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# Correlation Between Archer's Hands Movement While Shooting and Its Score

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**Abstract**

In archery, the most critical time is a few seconds before the release of the arrow because the trajectory of the released arrow is dependent on the movement of the archer's arms in the release phase. An archer use's two hands while drawing a bow, one hand to push on the bow riser and the other to pull the string. The archer's performance can be quantified through the analysis of the movement of both the archer's arms while releasing the arrow. In this paper, a study of the arm movement of an archer while shooting using recurved bow is presented. In the experiments, university level archers shot six arrows per frame and each archer shot three frames each whilst wearing a dedicated small sized accelerometer in both arms. The generated data, in terms of linear acceleration, was streamed in real time to a computer wirelessly via Bluetooth. The sampling rate of the accelerometer was about 15Hz. The forward-reverse, up-down, left-right motion of both arms as well as the score and the position of the arrow of each shot were recorded. A high score category is when an archer shot ten, nine, and eight points while three, two, and one points score is a low score category. The analysis of the data showed a correlation between the archers' arm movement and their score. Although the arm movement generated a similar displacement pattern for a higher score and a lower score, a high bow arm's movement in transverse plane upon releasing the string may lead to a lower score.


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*Keywords:* archery; recurved bow; accelerometer; vibration;

## 1. Introduction

In archery, the most critical time is a few seconds before the release of the arrow. This time is the most critical because the trajectory of the released arrow is dependent on the movement of the archer's arm in the release phase. The World Archery Federation defines ten stages for shooting an arrow using recurved bow namely stance, setup, hooking, grip, drawing, anchor-ing, full draw, extending, release, and follow through [1]

Archers usually extend the drawing until the clicker on their bow fall then release the bow string to launch the arrow. During extending, the archer has to maintain the static balance of forces between the external tension of the bow and their muscular forces at the time of shooting [2]. Therefore, it is hypothesized that a severe movement of the arms during extending and release may influence the scores as it marks the point where the arrow acquires its initial trajectory and leaves the bow at a specific speed.

## 2. Related work

Several researchers had published several methods to monitor the forearm movement by an archer. Ertan et al. analyzed electromyography signals of extensor digitorum muscle and flexor digitorum superficialis of elite, beginner and non-archer [3].

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Their works showed that the release reactions of elite archers after the clicker fall were faster than beginner archers or non-archers. Thus, they concluded that the development of extensor digitorum muscle and flexor digitorum superficialis coordination were critical in order to react efficiently to the clicker fall.

Apart from the forearm muscles, Tinazci published a study, which correlate the forearm muscle activities with the postural sway of the archer [4]. He established that coordination of specific muscular strategy, aiming behavior and postural sway can increase the archer scoring performance. Their work showed that the acceleration of the arm caused by postural sway may contribute to an archer's scoring performance.

Ganter et al. developed three methods to monitor bow movement form three archers. They have used an optoelectronics system, a 3D video system and a 2D video system [5]. They concluded that optoelectronics device and 3D video system cannot be used in competition due the additional device mounted on the bow and time constraint to setup the 3D system. Both systems however were very useful in measuring individual techniques during training.

However, tracking human movement using wearable electronics devices is being researched across all sports disciplines. Sports, such as tennis [6], swimming, [7], cricket [8] have been using wearable electronics devices to assess athlete's performance. The wearable electronics devices typically consist of inertial measurement unit that is capable of measuring linear acceleration, radial acceleration as well as the orientation. The analysis from these inertial measurement units worn by an athlete usually gave the researcher insights on the athlete's technique during a training session or even the actual competition.

## 3. Method

In this paper, a simplified method is used to monitor the arm movement of the archer. Accelerometers were strapped to both, right and left arms of the archer. The hand, which handled the bow, is called the bow arm while the hand, which pulled the string, is called the string arm. The position of the accelerometers with its positive direction is shown in figure 1. For the bow hand, the measured acceleration in x-axis is positive in a leftward direction with respect to the archer and the measured acceleration in the z-axis is positive in a backward direction with respect to the archer. For the string hand, the measured acceleration in the x-axis and z-axis is positive in the opposite directions of the x-axis and z-axis acceleration of the bow hand respectively. However, the measured acceleration in y-axis for both hands is positive in the downward direction with respect to the archer.

The generated data was transferred wirelessly using Bluetooth. The device, as shown in figure 2, is programmed to take samples at about 15Hz rate. The measured acceleration data was integrated to calculate the velocity and the calculated velocity was integrated again to calculate the displacement of the archers' arm. This calculated displacement was used to analyze the movement of the archers' arm.

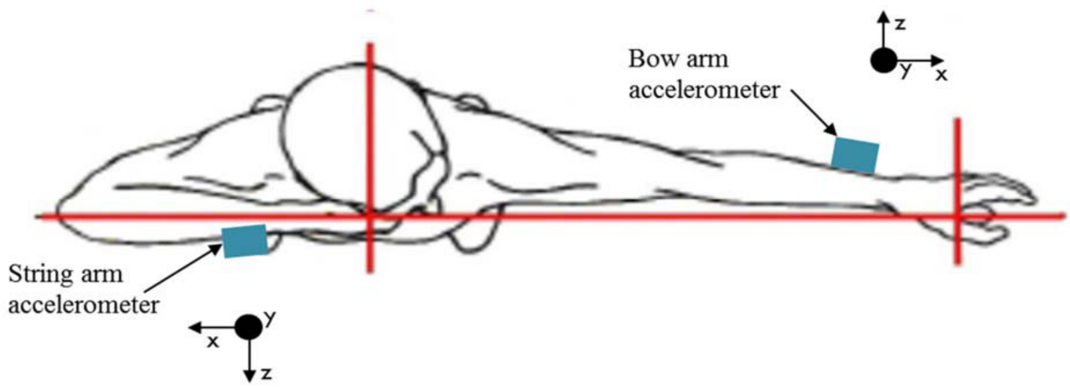


Fig. 1: The position of the accelerometers with its positive direction

(a) (b) (c)

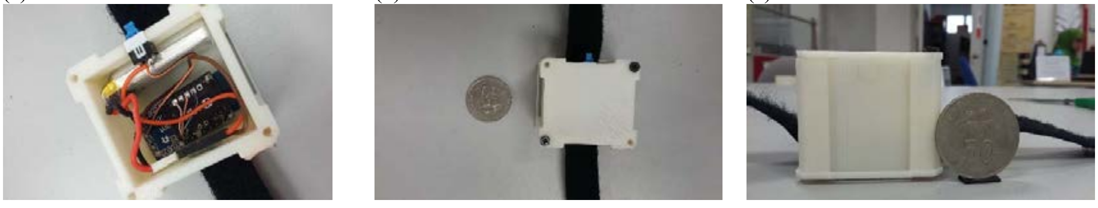

Fig. 2. The accelerometer used in this experiment. (a) Inside view. (b) Top view. (c) Side view.

Two university level male archers were involved in this study. They were under training to represent their university in a National University Games. In this study, all archers are right-handed and used recurved bows. Both archers weigh about 70kg and about 170cm in height, with at least one year experience competing in university level competition. Each archer shot six arrows per frame and three frames each. Therefore, each archer shot 18 shots of arrows. The distance between the target and the archer was 70m. Every score from each shot was recorded.

## 4. Result and Discussion

The distribution of the score is as shown in figure 3. The highest number of score shot is eight with seven times. The maximum score occurred four times and the worst score two times. The scores were categorized as low, medium and high. The low category consists of score 1, score 2, score 3, and score 4. The medium category consists of score 5, score 6, and score 7, while the high category consists of score 8, score 9, and score 10.

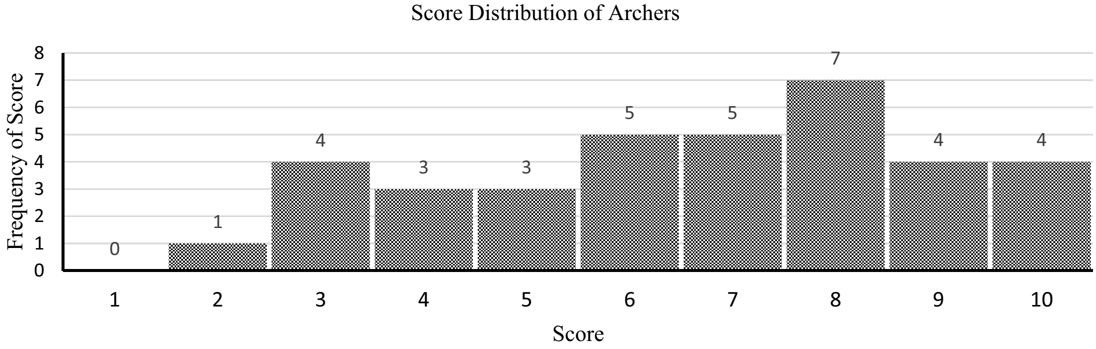


Fig. 3. Distribution of the archer's score

The typical displacement patterns of the bow and string arms are shown in figures 4 and figure 5 respectively. A distinct feature observed is the sudden movement in all three axes of both the string and bow arms upon release of the arrow. The beginning of the aiming phase is identified by the z axis in a steady state after a significant drop of the bow arm during the anchoring phase and the string arm rising in the x axis during the anchoring phase before settling in a steady state at the aiming phase. These are then followed by the sudden movement marking the releasing phase.

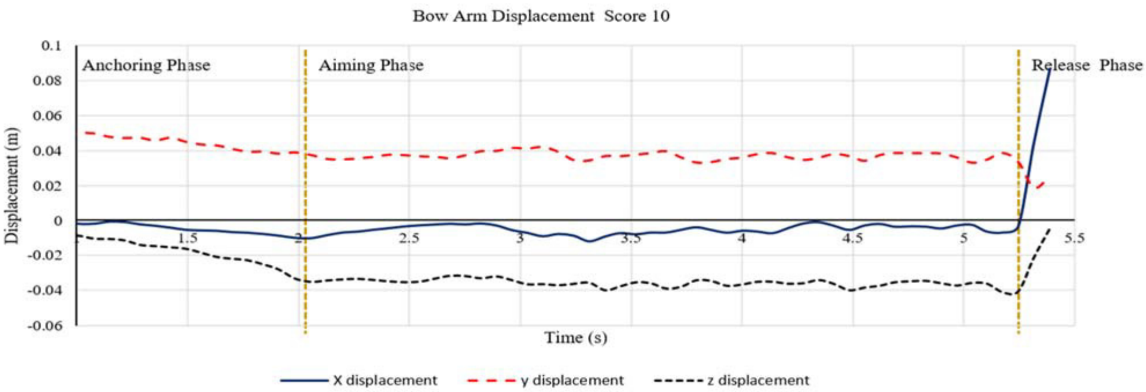


Fig. 4. A typical displacement pattern for string arm


Fig. 5. A typical displacement pattern for bow arm

### *4.1. Analysis of arm movement related to highest and lowest score.*

The arm movements during the highest score of ten and lowest score of three were analyzed. The analysis was done on one archer who shot several score of three and several score of ten. The movement patterns of both arms are similar as shown in figure 6 for the string arm and figure 7 for the bow arm.

However, there were certain characteristics that differentiate the movement patterns of the highest and lowest scores. Firstly, the amplitude of the arm movement during the releasing phase of score 10 was significantly higher than the releasing phase of score three especially in the z-axis for the string arm and x-axis for the bow arm. The high amplitude during release may indicate the speed of the archer arm pulling away from the string. A slow pull away reaction may hinder the string to launch the arrow properly thus resulting in a lower score.

Secondly, the arm in the y-axis direction moved slightly later than the movement in the x- and z-axes directions for score 10 compared to almost simultaneous movement in all three axes direction for score three. A simultaneous movement of the arm in all three directions during the release stage may cause the bow to be tilting as the arrow leave the bow. The tilt of the bow will result in a poor score as the arrow will fly in an off center trajectory towards the target.

Focusing on the bow arm displacement, during the aiming phase the arm oscillation is less for score ten compared to the aiming phase of score three especially on the y-axis. The duration of the aiming phase is also significantly longer for score 3 compared to score 10. The higher oscillation of the bow arm coupled with longer aiming duration may introduce fatigue in the archer's bow arm. This may affect the potential energy stored in the bow during a full draw thus contributing to a lower score.

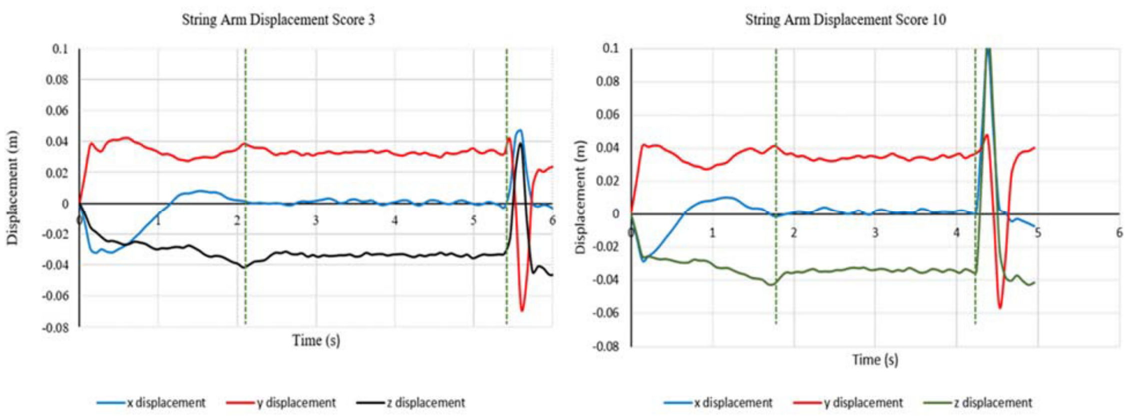


Fig. 6.Comparison of string arm movement pattern between score 10 and score 3.

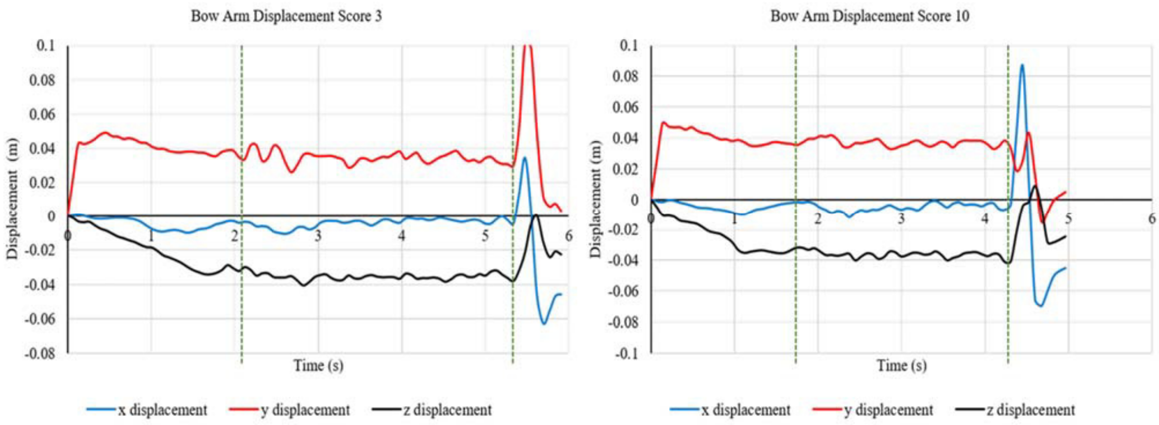


Fig. 7.Comparison of bow arm movement pattern between score 10 and score 3.

As the release phase is critical, the maximum displacement amplitude on release were analyzed. The average maximum displacement of the arm movement on release of all axes is tabulated against the low, medium and high scores shown in Table 1. Generally, the maximum displacement amplitude shows an opposite direction between the bow arm and the string arm across all axes except for the movement in z-axis that resulted in medium score.

Focusing on the movement in x-axis direction, the result shows to be very similar for low, medium and high score where the bow arm movement upon release is significantly higher than the string arm movement. This movement pattern can be explained by the forward movement of the bow upon string release. On the other hand, both arms movement in y-axis shows almost equal displacement across all score albeit in opposite direction. However, the movement in z-axis shows a significant difference between low score and high score. For the low score, the average maximum displacement in z-axis is high in the bow arm movement and low in the string arm movement while for the high score, the average maximum displacement in z-axis is high in string arm movement and low in the bow arm movement. This movement in transverse plane upon release may affected the bow positioning and changing the initial trajectory of the arrow away from the center target.

Table 1. The average maximum displacement amplitude on release.

| | | The average maximum displacement amplitude on release (m) | | |
|---|---|---|---|---|
| | | x-axis | y-axis | z-axis |
| Low score | Bow arm | 0.068 ± 0.05 | 0.028 ± 0.04 | 0.029 ± 0.03 |
| | String arm | 0.012 ± 0.01 | -0.028 ± 0.02 | 0.013 ± 0.05 |
| Medium score | Bow arm | 0.011 ± 0.07 | 0.015 ± 0.02 | 0.010 ± 0.08 |
| | String arm | 0.012 ± 0.03 | -0.018 ± 0.03 | -0.010 ± 0.03 |
| High score | Bow arm | 0.092 ± 0.03 | 0.024 ± 0.04 | 0.014 ± 0.03 |
| | String arm | 0.016 ± 0.02 | -0.030 ± 0.03 | 0.033 ± 0.03 |

Another aspect of the displacement pattern is the time taken for the archer to aim before releasing the string. An average time taken in the aiming phase is shown in table 2. From table 2, it can be seen that the average time taken in the aiming phase decreases as the scores get higher. Although the average time taken for medium and high score were similar, the standard deviation for the high score is smaller. The longer time taken during aiming phase may contributes to archer's arm fatigue.

Table 2. Time taken in aiming phase.

| | Average time taken in aiming phase (s) |
|---|---|
| Low score | 4.2 ± 1.4 |
| Medium score | 3.0 ± 1.4 |
| High score | 2.9 ± 0.4 |

## 5. Conclusion

In this paper, correlation between archer's arm movement pattern and its score using accelerometer had been identified. By analyzing the average maximum displacement amplitude upon release, a high bow arm's movement in transverse plane may lead to a lower score. Furthermore, the longer time taken in aiming phase may also contributes a lower score. However, the archers featured in this paper were only competing in college/university level tournament. Higher-level athletes, such as those who are competing in Olympics, Commonwealth, or Asian Games may produce different movement pattern.

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## References

[1] World Archery Federation, Coach ' s Manual RECURVE BOW Intermediate Level,

[2] M. Heller, Evaluation of arrow release in highly skilled archers using an acoustic measurement system, Procedia Eng. 34 (2012) 532–537.

[3] H. Ertan, B. Kentel, S.. Tümer, F. Korkusuz, Activation patterns in forearm muscles during archery shooting, Hum. Mov. Sci. 22 (2003) 37–45.

[4] C. Tinazci, Shooting dynamics in archery: A multidimensional analysis from drawing to releasing in male archers, Procedia Eng. 13 (2011) 290–296.

[5] N. Ganter, K.C. Matyschiok, M. Partie, B. Tesch, J. Edelmann-Nusser, Comparing three methods for measuring the movement of the bow in the aiming phase of Olympic archery, Procedia Eng. 2 (2010) 3089–3094.

[6] A. Ahmadi, D. Rowlands, D. James, Using wearable inertial sensors for skill assessment of the tennis serve, J. Sci. Med. Sport. 13 (2010) e33.

[7] J.B. Lee, B.J. Burkett, D.V. Thiel, D.A. James, Inertial sensor, 3D and 2D assessment of stroke phases in freestyle swimming, Procedia Eng. 13 (2011) 148–153.

[8] A. Wixted, D. James, A. Busch, M. Portus, Wearable sensors for the monitoring of bowling action in cricket, J. Sci. Med. Sport. 12 (2010) e38.