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BIOMECHANICS MEASUREMENTS IN ARCHERY

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ABSTRACT

The purpose of this study is to measure the biomechanics parameter of the archery sports and correlate to the games performance. Archery becomes as one of the prospect sports to contribute medal in Olympics Games 2016. Therefore, the research in this sport is directly affected to the athlete performance during games tournament. This research is considered as preliminary study to measure the biomechanics parameters for applied to the professional athlete. The biomechanics parameter such as muscle activity, heartbeat, balancing and body posture as well as draw force line were chosen as important parameters related to the athletes performance. The subject was shooting the arrow on the force plate meanwhile the high speed video camera capturing the arrow velocity, body posture and elbow angle. Furthermore, those parameters will correlate to the point of target in order to propose the right technique for the player. The finding in this study will help the coach and athlete to improve the performance of the games, especially for the beginner level to become expert as an elite player.

***Keywords*:** Biomechanics; Sport; Archery; Muscle; Performance.

1.0 INTRODUCTION

Archery is a sport which propel arrow with a bow to the target during shooting (Lee, 2009). Shooting in archery can be summarized as drawing the bow, aiming and released the arrow (McKinney and McKinney, 1997). In archery it is important that the archer is able to hold the pulling force of the bow isometrically at release. Any collapse or movement forward of the draw arm results in a reduction of velocity of the arrow and this results in the arrow going slow on the target. High performance shooting in archery is defined as the ability to shoot an arrow at a given target with accuracy (Soylu, et al., 2006). Alignment of bow arm is important as it will produce certain angle and if the alignment is incorrect the force applied to muscles may increase. Forces that acting on archer may be differ as the skill and technique are different from each other. It also involves the rhythms of releasing the arrow which is differ between elite and sub-elit archer (Hu and Tang, 2005).

Application of biomechanics in archery is very useful. It helps in control the movement of muscles and reducing the fatigue effects that may occur which causes serious injuries in long term. Moreover, the joint moment also crucial in analyse the motion of human body and to be more understand about how or why the injuries occur (Kristianslund, et al., 2012). According to the biomechanics principle in archery, the forces acting on the bones should be maximize while force acting on muscles should be

minimize in order to reduces the injury impact to the archer. The force applied should be more on bones rather than muscles is because bones do not get tired yet muscles most certainly fatigue.

The angle and position of the elbow plays an important role in subjecting force to the shoulder. Therefore, the position of elbow should be aligned with the line of force as the distance of the shoulder line and line of force at the shortest. This line called as draw force line (DFL). On the other hand, the incorrect position of elbow caused muscle action to maintain lever draw force in line. If it happens continuously, it may cause muscle fatigue, afterwards decreased the performance. In order to minimize the lateral forces of arm, the angle between forearm and DFL should be small.

During archery shooting, upper limb muscles are the most active muscle compared to the lower-limb muscle due to the needs to pull and hold the bow until released the arrow. However, the extremely vigorous muscle and needs more strength to pull and hold the bow in the forearm. The common forearm muscles which is involved in this shooting are; flexor digitorum and extensor digitorum. Furthermore, It also involves deltoid muscle, trapezius muscles, medial epicondylitis and pectoralis major muscle. By using electromyography (EMG) equipment, the muscle activity can be detected and analyse.

One of the key elements to obtain better stability in archery is having a good stance. The term stance specifically refers to the standing posture of the archers. Stance requires the strength in the legs, and the right stance can help to maintain the stability while standing for an extended duration. Therefore, the release phase must be well-balanced and highly reproducible to achieve commendable results in an archery competition (Tinazci, 2011). In archery, the archers are required to stand statically for a quiet period of time and having the accurate stance helps them to maintain the body balance for the overall arrow shooting process. A good stance can help the archer to sustain their stability for a longer time hence helps them to aim to the target board. When the body is stable, the archer's shots will be more consistent and less frustrating. The different levels of archers are represents different style of stance and different weight distribution depends on the body posture, height and bone structure.

General biofeedback is a tool to provide human beings with enhanced awareness of their mind-body lineage, increased control over their physiology, and increased access to self-regulation strategies (Donald and Sue Vietta, 2012). The biofeedback would awaken human creativity and enable human beings to reach higher states of consciousness. The biofeedback device will help to show the concentration of an archer. Therefore, the higher-frequency level of an athlete, the more concentrates of an athlete to the target.

The purpose of this study is to measure the biomechanics parameter based on the archer performance. All the measurements are considered as preliminary study in order to optimize the equipment, location and subject constraints. In conducting this experiment, there are several hypotheses to comply as well as increased the performance which draws force should be in line, reduce the muscle activity, weight balancing and aiming concentration.

2.0 METHODOLOGY

An experience coach was selected to be as a subject to shot the arrow on the force plate indoor. The archer was right handed and recurve bows were used in this study to shoot the arrow. The subject physical characteristics are 23 years of age, height (180 cm) and

body weight (84 kg). EPIX High speed camera, SHIMMER Electromyography, AMTI Force Plate and Biofeedback device were used to setup the experiment. Since the experiment is simultaneously, therefore some equipment's were install on the subject body such as EMG and Biofeedback device.

EPIX High Speed Camera

High speed camera was performed to ensure that the subject in correct position of draw force line. Furthermore, the correct technique will prevent the injury called "rotor cuff" which is very painful and requires a long time to repair. Figure 1 show the position of two high speed cameras required to record the top view and the sagittal view of the athlete from drawing the bow, aiming and releasing phases. Both cameras were synchronized together and set to 150 frames/sec as shown in Figure 2. In order to measure the draw force line, 12 reflective markers were placed at the each joint such as wrist, elbow and shoulder for both arms. Then, XCAP software was used to measure the angle, distance and draw force line accurately.

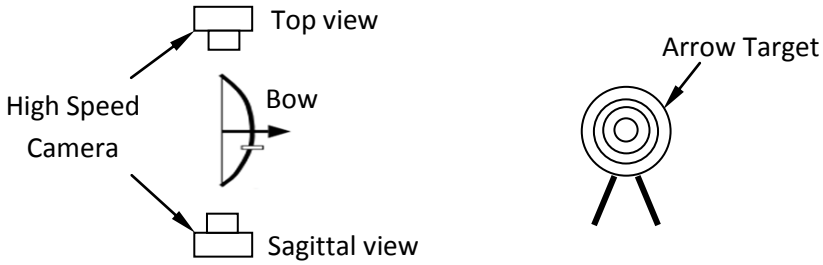

Figure 1. High speed camera set up.

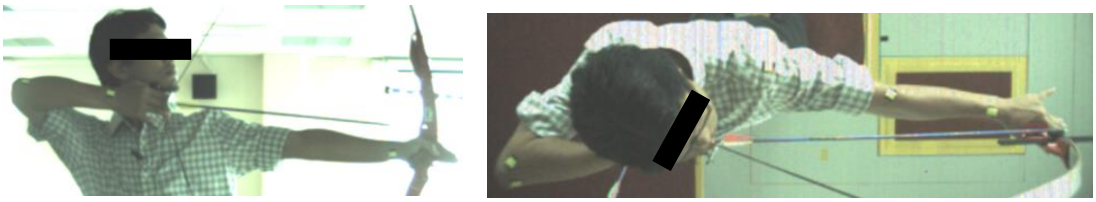

Figure 2. Camera synchronization for lateral view (left) and top view (right)

Shimmer Electromyography

Electromyography (EMG) is an equipment for analyse the muscle activity by evaluating and recording the electrical activity produced by skeletal muscle. During archery shooting there are muscles involve which is deltoid, flexor digitorum and extensor digitorum. However, only right deltoid and flexor digitorum were selected to be observed due to the most muscle activity are there. The muscle activation were recorded at a sampling frequency of 1000Hz. All the signals were recorded for three stages; drawing, aiming and releasing. Then the results will obtain and plotted in the graph. Figure 3 indicates the EMG location of measurement on the subject.

Figure 3. EMG location of measurement

AMTI Force Plate

The AMTI Force Plates will be used to acquire the signal of force acting on the feet and it called ground reaction force (GRF). During this experiment, the subject was took his position on the platform with his left foot placed on the force plate 1. The data was collected for five seconds, however, only the data from the first four seconds of experiment are used due to the time shooting attempts period. It consists of all stages in shooting which are drawing, aiming and releasing the arrow. The subject weight and height was measured before start the experiment. After completed the shooting process, the force data can be analyzed using BioAnalysis software to obtain the weight distribution of foot for each milliseconds.

2.4 Biofeedback Device

The biofeedback device is inserted in Figure 4 below to get the frequency level of an archer. The device should be calibrated first about 60 seconds in order to get the signals. After finish the equipment setup, the archer will start to shoot. The archer will release the arrow after aiming for three seconds and countered by stopwatch. The results of the shot points will be view from the digital camera. For the biofeedback analysis, the BioGraph Infiniti Physiology Suite software was used to record and analyze the data. The blood volume pulse (BVP) sensor was placed to the archer finger as shown in Figure 4.

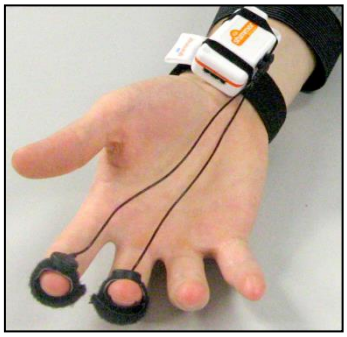
Figure 4. The BVP sensor attached to the finger

The BVP sensor does not require skin preparation as it is placed directly in contact with the skin. Furthermore, the device also will take the data on BVP of the archer. The BVP sensor shines infrared light through the finger and measures the amount of light reflected by the skin. The amount of reflected light varies during each heart beat as more or less blood rushes through the capillaries. The sensor converts the reflected light into an electrical signal and processed using biofeedback software.

3.0 RESULTS AND DISCUSSION

The findings in this study were divided into four sections such as describing in the methodology. There are draw force line, muscle activity, weight balancing distribution and aiming concentration during shooting. This section presents the biomechanics parameters were obtained from the experiment as follows:

Draw Force Line

The origin point is at the elbow act as reference point to get the distance and angle from elbow to the shoulder. As referred to the Figure 5, the angle was measured 45° clockwise. The line was connected between each joint that marked by yellow marker. The elbow is not in line and it is common for recurve archer. However, that size of angle still considered acceptable since the small distance from dotted arrow DFL.

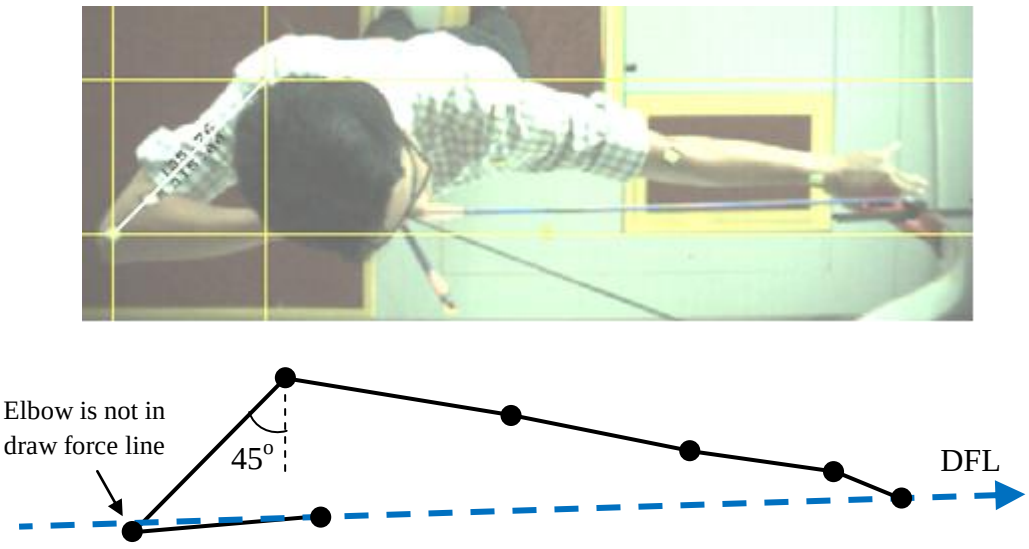

Figure 5. DFL was measured from top view

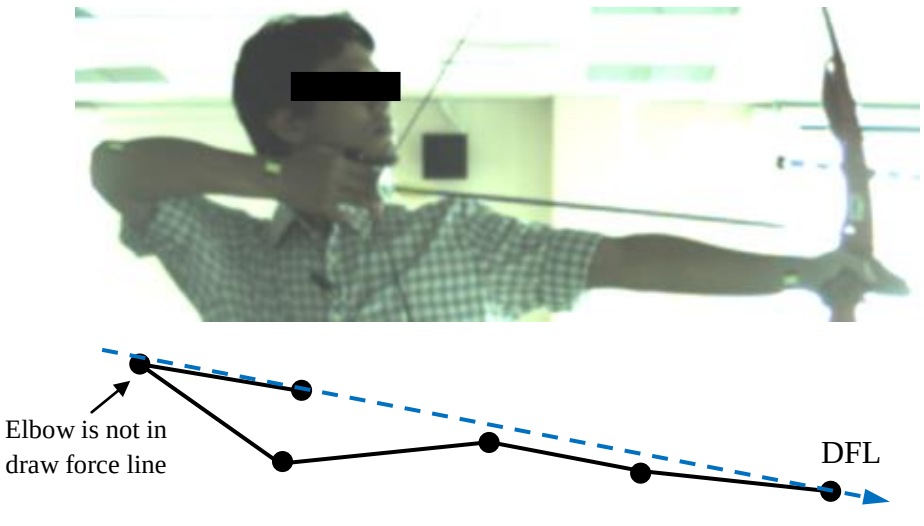

Figure 6. DFL was measured from lateral view

That kind of measurement also occurred to the DFL from lateral view. The elbow still not in line and require the drawing arm bicep and tricep to take all the force which creates fatigue. Ideally, an elbow should be within the DFL in order to reduce the muscle fatigue as well as to prevent the injury. The same technique continuously will affected to the performance of the archer.

Muscle Activity

The measurement obtaining from this equipment is the signal from muscle activated during shooting process. The signal from Figure 7 shows the muscle activity during shooting archery for deltoid. There are three phases involves in this result; drawing the bow, aiming and release the arrow. The muscle started to activated when the archer draw the bow until aiming stage which represent in the first phase. The muscle activity in this time is in the peak value since the transition phase between draw and aiming. About three seconds of aiming, the archer releases the arrow and the muscle activity was drop abruptly.

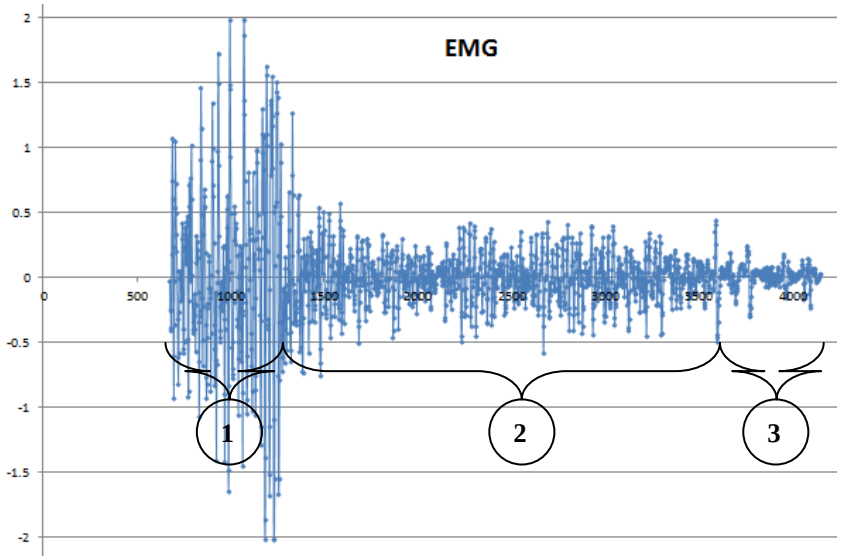

Figure 7: Muscle activity for deltoid muscle

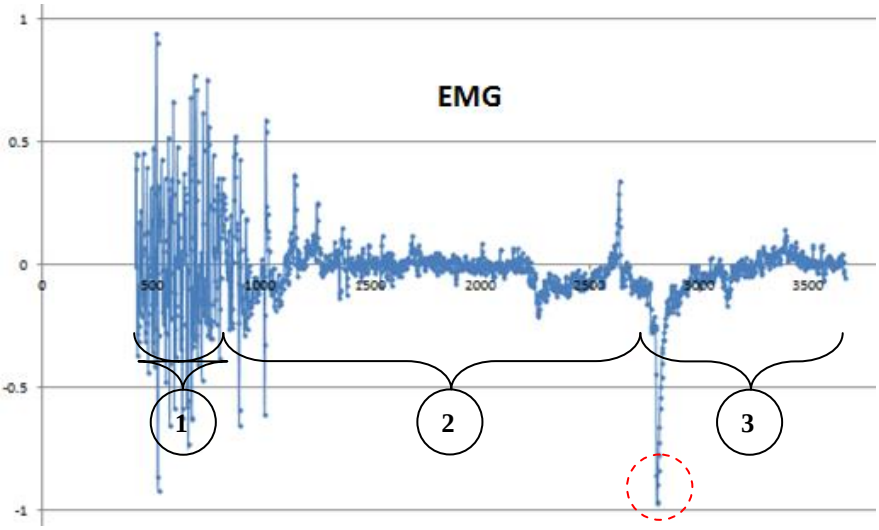

Figure 8: Muscle activity forearm (flexor digitorum)

The same pattern was occurred to the forearm muscle (flexor digitorum) in Figure 8. However, after aiming phase finish, the archer release down his finger and quickly maintain back again. Therefore, that muscle is in relaxation state for a while as signed in circle but it did not affect to the deltoid. Another different between both muscles is the value of muscle activity. It illustrates that the deltoid muscle is higher than flexor digitorum in terms of forces subjected. Hence, deltoid muscle in the shoulder joint is crucial rather than flexor digitorum due to drawing arm force was depends on that muscle strength. Despite the time trigger of the signals are not synchronized, but the total duration time still same for both measurement.

Weight Balancing Distribution

To get a good record in an archery competition, one requires a well-balanced and highly reproducible release during the shooting. However, only left foot was measured by force plate due to the size of the plate is small compared to his stance distance. The total weight of the subject is about 84 kg. To ensure a well-balanced, the total weight was divided half into 42 kg. Since the weight related to the gravity, z-axis value was selected to be as an observation data to analyse. The maximum weight subjected onto the force plate is 44.12 kg as plotted in Figure 9.

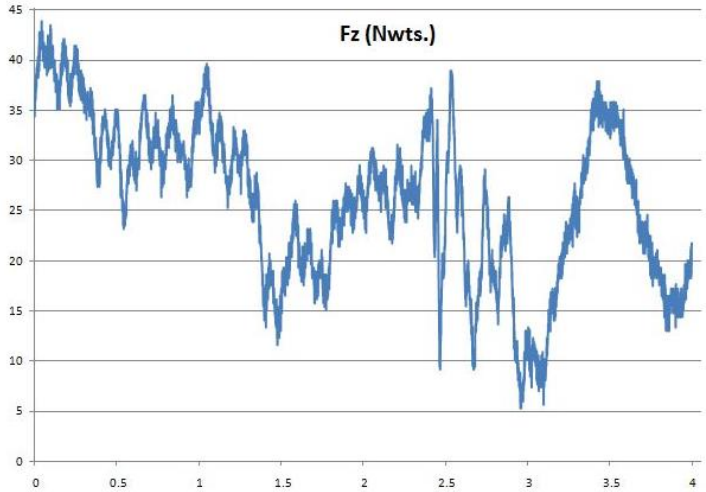

Figure 9. Weight distribution in z-axis

The data was separated into three stages also; drawing, aiming and releasing. Drawing stages start from 0 second to 1.2 second, then 1.2 to 2.8 seconds is aiming and 2.8 to 4 seconds is releasing. During drawing stage, the body balanced is not consistent also to the aiming stage due to the bow affected and create the moment for subject stance. It shows that the shooting process, the weight distribution is contributed more to the right foot than left foot.

Aiming Concentration

The results here present the measurement of aiming concentration for three seconds period. The BVP value for each frequency was stated in the Table 1. The total heart rate mean for three attempts is 112.10 bpm. Physically, it is higher than the normal heart rate which is 90 bpm. In this condition, the subject is in under pressure but still can do the shooting.

Table 1. BVP value for aiming

Description	Value
B: BVP HR mean (beats/min)	112.10
B: BVP VLF % power mean	16.61
B: BVP LF % power mean	36.51
B: BVP HF % power mean	46.88
B: BVP VLF total power mean	1216.70
B: BVP LF Total power mean	3183.65
B: BVP HF total power mean	3980.56
B: BVP LF/HF (means)	0.80

Table 2: Frequency value with shot points results

Attempts	Very Low Frequency (VLF)	Low Frequency (LF)	Higher Frequency (HF)	Results
1	22.34	30.41	47.83	8
2	8.21	52.31	40.19	7
3	17.92	31.57	50.51	8

Figure 10: (a) 1st attempt, (b) 2nd attempt, and (c) 3rd attempt

Referring to the Table 2, it shows the frequency level of the archer during the aiming phase. The concentration of aiming depends on the higher frequency (HF) and can be related to the results performance. The higher frequency level, the more concentrate of the archer. Three attempts were done for the same aiming time. The results were count from target board for each attempt. During the first attempt, the frequency level of the archer is quite high and the results attached to the yellow area. From the second trial, the frequency level is lower than before and the arrow goes for the red area which is quite far from the centre. For the last trial, the frequency level increase again and the arrow goes near to the yellow area. It founds that the frequency level is direct relationship with subject performance in terms of concentration factor.

CONCLUSION

In conclusion, the biomechanics parameters were selected in this study are really affected to the archer performance. The wrong drawing technique will created the muscle fatigue due to the increasing the muscle activity. Furthermore, it also will caused injury to the archer if continuously occurred. In order to get a good result, stabilization of weight balancing is very crucial. It will reduce the vibration of body and equipment

itself before shooting the arrow. Aiming concentration has direct relationship with the frequency level of the archer. Consequently, all biomechanics parameters were discussed in this study really associated with the archer performance. For the future study, experience athletes will be used as a subject with different level of categories; beginner, intermediate and elite. Therefore, the beginner will be train to be as good as an elite player in short time.

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