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Original paper

Muscular activation patterns of the bow arm in recurve archery

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Abstract

In archery shooting, the archer should hold the bow in place using only the pressure produced through drawing back the bowstring. Most coaches discourage the archer from gripping the bow as this is believed to produce a sideways deflecting torque on the bow and arrow during the release. The purpose of this study was to compare the bow hand forearm muscular activation patterns of elite archers with beginners to define the muscular contraction–relaxation strategies in the bow hand forearm muscles during archery shooting and investigate the effects of performance level on these strategies. Electromyographic activity of the M. flexor digitorum superficialis and the M. extensor digitorum of 10 elite and 10 beginner archers were recorded together with a pulse synchronized with the clicker snap. Raw electromyographic records as 1 s before and after the clicker pulse were rectified, integrated, and normalized. The data was then averaged for successive shots of each subject and later for both groups of archers. The main difference between the elite and beginner archers was that the elite archers had a greater activation of the M. extensor digitorum, which indicates that they avoid gripping the bow-handle not only relaxing the flexor muscles, but also contracting the extensor muscle groups. This muscular contraction strategy secures the archer to not interfere with the forward movement of the bow, which is the forward acceleration of the bow caused by the pushing power of the bowstring.

Keywords: Archery; Electromyography; Muscular contraction; Muscular relaxation, Motor skill

1. Introduction

Skilled archers use a consistent sequence of movements during the execution of a single shot.[1,2] The archer adopts a stance position, inserts the arrow, holds the bowstring and creates a pressure point on the bow-grip.[3] She/he continues with drawing the bowstring, reaching to the full-draw, aiming, releasing and follow-through.[4]

Earlier studies mostly combine the muscular contraction–relaxation strategies with the snap of the clicker.[5–9] Clicker creates an audible impetus considered as "go" signal in archery. The clicker, which is reputed to improve the archer's score, is used by all target archers as a draw length check. A repeated contraction–relaxation strategy by both drawing and bow hand forearm muscles should be developed to react to the clicker as quickly as possible.[5]

Hennessy and Parker[10] conducted a study to define the muscle action in archery shooting. They have selected bilateral eight different muscle groups and involved two archers (one high level, one club level archer). It was stated that before the release, a static equilibrium was achieved at the wrist and elbow of the bow arm. It has been discussed that the component of force from the drawn bow was matched by the isometric co-contraction of the flexors and extensors to achieve the equilibrium. They have chosen two archers to provide a contrast in the performance level. The changes at the bow arm wrist and elbow were similar in both performers indicating that the type of response produced is probably learnt early in the archer's shooting career.[10]

The coaches' point of view on the current topic can be summarized as follows in addition to Hennessy and Parker: The bow-grip is placed between the thumb and index fingers. This bow arm/bow-hold alignment technique, which will produce better balance between the pressures on the bow-handle and pulling line of the bowstring, should position the middle of the bow arm with the centre of the bow. That balance between the forces tends to reduce bow twist or torque as the shot is made. Most coaches recommend that the archer should not hold or grip the bow during the shot. The bow is only held while nocking (inserting the arrow onto bowstring) and after

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the arrow reaches to the target. During the all other processes of shooting, the bow is not gripped. The archer is supposed to not interfere the forward movement of the bow, which is the forward acceleration of the bow caused by the pushing power of the bowstring, by holding/gripping the bow-grip.[11]

Both forearm flexor and extensor muscles would be relaxed and/or not activated to avoid gripping the bow-handle. Activating the flexor muscles can be considered as a bad shooting technique causing the gripping the bow. In the current study, it is hypothesized that elite archers will not contract both M. extensor digitorum (MED) and M. flexor digitorum superficialis (MFDS) or they will only contract the MED. However, beginner archers will contract MFDS that is consistent with excessive gripping of the bow.

Adding to this accumulated knowledge, the aim of the current study is two-fold: (i) to define the muscular contraction–relaxation strategies in the bow hand forearm muscles during archery shooting; (ii) to investigate the effects of performance level on this strategies.

2. Methods

Two groups (i) elite ($n = 10$) and (ii) beginner archers ($n = 10$) were involved in the study. The first group consisted of both German and Turkish national team archers. The beginners were formed by archers from the city clubs in Cologne and Ankara. 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. The study protocol was approved by the Medical Ethical Committee of Başkent University, Medical Faculty Ankara (Certificate No: 2004/85).

The measurement sites were prepared according to SENIAM's recommendations.[12] Ag/AgCl electrodes with a centre-to-centre distance of 2 cm were placed longitudinally on the muscle belly along the MFDS and MED. The positive and negative electrodes were positioned parallel to the muscle fibres. During the piloting of the current study, some alternatives have been tried for the placement of reference electrode (e.g. cervical notch of sternum, acromion process of scapula and olecranon process of ulna). 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[13] and suitable for archery shooting without disturbing the archer during the shots.[5–7] Pass band of EMG amplifier, sampling rate, maximum intra-electrode impedance and common mode rejection ratio (CMMR) were 8–500 Hz, 1000 Hz, 6 kOhm 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 MFDS and MED were quantified. Although cross talks of forearm muscles' EMG activity may exist, it has been accepted that the EMG activity of MFDS (or MED) as recorded from MFDS (or MED) itself for simplification.[14] Two-second periods of twelve shots' EMG data were full-wave rectified and filtered (moving average filter with 60 ms time-window) for each archer.

Prior to the shootings, the maximum voluntary contractions (MVC) of MFDS and MED of each archer were determined. Archers contracted these muscles to the highest level by forcing the metacarpophalangeal joints to extension and flexion. The angle between metacarpal and proximal phalangeal joints was set to 90°. 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.[7] Normalized/relative EMG signals were calculated according to formula given below:

$$\mathrm{EMG_{rel}}(\%) = \frac{\mathrm{EMG_{actual}}}{\mathrm{EMG_{max}}} \times 100$$

After full-wave rectifying, filtering (moving average filter with 100 ms time-window) and integrating, $\mathrm{EMG_{rel}}$ (%) was calculated for each muscle and for each archer. So, relative EMG signal values were obtained on the basis of muscle and performance level.[15] Totally 2-s period, which has been divided into 20 equal time intervals, was used to make comparison between the given muscles and archers.

The snap of the clicker triggered a 5 V Transistor–Transistor Logic (TTL) signal, which was registered simultaneously with the myoelectric signals. According to the rise of the TTL signal two 1-s periods were identified as pre and post-clicker intervals. Figs. 1 and 2 show the processed EMG data for each muscle group separately.

Descriptive statistics were applied to identify the characteristics of the archer groups. Paired samples *t*-tests were used for within-group analyses. One-way analysis of variance (one-way ANOVA) was conducted to compare MFDS and MED activity during each time interval between 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.

3. Results

The analysis of bow arm EMG data has shown that MED has higher values than that of MFDS during the all time intervals ($p < 0.05$). But the difference was not significant at 100, 200, and 300 ms time intervals. Both muscle groups reached their peak amplitudes at 200 ms interval and directly start relaxation after the peak amplitude (Fig. 1).

Beginners have shown different co-contraction strategies of bow arm forearm muscles. The contraction values of the MED and the MFDS were not different from each other ($p > 0.05$). A sharp increase has been observed in the MFDS just after (100 ms) the fall of the clicker and reaching the peak value at about 200 ms. The difference was significant at 100 and 200 ms after the fall of the clicker ($p < 0.05$). Both mus-

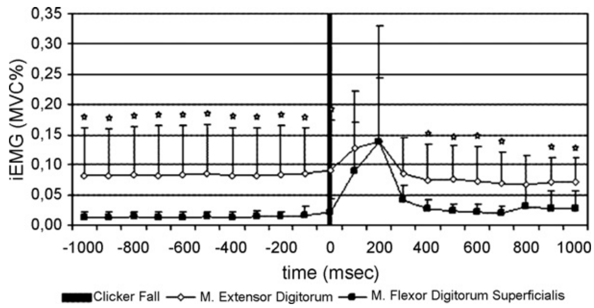

Fig. 1. IEMG values for elite archers ((*) the difference is significant at 0.05 significance level between the M. extensor digitorum and the M. flexor digitorum superficialis).

cle groups returned to their baseline values at about 300 ms (Fig. 2).

When MED contraction values from elite archers were compared with beginners, the data for elite archers showed higher contraction values at all time intervals than that of beginner archers ($p < 0.05$). However, comparison of MFDS values indicated that beginner archers had higher contraction values than that of elite archers at all time intervals except for 200 ms. The difference was significant at 500, 600, and 700 ms time intervals ($p < 0.05$) (Refer to Appendix A).

4. Discussion

High level archers tend to produce a MED-dominant contraction strategy during the all phases of archery shooting. Elite archers relax their finger flexors so as not to grip the bow-handle and contract extensors to avoid holding/gripping the handle during the whole shot. However, this strategy by elite archers changes at about 200 ms after the fall of the clicker by active contraction of both muscle groups. The archers equalize the values of both muscle groups and reach equilibrium and than return to the pre-clicker values. But the difference from pre-clicker strategy is that both muscle groups have almost equal contraction values. So, the high level archers equalize the contraction levels of both musculature to not to change the range of motions in metacarpophalangeal, proximal and distal interphalangeal joints. This strategy just after

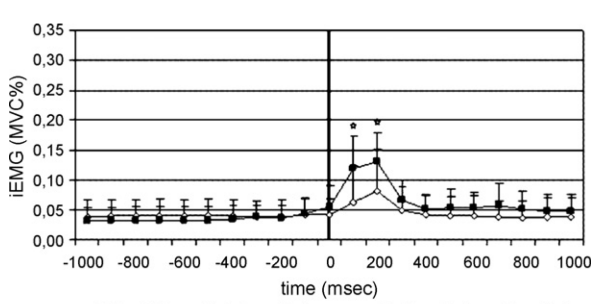

Fig. 2. IEMG values for beginner archers ((*) the difference is significant at 0.05 significance level between the M. extensor digitorum and the M. flexor digitorum superficialis).

the fall of the clicker can be considered as an action to avoid the gripping of the bow-handle.

With beginner archers, however, they have an almost totally different co-contraction strategy in bow-hand forearm muscles. Before the snap of the clicker, they produce same contraction patterns of both muscle groups. However, it seems novice archers wrap the bow-handle by index, middle, and ring fingers and thumb by relaxing muscles which are responsible for extending and flexing the metacarpophalangeal, proximal and distal interphalangeal joints. They tend to contract the finger flexors just after (100 and 200 ms) the snap of the clicker. It shows that they produce an active holding/gripping action of the bow-handle instead of permitting it to move in the direction of the target along with the arrow.

As the arrow-point (metal) and shaft (carbon/aluminium) are made of different materials, the acceleration (Newton's second law) of the shaft may be higher than the point.[16] So, the inertia of the point will create a bending or "spine" of arrow shaft. The flexing of an arrow shaft during shot is known as archer's paradox. Coined by R.P. Elmer in the 1930s, it centres on the idea that, in order to be accurate, an arrow must have the correct stiffness, or "spine", to flex and return back to the correct path as it leaves the bow.[17] When there is no interference of accelerations of both bow-handle and arrow, there will be a balanced interaction between bow-handle and arrow. The strategy developed by high level archers can be interpreted as not interfering to the interaction between bow-handle and the arrow. So, one of the reasons why high level archers have higher scores may be performing the correct bow hand forearm muscular contraction strategy (Refer to Appendix A).

The findings in the current study contradict with an earlier study.[10] The reason for the difference may be involving only two archers in Hennessy and Parker's study. So, the findings in their study may be considered as specific to the archers involved. However, in the current study, 10 high and 10 club level archers have been involved from two national teams and from different city clubs. So, the findings in the current study make itself more general than that of the study by Hennesy and Parker.

It has been concluded that not contracting the both MFDS and MED or only contracting MED during archery shooting is an indicator of performance level. Because the contraction of MFDS manifests the gripping the bow-handle, which may decrease the score on the target. Gripping of the bow-handle is supposed to produce a torque or twisting of the bow when arrow is released. Not involving the MFDS into action secures the archer both to not interfere with the interaction between bow and arrow and the forward movement of the bow, which is the forward acceleration of the bow caused by the pushing power of the bowstring. So, one of the reasons why high level archers have higher scores on the target may be the performing of correct muscular contraction in bow hand forearm muscles.

5. Practical implications

The findings of the current study can be used for:

- assessing shooting techniques;
- evaluation of archers progress; and
- selection of talented archers.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2008.01.003.

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