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ORIGINAL ARTICLE

Comparison of Shooting Time Characteristics and Shooting Posture between High- and Low- Performance Archers

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ABSTRACT

Background. Archery is a precision sport that requires high levels of consistency and reproducibility in the shooting movement to achieve the highest score. **Objectives.** This study aimed to compare and correlate the shooting time characteristics and shooting posture on the archery shooting performance of high- and low-performance archers. **Methods.** Terengganu state team and Malaysia Pahang Sports School archers (n = 16; male: 11 and female: 5; Mean age: 16.19 ± 1.55 years) participated in this study. They were divided into high-performance archers (HPA) and low-performance archers (LPA) based on the total score of 36 arrows shot from 70 meters distance obtained at the beginning of the study. The shooting movements were recorded with a video camera and were then divided into four phases. The duration of each phase was analyzed against the performance of archers. The deviation angle of the right elbow away from the draw force line during anchoring and releasing were measured as the shooting posture. **Results.** The Mann-Whitney test showed that the shooting time of phases 3, phase 4 and the total shooting time were significantly different between the groups (P<0.001). Spearman correlation showed that phase 4 and the deviation angle of the elbow during release were significantly correlated with scores (r= -0.11, -0.08). **Conclusion.** This study showed that HPA and LPA have the same shooting posture with different shooting time characteristics. Archers with a shorter duration in phase 4 and a smaller angle of deviation during release recorded a better result. This finding helps coaches and athletes to improve their shooting techniques.

KEYWORDS: ***Archery, Draw Force Line, Performance, Posture, Timing.***

INTRODUCTION

Archery is a precision sport that uses a bow to launch arrows toward a set target (1). Archery is listed as one of the Olympic sports and recurve bow is the only category in the Olympic Games. In archery, performance is evaluated based on the total scores of the arrows shot within a given period (2). Factors that influence the performance in archery include the physical conditions, techniques, tactics, and psychology (3). An archer needs to perform a fixed sequence of movements that includes drawing a bow, aiming, and releasing (4). Some researchers further divided the movements into six steps: bow holding, drawing, full draw, aiming, release, and follow-through (5, 6). In addition, a well-known coach, Kisik Lee had produced a Biomechanically Efficient Shooting Technique (BEST) method which consists of 13 steps: stance, hook and grip, mind-set, set-up, draw, loading, anchor, transfer, holds and aiming, expansion, release, follow-through, relaxation, and feedback (7). Technically,

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the archer needs to repeat the same sequence of movements consistently for every arrow shot to achieve good results (4).

In a tournament, archers need to shoot six arrows within four minutes in the qualification round. Thus, archers need to manage their time properly in order for them to complete all their shots in the specified timeframe. Takai and colleagues (2012) in their study on the world's top archers concluded that the medalists had a shorter preparatory phase time than the non-medalists (8). A study had claimed that a shot with a shorter drawing duration has higher accuracy (Tinazci, 2011). In addition, the duration of aiming time can have negative effects on the performance of some archers as when the aiming time increased, the quality of the arrow shot deteriorated (9).

Other than shooting time characteristics, the reproducibility of shooting posture is another important factor influencing the shooting performance (10-12). From the drawing to the release phase, an archer extended one arm to push the bow towards the target, while the other arm pulls the bowstring towards the anchor in a rhythmic movement (5). In this posture, a draw force line (DFL) is formed where the position of the elbow and the line of force are aligned with the distance of the shoulder line and the line of force is at the shortest (1, 13). To reduce the vibration of the body, it is crucial to minimize the angle between the elbow and DFL as it will reduce the lateral forces of the arm (1) and stabilize the DFL (13). Researchers also highlighted that the elbow should be within the DFL to reduce muscle fatigue as well as to prevent injury (14).

To the best of the authors' knowledge, no study has yet to compare and correlate between high-performance and low-performance archers in terms of their shooting time characteristics and shooting posture towards their shooting performance. There are few studies conducted on the shooting posture and shooting techniques using infrared motion tracking systems (15, 16). However, there are limited studies that analyze the shooting posture and shooting techniques using two-dimensional video. Furthermore, the previous study only recruited the elite archers to understand to the importance of shooting duration (8, 9) and shooting posture (13). Therefore, this study aimed to contribute to the existing body of knowledge in terms of comparing and correlating the shooting time characteristics and shooting posture variables on archery performance between high- and low-performance archers.

MATERIALS AND METHODS

Ethical Consideration. This study has been approved by the Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPeM/18070335). Official permission has been granted from the Director of Terengganu State Sports Council, the Principal of Malaysia Pahang Sports School, and all the coaches. All the procedures in this study conformed to the ethical guidelines of the 1975 Declaration of Helsinki (17). Informed consent forms were given to all the participants after being briefed on the procedures, the potential risks, and the benefits of the study. Participants that age ranged from 12 to 15 years old received assent forms, while the participants that age ranged from 15 to 18 years old received co-sign informed consent forms with parents. Participants who agreed and signed the consent form were recruited. Participants were free to withdraw from the study at any time without any consequences.

Participants. The sample size was calculated using the software G∗power (18) based on procedures suggested by Beck (2013) (19). Values for α were set at 0.05 and power on 0.80. Based on previous literature (20) and discussions between the authors, effect sizes were estimated as 0.80. It resulted to have at least 13 participants. Considering 20% of the participants dropped out, a total of 16 participants was recruited.

Sixteen (n=16; 11 male; 5 female) youth recurve archers were recruited in this study. They were under the archery development program and represented their state at the national level tournament. The characteristics of the participants are displayed in Table 1. The inclusion criteria of this study included: (1) The participants must be recurve archers and (2) the participants must be a right-handed archers. Archers with injuries in the past three months before the data collection process were excluded.

Study Procedure. In this study, the participants were required to shoot a total of 36 arrows at a distance of 70 meters based on the World Archery format. The shooting movement was recorded with a video camera. The video camera was set at the side (parallel) of the participants at a distance 1.5 meters (Figure 1). Upon completion, the shooting time characteristics and shooting posture of each

shot were further analyzed with motion analysis software, Kinovea (version 0.8.15, France).

Table 1. Participants' Characteristics in Mean±Standard Deviation

Variables	Participants (n=16)
Age (year)	16.19±1.55
Height (m)	1.66±0.07
Weight (kg)	73.78±17.01
Arm span (cm)	1.72±0.10
Experience in state team (years)	2.43±1.84

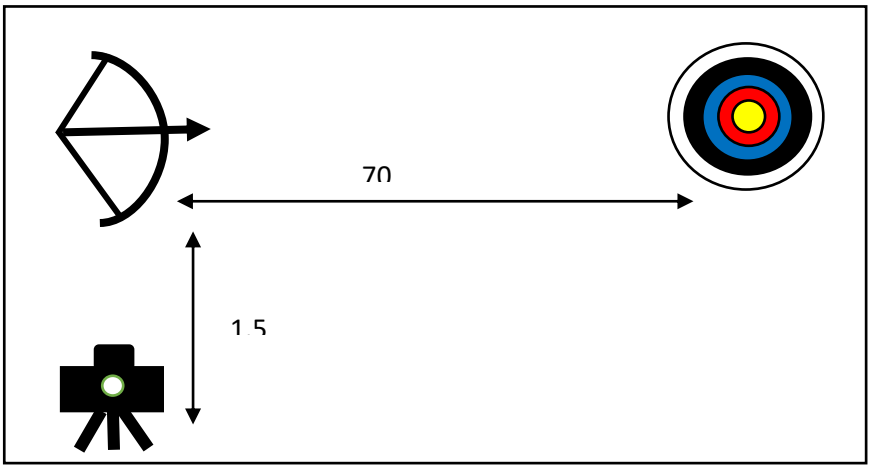

Figure 1. Schematic Drawing of Field Setting for Data Collection

Archery Shooting Performance. The participants shot 36 arrows toward the target set at a distance of 70 meters. The score of each arrow shot was spotted and recorded by the coach with a monocular telescope. All the recorded scores were reconfirmed during the arrow retrieval process. The score of each arrow ranged from miss as "0" to "10" points for the maximum score, and the maximum total score is 360 points. The total score was evaluated as the archery shooting performance. Based on the shooting performance, the sixteen (n=16) participants were ranked and assigned into two groups consisting of high-performance archers (HPA) [HPA = top 8 archers; score: above or equal to 285/360 points] or low-performance archers (LPA) [LPA = bottom 8 archers; score: below 285/360 points].

Video Recording. A video camera (Sony HDR-CX 160, Japan) was used to record the shooting movements of the participants. The shuttle speed of the video camera was set at 30 frames per second. The video camera was placed on a level tripod and the height was fixed accordingly to the sternum height of each participant and perpendicular to the center of the archer at a distance of 1.5 meters to allow a good capture of the position of drawing the bow, aiming, and releasing the arrows from sagittal view. This setting ensured that the calibration area covered the upper body and bow by the participants which were set for field of view for this research. Focus and aperture were adjusted by the video camera produced clear and sharp 2D images (21). Three reflective markers were placed on the left radial styloid process, right Lister's tubercle, and right olecranon process to analyze the shooting posture during anchor and release. In this study, the left arm that holds the bow handle was described as the bow hand while the right arm that pulls the bow string was described as the draw hand.

Shooting Time Characteristics. This study breaks down the shooting movements into four main phases, as highlighted by Leroyer et al. (5). Phase 1 begins when the archer lifts the bow until the pre-draw movement. Phase 2 is from the pre-draw until the full draw and anchoring. Phase 3 is from full draw until the release of the arrow, denoting the time taken for aiming and phase 4 is from the release of the arrow until the end of the follow-through (Figure 2). The time taken for each phase and the total time taken to shoot an arrow were measured using motion analysis software, Kinovea (version 0.8.15, France).

Shooting Posture. The shooting postures during anchoring and release were analyzed using the motion analysis software, Kinovea (version 0.8.15, France). The recorded videos were then converted into 0.04 seconds per frame. The recorded videos were played back frame by frame to detect the frame of the arrow released. The frame before arrow release was used to measure the shooting posture during the anchoring while the 10th frames after releasing the arrow were used to analyze the shooting posture of release.

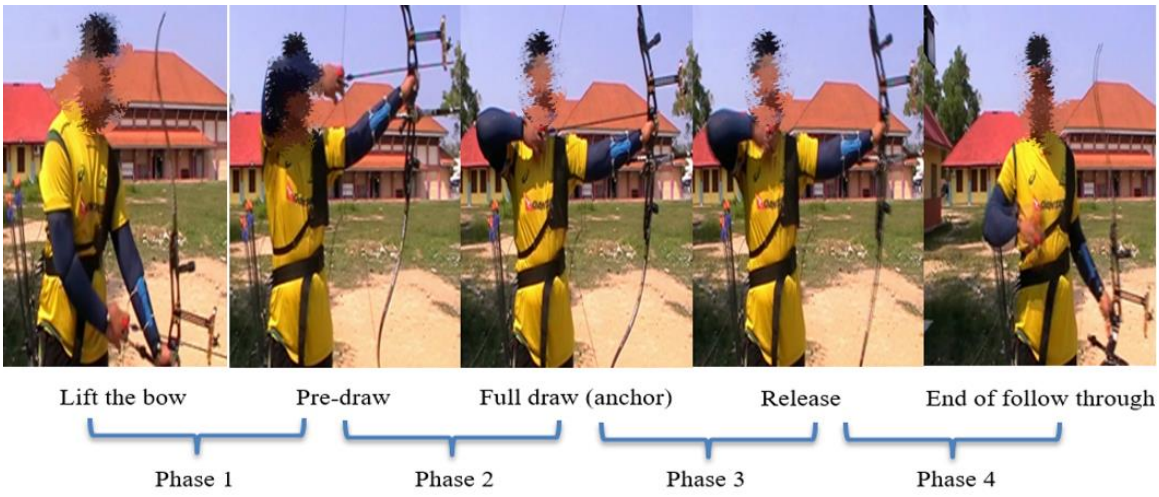

Figure 2. Four Phases in Shooting an Arrow.

The shooting postures were analyzed based on the deviation angle of the elbow away from the DFL during anchor and release. To measure the deviation angle, a straight line was drawn from the left radial styloid process to the right Lister's tubercle and another line was drawn from the right Lister's tubercle to the right olecranon process (13). The angle between the lines was the elbow deviation angle from DFL (Figure 3).

Figure 3. Shooting posture. (a) The elbow deviation angle from DFL during anchoring. **(b)** The elbow deviation angle from DFL during releasing.

Statistical Analysis. Statistical analysis was conducted using Statistical Package for the Social Science (SPSS) version 26.0 (SPSS Inc., Chicago, ILL, USA). The Kolmogorov-Smirnov test was used to test the normality distributions of the data. With the significance value was set at p-value <0.05. As the data were not normally distributed, the shooting time characteristics and shooting postures between HPA and LPA were comparatively analyzed using the Mann-Whitney test with the significant value was set at $P \leq 0.05$. The Spearman correlation test was used to understand the correlation between the shooting time characteristics and shooting postures with the

arrow scores with the significant value was set at P≤0.05. The percentage of difference was calculated with the formula:

$$PD = \frac{HPA - LPA}{(HPA + LPA)/2} \times 100\%$$

PD: percentage difference, **HPA:** high performance archer, **LPA:** low performance archer

RESULTS

Descriptive Statistics of the Tested Variables. Table 2 depicted the descriptive statistics of the tested variables. From the table, the minimum and maximum values, mean and standard deviations of the archery performance, time taken for each phase and shooting postures during anchor and release are displayed.

Comparison of Shooting Time and Shooting Posture. Based on the result of the Mann-Whitney test (Table 3), HPAs have a significantly higher score than the LPA (HPA= 8.00±1.00 vs. LPA= 7.00±2.00, P<0.05, percentage differences= 13.33%). There was a significant difference in shooting time between phases 3 and 4. For the HPA, phase 3 was longer (HPA= 3.38±2.18 vs. LPA= 2.72±1.72, P<0.05, percentage differences= 21.64%) while phase 4 was shorter (HPA= 2.40±0.44 vs. LPA= 2.72±0.51, P<0.05, percentage differences= 12.50%) as compared to the LPA. Furthermore, HPA took a significantly longer time to complete a shot than the LPA (HPA=10.46±2.39 vs. LPA=9.74±2.84, P<0.05, percentage of differences=7.13%). However, for the shooting posture, there were no significant differences during anchoring and releasing between HPA and LPA (P>0.05).

Correlation between Shooting Time and Shooting Posture with Score. All phases did not show any significant correlation with an arrow score (P>0.05) using the Spearman correlation test (Table 4) except for phase 4, which showed a negative correlation (r=-0.111). The shooting posture during release is negatively correlated with the arrow score (r=-0.083) while the shooting posture during anchor did not show any significant correlation with the arrow score.

Table 2. Descriptive Statistics of the Tested Variables

Variables	Min	Max	Mean	STD
Archery performance				
Score of arrow	**0**	**10**	**7.58**	**1.94**
Shooting time characteristics (second)				
Phase 1	1.76	4.71	2.85	0.65
Phase 2	0.56	3.12	1.48	0.50
Phase 3	0.56	10.04	3.32	1.60
Phase 4	1.76	4.68	2.69	0.47
Total time taken	6.24	16.68	10.33	1.89
Shooting posture (°)				
Anchor	1.00	8.00	4.26	2.19
Release	32.00	79.00	59.75	7.05

MIN: minimum; MAX: maximum; MEAN: mean; STD: standard deviation

Table 3. Comparison of the archery performance, shooting posture and shooting time characteristics between high-performance archers and low-performance archers

	Median (IQR)		P-Value	Percentage Differences (%)
	High-Performance Archers (n=288)	Low-Performance Archers (n=288)		
Archery Performance (point)				
Score	8.00 (1.00)	7.00 (2.00)	<0.001**	13.33
Shooting time characteristics (second)				
Phase 1	2.80 (0.83)	2.84 (1.35)	0.329	-1.42
Phase 2	1.46 (0.86)	1.36 (0.64)	0.174	7.09
Phase 3	3.38 (2.18)	2.72 (1.72)	<0.001**	21.64
Phase 4	2.4 (0.44)	2.72 (0.51)	<0.001**	-12.50
Total time taken	10.46 (2.39)	9.74 (2.84)	<0.001**	7.13
Shooting posture (°)				
Anchor	4.00 (4.00)	4.00 (3.00)	0.132	0.00
Release	59.00 (9.00)	59.5 (11.75)	0.373	-0.84

****P-Value<0.001**

Table 4. Correlation between shooting posture and shooting time characteristics with score of arrows.

Variables	Score (n=576)	
	r	P-Value
Shooting time characteristics (second)		
Phase 1	-0.004	0.921
Phase 2	0.031	0.456
Phase 3	0.016	0.704
Phase 4	-0.111	0.008*
Total time taken	-0.006	0.884
Shooting posture (°)		
Anchor	-0.032	0.442
Release	-0.083	0.047*

***P-Value<0.05**

DISCUSSION

This study aims to investigate the differences in shooting time characteristics and shooting posture line between HPA and LPA. The outcomes revealed that HPA has a relatively longer duration in aiming and shorter duration in follow-through than the LPA although their shooting position is almost similar. In addition, this study indicated that shooting posture during release and the duration for follow-through have effects on the shooting scores.

In archery, it is crucial for the archers to manage their shooting time as the archers are required to finish six arrows within 240 seconds (approximately 40 sec./Arrow). In this study, the archers spent more time in phase 3 than the other phases, which refer to the time for them to aim at the target. HPA spent approximately 0.70 seconds more than the LPA during the aiming phase. Although the current study did not test for muscle strength and endurance, a possible reason for this is that HPA has better endurance and strength to hold the bow tension and aim to the center target before their hand starts to tremor (2, 22). Besides, due to the time pressure, the LPA may feel stressed with the time constraint and reduce their aiming time to cope with the limited time. Time pressure is known as a psychological stressor that can deteriorate performance and decision-making behavior (23, 24). The result of this study contradicts the findings that aiming duration is negatively correlated with performance (10, 25). Interestingly, one study had shown that medalists have a shorter aiming duration than non-medalist (8). It is important to note that the participants of this current study were state-level archers meanwhile the previous study recruited elite-level archers. The elite archers may have more experience in archery and they are able to stabilize their aiming faster than others.

This study revealed that HPA spent approximately 0.32 seconds less than LPA in phase 4, reflecting the time used to release the arrow and follow through. The scholar has identified that elite archers have a better reaction time towards the clicker sound and perform their release faster than novice archers (1). Besides better reaction time, research has also identified that the speed of release plays a significant role, as a better score can be achieved when the archers perform a faster release. This is due to a slow-release action may interfere with the string to launch the arrow properly (26). Another possible reason is that the additional weight on the stabilizer of HPA is heavier than LPA, thus making the bow swing faster during the follow-through. Besides comparing HPA and LPA, the correlation test of the current study also showed that a better score was achieved when the duration of phase 4 is shorter. The result of time spent in phase 4 of the current study contradicted by another study where they found that medalist and non-medalist archers have similar time spent in phase 4 (8). One possible explanation for this might be that medalists and non-medalists in the latter study were categorized as top-level archers.

In terms of overall shooting time (performing a full shooting sequence), HPA spent more time shooting an arrow as compared to LPA where HPA used approximately 10.46 seconds and LPA used 9.74 seconds to complete a shot. This is due to HPA spent about 32% of the time in aiming as this is one of the crucial phases to determine the score of the shot. Again, the result contradicts a study that non-medalist spent approximately 10 seconds more than medalist to finish a shot as they spent about 14 seconds in their preparatory phase while the medalist spent approximately 8 seconds only (8). It is important to note that, the current study starts phase 1

when the archers lift the bow, whereas in the previous study, it includes the time to stand, set, and nock arrows in their phase 1. However, in terms of the overall sequence of the shooting pattern, the HPA indicated the same trend as the shooting characteristics of the medalist where phase 1 and 3 duration is longer than phase 2 and 4. For LPA, this pattern is not depicted, based on the result in the Table 3, the median duration of phase 3 and 4 is almost the same for LPA.

Consistency of body posture is very important in archery (12). In this study, the deviation of elbows away from the draw force line (DFL) during anchoring and releasing were measured as the shooting posture. The results showed that there are no significant differences between HPA and LPA in the shooting postures as both of the groups maintain the elbow elevation at 4° from DFL during anchoring. There are no differences in the shooting posture (technique) because the training program for both groups (HPA and LPA) follows a similar technical module from Korea. The Korean module stated that 3° to 6° of elbow elevation from DFL is acceptable as it is able to maintain the posture stability and the release consistency to prevent the arrow deviated from the string during the release movement (27). In archery, the technique used in the release phase is one of the most crucial factors to achieve a high score (28).

In archery, it is important to keep the elbow in line with the DFL. When the elbow is not in line with the DFL, the biceps and triceps of the drawing arm require more force to hold the string and it will cause muscle fatigue and lead to injury (1). However, it is common to have some deviation from the DFL in recurve category. In this study, there is a negatively related correlation between the shooting posture during release and the score of the arrow. This finding is in concordance with the previous study which indicated that the smaller the deviation from the DFL in anchoring and release shows a better score for an international level archer (13). Besides, a study by scholars in Korea found that as the lower back muscle strength increased, the degree of the elbow elevation away from the DFL decreased while the shooting performance improved (29, 30).

There are a few limitations acknowledged in this study. Firstly, the video was taken in a sagittal view only. It would be more informative to analyse the shooting posture from both axial and sagittal views. Secondly, this study was conducted with a video camera. It is recommended for future studies to use 3-dimension (3-D) motion analysis to analyse more variables such as the angular speed in releasing and the postural sway. Finally, the participants of this study were mainly adolescent archers in the state training program. It is highly recommended for future studies to recruit different experience levels such as novice and international levels for comparison as the shooting characteristics and shooting posture could be different.

In conclusion, archers and coaches should focus on the shooting time management from aiming to end of follow-through as well as the body posture during release. They are the most significant variables that can affect the arrow scores based on this study.

CONCLUSION

Variation in the shooting characteristics was reported in the previous study for different archers. In order to improve the performance, the study of shooting characteristics were done in two different groups of archers. This study analyzed the shooting time characteristics and shooting posture towards an archery performance for different groups of archers. This study has found that there are significant differences in shooting time characteristics between HPA and LPA. Furthermore, archers with a shorter duration in follow-through and smallest deviation in the angle of the elbow from DFL have a higher chance to shoot a better score.

APPLICABLE REMARKS

- It is important for coaches and archers to apply the correct and proper shooting posture and techniques to excel in the sport.
- Subsequently, the use of simple technology such as video camera and motion analysis software were able to analyze shooting movements. This method is ideal and applicable for the coaches and archers to analyze and understand their shooting techniques in field settings.

CONFLICT OF INTEREST

There is no conflict of interest between the authors.

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FINANCIAL DISCLOSURE

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AUTHORSHIP CONTRIBUTION

Study concept and design: Lau Jiun Sien, Rosniwati Ghafar, Erie Zuraide Zulkifli, Hairul Anuar Hashim. Acquisition of data: Lau Jiun Sien. Analysis and interpretation of data: Lau Jiun Sien, Rosniwati Ghafar. Drafting of the manuscript: Lau Jiun Sien, Rosniwati Ghafar, Erie Zuraidee, Harsa Amylia Mat Sakim. Critical revision of the manuscript for important intellectual content: Hairul Anuar Hashim. Statistical analysis: Lau Jiun Sien, Rosniwati Ghafar. Administrative, technical, and material support: Lau Jiun Sien, Rosniwati Ghafar, Hairul Anuar Hashim. Study supervision: Lau Jiun Sien, Rosniwati Ghafar, Hairul Anuar Hashim, Erie Zuraidee Zulklfli.

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