KINETIC AND KINEMATIC ANALYSIS OF RECURVE ARCHERY SHOOTING TECHNIQUE

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The study investigated shooting techniques of the archers with kinetic and kinematic methods. Twenty-seven archers of different skill levels have been involved into the current study to investigate both muscular activation strategies of nine muscles and some kinematic data on drawing hand side. A statistical significant difference ($p<0.05$) has been observed in terms of muscular activation among the archer groups. Although there was no statistical significance ($p>0.05$) in the time-dependent exchange values of the angle of the joints, a difference was detected in the graphical sense. Elite archers use distal muscles less but proximal and axial muscles more, and mid-level and novice archers use distal muscles more to pull the bowstring. This was interpreted to be the most important factor affecting the horizontal oscillation (lateral diflection) of bowstring.

KEY WORDS: electromyography (EMG), muscle activation, relaxation strategy

INTRODUCTION: Archery can be described as an elegant, impulsive and closed motor skill, is a static sport requiring strength and endurance of the upper body, in particular the forearm and shoulder girdle (Mann & Littke, 1989). The contraction and relaxation strategy in forearm muscles during the release of the bowstring is critical for accurate and reproducible scoring in archery. Two different approaches to this strategy were proposed in previous studies; however, they were not well defined (Clarys et al., 1990; Nishizono et al., 1987, Ertan et al., 2005). The first approach suggested that an archer should release the bowstring through a sudden relaxation of the muscles that maintain the flexed position of the fingers around the bowstring rather than attempting to effect the release moment by willingly extending the fingers through concentric antagonistic muscle action (Martin et al., 1990; Ertan., 2005). The second approach suggested the relaxation of the flexors and contraction of the extensors. Muscular coordination between the agonist and antagonist muscles of the forearm is essential in this strategy and requires a relatively long training period (Clarys et al., 1990; Hennessy & Parker, 1990; Nishizono et al., 1987). Previous studies were not able to clarify the contraction and relaxation strategy of the forearm muscles that was used by archers. All studies were confined to a limited number of elite archers and both strategies were sometimes observed in the same group. Moreover studies did only involve the forearm muscles that are crucial for accurate and reproducible scoring, but the activity of upper extremity muscles was not measured. Furthermore, the effect of performance level on this strategy was not investigated. We hypothesized that archers develop a specific forearm and pull finger muscle activation strategy by active contraction of the forearm extensors with the fall of the clicker. Furthermore, the reaction time is expected to be shorter as the level of performance of the archer increases.

METHODS: Three groups, (i) elite (n=9), mid-level (n=9) and novice (n=9) archers, were involved in the study. All subjects gave their informed consent after being informed of the possible risks of the study. The experimental procedures conformed to the Declaration of Helsinki and were approved by the local ethics committee. Before starting the test session, the participants performed a 15 min standardised warm-up, consisting of 5-min upper body active movement, 5 min upper body stretching and 5 min arrow shooting. Each participant engaged in a single test session consisting of 6 shots. Prior to the shootings, the isometric maximum voluntary contraction (MVIC) was optained of M. Flexor Digitorum Superfacialis (MFDS), M. Extensor Digitorum Communis (MEDC), M. Deltoid Anterior (MDA) M. Deltoid

Middle (MDM), M. Deltoid Posterior (MDP), M. Upper Trapezius (MUT), M. Middle Trapezius (MMT), M. Lower Trapezius (MLT), M. Pectoralis Major (MPM) (Rota et al., 2013).

EMG data collection and analysis: EMG activity of the nine muscles studied MED, MFDS, MDA, MDM, MDP, MPM, MUT, MMT and MLT was recorded using surface electrodes (16-channel Delsys Wireless Trigno Electromyography (EMG) system). The pass band of the EMG amplifier, sampling rate, maximum intra- electrode impedance and CMMR were 20–500 Hz, 2000 Hz, 6 kOhms and 95 dB, respectively).The snap of the clicker triggered a 5V Transistor- Transistor Logic (TTL) signal, which was registered simultaneously with the myoelectric signals. According to the rise of the TTL signal, muscular activation 400ms before and 800ms after were identified as pre-clicker and post-clicker intervals. The respective EMG data sets of each of the twelve shots were fully-wave rectified and filtered (a moving midlevel filter with a 100ms time-window).

Kinematic data collection and analysis: Two motion BLITZ Cube7 brand, 500Hz high-speed video cameras were used to record the scene during full draw, aiming and releasing phases in our experimental design. The cameras were settled at an angle of 70^0 towards each other at a height of 1.5 meters. The successful trials of 6 shots were digitized from camera records. 17 markers (Distal Falanks (DF), Distal Interfalangeal Joint (DIJ), Proximal Interfalangeal Joint (PIJ), Metakarpo-Falangeal Joint (MJ), Ulnar-Styloid (US) Lateral-Epicondyle (LE) Termination alignment triceps brachii, Trochanter Major (TM)) were automatically digitized using WINanalyze Automatic Motion Analyse system.

Statistical analysis: Descriptive statistics were applied to identify the characteristics of the subjects and groups. Mean scores were calculated for each subject's 6 shots and each group separetelly. One-way analysis of variance (one-way ANOVA) was conducted to compare forearm muscular activity during each time interval among groups. ANOVA was followed by Tukey posthoc comparisons to determine the intervals where significant differences did occur. A probability of $p < 0.05$ was selected to indicate statistical significance.

RESULTS: For each group of archers, muscular activations 400ms before and 800 ms after the snap of the clicker and kinematic values have been measured.

Muscular Activation Strategies*:* Muscular activation values of MEDC, MFDS, MDA, MDM, MDP, MUT, MMT, and MPM were compared among the archery groups in terms of their amplitudes. The activation level of MEDC, MFDS, MDM, MDP, MUT, MMT and MLT among groups have shown significant differences ($p<0.05$), however no significant differences ($p>0.05$) have been calculated in MDA, MUT and MPM.

Kinematic Data: In addition to kinetic data collected by EMG, some kinematic measurements were also conducted to analyse the effect of muscular involvement on angular changes of 2., 3., 4., finger distal and proximal interfalangeal, Ulnar-Styloid and Lateral-Epicondyle joints. Although there has been no statistical significance ($p>0.05$) in the time-dependent exchange values of the angle of the joints, a difference has been detected in the graphical sense (Figure 1).

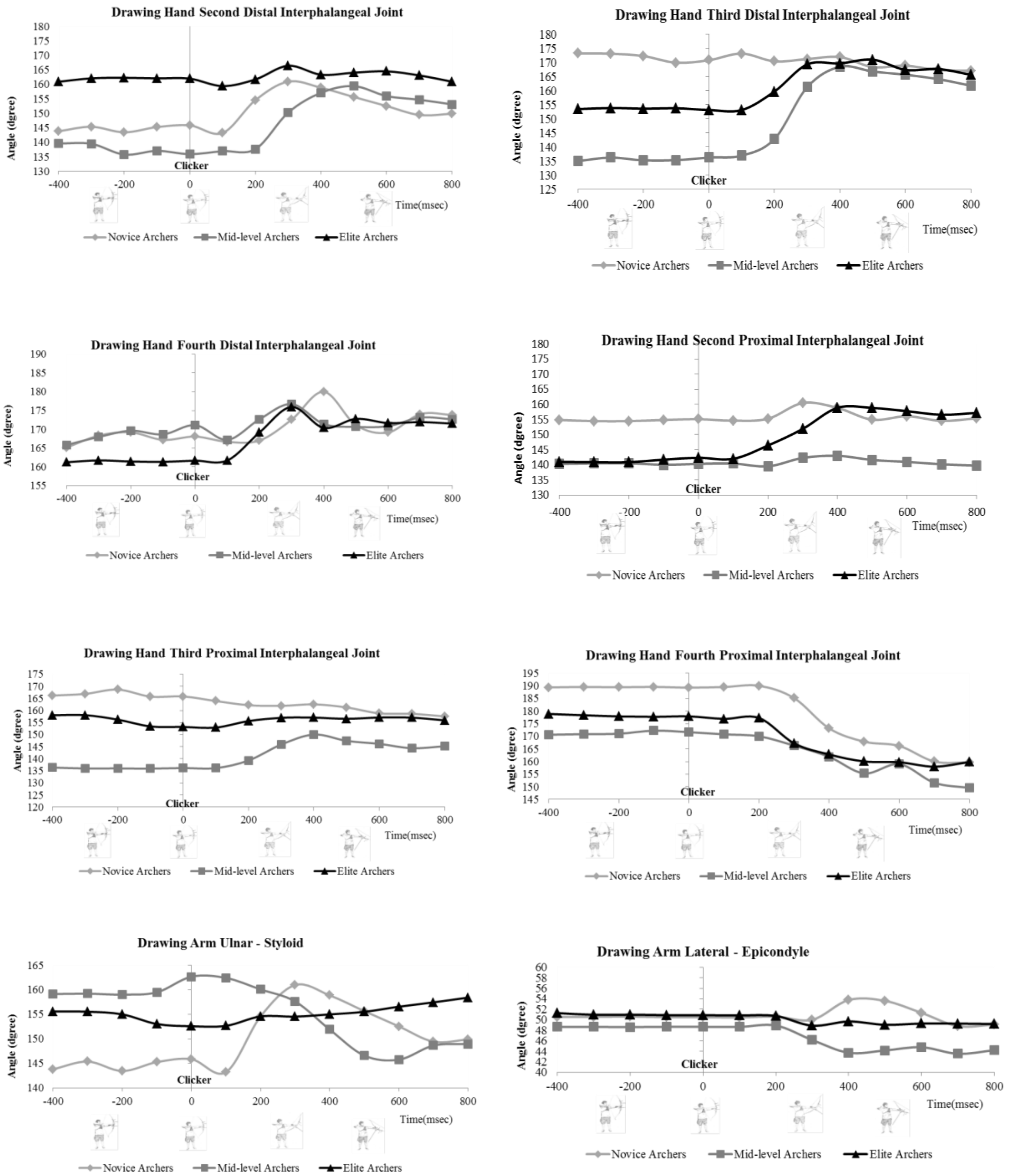

Figure 1: Comparision of kinematic data among different archery performance levels.

DISCUSSION: In this study, EMG activities of flexor and extensor muscles had statistically significant difference among elite, midlevel and novice archers. Novice archers were observed to activate forearm flexor and extensor muscles higher than their own maximal values in 400msec time before dropping the clicker at aiming phase. As they release the sting the flexor muscle activity starts decreasing gradually whereas the extensor muscle activity starts increasing. Compared to novice archers, midlevel archers showed lower MVC percentages of flexor and extensor muscle activities. However, both flexor and extensor activities tended to increase as soon as the clicker was dropped. As for the elite archers, in addition to their lower maximal value percentages than both novice and midlevel archers, their muscular activation values gradually decreased as well. Nishizono et al. (1987) defined M. extensor digitorum as the main muscle responsible from releasing movement of string.

However, Hennesy and Parker (1990) explained this situation as active contraction of muscle after releasing the string towards flexion extension. Muscular activation strategies at 400msec before dropping clicker during aiming and shooting phase were observed to show similar results with the previous studies in literature. On the other hand, there are limited research related to muscular activation of shoulder and back muscles. Nishizono et al. (1987) conducted a study on bow arm and pulling arm of novice archers during whole pulling and releasing steps and found out that trapezius and deltoid muscles had unbalanced activities and biceps muscle had strong activities during the pulling step. , It was observed that when the main pulling step was approaches posterior deltoid muscle and trapezius middle muscle of elite archers were actively involved with higher level of MVIC in the process. On the contrary, Lower trapezius muscles of midlevel and novice archers were more active. This situation can be explained with resultant force concept of basic physic theories. Elite archers approximate scapula bone to spine forming a 45 degree angle with the help of the horizontal force applied by middle trapezius and rhomboideus major-minor muscles as a result of resultant of vertical force applied by trapezius. As for midlevel and novice archers, they usually call out lower trapezius muscle and move scapula bone downward vertically. This contraction strategy applied by novice and mid-level archers cause the demolishment of the kinetic chain among scapular, gleno-humeral, elbow, wrist and hand joints.

CONCLUSION:

As a conclusion, the current findings may demonstrate that as the performance level increases in archery, the weight of the bow string is carried by proximal muscles. On other saying, beginner and mid-level archers tend to use distal musculature to pull the bow string.

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