Department of Veterans Affairs

Journal of Rehabilitation Research and Development
Vol. 39, No. 6, November/December 2002
Pages 701–710

Shooting mechanics related to player classification and free throw success in wheelchair basketball

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Abstract—To determine what factors are associated with successful free throw (FT) shooting in wheelchair basketball and to examine the relationship between shooting mechanics and player classification, a biomechanical analysis of clean shots was undertaken. Significant differences were observed between the player classes in FT shooting mechanics employed for a clean shot. Players from Classes 1 and 2 tended to release the ball from a lower height, with greater velocity and release angle. They demonstrated a smaller shoulder flexion angle at release and a greater maximum velocity at the shoulder and elbow. The clean shots of Classes 1 and 2 demanded greater accuracy with respect to release velocity and angle, yet the resulting ball trajectory displayed a greater margin for error than the shots observed in the upper classes. However, based on overall shooting percentage, the upper classes did not appear to take advantage of the predicted benefits provided by a higher ball release height.

Key words: *biomechanics, classification, foul shot, sports performance.*

INTRODUCTION

Wheelchair basketball is an exciting, highly competitive sport. To gain the competitive edge required for success in basketball, one needs to fully understand and develop the fundamental skills involved (e.g., shooting, passing, dribbling). Of the basic skills, shooting can be considered as the most important for determining the score and outcome of a game. The free throw (FT), in particular, is especially important because it provides an opportunity for a team to score free or uncontested points and is often the deciding factor in a close game or even of a championship title.

Although a relatively constant success rate of 69 percent in FT shooting has been observed in men's college basketball in the United States since the 1970s, Krause and Hayes believe that FT shooting percentages can be improved with increased practice and development of proper technique [1]. In comparison, Owen indicates a success rate of only 45 to 55 percent from the FT line in wheelchair basketball [2]. Data collected during the 1994 Gold Cup Tournament confirmed these low shooting percentages, with team FT percentages ranging between 36 to 59 percent and the average individual player success percentage at only 47 percent [3]. Can these shooting percentages in wheelchair basketball be improved? Although shooting a basketball from a seated position has obvious disadvantages compared to standing up, most likely the difference in success rates cannot be attributed solely to differences in the required shooting mechanics [2]. Individual

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This material was based on work supported by the Alberta Paraplegic Foundation; the Alberta Recreation, Parks and Wildlife Foundation; and the Steadward Centre.

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players in wheelchair basketball have demonstrated consistent shooting averages beyond 70 percent [2]; so what is it that they do to achieve such success?

As described by Elliott [4], an understanding and application of movement mechanics are necessary if an athlete's potential is to be fully developed. Several authors have suggested that a player's shooting success can be enhanced with proper training using a scientific approach [5–7]. Burns and Hudson highlight the importance of developing good shooting technique [5,8], and as noted by Ingram and Snowden [9, p. 79], "the free-throw line is an excellent place to analyze a player's shooting mechanics." Furthermore, the free throw is an unopposed shot and can be easily replicated in practice for developing proper technique. As pointed out by Elliott [4], only when "good technique" is used in training practices and game matches can a player reach his or her full potential. According to Owen [2], one reason why wheelchair basketball FT percentages are so low is that most players never learned the proper technique. Consequently, the identification of key components related to success in FT shooting is necessary for proper training and technique development in wheelchair basketball players.

Although several characteristics of FT shooting performance by stand-up basketball players have been discussed in the literature, wheelchair basketball has received little attention. According to Skillen [10], the fundamental skills of shooting, passing, and dribbling are the same in both stand-up and wheelchair basketball. One must note however that skill, although a result of practice, is influenced by the physical attributes and ability of a player [11]. With wheelchair basketball players being positioned lower and the generation of propulsive forces coming mainly from the arms and upper body, it seems reasonable to expect that some degree of skill modification would be necessary.

To ensure fair and equitable competition and to include players at all levels of physical potential, the International Wheelchair Basketball Federation (IWBF) Functional Player Classification System was implemented in 1984. The player classification system uses level of trunk movement and stability as the fundamental elements in the definition of each class.

The current player classification system (www.iwbf.org) consists of four classes (Classes 1, 2, 3, and 4), with half-point classes (Classes 1.5, 2.5, 3.5, and 4.5) designated for borderline cases. Level of functional ability increases with each level of classification, with those in Class 4.5 having minimal disability. A player in Class 1 will have significant loss of stability in the trunk as the shooting arm is extended over the head during follow-through, often requiring arm support following the shot. A Class 4 player on the other hand will have the ability to move the trunk forcefully in the direction of the follow-through after shooting.

To date, little if any quantitative research has been completed on the mechanics of wheelchair basketball. Instead, the available literature tends to be qualitative in nature, based on coaches' opinions and subjective analyses. If the shooting potential of wheelchair basketball players is to be developed, an understanding of the mechanics of the movement is essential. In addition, a further distinction must be made—one that identifies the differences in mechanics of movement demonstrated by each of the player classification groups.

To determine what factors are associated with successful FT shooting in wheelchair basketball, an analysis of clean shots taken at the 6th Men's Gold Cup World Wheelchair Basketball Championship was undertaken. A clean shot was defined as a successful shot that passed through the hoop without hitting the rim or backboard [12]. Player classification and shooting mechanics were compared, with the objective of addressing the following question: Is there a difference between the four player classes in the shooting mechanics (ball parameters, joint kinematics) in successful FT shooting?

Based on the above question, the purpose of this investigation was (1) to identify the differences in ball release parameters (height, angle, and velocity of ball release) between the classes and (2) to determine the shooting technique used to achieve the release parameters required for successful shooting within each class, focusing on angular displacements and velocities of the major joints involved (shoulder, elbow, wrist).

METHODS

Data Collection and Reduction

Data collection took place at the 6th Men's Gold Cup World Wheelchair Basketball Championship. Free throws taken at one predetermined end of the court during the tournament were recorded with the use of methods for three-dimensional (3D) video data collection.

A calibration space of 150 cm × 225 cm × 300 cm was measured. During recording, the field of view included the complete movement of the player during a free throw and the path of the ball for approximately 15 frames after release. Sixteen control points surrounding the activity space were used during the calibration procedure. Two Panasonic SVHS (Super Video Home System) Reporter AG-450 video cameras, operating at 60 Hz and placed at different angles to the FT line, were positioned securely at one end of the court to record the free throws of right-handed shooters. One camera was set parallel to the FT line to obtain a side view of the player. The second camera, oriented obliquely to the front line, was set to obtain a more frontal view of the player. The entry of the ball into the basket was not recorded on video, but the success of each was recorded manually. For the synchronization of the cameras, a manually triggered light-emitting diode (LED) was visible to each camera during filming.

For the process of data reduction, the Ariel Performance Analysis System (APAS) was used (Ariel Dynamics, Inc.). On each video frame, the following points were manually digitized:

- Metacarpophalangeal joint of the right middle finger.
- 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.

Connections were made between specific points to create the segments (1) knuckle-wrist equals hand, (2) wrist-elbow equals forearm, (3) elbow-shoulder equals arm, and (4) shoulder-hip equals trunk. The 2D digitized views from each camera were then converted into a 3D image sequence with the use of the direct linear transformation (DLT) algorithm implemented on the APAS system [13]. To minimize potential errors related to precision, one individual, knowledgeable in both anatomy and skill analysis, completed all digitizing. To monitor digitizing precision and to provide an a priori smoothing factor, the technician redigitized randomly selected video frames. Before further analysis, the 3D coordinate data were smoothed with the use of a Quintic spline algorithm, with a smoothing factor of 0.5 cm to 1.0 cm based on these measures of precision.

The center of the ball was found with the use of a manual digitizing procedure similar to that proposed by Hudson for tracking a round object, such as a basketball [14]. Hudson suggested using points on the periphery of the ball. For this study, a template consisting of graduated perpendicular lines was used to locate the ball's center point for each view as illustrated in **Figure 1**.

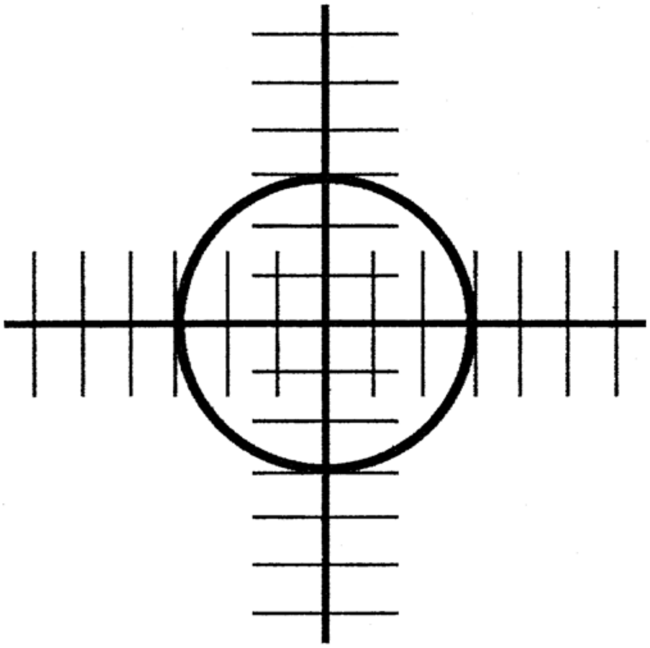

Figure 1.
Template used to find point representing center of basketball on video records. The operator adjusted template's horizontal and vertical position until ball was aligned on crosshairs as illustrated.

At the same time that free throws were being recorded on video, the same shots were visually observed from a point parallel to the FT line, and schematic diagrams depicting ball movement patterns at the basket were recorded (**Figure 2**). The same investigator conducted all observations. Views from an overhead camera were available for two games and confirmed that 35 of the 37 (95 percent) schematic diagrams were found to reflect accurately and completely the information that the video recordings provided.

On each diagram, the ball pattern at the basket was tracked in a numerical sequence and later encoded for descriptive purposes. According to the pattern of ball movement at the basket, free throws were then grouped into five categories or types of shots, namely, (1) clean shot, (2) long success, (3) short success, (4) long miss, and (5) short miss. An extensive analysis of these recordings was conducted elsewhere and is reported by Malone, et al. [3].

Data Analysis

Clean shots with acceptable video data (i.e., both camera views clear) were then compiled for kinematic analysis. Because of unavoidable limitations associated with

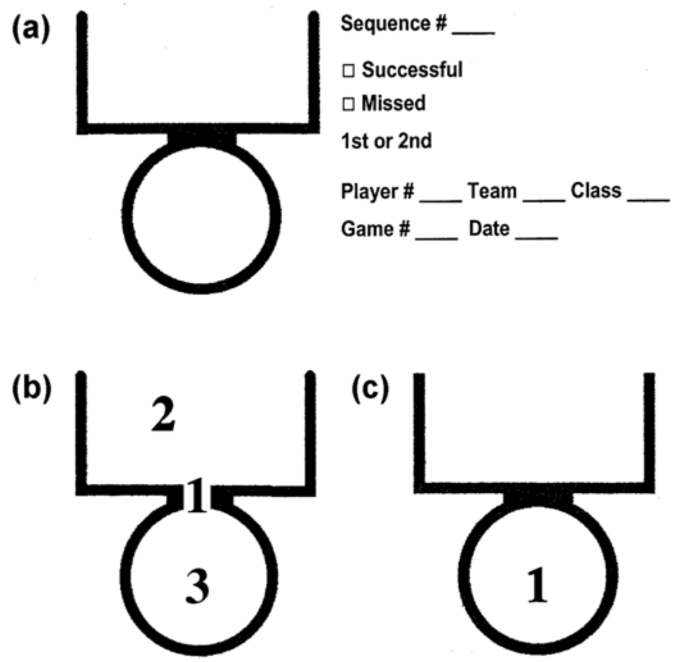

Figure 2.
Schematics for manual recording of FT outcomes based on visual observation. Two different shots are illustrated. (**a**) Sample recording sheet. (**b**) Recording of a long success, a successful shot after hitting back rim and backboard. (**c**) Recording of clean shot, a successful shot without hitting rim or backboard. 1 = first bounce, 2 = second bounce, and 3 = third bounce.

videotaping during actual game performances (such as, camera obstruction by the coach and/or referee or a camera malfunction), a large number of video recordings could not be used for 3D analysis. For this paper, we have combined classes to form four classes (Class 1 = 1.0 and 1.5, Class 2 = 2.0 and 2.5, Class 3 = 3.0 and 3.5, and Class 4 = 4.0 and 4.5) described by Strohkendl [15]. This was done because of particularly small numbers of athletes in some classes and to meet the assumptions necessary to permit appropriate statistical analysis. It was assumed that combining each half-point class with the adjacent lower class would have similar effects across each group. This combination enabled information to be collected on the following number of clean shots within each player class: Class 1 (n = 7), Class 2 (n = 16), Class 3 (n = 18), and Class 4 (n = 26).

To examine shooting mechanics and trajectory of the ball, we analyzed the identified free throws using the APAS system. Three-dimensional joint angular displacements and velocities of the shoulder, elbow, and wrist were calculated with a relative reference system. The angular motion of each joint was computed as the relative motion between the two adjacent segments sharing this joint as their center of rotation. In describing the angle at a particular joint, the relative angle was defined as the angle between the longitudinal axes of the two segments [16]. Angular motion of each joint was computed as (1) shoulder joint, relative motion between the trunk and arm; (2) elbow joint, relative motion between the arm and forearm; and (3) wrist joint, relative motion between the forearm and hand.

Release parameters of the ball (**Figure 3**) were calculated with the 3D displacement data of the center of the ball. Time of ball release was defined as the first frame in which the ball was no longer in contact with the hand. Release height was measured as the vertical distance from the ground to the center of the ball. Velocity of the ball at release was measured as the resultant of the three velocity vector components. Angle of ball release was calculated using

$$\theta_r = \arctan[(Y_{\mathrm{aft}} - Y_{\mathrm{rel}})/(X_{\mathrm{aft}} - X_{\mathrm{rel}})] \ ,$$

where θ_r equals the angle of the ball release; X_{rel} and Y_{rel} equal x and y coordinates of the center of the ball in the frame of release, respectively; and X_{aft} and Y_{aft} equal x and y coordinates of the center of the ball in the frame after release, respectively.

To further describe the trajectory of the basketball, additional variables were calculated for each free throw, including angle of entry, margin for error, minimum projection angle, and minimum-speed angle. Angle of entry (θ_e) is defined as the angle formed by the tangent to the ball's center of mass pathway and the horizontal as the ball passes through the plane of the rim and was calculated as [7]

$$\tan \theta_e = \tan \theta_r - 2h/L \ ,$$

where θ_e equals the angle of entry, θ_r equals the angle of the ball release, h equals the vertical distance between the rim of the basket and the point of release, and L equals the horizontal distance from the point of release to the center of the basket. Margin for error (E_m) is defined as the horizontal distance (±) that the center of the ball at approach can be away from the center of the hoop and still go cleanly through the basket. The margin for error was calculated with the use of [17]

$$E_m = \pm(r_h \sin \theta_e - r_b) \ ,$$

where E_m equals the margin for error, θ_e equals the angle of entry, r_h equals the radius of the hoop (22.85 cm), and r_b equals the radius of the basketball (12.11 cm). Minimum

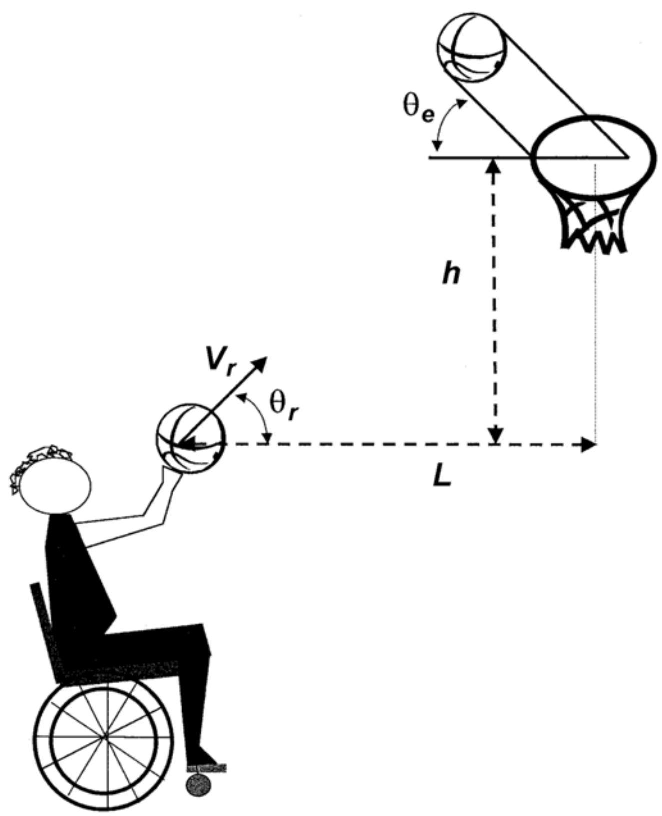

Figure 3.
Illustration of release parameters for ball and angle of entry into basket: θ_r = angle of ball release, h = vertical distance between rim of basket and point of release, L = horizontal distance from point of release to center of basket, V_r = release velocity, and θ_e = angle of entry.

release angle (θ_{mr}) is defined as the smallest release angle that can be used with a particular release height and distance from the basket and still produce a clean shot. The minimum release angle was found with the use of [7]

$$\tan\theta_{\mathrm{mr}} = \tan 32° + 2h/L ,$$

where θ_{mr} equals the minimum release angle, h equals the vertical distance between the rim of the basket and the point of release, and L equals the horizontal distance from the point of release to the center of the basket. (Note that 32° is based on $E_{\mathrm{m}} = 0$, i.e., when $\sin\theta_e = r_b/r_h$.) Minimum-speed angle (θ_{ms}) is defined as the angle of release for a clean shot from a given release position, which requires the least amount of speed, and thereby muscle forces. This angle was found with the use of [7]

$$\tan\theta_{\mathrm{ms}} = h/L + (1 + h^2/L^2)^{1/2} ,$$

where θ_{ms} equals the minimum-speed angle, h equals the vertical distance between the rim of the basket and the point of release, and L equals the horizontal distance from the point of release to the center of the basket.

Finally, to indicate the accuracy of the results, we compared the calculated vertical acceleration of the ball after release to the known value of acceleration caused by gravity (9.81 $\mathrm{m/s^2}$). The calculated acceleration value of the ball was considered to be the greatest potential source of error for two reasons: (1) error because of inaccurate determination of the ball's center of mass and (2) magnification of error in the process of double differentiation for determining acceleration values from position data [18]. Results indicated that the calculated vertical accelerations of the ball during free flight were on average within 5 percent (standard deviation [SD] ± 4%) of the known value. Presumedly, the calculated displacements and velocities were subject to less noise as they underwent fewer differentiations.

Statistical Procedures

Using SPSS for Macintosh version 6.1.1, we ran statistical tests to determine if differences existed between the four classes on the ball trajectory and joint kinematic variables. One-way analysis of variance (ANOVA) tests were conducted followed by Tukey HSD (honestly significant difference) post hoc tests where needed. To examine concerns related to unequal group sizes, we conducted a Levene Test for homogeneity of variances on the groups for each of the variables. In addition, for controlling possible inflation of alpha with multiple ANOVAs, a Bonferroni adjustment ($\alpha = 0.01$) of the original alpha level was used. Moreover, to examine the magnitude of differences between the groups and meaningfulness of the findings, we calculated the effect size using the eta-squared index (η^2) for each variable. As defined by Cohen [19,20], a small effect size equals 1 percent, medium effect size equals 6 percent, large effect size equals 15 percent. Statistical tests were run on 67 right-handed free throws: 7 shots (Class 1), 16 shots (Class 2), 18 shots (Class 3), and 26 shots (Class 4). The independent variable was player classification (1 to 4), and the dependent variables were height, angle, and velocity of ball release; start angle of elbow; shoulder and elbow position at release; and maximum shoulder, elbow, and wrist velocity.

RESULTS

Ball Parameters

Results of the ANOVA tests revealed statistically significant differences between the groups on parameters of ball release and are supported by the large calculated effect sizes for each variable (**Table 1**). Means and standard deviations of the three ball variables (height, angle, and velocity of ball at release), together with the effect size for each variable, are shown in **Table 1**. If one assumes that the objective in FT shooting is to get a clean shot, then the combination of the three interdependent release parameters will dictate the shooters success and how much of a margin for error the shooter has given variations in those parameters. The data here indicate that the lower classes because of a lower release height adopted a strategy that favored a predictably higher release velocity accompanied by a steeper ball trajectory. The upper classes, because of the higher release position, illustrated little difference in release angle and a predictably lower release velocity. These consequences related to release position are confirmed through the statistically significant differences observed between release angle and velocity among the classes as indicated in **Table 1**.

Statistically significant differences were seen in release height of the ball between the classes. The release heights of Classes 1 and 2 (162 cm and 160 cm, respectively) were both significantly lower than the release heights of Classes 3 and 4 (179 cm and 184 cm, respectively). In labeling Classes 1 and 2 as the lower classes and 3 and 4 as the upper classes, one can say that a significant difference exists between the upper and lower classes, with the upper classes releasing the ball from a greater height.

Statistically significant differences were also seen in release angles between the classes. The release angles of Classes 1 and 2 (59° and 58°, respectively) were both significantly different from the release angles of Classes 3 and 4 (55° for both). The upper classes were found to use a smaller angle of release as compared to the lower classes.

In terms of velocity of ball release, statistically significant differences were found between Class 1 (743 cm/s) and the upper classes (Class 3, 707 cm/s; Class 4, 699 cm/s). In general, release velocity tended to decrease with an increase in class.

Although the three release parameters may have an infinite number of mathematical combinations that would result in a successful shot, other factors do affect the potential for success. Given the release parameters, the amount of variance available to the shooter at the time of release can be predicted from the angle of entry into the basket. In **Table 2**, descriptive statistics (mean and SD values) for the additional trajectory variables are shown for the four classes. On average, the free throws approached the basket with an angle of entry of 43° for the lower classes and 40° for the upper classes. The lower classes tended to have a higher angle of entry and, therefore, slightly greater margin for error, because of larger release angles. The average minimum release angle required for the lower classes was calculated as 53°, while the angle for the upper classes was determined to be 50°. On average, players used a release angle that was 5° greater than the minimum required. The minimum-speed angle was determined to be 55° for the lower classes and 53° for the upper classes. A comparison of **Tables 1** and **2** reveals that on average, players in the upper classes used a release angle closer to their minimum-speed angle.

Table 1.
Ball parameters at release.

Variable	Class 1 (n = 7)		Class 2 (n = 16)		Class 3 (n = 18)		Class 4 (n = 26)		
	M	SD	M	SD	M	SD	M	SD	η^2 (%)
Release Height* (cm)	162	4	160	6	179	13	184	17	40
Release Angle* (°)	59	2	58	2	55	3	55	3	30
Release Velocity† (cm/s)	743	22	719	32	707	30	699	21	22

*Significant difference ($p < 0.01$) between lower classes (1 and 2) and upper classes (3 and 4).
†Significant difference between Class 1 and upper classes ($p < 0.01$).
SD = standard deviation
M = mean

Table 2.
Additional ball trajectory variables.

Variable	Class 1 (n = 7)		Class 2 (n = 16)		Class 3 (n = 18)		Class 4 (n = 26)	
	M	SD	M	SD	M	SD	M	SD
Angle of Entry (°)	44.0	3.0	42.0	4.0	40.0	4.0	40.0	5.0
Margin for Error (cm)	3.5	0.9	2.9	1.1	2.5	1.1	2.5	1.4
Min Release Angle (°)	52.0	0.4	53.0	1.0	51.0	2.0	50.0	2.0
Min Speed Angle (°)	54.0	0.2	55.0	0.4	53.0	0.8	53.0	1.0

SD = standard deviation
M = mean
Min = minimum

Joint Kinematics

Statistically, significant differences between the groups were identified on several of the joint kinematic variables. Of the variables measured, shoulder position at release, maximum shoulder velocity, and maximum elbow velocity showed a significant difference between the classes and a large effect size. Mean and SD values of the upper-limb joint positions and angular velocities, together with the effect size for each variable, are given in **Table 3** for each of the classes.

As shown in **Table 3**, shoulder position at release showed a significant difference between the upper (Class 3, 133°; Class 4, 132°) and lower (Class 1, 116°; Class 2, 123°) classes. On average, the upper classes demonstrated a larger angle of shoulder flexion at release.

Class 2 had significantly faster maximum angular velocity at the shoulder than Classes 3 and 4. As shown in **Table 3**, average velocity for Class 2 was 533°/s, whereas Classes 3 and 4 had an average velocity of 441°/s and 412°/s, respectively. Maximum elbow velocity showed a significant difference between Classes 1 and 3, 1 and 4, and 2 and 4. Values of 957°/s, 888°/s, 798°/s, and 776°/s were seen for Classes 1 to 4, respectively. In general, a decrease in velocity was identified with an increase in class.

DISCUSSION AND CONCLUSION

The results of this study revealed significant differences between wheelchair basketball classes in the FT shooting mechanics required for a clean shot. Apparently, different techniques, as demonstrated by several aspects of the shooting motion and ball trajectory, are used by the upper classes (3 and 4) and lower classes (1 and 2).

Table 3.
Upper-limb joint positions and angular velocities.

Variable	Class 1 (n = 7)		Class 2 (n = 16)		Class 3 (n = 18)		Class 4 (n = 26)		
	M	SD	M	SD	M	SD	M	SD	η^2 (%)
Start Angle of Elbow (°)	48	4	46	5	52	10	51	6	10
Position at Release (°)									
Shoulder*	116	8	123	7	133	9	132	8	35
Elbow	139	8	142	7	145	8	143	7	5
Maximum Angular Velocity (°/s)									
Shoulder†	462	61	533	75	441	128	412	89	20
Elbow‡	957	111	888	113	798	117	776	79	29
Wrist	791	231	940	212	1,003	175	1,038	248	11

*Significant difference ($p < 0.01$) between lower classes (1 and 2) and upper classes (3 and 4).
†Significant difference ($p < 0.01$) between Class 2 and upper classes.
‡Significant difference ($p < 0.01$) between Class 1 and upper classes and between Class 2 and Class 4.

In terms of ball parameters at release, a clear distinction was seen between the upper and lower classes. The lower classes tended to release the ball from a lower height with a greater velocity and angle of release. The technique of the lower classes in using a higher angle of release, although providing a larger margin for error, demanded greater accuracy because of the seriousness of errors as the release angle is increased [17]. However, players in the lower classes appear to have developed the required accuracy and achieved similar FT shooting percentages (Class 1, 52%; Class 2, 53%) as players in the upper classes (Class 3, 49%; Class 4, 54%), as calculated from the official tournament statistics [3].

For a player to achieve a high angle of release requires not only greater accuracy but also higher release velocity and force production as well. This may pose a problem for some players in the lower classes who have functional limitations affecting their strength [2]. If the necessary release velocities are not attained and the margin for error is exceeded, the shots will tend to fall short. To reduce the force requirements of a shot and reduce the number of short misses that tend to occur [3], players shooting with an angle closer to the minimum-speed angle as recommended by Brancazio may gain an advantage. [7]. However, one must be cautious because such a strategy would reduce the margin for error by lowering the angle of entry.

To shoot successful free throws, players in the lower classes adopted a strategy, which used a steeper ball trajectory. This however required players to generate more force and velocity in the shooting arm. As the results indicated, the lower classes accomplished this by using greater maximum angular velocities at the shoulder and elbow. These results coincide with those of Miller and Bartlett [21], who found that elbow extension angular velocity increased as shooting distance increased. In addition, the lower classes tended to use a smaller start angle of the elbow (more flexed), which may have been an effort to increase elbow range of motion and generate the necessary impulse during arm elevation required for the ball to reach the basket.

The present analysis of clean shots indicated that, on average, players in the upper classes used a higher point of release than did players in the lower classes. As indicated by Brancazio [7], the higher the point of release, the more likely a shot will be successful. The upper classes, therefore, had an advantage over the lower classes in shooting free throws by virtue of having a higher release point. Not only might players in the upper classes tend to be taller, but they also have the ability to lean the trunk forward and reach the arms upward while shooting without loss of stability. Based on the FT percentages, as determined by the official tournament results, the upper classes appear not to have fully used this advantage of a higher release point. As the height of release is increased, margins for error in both speed and angle become larger, and the necessary force and velocity of release becomes smaller [7]. With such advantages, the FT shooting percentages of the upper classes are expected to be greater. Using as a guideline the speed and angle found for clean shots and any height advantage that they have, players can perhaps improve overall FT shooting performance.

Numerous possible combinations of release parameters can result in a successful free throw. Although it appears that certain guidelines can be recommended for the upper and lower classes in wheelchair basketball, every player should determine the best combination of speed and angle that produces the greatest consistency and accuracy in their own shot. Owen's suggestion of a minimum projection angle of 45° appears too small for wheelchair basketball players [2]. Based on the minimum trajectory angles calculated in this study, a more reasonable suggestion appears to be a minimum of 50°. As indicated by Brancazio [7], a shooter has very little leeway in release velocity for a successful shot. For a given release angle, the difference in speed between a shot that passes through the center of the basket and one that just clears the rim is generally less than 1 percent [7]. Therefore, instead of shooters using high angles of release, Brancazio indicates that successful shooters learn to shoot at or near the minimum-speed angle [7]. In addition to providing the greatest margin for error in angle, a shot projected with the minimum-speed angle requires the smallest projection force [7]. This is important to consider in wheelchair basketball where force requirements are increased because of increased distance from the basket, whereas force-producing capabilities are reduced because of lack of available power from the legs. Furthermore, as release height increases, the minimum-speed angle decreases. Although a person's height is fixed, one can increase release height using strategies such as increasing shoulder flexion and elbow extension. To develop the best possible trajectory for success, each player and the coach should carefully consider the numerous options available for adjusting technique.

The present investigation has provided some preliminary information as to the proper shooting mechanics used for successful FT shooting by wheelchair basketball players in each of the classes. Although shooting is one of the most important fundamental skills in basketball, Smith notes that it is one of the least taught and is rarely practiced enough [22]. Likewise, Brancazio argues that coaching practices have often shied away from altering a shooter's technique [7]. Because percentages are so low in wheelchair basketball, persons should take extreme efforts to emphasize the importance of devoting time to practicing this fundamental, yet critical, skill. According to Brancazio [7, p. 307], "it is possible to develop and improve one's ability to shoot a basketball accurately by taking a scientific approach to basketball shooting." This should be especially true for a standardized, unopposed shooting setting such as the free throw.

ACKNOWLEDGMENTS

The support of the Alberta Paraplegic Foundation, the Alberta Recreation, Parks and Wildlife Foundation, and the Steadward Centre, as well as the assistance of Robert L. Malone are gratefully acknowledged.

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Submitted for publication April 2, 2001. Accepted in revised form March 14, 2002.