FATIGUE EFFECTS ON SHOOTING ARCHERY PERFORMANCE

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INTRODUCTION

In archery shooting, there is a fixed sequence of very accurate movements that the shooter performs: bow holding, drawing, full draw, aiming, release and follow through stage (Haywood, 1989). This sequence allows the archer to get highly reproducible releases for achieving and maintaining good results.

As archery competitions normally last many hours requiring a great deal of shoots, the athletes are usually subjected to a deterioration of muscle performance. Deterioration of mechanical performance of one or more muscles, which are not able to maintain longer the desired force level, may be related to technique and motor strategy changes. Although these modifications are probably very subtle, their effects may produce undesirable impact on arrow scores. To our knowledge the only study focused on fatigue in archery was that of Martin (1992) which investigated the relationship between fatigue and changes in bow grip force distribution. No attempts were made to assess the effects of fatigue on archers' motor strategy.

It was the purpose of this study to analyse the possible effects of muscular fatigue on athletes' strategy and techniques. An additional objective was to determine whether or not fatigue effects are somehow dependent on skill level of athletes. To accomplish these tasks a simultaneous investigation of different kinds of variables, including kinematics, kinetics and EMG, were performed.

METHODOLOGY

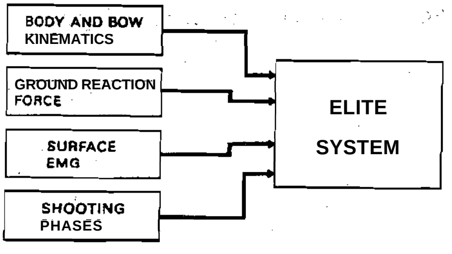

Figure 1. *Organization of data acquisition*

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Twelve archers of Italian Archery Federation were the subjects of this study. According to their FITA scores they were classified as intermediate (n = 7; FITA scores ranging from 1180 to 1300) and high level archers (n = 5; FITA scores > 1300). Each subject was asked to stand at a point 12m from the target. At first ten shoots for each archer were recorded and analysed . After these measurements a fatigue protocol was performed.

The athletes come to a full drawing position and remained in the aiming phase for.20 s. Each athlete performed six series of ten repetition with rest interval of 20 seconds between the sets. Immediately following the fatigue protocol, the subjects performed ten shoots more. EMG, kinematics and force platform data were acquired simultaneously online and processed using the ELITE motion analysis system (Pedotti & Ferrigno, 1985) (BTS srl, Milan) as reported in figure 1. The 3-D coordinates of 23 retroreflective anatomical landmarks (10 mm in diameter) were detected with a sampling rate of 100 Hz.

In order to synchronise the recorded variables with the shooting phases, electrical switches were used to detect the moment of clicker closure, arrow release, and contact loss of the arrow with the bowstring (figure 2). The phases have been evidenced by using an electronical device, whose output was sampled at 1000 Hz.

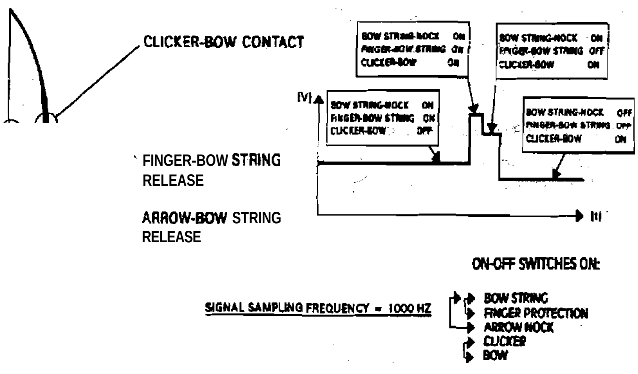

Figure 2. On-off switches placement for the detection of the different shooting phases. The phases are evidenced by the signal on the right side of the figure.

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Surface EMG was collected from the finger flexor muscles and biceps of the drawing arm (the arm used to draw the bow string backward), and from upper and lower back muscles, with a sampling rate of 1000 Hz. The EMG recordings were subsequently analysed by first full-wave rectifying the signal and then integrating the results for 100-ms intervals. The IEMG values were then normalised to IEMG values calculated for standard maximum isometric actions.

Markers were placed on: the temporal bone and the mandibular joint to mark the head; the shoulders, elbows, wrists and hands to mark the arms; the iliac crests, knees, ankles, and third metatarsal heads to mark the lower limbs. In addition, three markers were placed on the backbone and other three were attached to the bow. Ground reaction forces and center of pressure displacements were measured with a Kistler force platform at a sampling rate of 1000 Hz. A special designed software (BTS) was used to analyse the COP migration pattern and to compute summary statistics.

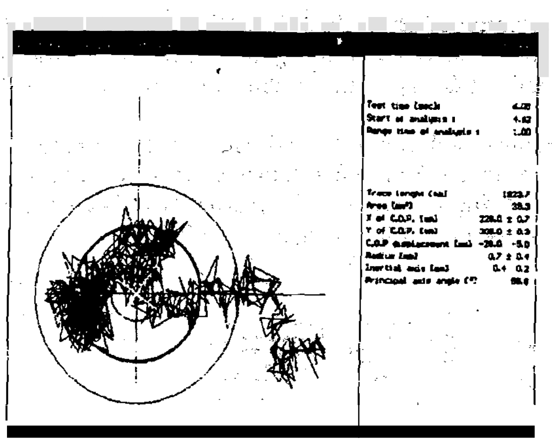

Figure 3. Center of pressure migration during the last second before the arrow release. On the right are reported the numerical parameters of interest.

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RESULTS AND DISCUSSION

The following is a brief synopsis of the main results obtained from this investigation. In each subject no significant variation in performance scores was evident with fatigue, in all the subjects a significant increase in bow lateral sway was observed after the fatigue protocol. The increase ranged from 6% to 39% (mean 20%) and was much more evident in less skilled subjects. The correlation coefficient between FITA scores and sway increases was -0.65 ($p < 0.05$). Central fatigue (diminished central nervous system stimulation to muscle) and/or localised muscular fatigue may be factors associated with the observed increases in bow sway.

Poorer performers displayed longer aiming phase duration after fatigue protocol. The correlation coefficient between FITA scores and increases in aiming duration was 0.81 ($p < 0.05$).

EMG analysis showed as each subject displayed very repeatable muscle action before and after the fatigue protocol. General trends showed increase in IEMG amplitude after fatigue protocol (see table I), with the greatest rate changes occurring in the biceps of the less skilled subjects.

	Flexor Digitorurn	Biceps	Trapetius Desc. right	Trapetius Sup. right	Trapetius Desc. left	Trapetius Sup. left
High level	7	12	10	9	8	10
Interm. level	9	16	8	7	14	7

Table I. Average percentage of peak IEMG changes after fatigue protocol

	Flexor Digitorum	Biceps	Trapetius Desc. right	Trapetius Sup. right	Trapetius Desc. left	Trapetius Sup. left
Subject 1	7	21	-3	-2	14	9
Subject 2	5	5	7	9	0	4

Table II. Average percentage of peak IEMG changes in two subjects belonging to the High Level group, after fatigue protocol

By considering individual IEMG changes, these variations appear to be dependent to subject and muscular group, as it can be seen by data reported in table **II,** where peak IEMG changes in two archers of the same **skill** level were compared. After fatigue some athletes (3 of the intermediate group, and 2 of the high level one) showed a higher activation of the left sided muscles of the upper back when holding the arrow in the full draw position. In these subjects a link between the alignment of the shoulders line with the bow arm and increases in IEMG amplitude were evident.

Subsequent to fatigue protocol some archers showed significant changes in the length of the COP trajectory (indicating faster corrections in movements) while preparing to release arrow. No statistical correlation between the **skill** level and the degree of the changes was found. No significant differences in COP displacement **(y-x)** were found both for individuals and groups considered.

CONCLUSION

In summary the method here presented seems to be an useful tool to assess and evaluate **biomechanical** data in shooting archery. The proposed **kinematic** model and the monitored muscles give in fact a good representation of the archers during a complete trial, allowing the identification of subtle changes in shooting techniques. Part of the observed changes after fatigue protocol seems to be related to the **skill** level, part seems to be specific for each subject.

The results indicate the need to train the muscle groups more critical both for strength and endurance. Furthermore, attention should be placed on the development of the more convenient motor strategy to create quasi-static equilibrium by means of the skeletal system **(i.e.** correct anatomical segment relationships) rather than the muscular system.

REFERENCES

Haywood, K.M. **(1989).** Teaching archery: Steps to success. Champaign, IL: Leisure Press.

Martin, P.E., Heise, D. **(1992).** Archery bow grip force distribution: relationships with performance and fatigue. International Journal of Sport Biomechanics, **8,305-319.**

Pedotti. A., **&** Femgno, G. **(1985).** ELITE: **a** digital dedicated hardware system for movement analysis via real time TV signal processing. **IEEE** Transaction on Biomedical Engineering. **32, 943-950.**