3D MOTION ANALYSIS SYSTEM FOR ANALYZING RECURVE ARCHERY TECHNIQUE: A PILOT STUDY

By

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TABLE OF CONTENT **PAGES**

LIST OF TABLES AND FIGURES

ABSTRACT

The purpose of the study is to evaluate 3D motion analysis system for analyzing recurve archery technique. The subject is highly-skilled archer (Kelantan state archer) who volunteered to participate in this study. Pre and post-test score consisted of the total points for six arrows shot at ten feet were collected.3D motion analysis (Qualysis) system was used to record the technique of the archers (stance, posture and aiming) and it was measured simultaneously. After practicing for several minutes to accustom to the markers and testing environment, the subject was asked to shoot 12 arrows where six with their own techniques and another six with modified techniques according to Kirsik Lee books – *Total Archery.* The technique of recurve archery was further divided into 11 steps for analyzing purposes. Wilcoxon signed rank test was used to detect the difference between elite's technique and suggested technique based on 3D motion analysis data. The results of using Wilcoxon sign rank test proves that there is significance difference of eight steps which are stance that should be approximately shoulder width apart, 30 degree stance open to the target, 60/40 ratio of weight on the balls and heels of the feet, the toes should point roughly parallel, the legs must be straight but not locked, the head sits out over the chest and drawing elbow torque show significance difference where $p (<.05) = .028$. Another 3 steps showed no significance difference, which are the posture where hips must be tucked forward to create a flat back $p (<.05) = .916$, shoulder alignment must point well past the line of the arrow (to the right of the target) $p (<.05) = .173$, and the front shoulder should push forward the target as far as possible $p (<.05) = .600$. From the result it showed that 3D motion analysis system can be used and reliable in detecting the difference of archery technique. It can be used in measuring and analyzing archery technique in the future.

ABSTRAK

Tujuan kajian ini adalah untuk menilai kesesuaia n sistem 3D *motion analysis* untuk menganalisa teknik memanah acara recurve. Subjek yang terlibat adalah pemanah yang mahir dan mempunyai pengalaman (pemanahnegeri Kelantan) yang menawarkan diri untuk mengambil bahagian dalam kajian ini. Skor pra dan pasca-ujian terdiri daripada jumlah mata untuk enam anak panah ditembak pada jarak sepuluh kaki telah dikumpulkan. Sistem 3D *motion analysis (Qualysis)* digunakan semasa rakaman teknik pemanahan (teknikberdiri, postur dan kedudukan bahu) dan pengukuran dibuat secara serentak. Selepas berlatih selama beberapa minit untuk menyesuaikan diri kepada penanda dan persekitaran ujian, subjek diminta untuk menembak 12 anak panah di mana enam dengan teknik mereka sendiri dan enam lagi dengan teknik diubahsuai mengikut buku Kirsik Lee - *Total Archery*. Teknik memanah dibahagikan lagi kepada 11 langkah untuk tujuan analisa. Ujian *Wilcoxon signed rank* digunakan untuk mengesan perbezaan di antara teknik elite dant eknik yang disyorkan. Keputusan menggunakan Wilcoxon tanda ujian pangka tmembuktikan bahawat erdapat perbezaan yang signifikan pada lapan teknik iaitu teknik berdiri dimana ianya perlu selebar bahu, berdiri perlulah 30 darjah terbuka kepada sasaran, 60/40 nisbah berat pada bola dan tumit kaki, kaki mesti lurus tetapi tidak dikunci, kedudukan kaki hendaklah setara, kepala melebihi dada dan kuasa siku ketika melepaskan anak panah menunjukkan perbezaan yang signifikan di mana p (<.05) = 0,028. Manakala 3 langkah menunjukkan tiada perbezaan yang signifikan iaitu pada kedudukan di mana punggung hendaklah terletak kehadapan untuk mewujudkan tulang belakang yang rata p (<.05) = 0,916, penjajaran bahu mesti menunjukkan ianya lalu segaris dengan anak panah (di sebelah kanan sasaran) p (<.05) = 0,173, dan bahu depan hendaklah menggerakkan sasaransejauh mungkin p (<.05)

= 0,600. Keputusan yang diperolehi menunjukkan bahawa system 3D *motion analysis* boleh digunakan dan dipercayai untuk mengesan perbezaan di dalam teknik memanah. Ia boleh digunakan untuk mengukur dan menganalisa teknik memanah pada masa hadapan.

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Public interests in archery in Malaysia have increased since the recurve archer team won a bronze medal in Olympics Game 2004. Due to that particular achievement, we believe that we have the ability to excel in archery. This is one of the researches conducted to understand more about archery with the help of motion analysis system.

Qualysis three-dimensional (3D) motion analysis system is a new system that can capture any kind of motion easily. It comes with software for the analysis process, thus the motion can be analyzed on the site. It is being adapted into different field of research applications such as medical, rehabilitation process, industrial application, car development and many others. In medical field, researchers and clinicians use the movement data to study the normal human movement. The information from normal human movement is used to improve the treatment during rehabilitation process. In industrial application, motion data is used to analyze and quantify the vibration problem in specific areas. In car development, the data from 3D motion captured is used to improve the level of comfort and safety for the driver. The data from 3D motion analysis is also being used widely in animation and virtual reality. Animation movie is made livelier by the very fine movement that can be transferred and simulated using 3D motion analysis. In sports, motion analysis is being used to study the characteristic, kinematic and kinetic of a specific sport. Most of the researches done using 3D motion analysis system in sport performance were dedicated to golf. Only a few studies utilized motion analysis for archery.

Archery is described as a static sport, as archers do not move much. The shooting skill need to be developed in archery. In archery, skill is defined as the ability to shoot an arrow to a given target in a certain time span with a precise accuracy (Leroyeretal, 1993).Developing shooting skill involves a stable sequence of performed movement's patterns such as the stance, the drawing and the sighting (Ertan et al, 2003). These movements are reproducible, so they can be compared and analyzed using a specific system such as motion analysis system.

Based on the history of Korean archery group, it is said that skill in archery can be developed. Coach Lee has proven himself over the past 20years as one of the most successful coaches in training Olympic, World Champions and medalists. According to him, any system should be dynamic, which doesn't mean drastic changes, but continuous refinements to become a successful and proven system (Lee, 2005). Kirsik Lee collaborated with Tyler Benner who is an archer to produce Biomechanically Efficient Shooting Technique (BEST). They spent two years together at the Olympic Training Center learning these techniques firsthand and refining the movement time. In this study, we suggest the right technique based on BEST system which is widely known and applied by coaches and archers all around the world. The BEST system is fundamentally a 12 step system. The system is explained in detail by Coach Kirsik Lee in 'Total Archery- *Inside the Archer*', which he published in 2005.

1.2 PAST STUDIES

There are only a few studies about recurve archery involving motion analysis system. The protocol needs to be set in order to standardize the analysis and make it easier to

analyze. In 2005, Lin and co-researchers did research on archery. His study is about obtaining the relationship between the aiming adjustment trajectory and the location of the arch on the target. A type of motion analysis system, Ariel Performance Analysis System (APAS) was used to obtain the results. He also uses APAS to study the stability of the archer. His study showed that stability is an important factor in determining the performance in archery.

Another study by Lin et al. (2005), which is about hand grip stability during aiming and releasing the bow after shooting an arrow. They used ultrasound sensor and Graphical User Interface (GUI) system to obtain and analyze the motion of the archers. The system used in the study was capable of achieving their objectives with several limitations. An improvements needs to be developed to produce a more accurate system for a better performance in archery (Loke et al., 2009).

As of today, there is not much research on motion analysis system in archery. Most of the existing researches on motion analysis system concentrated on golf, tennis, cycling, and rowing (Nesbit & Serrano 2005, Urtasan et al. 2005, Sun et al. 2012, Rowe 2012). Previous study about archery mainly stressed on neuromuscular aspect and trajectory of an arrow (Gros 1997).

Motion analysis system is used in this study to compare between the technique used by Kelantan elite archers and the suggested technique by Coach Kirsik Lee. Motion analysis system is used to analyze different techniques used in archery. The conclusion about motion analysis system and the best technique to be used by archers will be made based on the findings from this research.

1.3 OBJECTIVES OF THE STUDY

The objectives of this study can be divided into general and specific objectives.

General objective:

1. To evaluate 3D motion analysis system for analyzing recurve archery technique.

Specific objectives:

1. To determine specific marker placement for recording archery technique using 3D motion analysis system.
2. To determine the most important marker for monitoring changes in every archery technique.
3. To analyze the difference showed by the specific marker in different techniques.

1.4 SIGNIFICANCE OF THE STUDY

The analysis is important in providing better understanding about archery. The findings can be used to correct an athlete's movements in archery; this will lead to a better accuracy in shooting an arrow. On rehabilitation stage, the findings are useful to develop new treatments for archery-related injuries. This research helps in promoting archery as an excellent sport.

CHAPTER 2

LITERATURE REVIEW

Qualysis motion analysis

In this study, we use Qualysis Motion Analysis because it is precise and offers a lot of advantages (Aggarwal, 1998). It also comes with software that can measure various parameters. Measurements can be obtained directly from the software for the calculation of joint angles, acceleration, moments, force, elasticity, deformations, body posture, balance, and other parameters.The system can also easily synchronized with other systems such as force plates, EMG, and accelerometers by using the Qualysis portable analog interface. According to Hillary et al. (2009), the integration of motion analysis system with optoelectronic systems are suitable to be used in equine researches including MacReflex and ProReflex (Qualysis Inc, Glastonbury, CT). These systems can perform online digitizing, and data are available immediately after the recording.

Another advantage of motion analysis is that the result can be viewed as the evidence whether the archer used the right technique suggested (Sport Analysis Article, 2006), and this is technique is known as motion capture. Motion capture is ideal to be used in a wide range of sports applications-in research, rehabilitation, physical education, and practice. Since physical limitations and movement optimization are important to athletes, coaches, researchers and doctors, the implementation of motion capture is needed. Motion capture allows the users to learn more about injury mechanisms and how to prevent them, and this

can be used to optimize the performance of an athlete, not only in archery, but also in other sports.

As an example, motion analysis has been used widely in golf analysis. In a past research, the output of the golf motion analysis included club trajectories, golfer/club interaction forces and torques, work and power, and club deflections. These data formed the basis for statistical analysis of all the output subjects, and detailed analysis and comparison of the swing characteristics of the four subjects were carried out. The analysis was able to generate new data concerning the mechanics of the golf swing. It was revealed that a golf swing is a highly coordinated and individual motion, and subject-to-subject variations were significant (Steven M. Nesbit, 2005)

Most of the studies done on archery and motion analysis were based on individual or institutional interests; therefore, there are variations in one research to another, especially in marker placement and research protocol. Marker placement plays an important role in getting the right result. 0'Connor et al. (1993) investigated the effect of deviations in reflective marker placement on Spinal range of motion (ROM) measurements obtained via video motion analysis. The results obtained from his study indicated that the level of error from a 2.5-cm marker movement is acceptable. But as stated, there are variations in the protocol and research interest from one research to another, so it is difficult to make any comparison. In short, the results obtained from this kind of research depend on the requirement of that particular study.

ARCHERY

There are some variations in archery techniques taught by the instructors at archery clubs and adopted by the archers. The techniques are into six phases which are bow hold, drawing, and full draw, aiming, release and follow through. Each of these phases is represented by a stable sequence of movements, and is ideal to be used in researches (Nishizono et al., 1987). Some coaches divided the techniques into 10 steps, as shown in Figure 2.1. Some coaches divided the techniques into nine steps. Nine steps start with position stance, followed by inserting the arrow, holding the bowstring, creating a pressure point on the bow-grip, drawing the bowstring, reaching to the full-draw, aiming, releasing, and follow-through. (Nishizono, 1984).

Even though there are variations in the archery technique, the sequence of the technique is usually the same. The only difference lies in the positioning, and different point are stressed in difference techniques. The technique is explained during the class, and is continuously practiced by the archers.

Figure 2.1Ten steps archery shooting

Biomechanically Efficient Shooting Technique (BEST)

The Biomechanically Efficient Shooting Technique (BEST) method aims to improve an archer's performance through specific shooting forms, equipment configurations, training methods and coaching techniques. In addition to improving scores, BEST method reduces athletes' fatigue and can help reduce the risk of injury (USA Archery, 2006). According to Ruth Rowe (2007), BEST method helps in aligning the body so that it is in the most stable position. By aligning the shoulder and arm bones to carry the draw weight, it also produces greater accuracy on the target and lessens the chance of injury.

BEST is fundamentally a 12-stepsystem, and it is also known as Kirsik Lee (KSL) shot cycle. The steps in BEST method are the stance, knocking the arrow, hooking and gripping, mindset, set-up, drawing, anchoring, loading, aiming and expansion, release, follow-

through and relaxation, and feedback (Lee &Bondt, 2008). The steps are depicted in the diagram in Figure 2.2. The detail of thesetechniques can be referred in the book by Kirsik Lee and via website at http://www.kslinternationalarchery.com/index.html.

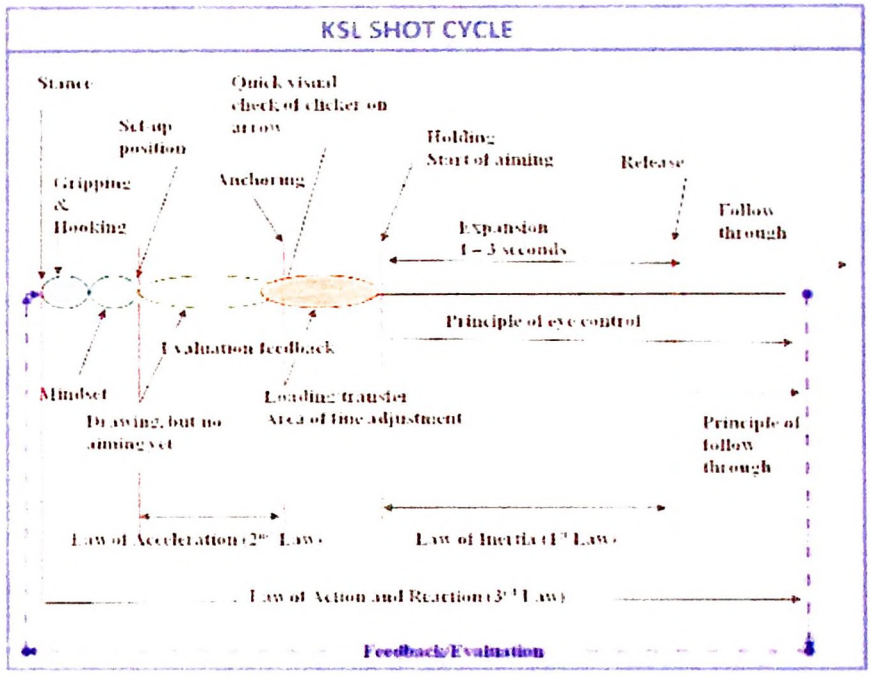

Figure 2.2 KSL shot cycle

Past studies on archery

Early researches on archery stress on neuromuscular aspect where most of the earlier researches combine the muscular contraction–relaxation strategies with the snap of the clicker (Ertan, 2009). Hennessy and Parker (2010) conducted a study to define the muscle action in archery shooting. They found that the bow-grip placement between the thumb and index fingers. These produce a better balance to the archers. This technique is known as the

bow arm/bow-hold alignment technique. Ertan et al. (2003) did a study on the contraction and relaxation strategy in the forearm muscle during the release of the bowstring, and this strategy is believed to be critical for accurate and reproducible scoring in archery. EMG (electromyography) is a technique used to measure the electrical muscle potentially. It was used in a study by Nishizino et al. (2009), where the shooting techniques of the world class archers were analyzed and compared with the middle-class and beginner archer. Some researchers also believe that body sway plays an important role in archery, based on the research by Tinazci (2011), where his research focus more on the archer's swaying motion in correcting the score (Tinazci, 2011). He also examined some physiological and mechanical dynamics in shooting simultaneously with reference to the clicker reaction time.

Studies were also conducted to improve the performance of archery in different aspects. Since archery is considered as a static sport, some detailed measurements can be taken using fixed cameras in the early stage of a research (Oliver Logan, 2007). The video is then analyzed after a training session and is used to improve athlete's performance (Hemauer et al., 2005). The advancement of technologies made the analysis easier to carry out, by integrating the modern analysis system with the recording apparatus. On top of that, motion analysis system is one of the latest technologies in the analysis of human motion. It offers a lot of advantages over the old methods which use camera and video recorder.

CHAPTER 3

METHODOLOGY

3.1 SUBJECT OF EXPERIMENT

The subject is a highly skilled archer (Kelantan state archer) who volunteered to participate in this study. She is 17 years old and has been practicing archery for almost 5 years. The archer is right-handed and recurve bows are used in this study. During the recording, she had to shoot 12 arrows, each at a distance of 10 m, indoors at the official FITA target face (diameter 60 cm; diameter of the "Ten": 6 cm). The score for each shot was registered. The steps of the archer's technique and suggested technique (stance, posture and aiming) were recorded continuously using 3D motion analysis system.

Before the research was carried out, the subject was briefed on the procedure that she had to go through. The subject also had to sign a consent form stating that she agrees with the experimental procedure. Firstly, reflective markers were placed on certain parts of her body. Next, she was given several minutes to practice in recording environment. Lastly, the subject was asked to shoot a total of 12 arrows; six using her own technique and another six with the suggested techniques.

3.2 RECORDING

Recording was made under certain conditions. As illustrated in Figure 3.1. Subject was given some time to do trial shots to get a sight and to get acquainted with the new environment. After the sight had been confirmed, the archer started to shoot the first end with their own skill and technique. The archer's movements were captured using motion analysis camera within 4 minutes during which the subject completed her first six successive shots (one ends) using her own technique. The remaining six shots were done after half an hour, using the suggested technique. Prior to that, the subject was taught a new technique based on Kirsik Lee book – *Total Archery*. She was given half an hour to learn the new technique before finally making the remaining six shots (one end) within four minutes. Similar to the first six shots, her movements were again recorded using motion analysis camera.

Figure 3.1: Archer shooting line

3.3 ANATOMICAL LANDMARKS

Markers are placed on the subject's body so that the system is able to detect her movements during recording. The markers are placed based on the suggested points by Vicon Motion System. Correct positions of the markers are the key in achieving a good quality motion capture. According to Vicon Motion System (2006) even though the markers can be placed anywhere, the optimal points of motion capture are in the underlying skeleton. The anatomical placements can be seen in Appendix 1 and Appendix 2.

The markers placements were determined based on the need for the technique suggested by Kirsik Lee and were located the bony landmarks, which are at particular bones and joint. All the markers are securely attached with two-sided tape (on skin) or Velcro (on clothing). Markers were attached directly to the skin wherever possible to obtain best results.

3.4 ARCHERY TECHNIQUE AND MARKER PLACEMENTS

The subject's movement in the laboratory was recorded with 3D motion analysis system. During the recording, six Qualysis Motion Analysis cameras were used. Before the experiment was initiated, the cameras were calibrated according to the manufacturer's manual. The first camera was placed diagonally behind the archer and the second one at an angle of approximately 90°laterally, the third one is behind the archer, the fourth one is at the left side of the archer, the fifth one is at the left front, and the last one is at an angle of approximately 90° in front of the archers. All cameras were placed at about 5-6 m to the subjects, and the positioning of the cameras is roughly illustrated in Figure 3.1. As for the

markers, 32 passive reflective ball markers, each with a diameter of 3 mm, were attached to the subject and one was attached at the bow handle

The proposed archery technique is based on BEST method. The important steps from BEST method (the KSL Shot Cycle 11), which had been explained in previous chapter, can be further simplified into stance, posture and shoulder alignment for measurement using 3D motion analysis. The marker placement for each step is shown in Figure 3.2 to Figure 3.6.

Stance

Marker placements for the subject's stance are shown in Figure 3.2 and Figure 3.3. Alphabets (A-D) in the figures refer to the important markers stated in the technique. The requirements needed for the stance position areas listed down below:

A. The ball markers have to be placed equidistantly on either side of the shooting line (TIPS)
B. The distance between two ball markers should be approximately shoulder-width apart (<4cm wider)
C. Stance alignment should be 30 degrees open to the target
D. The toes should roughly be parallel to each other
E. 60/40 ratio of weight on the ball markers to the heels of the feet