair basketball players from various classes. Because practicing the correct technique of a free throw shot can lead to an improvement in the players' contribution and thus affect the final result of the match.

Methods

The sample of participants

For the purpose of the pilot study, three male wheelchair players from the wheelchair basketball club "Nais" were recorded. The first participant was from class 1.0 (39 years); second player was from class 3.0 (34 years); and third player was from class 4.5 (38 years). The first participant was from class 1, the second from class 3, and the third from class 4.5. All of the participants were right-handed. The survey was conducted following the principles of the Declaration of Helsinki.

The research

The pilot study was carried out in the sports hall of the Cair sports facilities in Nis, Serbia, on December 20, 2019 from 10:00h to 11:00h. It was overseen by experienced researchers who set and checked the equipment needed to perform the experiment. The fixed camera "Sony", enabled a video recording of 30 frames per s, with a resolution of 1920x1080. It was positioned at the center of the extended foul line at a distance of 7.5 m from the center of the free throw line, and 25 cm behind the free throw line. The players took part in a standard training session, following a predetermined plan and program designed by the coach at the wheelchair basketball club "Nais", where they performed free throws after the session. Each participant performed one successful and one unsuccessful free throw. We used reflected markers in center of joints: center of the right wrist joint; right elbow (between lateral epicondyle of humerus and head of radius); right shoulder (greater tubercle of the humerus); right hip (greater trochanter of the femur); center of the ball, of right arm (shooting arm) from frontal axis (Malone et al., 2002).

Data analyses

The video recording of the experiment was analyzed using the "Kinovea" program for video analysis.

The kinematic parameters were assessed from three positions: the first was when player was in starting position before initial start of movement of arms that hold the ball: the second position was when player was achieved maximal elbow height through movement of free throw shoot, and the third position-final position was right before ball releasing moment (last contact with tips of fingers which add movement to the ball and rotation), and additional analysis was made from third position for assessment of ball trajectory of independent movement to the rim and maximal height of ball flight from the ground. The kinematic parameters were determined: the angle between the forearm and upper arm (the elbow joint) in three positions (the first, second and the third position), along with the time needed to perform the shooting technique and the ball flight to the rim of the basket with points of intersection in two positions of the body (the second and the third), the angle of ball release (the ball trajectory in relation to the horizontal line), angular velocity of the elbow joint and wrist in two positions (the second and the third), and the height of the ball in relation to the surface in all three positions, both in the case of successful and unsuccessful shots made by the participants.

Even if there is not data about optimal range of kinematic parameters of successful and unsuccessful shots of wheelchair basketball players for each class, there is a few data from study Malone et al. (1999), that we used like reference points in our research.

Results

The pilot study results are shown in table 1 based on the class of disability of the participants and the kinematic parameters of the successful and unsuccessful shot. The parameters are shown in three positions: The initial position, the moment of rest (of the angle between) the elbow and arm being used to perform the free throw in the direction of the basket; The release position, the moment when the angle between the forearm and upper arm in the elbow is smallest, prior to the push of the ball towards the basket and any additional increase in the velocity of ball release; The final position, the angle the elbow assumes when the ball is no longer touching the fingertips of the hand and proceeds to move on its own towards the basket.

The participant from class 1 had almost equal parameters of the duration of the performance of the free throw shooting technique for the unsuccessful and successful throw, the angle of the elbow at the initial, 78° or 80°, and final position, 150° and 151°, as well as height of the ball in the initial and final position. The results indicate that in the case of a successful throw, the angular velocity of the wrist and the elbow is smaller in all three positions, with an angle of ball release of 50°, compared to 45°, as well as flight time of the ball to the rim of the basket. In the release position the height of ball release is low, and the elbow joint is smaller, 65° compared to 89°.

For the participant from class 3, almost completely equal parameters of time needed to perform the free throw shooting technique were recorded for the unsuccessful and successful throw, angle of ball release, 50°, and ball flight, and approximately similar values for the angle of the elbow at the initial, 100° and 95°, and the release position, 53° and 51°, as well as height of the ball at the initial and final position. For the successful throw, the parameters of angular velocity of the wrist and elbow joint are smaller in the release position and drastically so in the final position, 8.23 m/s compared to 6.25 m/s. The height of the ball in the release position is lower by more than 5 cm.

For the participant from class 4.5, a different pattern of move-

ment when performing the free throw technique was noted. Both in the case of the successful and unsuccessful throw the angular velocity of the wrist and the elbow increased and decreased in the release position, only to continue to increase until the final position. Identical parameter values were noted for the angle of ball release (45° and 47°), the angle of the elbow during the release and final position, the angular velocity of the wrist in all three positions, and the duration of the performance of the shooting technique and ball flight. For the successful shot, the angle of the elbow joint in the initial position is greater than 92°, compared to 82°, while the angular velocity of the elbow is drastically lower, 2.60 m/s compared to 3.71 m/s. The initial height of ball release is much greater, 99.15 cm compared to 90.70 cm. For the successful shot, the height of the ball in the release and final position is lower by 5 cm (147.88 cm compared to 152.96 cm and 190.86 cm compared to 194.92 cm).

Table 1. Kinematic results of successful and unsuccessful free throw shots of wheelchair basketball players

Category	Ag1	Ag2	Ag3	Ar	Av	Avw2	Avwe3	H1	H2	H3	T2	T3	TT
Unsuccessful 1	78°	89°	150°	45°	3.70m/s	3.05m/s	8.08m/s	76.48cm	123.52cm	164.48cm	633ms	700ms	1566ms
Successful 1	80°	65°	151°	50°	3.59m/s	2.33m/s	7.58m/s	76.49cm	114.40cm	164.49cm	600ms	700ms	1733ms
Unsuccessful 3	100°	53°	150°	50°	5.01m/s	2.76m/s	8.23m/s	75.85cm	127.21cm	178.58cm	233ms	366ms	1400ms
Successful 3	95°	51°	128°	52°	5.01m/s	2.36m/s	6.25m/s	77.89cm	122.11cm	180.71cm	233ms	366ms	1400ms
Unsuccessful 4.5	82°	66°	149°	45°	3.71m/s	0.23m/s	7.26m/s	90.70cm	152.96cm	194.92cm	566ms	733ms	1600ms
Successful 4.5	92°	63°	151°	47°	2.60m/s	0.23m/s	7.27m/s	99.15cm	147.88cm	190.86cm	533ms	700ms	1633ms

Note: Ag1 – the angle of the elbow in the initial position; Ag2 – the angle of the elbow in the release position; Ag3 – the angle of the elbow in the final position; Ar – the angle of ball release; Av – the angular velocity of the elbow; Avw2 – the angular velocity of the wrist from the initial position to the release point; Avwe3 – the angular velocity of the wrist from the release position of the elbow to the moment the ball takes on independent flight; H1 – the height of the bottom curve of the ball in the initial position; H2 – the height of the bottom curve of the ball from the surface in the release position of the elbow; H3 – the height of the lower curve of the ball from the surface in the final position of the elbow; T2 – the duration of the hand movement from the initial position to the release position of the elbow; T3 – the duration of the hand movement from the release position until the final position of the elbow; TT – the time needed to perform the shooting technique with independent ball flight to the rim of the basket.

Discussion

There are very few studies which focus on the kinematic parameters of the free throw in wheelchair basketball (Goosey-Tolfrey et al., 2002; Malone et al., 1995; Malone et al., 1999; Malone et al., 2002; Schwark, Mackenzie, & Sprigings, 2004). The findings of Malone et al. (1999) and Malone et al. (2002) point to the differences in kinematic parameters and also in the performance of the free throw shooting technique among wheelchair basketball players of various classes. In addition, statistically significant differences for successful and unsuccessful throws emerge between different classes of wheelchair basketball players, a finding which is supported by the research results of this pilot study. Players from class 1 have lower elbow joint velocity, lower height of ball release and initial height of holding the ball, as well as a greater angle of ball release, which is supported by the findings of this study. It is more difficult for a player from class 1 to properly perform a movement in the set kinematic framework, as he needs to generate greater force from a smaller number of muscles and achieve better movement control compared to basketball players from upper classes. Malone et al. (2002) cite that greater arm force is needed to compensate for the lack of movement of the torso, which basketball players from upper classes can achieve. Participants from upper classes have displayed negligible differences in kinematic parameters compared to basketball players from class 1 and 2, which indicates that they do not use the advantage that they have in relation to players from class 1 in terms of the greater initial and final height of ball release, as well as greater angles, which have emerged as key kinematic parameters for successful throws (Malone et al., 2002). Similar findings were noted in this pilot study as well. The participant from class 4.5 has a greater initial and final height of ball release, as well as a different pattern for performing the shooting technique compared to the other participants. A different use of the musculature compared to the participants from class 1 and 3 was noted. The latter, as a result of their disability, have to adapt their shooting technique and the kinematic parameters to their current circumstances, while the participant from class 4.5 can perform the shooting technique within a framework which increases the percentage of precision.

Malone et al. (1995) state that athletes from class 1 have a shooting performance technique which is solely based on an individual model, while taking into consideration the small number of seven participants based on which this conclusion was drawn. The kinematic parameters of the height of the ball in the final position during the throw are 156 cm, 166 cm and 188 cm, while those recorded by Malone et al. (1999) were 162 cm, 179 cm and 184 cm for the participants from class 1, 3 and 4, while in the study of Goosey-Tolfrey et al. (2002) the participant from class 1 had a value of 1.57 cm (compared to the results of the pilot study, 164.49 cm, 180.71 cm) and a somewhat greater height of 194.92 cm for the participant from class 4.5. The minimum angle of ball release of 45° was presented as the ideal in the work of Owen (1982), while Malone et al. (1995) determined that the ideal angle is slightly over 50°, which is supported by the findings of this pilot study. Malone et al. (1999) determined that the angles of ball release among wheelchair basketball players from class 1, 3 up to 4 are 59°, 55° and 55°, while in Malone et al. (1995) the values are 50° and 59° for wheelchair basketball players from class 1, while for the remaining participants they were 54° and 64°. These findings indicate greater values compared to the results determined in the pilot study: 50°, 52° and 47°. Malone et al. (2002) noted an angle of ball release of 55° among wheelchair basketball players from class 4 and 4.5 based on 26 analyzed throws. Interestingly enough, Goosey-Tolfrey et al. (2002) did not determine any statistically significant results in the difference for velocity of ball release among players from various classes, which was not the case in this study. It is worth mentioning that seated height among wheelchair basketball players from class 1 is lower compared to that of other wheelchair basketball players upper classes, which is one of the reasons for the lower recorded values. It is also interesting to note that the results of the comparison between wheelchair basketball and stand up basketball players indicate that the height of ball release is on average lower by 40 cm and the velocity of ball release by 0.39 m/s (Schwark et al., 2004). Goosey-Tolfrey et al. (2002) measured the angular velocity of the wrist during ball release for players from class 1, 3 and 4, which ranged from 7.0 m/s to 8.2 m/s, while in the work of Malone et al. (1999) the values ranged

from 6.99 m/s to 7.40 m/s, compared to the results measured in the pilot study which were 6.25 m/s to 8.28 m/s, which falls under the category of generally similar values.

Malone et al. (2002), who studied unsuccessful throws, have noted that most of the mistakes made by players from lower classes include striking the ball against the near rim of the basket, and that at the same time the correction of the throw is reflected in the increase of the angular speed with an increase in the angle of ball release. The other kinematic parameters remain the same, as does the pattern of movement. We can also note an increase in the height of ball release among successful throws. The kinematic parameters for angular velocity of the wrist and the angle of ball release are 7.4 m/s and 53.8°, but if we take Brancazio's criterion of least speed into consideration, they have a value of 7.08 m/s and 51.3° (Schwark et al., 2004). Hamilton & Reinschmidt (1997), taking into consideration the spin of the ball, calculated the kinematic value of the angle of ball release to be 60°, and angular velocity to be 7.7 m/s.

Conclusion

Based on the kinematic data results of the pilot study, we can conclude that wheelchair basketball players from various classes differ when it comes to performing a successful free throw, but that they also have some kinematic parameters in common. The parameters which are within the value range of existing findings originating from biomechanical studies, and have the greatest impact on performing a successful free throw, include: the angular velocity of the throw, the height of ball release during the initial and final position, as well as the angle of ball release. It can be concluded that there are differences in the pattern of performing the free throw shooting technique between players from different classes when it comes to successful and unsuccessful throws. In order for the conclusions to be generally applicable, it is necessary to include a greater number of participants for each class of players, as well as a greater number of successful and unsuccessful throws.

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Conflict of Interest

The authors declare that there is no conflicts of interest.

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