INDIVIDUAL VARIATION OF BOWSTRING RELEASE IN HIGH LEVEL ARCHERY: A COMPARATIVE CASE STUDY

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ABSTRACT

Purpose. The muscle-contraction strategy between the predominant forearm and pull finger used in archery is defined as a response to the fall of the "clicker" by active contraction of the m. extensor digitorum (MED) and the gradual relaxation of the m. flexor digitorum superficialis (MFDS). However, one archer with a long-term high performance history makes use of an entirely different strategy, which is thought to have positive effects on her performance. The purpose of this study was to make a more detailed analysis of the contraction strategy performed by this particular top-level archer and to consider the advantages this strategy may have on bowstring behaviour after release. **Methods.** A high level (world-class) archer volunteered to participate in this study. The subject has been ranked in the top 20 in the world and as one of the top 3 archers in Europe for almost two decades. The subject has a personal best score of 1354 points (pts) in a qualification round as well as receiving 168 pts in an 18-arrow match. The subject engaged in a single test session consisting of 12 shots. EMG activity of the MFDS and MED were quantified. **Results.** The subject's MFDS was found to be clearly relaxed even ~ 100 ms after the snap of the clicker was heard. The subject also showed a gradual relaxation of the MED after the snap of the clicker. **Conclusion.** The study results found that this different type of contraction-relaxation strategy can be used in the drawing arm with success, as it may avoid causing a lateral deflection of the bowstring.

Key words: archery, muscular contraction-relaxation, EMG

Introduction

To fire an arrow in archery, an archer pushes the bow with an extended arm, which is statically held in the direction of the target, while the other arm exerts a dynamic pulling of the bowstring from the beginning of the drawing phase until it is released through dynamic execution [1]. The release phase must be well balanced and highly reproducible in order to perform well in competition [2].

The bowstring is released when an audible signal is received from a device called a "clicker" which is used to check draw length [1]. Thanks to this device, every arrow can be drawn to an exact distance, and therefore a standard release can be obtained. The clicker is reputed to improve an archer's score and is used by nearly all target archers. The archer should react to the clicker as quickly as possible and for this reason a contraction and relaxation strategy in the forearm and pull finger muscles should be developed for repeatable performance.

Ertan et al. [3] identified a contraction-relaxation strategy used in archery during the response to the snap of the clicker, which was executed by a majority of archers irrespective of their performance level. This study described the response to the snap of the clicker as an active contraction of the m. extensor digitorum (MED) and gradual relaxation of the m. flexor digitorum superficialis (MFDS) in all subject groups (high level, beginner archers and non-archers). This active contraction of the MED was defined as the predominant forearm and pull finger muscle contraction strategy that is used in archery. However, one particular archer with a long history of high level performance showed a different strategy, which is thought to have had a considerable positive effect on her performance.

The purpose of the current study was to carry out a more detailed analysis of the contraction strategy performed by this particular top-level archer [3] and to consider the advantages that her strategy might have on performance.

Material and methods

Participant

A high level (world-class) archer volunteered to participate in the study. Before the taking of measurements, the subject was informed about the possible risks associated with the experiment. Written informed consent

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was obtained from the athlete before participating in the study. The study conformed to the ethical requirements of the 1975 Helsinki Declaration. The subject, whose competitive results are shown in the study, has been ranked in the top 20 in the world and as one of the top 3 archers in Europe for almost two decades. The subject had participated in 4 Olympic Games, 4 World Championships, 8 European Championships and several internationally recognized tournaments. The subject has a personal best score of 1354 pts in a qualification round (composed of four distances) and 168 pts in an 18-arrow match.

Materials

The measurement test sites were prepared as according to SENIAM's recommendations [4]. Ag/AgCl electrodes with a centre-to-centre distance of 2 cm were placed longitudinally along each muscle. The electrodes were placed on the muscle belly and the positive and negative electrodes were positioned parallel to the muscle fibres of the MFDS and MED. The reference electrode was placed on the olecranon process of the ulna [3, 5], which was found to be a relatively neutral test site [6] and suitable for archery shooting as it does not disturb the archer when shooting. The pass band of the EMG amplifier, sampling rate, maximum intra-electrode impedance and CMMR were 8–500 Hz, 1000 Hz, 6 kOhms and 95 dB, respectively.

Design and procedure

The subject engaged in a single test session consisting of 15 shots, the first three being trial shots. EMG activity of the MFDS and MED were quantified. Prior to shooting, the maximum voluntary contraction (MVC) of the MED and MFDS of each subject were determined by EMG as base variables. The subject was instructed to contract the aforementioned muscles to maximum effort against a stable resistance by forming a three-finger hook as is required when holding the bowstring. The MVC of the muscles was recorded.

The angle between the proximal and distal interphalangeal joint was not changed during the isometric contractions of the aforementioned muscle groups. The EMG amplitudes were normalized according to the maximum contraction effort (absolute amplitude) within a 100ms time-window of the highest activity recorded during the MVC.

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-clicker and post-clicker intervals. The respective EMG data sets of each of the twelve shots were fully-wave rectified and filtered (a moving average filter with a 100 ms time-window). Figure 2 shows the processed (averaged, rectified, filtered and normalized) EMG data for each muscle group separately.

Mean scores were calculated during the subject's 12 shots. One-way analysis of variance (one-way ANOVA) was conducted to compare the MED and MFDS activity during each time interval. 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

During the final moments of the full draw phase the archers' finger flexors and extensors showed an almost isometric contraction pattern indicating that the final drawback of the bowstring is obviously regulated by the shoulder and back muscles. As soon as the arrow had been drawn beyond the clicker device, extensor muscle activation increased and the fingers actively released the bowstring and arrow. It is evident that the timing and intensity of muscle activation show variations specific to an athlete's performance level. Novice archers increase muscle activity prior to release with a steady and continuous increase of extensor activity throughout the pre- and post-clicker phase and a delayed relaxation of finger flexors after the snap of the clicker. More experienced archers have developed an activation strategy which is characterized by a comparable level between flexor- and extensor muscles prior to the clicker signal but a pronounced active extension of the fingers in response to the clicker signal (see Fig. 1).

Comparing the activation patterns of this particular top-level archer to those of the different performance level groups reveals obvious differences [3].

The subject of this study presented a clear relaxation of the MFDS approximately 100 ms after the snap of the clicker. She also showed a gradual relaxation of the MED after the snap of the clicker. In other words,
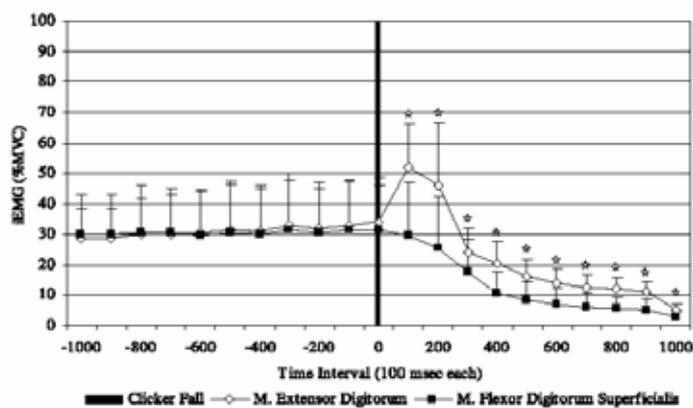
* denotes a statistical significant of 0.05 between the MED and MFDS

Figure 1. IEMG values for elite archers
(the figure is taken from Ertan et al. [3])
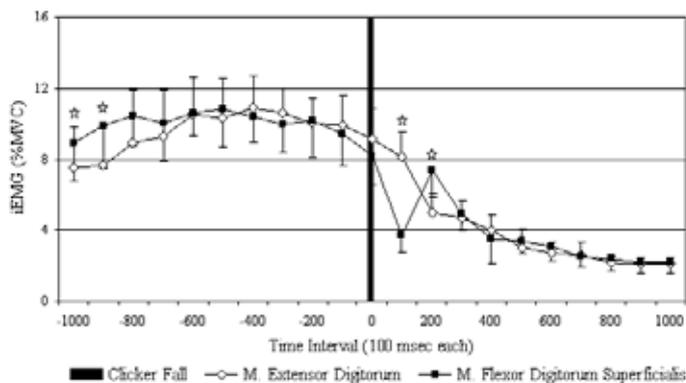
* denotes a statistical significant of 0.05 between the MED and MFDS

Figure 2. IEMG values for the elite female archer

there was no active contraction of MED. Throughout the entire shot, the normalized values of the MED and MFDS were significantly different ($p < 0.05$) at the time intervals of –1000, –900, 100, 200 ms (Fig. 2). However, an active contraction of MFDS was observed approximately 200 ms after the snap of the clicker and just after the period of sudden relaxation. From high-speed film observation it is known that the bowstring travels past the fingertips within a time period of about 60 ms [2]. The activation of the archer's MFDS consequently does not further influence bowstring travel.

Discussion

The contraction and relaxation strategy in the forearm muscle during the release of the bowstring is critical for accurate and reproducible scoring in archery. Up until now, two different approaches to this strategy were proposed in previous studies [2, 7–10].

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 affect the release moment by willingly extending the fingers through concentric antagonistic muscle action [9]. An active extension of the pull fingers is proposed to produce lateral deflections of the bowstring and to produce less consistency in shot-to-shot performance [10].

The second approach suggested, based on representative experimental data, was the relaxation of the flexors and an active contraction of the extensors [3]. Muscular coordination between the agonist and antagonist muscles of the forearm [11] is essential in this strategy and requires a relatively long training period [2, 7, 8].

The specific archer in this study responded to the snap of the clicker by the relaxation of the MFDS and without an active involvement of the MED. The subject's contraction-relaxation strategy is different from

those of other archers as described in earlier findings. In the subject's strategy, the release of the bowstring is accomplished by only relaxing the MFDS. Therefore, the force of the string on the fingers is sufficient to produce the extension of the three finger hook.

The relaxation of the muscles directly after the snap of the clicker makes the tension of the bowstring the only mechanism to open the fingers, which then provide no further resistance. An active, muscle driven extension of the fingers, as observed in other archers, could allow the fingers to drag against the bow string sideways and thus force it to deflect from a straight path until arrow delivery. It is most likely that the muscle activation strategy developed by this study's particular athlete avoids a deflection of the bowstring and considerably contributes to the repeatability and reliability of her performance.

Archery shooting is a good example of the isometric contractions present in the forearm muscles of the drawing arm. Before the snap of the clicker, the archer is not supposed to change the range of motion of the proximal and distal inter-phalangeal joints. To do so, the muscles involved in this specific movement pattern must be held at a constant length instead of being allowed to lengthen or shorten. However, the range of motion of the proximal and distal inter-phalangeal joints may be allowed to change, but to do so, requires responding to a specific stimulus by coordinating agonist and antagonist muscles which necessitates a long training period.

Conclusion

The current literature on forearm contraction-relaxation strategies for the drawing arm states, in general, that a response to the snap of the clicker requires an active contraction of the MED and relaxation of the MFDS. The performance level of a subject may also influence some change in such a strategy (refer to Ertan et al. [3] for more detail). However, the current findings prove that a different type of contraction-relaxation strategy can be used in the drawing arm as it may avoid causing a lateral deflection of the bowstring.

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