MULTIFACTORIAL ANALYSIS OF SHOOTING ARCHERY

ROBERTO SQUADRONE [1,2], RENATO RODANO [1]

[1] CENTRO DI BIOINGEGNERIA, POLITECNICO DI MILANO - FONDAZIONE PRO JUVENTUTE I.R.C.C.S., MILAN, ITALY

[2] ISTITUTO DI SCIENZA DELLO SPORT, ROME, ITALY

INTRODUCTION

In archery shooting there is a fixed sequence of 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.

This implies the following:

1) the programming of a proper movement sequence during the different phases;
2) the controlled action of the body segments;
3) the body and bow equilibrium maintenance.

In such a complex motor task which involves multijoint coordination, a distinctive feature of the motor system is maximally exploited, namely the potential to execute the same motor task through different combination of motor equivalent actions (Cole and Abbs, 1986). The purpose of this study was the identification of the various strategies utilised by a group of different skilled archers and the evaluation of the role that skill has in movement execution.

As the traditional evaluation performed by visual inspection appears insufficient for the analysis of these aspects the simultaneous investigation of different kinds of variables, including kinematics, forces and EMG is required. In addition, for a deeper understanding of the shooting motor action, the relationship among these variables has to be considered in a quantitative and qualitative way. In particular the quantitative multifactorial approach can validate the existence of a variety of motor strategies utilized by an individual or among individuals to accomplish a specific goal and to identify common components that may exist across different strategies.

METHODOLOGY

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 12 m. from the target. Twenty shoots for each archer were recorded and analysed. EMG, kinematics and force platform data were acquired and processed using the ELITE motion analysis system (Pedotti & Ferrigno, 1985) (BTS srl, Milan). The 3-D coordinates of 23 retroreflective anatomical landmarks (10 mm in diameter) were detected with a sampling rate of 100 Hz. Accuracy of the system was one part in 3000 of the field of view.

In order to synchronise the recorded variables with the shooting phases, an electrical device attached to the bow was used to detect the moment of clicker closure, arrow release, and contact-loss of the arrow with the bowstring.

From the finger flexor muscles and brachial biceps of the drawing arm, and from upper and lower back muscles. surface EMG was collected 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 EMG values were then normalised to EMG values calculated for standard maximum isometric actions.

Markers were placed on the temporal bone and the mandibular joint to markthe head, shoulders,elbows, wrists and hands to mark the arms iliac crests, knees, ancles 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. The final model of marker position is described in figure 1.

Ground reaction forces and centre of pressure displacements were measured with a piezoelectric force platform (Kistler 9281B) at a sampling rate of 1000 Hz. A special designed software (BTS srl, Milan) was used to analyse the center of pressure (COP) migration pattern and to compute summary statistics.

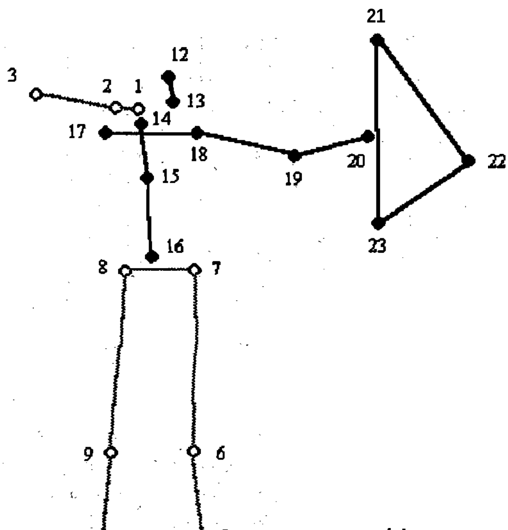

Figure 1. Kinematic model of the subject. Black markers are recorded by two TV cameras placed on the back side. White markers are recorded by two TV cameras placed on the front side.

Given the maximal sampling rate of the kinematic data (100 Hz), it is not possible to perform a detailed analysis of the releasing phase. which takes 0.03 seconds corresponding to only 3 frames. However, it is possible to measure movements and posture prior to the arrow release and analyse the follow through phase.

RESULTS AND DISCUSSION

Despite the apparent intra and intersubject similarities in performing the shoots, slight differences were observed in kinematic. EMG and kinetic variables. Some differences seem to be related to individual skill level and other appear to be idiosyncratic. Results, in fact, indicate that while there are common elements that are present in all subjects, strategies vary in some ways that can be attributed to the skill and in other ways that may not attributed to the skill. For example, the EMG patterns of the monitored muscle. and the kinematic of the bow rising phase as well as the ways to come to full drawing position appear to be idiosyncratic. In particular it has been identified two ways to come to a full drawing position: 1) lift and hold the bow in the right position and then move the drawing arm backwards; 2) lift both arms and, simultaneously. move them in the opposite direction.

EMG analysis revealed that each archer tended to display, across all the experimental trials, a very consistent and repeatable pattern for each of all the muscle examined. In other words, the timing and the magnitude of individual EMG records were so similar one among the other that we can choose random one of them as representative of all trials. The comparison of the EMG records across all subjects did not reveal any typical pattern as each athlete shows a unique configuration. To give an idea of how the subjects activated differently their muscle groups in table I the mean peak IEMG (integration intervals = 100 ms) for each subject are reported. As it can be seen, for each muscle group the values ranged over very different values.

Among the disparities that may be attributed to the skill, differences in the relative duration of the shooting phases, in arm and bow stability, and degree of activation of biceps brachial seem to be the most relevant. Correlation of the mean duration of the aiming phase and lateral bow sway with FITA score yielded coefficients. of r = -0.72 and r = -0.67 respectively.

	Flexor Digitorum	Biceps	Trapetius Superior *Right side*	Trapetius Des. *Right side*	Trapetius Superior *Left side*	Trapetius Des. *Left side*
S1 (HL)	32	37	67	42	31	30
S2 (HL)	58	36	52	13	24	59
S3 (HL)	31	37	66	40	33	31
S4 (HL)	56	42	24	26	61	22
S5 (HL)	23	73	31	12	62	60
S6 (IL)	28	46	26	47	60	57
S7 (IL)	26	78	25	48	24	28
S8 (IL)	35	64	14	32	46	47
S9 (IL)	34	88	30	17	21	22
S10 (IL)	25	68	49	21	30	34
S11 (IL)	39	72	40	46	65	68
S12 (IL)	51	62	62	27	59	27

Table I. ***Normalized peak*** IEMG: ***HL subjects belonging to the high level group, IL subjects belonging to the intermediate level group.***

An example of how this test allow to identify clear differences between subjects of the same **skill** level (subject **S5**, FITA score = 1330; subject S2 = 1350) is **furnished** by the inspection of the stick diagrams reported in figure 2, which allow the comparison of the posture of two top level archers in the sagittal plane, 0.2 s before clicker closure. Subject S2 was characterized by an almost perfect shoulder alignment in the sagittal plane, while subject **S5** showed a clear inclination of the shoulder line respect to the bow arm, and the **backbone** positioned oblique in relation to the legs. Comparison of the EMG patterns revealed that S2 was characterized by low activation of biceps brachial during all the **shooting** phases and almost the same level of activity of the right **and** left side back muscles. In contrast, S5 showed high biceps activation and the left back muscles more activated than the right ones. The latter findings may be related to the attempt made by the athletes to keep the left shoulder lowered during the last period of the aiming phase (see stick diagram of **S5**).

CONCLUSION

The method presented in this study seems to be an useful tool to assess and to evaluate **biomechanical** data in shooting archery. The proposed **kinematic** model and the monitored muscles give a **good** representation of the archers during a complete trial. Furthermore. considering the complexity of measurements performed the described test is not excessive time consuming. It takes less than 90 minutes for the equipment and athletes preparation and trials performing.

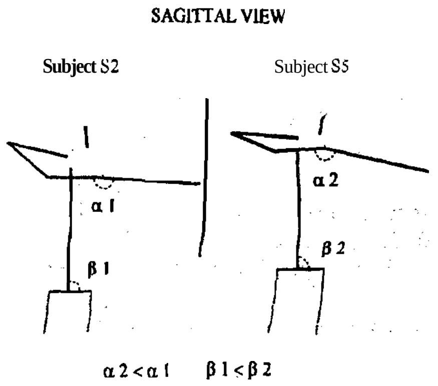

Figure 2. *Comparison of the posture of two subjects belonging to the High Level group.*

The main specific findings of the work may be reassumed as follows:

- despite apparent similarities in performing shoots, differences were observed in kinematic, EMG and kinetic variables;
- some differences seem to be related to individual skill level and other appear to be idiosyncratic;
- a clear and meaningful link between alignment of various body segments and degree of muscle activation has been found;
- CP analysis reveals that while CP displacement is not a sufficient measure to discriminate among archers of different skill level, the other indices considered in this study seem to be more useful to discriminate purpose.

Results can be used to:
evaluate and compare individual strategies and techniques;
compare one subject technique with the profile of an elite archer;
compare one subject motor and technical condition in different moments of the season;
to test coaching teories.

REFERENCES

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

Cole, K.J., Abbs, J.H. (1986). Coordination of three-joint digit movements for rapid, finger-thumb grasp. Journal of Neurophysiology, 55, 1407-1423.

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