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Differences in Activation Patterns of Shoulder Girdle Muscles in Recurve Archers

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Abstract

The purpose of this study was to observe the differences in activation patterns in shoulder girdle muscles of drawing and bow arm during archery shooting. 96 shots of eight associate archers for Turkish junior national team were analyzed in the current study. Each archer has shot 12 arrow to the target, EMG activities of M. Deltoid Middle (DM) and Posterior, M. Trapezius Middle (TM) and Lower (TL) were quantified in both drawing and bow arm. The measurement sites were prepared according to SENIAM's recommendations. Pass band of EMG amplifier, sampling rate, maximum intra-electrode impedance and common mode rejection ratio (CMMR) were 8-500 Hz, 1000 Hz, 6 Kohms and 95 dB, respectively. Three-second periods of twelve shots, which contain full draw, aiming and release phases respectively, EMG data were full-wave rectified and filtered (moving average filter with 60 ms time-window) for each archer. ANOVA test and Tukey post hoc were used to assess the differences in activation patterns in each muscle among periods. Drawing arm normalized DM iEMG activity was significantly low in release period (DM MVC %; Full draw; 17.892±7.505 aiming period; 20.941±10.556; releasing period; 8.312±6.3) ($p<0.05$). Drawing arm DP muscle activation was significantly higher full draw (16.593±4.585) and aiming period (18.801±5.546) then releasing period (6.787±6.068). TM and TL iEMG activities in the drawing arm have been statistically higher in aiming period ($p<0.05$). Bow arm DM and DP muscle activities were statistically lower (DM: 15.985±8.729; DP:10.03±5.865) in releasing period. Similar statistical differences in bow arm TM and TL muscles can be seen in releasing period.

Keywords: Archery, electromyography, muscular analysis, activation pattern

INTRODUCTION

During the archery competition, an archer shot during the whole day and drawing the bowstring weighing about 14-22 kg. An archer shoot totally 144 arrows except for the test shots. So, an archer pulls an average of 20 kg during every single shot and totally 144x20= 2880 kg. In addition to that an archer walk about 3600 m to pull out the arrows from the target. It is thought that, an archer draw almost 3000 kg and walk about 3,5-4 km in a single day competition period. Moreover, these quantities increase twice or three times during training period.

These numbers are paid attention and strength continuity is important in archery. However, bow drawing weight, which is pulled during each shot, does not constitute maximal strength. One arrow may be shot in average of 5-6 seconds. The athlete should pull the bowstring, aim on the target and finalize the shooting. There are a lot of factors affecting the score on the target which may be considered to be very easy. We can separate these factors as internal and external factors. Internal factors are reaction time, concentrating on the target, fitness level, technique and tactic properties, psychological condition, and readiness for competition. External factors are thought to be the material used should be suitable, adequate and modern, the weather condition should be appropriate for archery shooting, environment should be silent and financial situation should be adequately (Kolayis, 2000; Kalinichenko, 2005). It will be difficult to shoot an arrow in 5-6 seconds when all of them are combined. Skill in archery is defined as the ability to shoot an arrow to a given target in a certain time span with accuracy (Leroyer, 1993). The discipline is described as a six phase movement in terms of shooting technique by Nishizono et.al. (1987); Bow Hold, Drawing, Full Draw, Aiming, Release and Follow Through. These phases have some more details as like gathering high scores in the competition; using the time effectively, releasing should be stable and same each shooting and strong posture is important. Furthermore, position of the sight on the target when releasing, is determining place which arrow's destination.

Clicker consists of a flat spring with one end fixed at the window of the bow and the other resting on the arrow. When the archer reaches his/her final position the clicker is released, producing a light sound which is the stimulus for the archer to extend his/her pull finger, which induces the release of the bow string. The clicker is known to improve an archer's score and is used by all target archers (Leroyer, 1993). In particular, a repeated contraction and relaxation in the forearm and pull finger muscles should be developed for this reason.

The contraction and relaxation strategies have been investigated before and after the fall of the clicker on forearm muscles relating these strategies with different performance levels (Ertan, 2003). Moreover, there are some more studies investigating the muscular activation patterns during archery shooting. Almost all of the studies synchronize the EMG activation patterns with the snap of the clicker and relate the muscular activation with the scores on the target. The studies related with back and glenohumeral joint muscles are limited number and they have reported limited explanations of the muscular activities. Aim of this study was to observe the differences in activation patterns in shoulder girdle muscles of drawing and bow arm during archery shooting.

METHODS

Subjects

Totally 96 shots were analysed of eight subjects that have been involved in the current study were the associate archers for Turkish junior national team (age 16.38±0.86; years of training 1.94±1.04; FITA scores 1083.75±71.02). Each archer has signed a written informed consent and was informed about the possible risks associated with the experimentation before the commencement of the measurement.

Data Collecting Procedure

The measurement sites were prepared according to SENIAM's recommendations (Seniam). Ag/AgCl electrodes (Blue Sensor N electrodes)with a centre-to-centre distance of 2 cm were placed longitudinally on the muscle belly along the m. deltoideus middle (DM) and posterior portion (DP) and m. trapezius middle (TM) and lower (TL) portion of both drawing and bow arm sites. The positive and negative electrodes were positioned parallel to the muscle fibres. The archers were disturbed from both of the reference electrodes on cervical notch and acromion process during the shot. In accordance with the piloting, the reference electrode was placed on the olecranon process of the ulna, which was found to be a relatively neutral site (Sekulic, 2006) and suitable for archery shooting without disturbing the archer during the shots (Ertan et al., 2005a; Hennessy, 1990). Pass band of EMG amplifier, sampling rate, maximum intra-electrode impedance and common mode rejection ratio (CMMR) were 8-500 Hz, 1000 Hz, 6 kohms and 95 dB, respectively.

The archers engaged in a single test session consisting of 15 shots, the first three being trial shots. EMG activities of DM, DP, TM, and TL were quantified. EMG recordings were for 6 s;

4 second prior and 2 second after the clickers audible impetus. This time period included last seconds of Full draw, aiming and first seconds of release and follow through phases. Three-second periods- 2 s before and 1 second after the fall of the clicker- were used to obtain data of twelve shots for each archer. EMG data were full-wave rectified and filtered (moving average filter with 60 ms time-window).

Prior to the shootings, the maximum voluntary contractions (MVC) of DM, DP, TM, and TL of each archer were determined. Archers contracted these muscles to the highest level by forcing the glenohumeral joint to abduction and horizontal abduction where joint angle set to 90^0. The MVCs of TM and TL have been measured when the archer was imitating the drawing action by pulling a rope as he/she does during archery shooting. They started slowly increasing the force, reached the maximum effort after 3-5 s. and hold it 3 s. and repeated this procedure one time after 60 s. later. As the reference value were accepted by mean amplitude of the highest signal portion of maximal effort in 500 ms. Duration (Konrad, 2005). EMG amplitudes were normalized with respect to MVCs. Variations in the relationship could be found in the same muscle among archers by MVC normalization method (Ertan et al., 2005b).

After full-wave rectifying, filtering (moving average filter with 100 ms time-window) and integrating, $EMG_{rel}(\%)$ was calculated for each muscle and for each archer. So, relative EMG signal values were obtained on the basis of muscle and performance level. Totally three-second periods- 2 s before and 1 second after the fall of the clicker-, which has been divided into 100 ms time window, was used to make comparison between the given muscles and archers.

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 two one-second periods were identified as pre and post-clicker intervals.

Statistical Analysis

iEMG % values of twelve shots for each archer have been divided into three periods which are two second before clicker fall (First period), one second before clicker fall (Second period) and one second after clicker fall which can be define as releasing phase (Third period). Analysis of Variance (ANOVA) test for independent samples and Tukey post hoc were used to assess the differences among phases.

RESULTS

Drawing arm normalized Deltoid Middle activity was significantly different in all periods ($p<0.05$), in the second period Deltoid middle activation was statistically higher than the first period (20.941±10.556), and in the third period after clicker was statistically lowest period (8.312±6.3) for the deltoid middle muscle. Drawing arm Deltoid posterior muscle activation of first and second period (1. Period: 16.593±4.585; 2. Period 18.801±5.546) were significantly higher than third period (6.787±6.068), and there were no significant differences between first and second periods in before clicker fall. Trapezius middle and lower muscles iEMG activities in the drawing arm have statistical differences among all periods ($p<0.05$). The highest activity can be seen in the second period before clicker fall in both muscles.

Table 1. ANOVA table between periods of before and after clicker time drawing arm and bow arm muscles.

	Before Clicker		**After Clicker**	
	I. Period	II. Period	III. Periyod	F
	X	X	X	
DA Deltoid Middle (MVC %)	17.892±7.505□	20.941±10.556□	8.312±6.3□□	76.45731
DA Deltoid Posterior (MVC %)	16.593±4.585□	18.801±5.546□	6.787±6.068□□	72.12365
DA Trapezius Middle (MVC %)	18.636±7.83□□	20.524±7.536□□	11.345±6.202□□	86.32027
DA Trapezius Lower (MVC %)	17.260±4.281□□	19.617±5.12□□	12.121±4.665□□	63.68862
BA Deltoid Middle (MVC %)	30.405±12.404□	32.068±12.344□	15.985±8.729□□	83.46617
BA Deltoid Posterior (MVC %)	20.781±4.486□	22.990±4.819□	10.03±5.865□□	72.64326
BA Trapezius Middle (MVC %)	24.735±11.392□	26.902±12.636□	12.642±8.291□□	67.64211
BA Trapezius Lower (MVC %)	25.031±10.035□	27.329±11.506□	13.390±8.601□□	55.57471

□: refers statistically significant difference from I. Period,
□: refers statistically significant difference from II. Period,
□: refers statistically significant difference from III. Period

In the bow arm Deltoid middle muscle in before clicker first and second period has not statistical differences but after clicker time in the third period deltoid middle were statistically lower (15.985±8.729) then both first and second period. Deltoid posterior in the bow arm also has statistical differences between III. Period and I.-II. Periods., in the third period MVC % values statistically lower (10.03±5.865) than other periods. Similar statistical differences in Trapezius middle and lower muscles can be seen in III. Period

Drawing arm normalized DP, DM, TM and TL activities can be seen in Fig. 1 two seconds before (1. and 2. Periods) and one second after (3. Periods) the falling of the clicker.

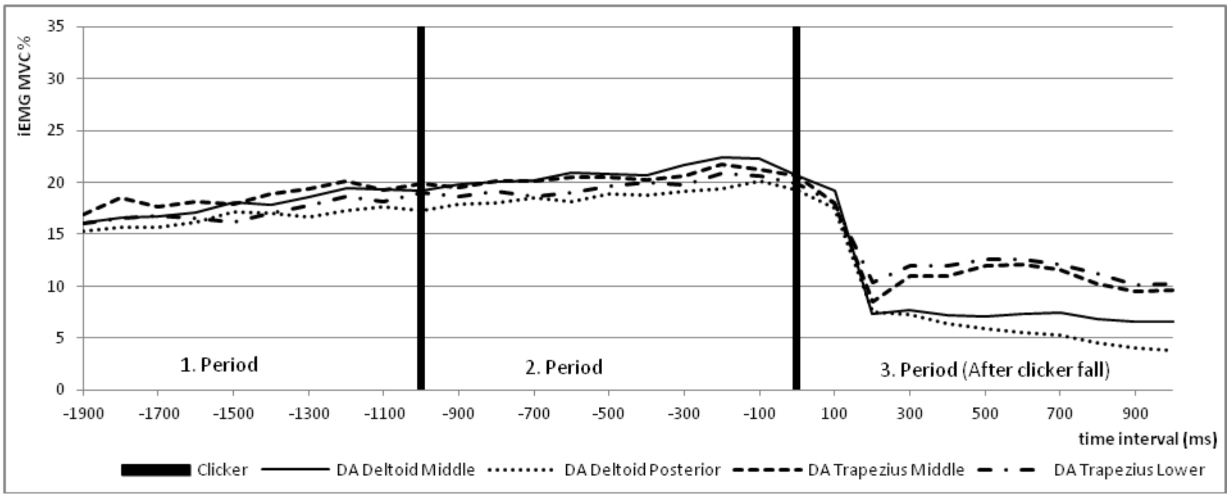

Figure. 1. Drawing arm M. Deltoid Middle, M. Deltoid Posterior, M. Trapezius Middle and M. Trapezius Lower iEMG values two seconds before and one second after for skilled archers.

When drawing arm shoulder girdle muscles observed together it can be seen gradually increase until falling of clicker especially in the second period of aiming phase. Then all these muscle naturally shows relaxing rapidly after clicker fall due to releasing.

Bow arm normalized M. Deltoid Posterior, M. Deltoideus Middle, M. Trapezius Middle and M. Trapezius Lower activities can be seen in Fig 2 two seconds before and one second after the falling of the clicker.

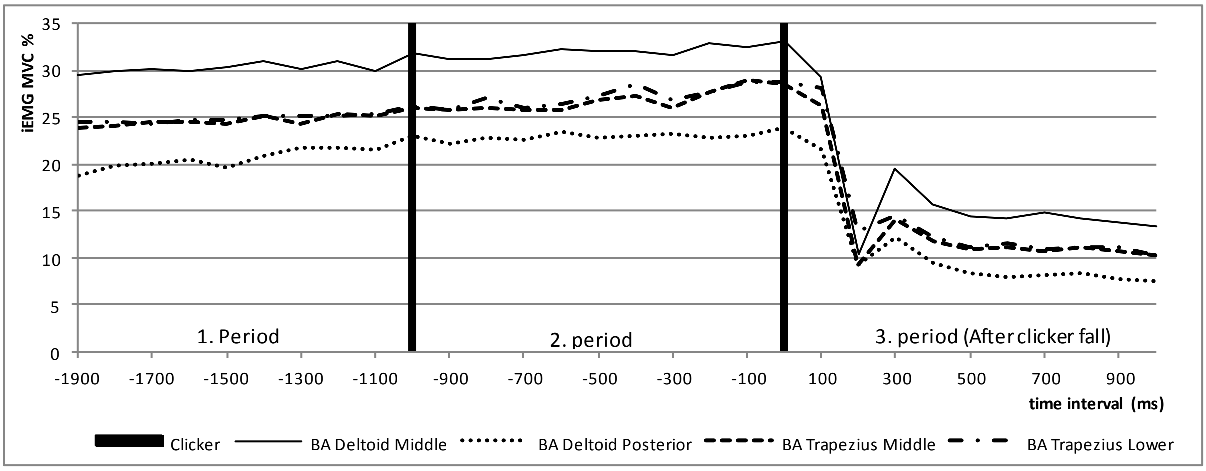

Figure. 2. Bow arm M. Deltoid Middle, M. Deltoid Posterior, M. Trapezius Middle and M. Trapezius Lower iEMG values two seconds before and one second after for skilled archers.

Bow arm is the stabilizator of the bow and carries the weight of the bow, and the muscles of this arm contract isometrically. Before clicker fall stable contraction can be seen in both first and second periods of aiming phase. After clicker fall sharp decreasing can be seen on Fig. 2 (3. Period) through 200 ms.in bow arm muscles.

DISCUSSION

Lander et all (1984) The kinds of variables included in the analysis depend on characteristics of the sport being examined. For instance, in determining predictive factors associated with running, aerobic capacity would form an important part of baseline information. However, in the study of less active, self-paced sports such as archery, this information may be less important (Landers, Hunt, Daniels, 1984) (as cited in Landers, 1986).

Archery can be described as a comparatively static sport requiring strength and endurance of upper body, in forearm and shoulder girdle (Mann, 1989). According to a suggestion, archer relaxes the flexors as the force of the string on the fingers is sufficient to produce extension (Martin, 1990; Mc Kinney, 1997) and according to another suggestion the relaxation of the flexors and contraction of the extensors. Muscular coordination between the agonist and the antagonist muscles of the forearm is essential in this strategy and requires a relatively long training period (Clarys, 1990; Hennessy, 1990; Nishizono, 1987).

Ertan et. al. (2003) has observed that elite, beginners and non-archers showed gradual relaxation of the M. Flexor Digitorum superficialis after the fall of the clicker and this relaxation was more rapid in elite archers then in beginners and in non-archers. Nishizono et. al. (1987) considered the M. extensor digitorum as the main muscle engaged in the releasing activity of the bow string. Active contraction of this muscle was associated with a change from flexion to extension to release the bow string (Hennessy, 1990). Ertan et. al. (2003) established that archers develop a specific forearm flexor and extensor muscular strategy to accurately shoot an arrow to a given target after the fall of the clicker. Martin et. al. (1990) demonstrated that fifteen highly skilled archers displayed similar patterns.

Previous studies focused especially on forearm muscles. They were not clarifying exactly the contraction of the shoulder girdle muscles and glenohumeral joint. Shoulder girdle and glenohumeral joint muscles activities are evaluated with this study in skilled archers. The findings about drawing arm Deltoid Middle and Posterior muscles which obtained from the archers, have been showed statistically decreasing in after clicker period. The M. deltoid middle and posterior that share the drawing weight of the bow, have contracted by progressive increasing until the fall of the clicker and they have relaxed rapidly at first then gradually by falling of the clicker.

Drawing arm normalized M. Trapezius Middle and M. Trapezius Lower activity has been showed in Table 1. Trapezius Middle and Lower muscles are the adductor of scapula. In the archery, adduction of scapula is the main supporter of drawing and carrying drawing weight of the bow, and MVC % values of these muscles have statistically increased until third period for reaching maximum drawing length. After the fall of clicker, they have statistically decreased, because of ending role of drawing movement.

When the activation percents of the drawing arm deltoid and trapezius muscles has examined, M. Deltoideus Middle has the highest contraction percentage of MVCs and it follows M. Deltoid Posterior, M. Trapezius middle and M. Trapezius Lower, respectively.

While the drawing arm gets the string under the chin to full draw position bow arm make drawing easy with its stable movement and exhibits isometric contraction to not to move the bow position in the phases of releasing and following through. While the bow arm which is under the isometric contraction props up the weight and vibration of the bow, it doesn’t disturb the flying of the arrow with its stable movement.

Pekalski (1990) differentiated shooting technique from bow-arrow-archer interaction. He stated the paramount importance of the movement of the arrow in archery. He divided arrow movement into two phases: (1) interaction between an arrow and archer-bow subsystem that lasts from the moment of releasing the bowstring until the arrow loses contact with the bow and the bowstring. (2) Ballistic flight: This lasts from the end of phase 1 until the arrow hits the target. In the first phase, that express releasing of the string and leaving of the arrow from the bow, any factor that can effect flying of the arrow negatively can cause bad point in the target. This is a mistake that can be seen frequently in the beginners and skilled archers and the source of this mistake is not to control the weight of the bow and imbalance of the string at releasing phase.

Bow arm normalized M. Deltoideus Middle and M. Deltoideus Posterior activity has been showed a significant decrease after the fall of the clicker according to first and second period of drawing. This can be thought as the archers relaxed their deltoid middle and posterior muscles by releasing on the other hand the releasing of these muscles are not entirely because of controlling the weight of the bow and imbalance of the string at releasing phase. These results show that the bow arm, which is approximately 90º abduction in full draw phase, take on important role to stabilize of the shoulder joint.

Bow arm normalized M. Trapezius Middle and M. Trapezius Lower activity has been showed presented a significant decrease after the fall of the clicker. Deltoid middle muscle can be said that is the main carrier of the bow weight on the bow arm.

As seen in drawing arm muscles, iEMG% is higher in M. Deltoideus Middle in the bow arm muscles and it follows with M. Trapezius Middle, M. Deltoid Posterior and M. Trapezius lower, respectively. The bow arm proves the stabilization of the bow and the own weight of the bow-that is approximately 10 kg is carried by bow arm. It seems that the muscles of the shoulder girdle are more responsible by holding the bow weight. In addition, M. Trapezius Middle is responsible from adduction of scapula and this muscles contracts symmetrically in drawing arm and in bow arm to share the weight of the drawing bow.

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