A BIOMECHANICAL ANALYSIS OF THE UPPER LIMB ON DIFFERENT SNOOKER BATTING TECHNIQUES

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The purpose of this study was to compare the kinematics of the upper limb in fellow shot and draw shot, to quantify the effects of the different rods on technical characteristics. Eight professional snooker athletes hit the placed snooker balls using the fellow and draw shots, respectively. Ten kinematic variables were collected for each shot. Paired t-tests were used to analyze the effect of different rod method on the performance of upper limbs. The flexion-extension angle of the elbow (p=0.03) and the hand-rod angle (p=0.02) were larger when the fellow shot was used, while the hitting speed (p=0.01)and the hitting angle (p=0.01) was less than draw shot. Stroke in the draw shot required a large range of elbow and hand-rod angles during the T1-T2 and T2-T3 stages. No statistical differences were found in the kinematics of the wrist. The fellow shot is more stable than the draw shot, and the rod speed may be the main reason for the difference in kinematics between different rod methods.

KEYWORDS: snooker, kinematics, technical analysis, fellow shot, draw shot

INTRODUCTION: As a kind of billiard sport, snooker requires high skill, stability and accuracy. Kanov & Stauch (2008) suggested that in order to improve accuracy, the moment of hit should be only the forearm swing, and in the follow-through, the elbow joint will naturally fall; but some others thought are the elbow joint movement is related to the rod method, only the fellow shot when the elbow drop situation Byrne & Byrne (1998). It can be seen that in the limited research of billiards, the quantitative biomechanics research is rarely been considered, and there are different opinions about the performance of upper limbs, so it need to be discussed in depth to determine how the movement of upper limbs. Therefore, the purpose of this study was to compare the kinematics characteristics of the upper limbs and the relative relationship between the hand and the rod during the shot processing by using the fellow shot and the draw shot. It is expected to further understand the basic technical movements of the snooker and provide fundamental kinematic data for intensive study of snooker movement.

METHODS: Eight professional snooker athletes (age: 30.7 ± 6.3 years, 173.7 ± 5.1cm, 74.0 ± 7.8kg), with more than 8 years' experience were selected and did not engage in strenuous exercise 48 hours before the experiment. All subjects were right-handed batting.
This paper anaylzed the fellow and draw shots batting techniques, which have different hitting position. A fellow shot is done by fitting the cue ball above center. The cue ball stops momentarily then follows the object ball's direction upon contact with the object ball. In a draw shot the cue ball stops momentarily then draws away from the object ball towards the player upon contact with the object ball. Each predefined position of balls has been previously marked on the table's cloth to guarantee identical conditions for all participants (Figure 1).The cue ball is always at the kick-off point, and the object ball placed at the point where the kick-off point meets the bottom bag line and the middle bag line. When the fellow shot hits the ball the object ball position it slightly shifts. By controlling the movement distance of the cue ball to unify the stroke force Kornfeind, Baca, Boindl, Kettlgruber, & Gollnhuber (2015), both of the rods require the subject to keep the cue ball in the shaded area after the object ball falls (Figure 1) and the object ball falling pocket. Only complete the above request is considered as a successful data acquisition. All players had to succeed in one given task within three attempts and the average value of three successful data was selected for statistical analysis.

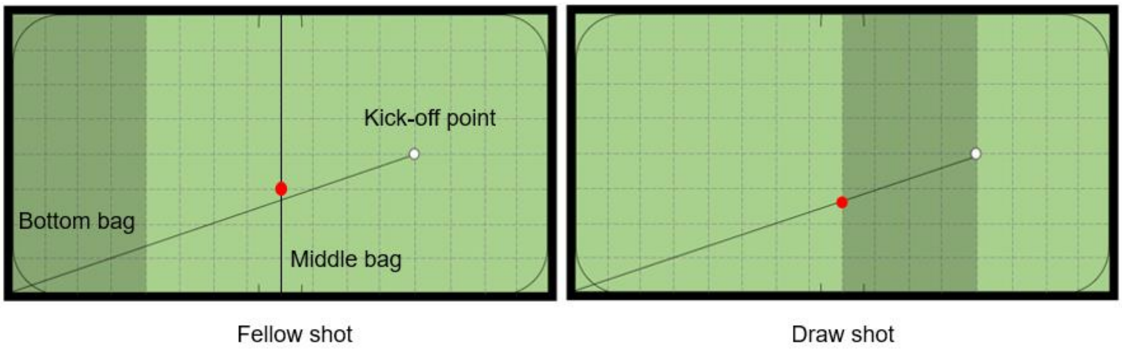


Figure 1. The placement of the cue ball and the object ball

All the subjects were asked to use the same snooker rod（LK.T，F.1.s，China）and affix four reflective markers on the rod for calculation without affecting the impact. The position of the rod, where cue1 is removed after the calibration is completed, and cue2-cue4 are not collinear (Figure 2). Forty-two reflective markers were attached to the body surface, where the mark points of the shadow aspect were removed after the calibration was completed (Figure 3). Before the test, the subjects performed appropriate warm-up exercises in tight sportswear and began testing after skilled use of the rod.

Figure 2. Rod marker scheme

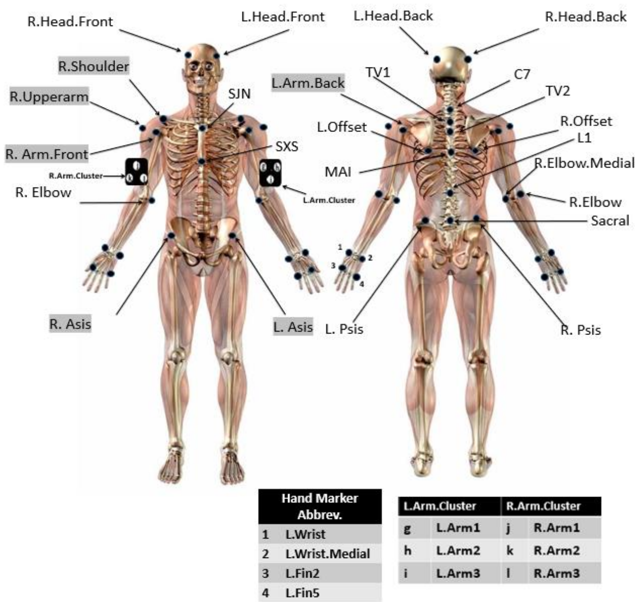
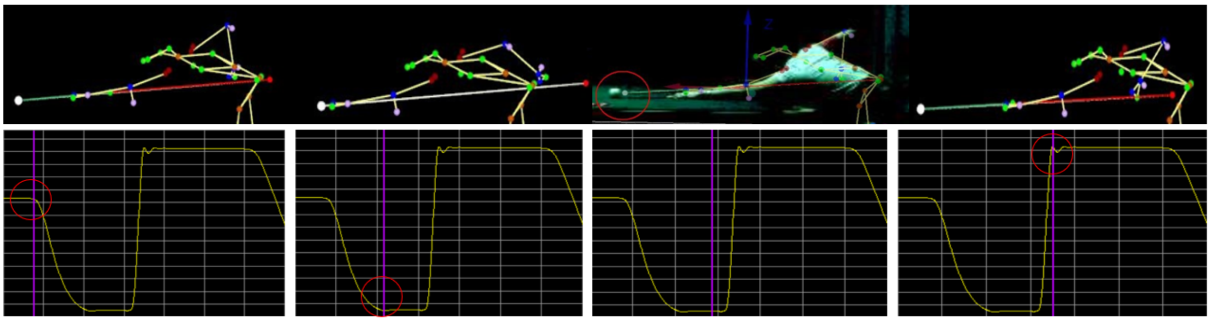


Figure 3. Reflective Markers on the body surface

Kinematic data of shot performance were collected using a 3D motion high-speed capture system (Qualisys-oqus700+, Swede, 200Hz) with 13 cameras, using QTrc software from Qualisys and Visual3D (C-motion, USA) to process data. The three-dimensional coordinates of all landmarks were smoothed using Butterworth low-pass filtering, and cut-off frequency was 13.3Hz Yu, Gabriel, Noble, & An (1999).

In this study, the batting action was divided into four characteristic moments (Figure 4) : the last time of the backwards start (T1), the last moment of the backward to the longest distance (T2), the cue ball impacted with the object ball (T3), and the extension of the rod to the farthest time after hitting the ball (T4). The curve in Figure 4 is the trajectory of cue 2 in the X direction of the rod. The joint angles were defined as the Euler angle between the local coordinate systems of two adjacent links.



T1 T2 T3 T4

Figure 4. Characteristic moments

As the snooker action is dominated by the movement of the elbow joint and the upper movement is small, the kinematic parameters selected in this study were: 1) the flexion-extension angles and range of motion (ROM) present in the elbow and wrist joint, 2) hand-rod angle, 3) hitting speed, 4) hitting angle. The flexion-extension angle of the elbow and wrist joint obtained from the characteristic moment. ROM were defined as the difference between the extreme values of the flexion-extension movement during the back-swing phase (T1-T2), hitting phase (T2-T3) and extension phase (T3-T4). Hand-rod angle were defined as the spatial vector angle formed by the temporal bone point of the wrist, the second proximal phalange point, and the cue1, which reflects the relative movement of the hand and the rod (Figure 5). Hitting speed means speed at the T3. Hitting angle was the angle of the vector formed between the rod and the table (Figure 5).

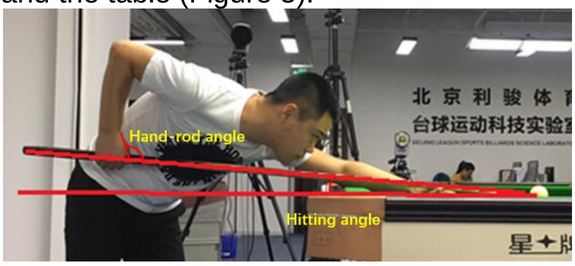


Figure 5. Explanation of hand-rod angle and hitting angle

SPSS12.0 (SPSS Inc, Chicago, Illinois) was used for statistical analysis, and the effect of fellow and draw shot on the movement performance of each index was analyzed by using paired T-Test. The level of significance is defined as a Type I error rate not greater than 0.05.

RESULTS: Mean values and standard deviations for all parameters and shot types are depicted in Tables 1 to 2. The asterisk (*) indicates a significant difference, as detected by the paired t-test. The effects of different rod methods on kinematic parameters of upper limbs are mainly manifested in the elbow joint and the hand-rod angle. The fellow shot is greater than the draw shot in the flexion-extension angle of the elbow (P=0.03) and the hand-rod angle (P=0.02) at T2. The fellow shot in the T1-T2 and T2-T3 phases of elbow flexion-extension ROM (P=0.02) and the hand-rod angle ROM (P=0.01) is significantly smaller than the draw shot (Table 1). Draw shot can achieve greater hitting speed (P=0.01) and angle (P=0.01) (Table 2).

DISCUSSION: The essence of the game of snooker is to strike the cue ball with accuracy and power to achieve the estimated shot outcome. A common consensus for snooker is that players must have good command of basic skills, namely the bridge arm, the cue arm, the grip and the stance (Chung et al., 2014). In snooker, the shoulder joint remains basically unchanged, and the movement of the elbow joint may play a leading role. Fellow shot's hitting angle is lower than draw shot, so the elbow joint does not need a larger joint angle to protect the hitting position when T2 is ready to hit the ball. The result showed that the ROM of the fellow shot elbow joint and the hand-rod angle during the back-swing and the hitting phase is also lower than the draw shot, which indicates that the fellow shot action mode is more stable. On the other hand, the draw shot uses the friction force generated by the rotation of the cue ball and the tablecloth, so it is necessary to provide a large back spin of the cue ball so that the cue ball will roll in the original direction after hitting the object ball. Therefore, hitting speed for a fellow shot will be lower than that of a draw shot. At the same distance, the rod methods result in different hitting speed. We infer that the snooker batting strategy is based on controlling the speed of the rod. Cheng, Tang, & Li (2008) pointed out that in order to increase stability of each hit, keeping all parts of the body in a controllable range without losing control of precision and strength is the main key to ability of the game.

Table 1: Kinematic Parameter of Upper Limb（°）

	Elbow Flexion\Extension Angle		Wrist Flexion\Extension Angle		Hand-Rod Angle	
	Fellow Shot	Draw Shot	Fellow Shot	Draw Shot	Fellow Shot	Draw Shot
T1	119.07±5.88	119.94±5.65	-1.18±10.01	-0.41±12.71	83.03±17.91	84.61±16.75
T2*	82.98±11.84	70.76±12.51	-1.03±10.75	-0.91±9.88	57.48±17.04	49.20±17.96
T3*	119.36±6.52	118.25±9.38	0.39±13.04	-0.75±14.30	83.16±13.73	85.21±12.36
T4	136.18±4.39	136.44±4.73	-0.49±11.47	-0.55±10.90	108.13±10.73	108.37±11.99
T1-T2 ROM*	36.07±9.04	49.17±8.38	2.71±4.50	2.96±3.16	25.55±9.07	35.41±9.00
T2-T3 ROM*	36.37±8.62	47.47±5.50	4.05±3.29	6.51±2.79	25.68±8.36	36.03±9.88
T3-T4 ROM	16.82±6.98	18.19±9.69	2.74±2.50	5.64±8.43	24.96±7.73	23.26±5.39

Table 2: Kinematics Parameters of Rod

	Fellow Shot	Draw Shot
Hitting Speed(m/s)*	2.52±1.21	3.69±0.61
Hitting Angle(°)*	2.42±0.66	4.53±0.43

CONCLUSION: The fellow shot is more stable with draw shot, and the rod speed may be the main reason for the difference in kinematics between different rod methods.

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