UPPER EXTREMITY KINEMATICS OF AN ELITE SNOOKER PLAYER ON STOP SHOTS

Yiran Jiao[12], Hanjun Li[1], Hui Liu[1], Yi Qu[2]

Department of Kinesiology, Beijing Sports University, Beijing, China[1]
Beijing Leaguen Sports Billiards Science Laboratory, Beijing, China[2]

Purpose: The purpose of this study was to identify kinematic characteristics of stroking upper extremity during final stroke when an elite snooker player using stop shots and compared them with the description of technical books. **Methods:** The participant was Stephen Maguire, an elite player and the data was recorded by Qualisys Analysis System. The sucessful stop shots was performed 3 times totally. **Results:** The hitting moment occurs near the minimum value of the forearm angle, as well as the elbow-shoulder-wrist projecting angle remained stable and was less than -4°. There was little displacement of the shoulder joint and the elbow joint. The Coefficient of Multiple Correlation (CMC) of all three joint movements in an upper limb was greater than 0.95. **Conclusion:** The elite snooker player might have a stable movement pattern in final stroke and the stop shot is not a pendulum movement theoretically. Elbow joint is in the inner side of shoulder and wrist joint and hitting moment always occurs when the elbow joint is at lowest position.

KEYWORDS: snooker, kinematics, stop shot, motion analysis.

INTRODUCTION: Normally, strokers need to consider techniques seriously and control force to achieve the object ball potting or to provide a good position for the cue ball which will facilitate the next shot. These are mainly affected by the batting action of the hitting upper extremity during final stroke. As the fundamental techniques, stop shots, push shots and draw shots are usually learned by beginner at first, and other complex and difficult techniques are learnt or used based on especially the stop shots. A research (Cheng, Tang & Li, 2010) proved that less displacement of the shoulders might improve the accuracy of the stroking for all three shots, but the motion of upper limbs in stop shots was less similar to the pendulum motion compared to push shot. However, some technical books such as Byrne (1998) suggested that a standard and good stop shot motion should nearly fix the elbow joints and only the forearm swing like a pendulum in final stroke except for push shot. Thus, it can be seen that there is limited quantitative evidence about the movement pattern of stop shots and also have different description for it. Besides, the pattern was much described in technical books is based on players' experience rather than scientific researches. As a world-class snooker player, Stephen Maguire is equipped with high success rate and excellent technologies. The purpose of this study was to identify elite snooker player's kinematic characteristics of stroking upper extremity during final stroke when using stop shots and compared them with the description of technical books. It was projected to be of guiding significance for the analysis and training of snooker.

METHODS: The participant was Stephen Maguire (age: 38 years old, snooker age: 22 years) who got the 1st runner-up of The United Kingdom Snooker Championship in 2019. His kinematic data of the upper limbs' movement of the hitting side during the final stroke was collected by Qualisys motion analysis system with 13 cameras (Qualisys-oqus700 + , 200HZ) when he was doing a stop shot. Other test equipment included the snooker cue (LK. T-F1s, 9.5-10.5 mm). The stop shot was defined in this paper as a technique that the hitting position is just the centre of the cue ball. Besides, the cue ball stops once contacting with the object ball without any spin theoretically during cue ball's movement. The subject was asked to use a stop shot with cue ball (white ball) at the kick-off point. The target ball (red ball) was also placed at the intersection point between the 'kick-off point and bottom pocket line' and 'two middle pockets line'. A successful shot was finished when the red ball enters the bottom pocket and the white ball stops within the shaded part (Figure 1). In total, data of three

successful strokes were collected. There were 20 reflective markers on the subject's body surface and 5 markers attached on the rod for calibration before stroking the ball. When the calibration was finished, the markers boxed were removed in case of preventing batting (Figure 2&3). Final stroke was regarded as the last stroke after warm-up strokes and divided into 3 phases with four characteristic moments: the last time of the backwards start (T1), the last moment of the backward to the furthest distance point(T2), the moment when cue ball touched the object ball (T3), and the farthest extension of the rod time after contacting the ball (T4)(Song, Qu., Qu, Zhao, & Zhou, 2018).

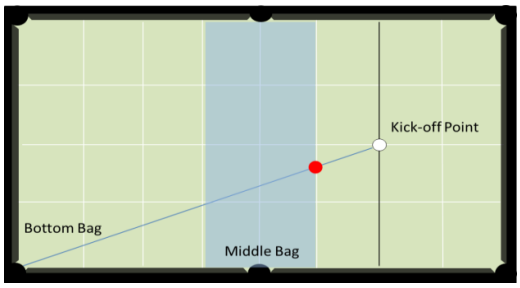


Figure1: The route of the stop shot.

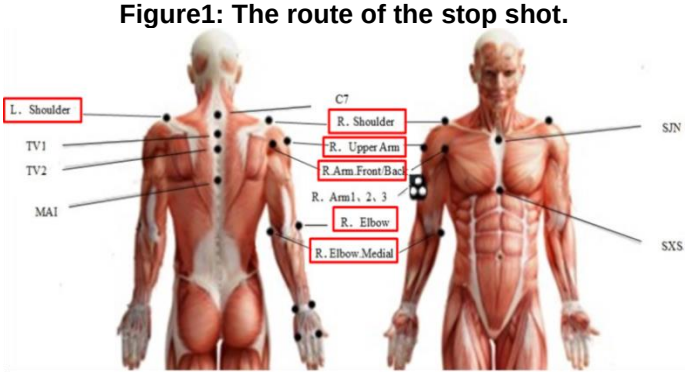


Figure2: Markers on body surface.

Figure3: Rod markers scheme.

Some kinematic parameters were calculated in this paper: 1) the flexion-extension angle and its range of motion (ROM) present in right shoulder and elbow joint as well as the abduction-adduction angle and ROM of wrist joint during different phases. 2) Coefficient of Multiple Correlation of movements mentioned above (Kadaba, Ramakrishnan, Wootten, Gainey & Cochran, 1989) which is used to assess Repeatability and stability among three trials. 3) the forearm angle defined as vector angle formed by elbow-wrist line and reverse z-axis (Figure 4). 4) the elbow-shoulder-wrist projecting angle which is defined as the projecting angle of shoulder angle formed between shoulder-elbow line and shoulder-wrist line on the horizontal plane and its ROM. 5) the displacement of shoulder and elbow joint points.

Figure4. Forearm angle

RESULTS: Mean values and standard deviations of ROM of three joints and their CMC

among three trails are demonstrated in Table 1. It is obviously depicted that the subject's upper arm has flexion-extension movement in all phases and there is a different ROM between T1-T2 and T2-T4 in elbow flexion-extension movement (41°, 39.7°). Angle fluctuations of these movements are shown in Figure 5&6. The Forearm angle experiences lowest number in the proximity of T3 during T2-T3 (Figure 7). Elbow-shoulder-wrist projecting angle keeps relatively stable during T1-T3 and negative value (Figure 8 & Table 2). Vertical lines in these figures represent T2 and T3 respectively. Table 3 shows the time radio of different stages. Displacement values are represented in Table 4 show that elbow displacement in the total final stroke is 3.9cm and variation value in T2-T4 is smaller than that in T1-T2 either for shoulder or elbow.

Table 1: ROM and CMC of Right Shoulder, Elbow and Wrist (°).

Position	Movement	ROM					CMC
		T1-T2	T2-T3	T3-T4	T2-T4	T1-T4	
Shoulder	Flexion/ Extension	14.1±0.5	8.2±0.3	15.1±2.4	17.0±2.3	22.9±1.8	0.992
Elbow	Flexion/ Extension	41.7±1.1	39.7±1.0	21.7±2.0	61.4±1.2	61.4±1.2	0.995
Wrist	Abduction/ Adduction	7.9±0.2	8.2±0.9	16.5±0.9	24.7±0.3	24.8±0.3	0.989

Table 2: ROM of elbow-shoulder-wrist projecting angle during different phases(°) .

	T1-T2	T2-T3	T3-T4
ROM	2.0±0.2	2.5±0.1	8.0±0.4

Table 3: Time and time ratio of different phases .

	T1-T2	T2-T3	T3-T4	T1-T4
Time (s)	0.9±0.0	0.7±0.1	0.1±0.0	1.7±0.1
Time Ratio (%)	52.5±1.9	41.5±1.4	6.1±0.6	100

Table 4: Displacement in Right Shoulder and Elbow Joint Points during Different Phases (cm) .

	T1-T2	T2-T3	T3-T4	T1-T3	T1-T4
Shoulder	4.3±0.2	3.7±0.3	3.0±0.2	1.6±0.2	3.9±0.0
Elbow	7.1±0.3	4.4±0.3	5.3±0.5	2.9±0.1	7.4±0.5

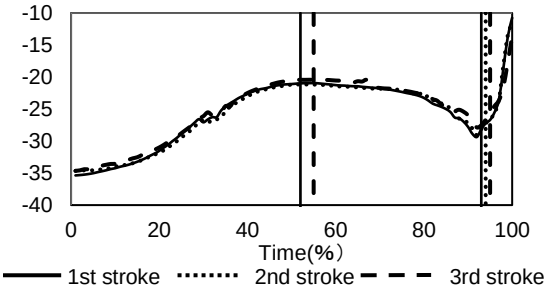


Figure 5: Flexion-extension angle of the shoulder.

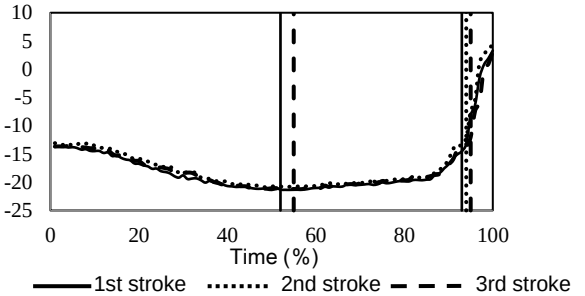
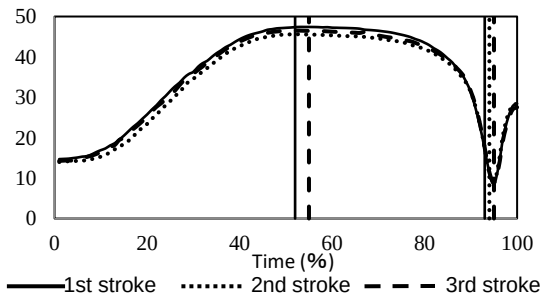


Figure 6: Abduction-adduction angle of the wrist.



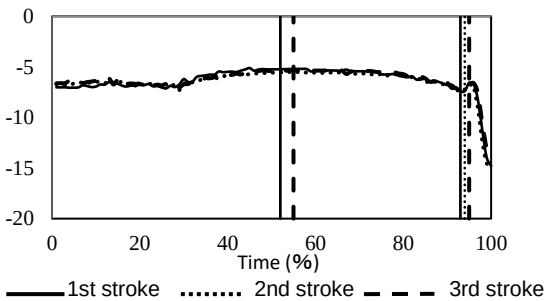


Figure 7: Forearm angle during stroking.

Figure 8: Elbow-shoulder-wrist projecting angle.

DISCUSSION:

Firstly, considering CMC values which are more than 0.75 means the waveforms are highly similar with each other (Li, Tong, Zhou & Qu., 2011), CMC values in this paper (0.992,0.995 and 0.989) depicts that Stephen Maguire has a stable movement pattern and he can hit the ball in final stroke repeatedly, which is a good quality of an elite snooker player.

Besides, Pendulum movement is defined as the motion of the pendulum in which a pendulum is swinging in a plane that is perpendicular to the ground with the effect of gravity. This kind of movement is the back and forth motion with a fixed period ratio and range of swing. The elbow-shoulder-wrist projecting angle is always less than -4° and keeps stable during T1-T3 (Figure 6), indicating that when Maguire hits the ball, the elbow joint is located on the inner side of the line connecting the shoulder and wrist joints. That is, the plane formed by the shoulders, elbows and wrists is not perpendicular to the ground. The time ratio of the three phases (8.65: 6.83: 1) (Table 4) but larger ROM of elbow in during T2-T4 compared T1-T2 (Table 1) reveal that the rhythm of the forward movement needs to be faster. All of these are different from pendulum movement mentioned before although technique books advise that upper extremity in final stroke should move like a pendulum (Byrne, 1998), which indicate players should keep a stable relative position among the shoulder, elbow and wrist joint during the spot shots training rather than imitate the absolute pendulum movement as technique books and some coaches said.

What is also worth mentioning is that hitting moments with minimum forearm angle means that wrist is almost in the lowest position of swing at T3 (Figure 5), which is beneficial to create a fastest horizontal hitting speed and efficient stroke.

Finally, there is an exponential increase for flexion-extension angle of shoulder after T3 (Figure 5) and displacement for shoulder and elbow joint (Table 4), implying that the upper arm will naturally fall after hitting the cue ball, which are similar with the conclusion from Kanov and Stauch (2008). And compared with the data in the 9-Ball study, the shoulder joint displacement in the stop shot of snooker(1.6 ± 0.2cm) is less than that of 9-Ball (4.1 ± 0.2cm) (Cheng, C. L et al., 2010), which suggests that shoulder joint point in the former one might have a higher stability and a good stability of shoulder point might be beneficial to stroke the cueball. Besides

CONCLUSION: The elite snooker player might have a stable movement pattern in final stroke. In addition, the stop shot is not a pendulum movement theoretically. Elbow joint is in the inner side of shoulder and wrist joint and keeping a stable lateral position of the shoulder, elbow and wrist joints may be helpful to hit the ball successfully. Hitting moment always occurs when the elbow joint is at lowest position.

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