A TRAINING AND FEEDBACK SYSTEM FOR ARCHERS

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INTRODUCTION

Archery is a skill that demands utmost precision and repeatability of motion. Minute deviations from the individual pattern are often below the JND threshold. Nevertheless they influence the score. More specifically, archers display radial or ulnar abduction of the bow-hand while aiming. This leads to changes in the energy stored in the upper and lower bow-limbs and thus to vertical deviations from the target. Also, a tremor of the drawing hand may occur. Furthermore, some archers tend to rotate the bow slowly about an axis parallel to the arrow. Since the arrow is well below the line of sight, lateral deviations occur even when the point of aim is dead on.

Beginners have rather large and random inconsistencies, skilled archers have intermittent problems. Intervening variables complicate the causal interpretation of an inaccurate shot.

REVIEW OF LITERATURE

Only few studies are devoted to the biomechanics of archery. The focus is on neuromuscular aspects (Gollhofer, 1996; Leroyer, 1993; Hennessy, 1990; Zipp, 1979).

Electromyography in conjunction with dynanometry and kinemetry yield information on the contribution of single muscles and on intersegmental coordination. Squadrone (1994[1] and 1994[2]) used dynamometry, kinemetry and surface EMG to measure body sway, body and bow kinematics, temporal parameters and muscle activation patterns. Zipp (1978) quantified performance relevant parameters including tremor, the force required to bend the bow, tilt angle, release action, body weight distribution and clicker-release time. Zipp correlated selected variables with the horizontal and vertical deviation from the center of the target and deduced individual strength and weaknesses of the archers. Gros (1991) developed a feedback system for tilt angle and force distribution on a Hoyt and an OK competition bow. Visual and acoustic feedback was generated by a dedicated measurement system.

RATIONALE

The quality of each shot can be quantified based on the horizontal and verticaldeviationsfrom the target center (Zipp, 1978). The ability to control and reproduce the wrist position is relevant for performance (Gros, 1991). Deviations from an individual set pattern tend to increase the vertical inaccuracy. The tilt of the bow is a result of pronation or supination and usually takes place slowly during the aiming phase. It leads to horizontal deviations from the target.

Small differences can have pronounced effects on the performance and may not be observable by the coach. Hence there is potential for a dedicated 'archery measurement' system that delivers fast and objective supplementary information for coaches and archers. The aim of the project was to develop a precise and 'easy to use' tool in order to provide feedback.

DESIGN AND FEATURES OF THE SYSTEM

A HOYT competition bow was instrumented with strain gauges above and below the bowgrip. The signals are pre-amplified and fed to an amplifier with gain and offset adjustment to accommodate bow-limbs of different stiffness. The difference between the forces F(a) and F(b) is supplied. The tilt of the bow is measured with a silicon damped inclinometer HBM NM 122, The analog data are digitally converted using a National Instruments PC-LPM-16 board. Sampling frequency for all channels is 1 Khz. 5000 sets of samples are recorded for each shot.

Based on the LAB VIEW© software an application was programmed to fulfill all user requirements regarding the data acquisition and processing as well as ease of operation and stability. In addition to the forces F1, F2, DF and the tilt angle a, two channels may be user defined. In the present study EMG and data from an accelerometer were recorded. Them. pectoralis EMG is an indicator for premature internal rotation of the bow arm that is present in some archers in anticipation of the release. The ECG content of the signal is used to determine the moment of release in relation to heartbeat.

The accelerometer was mounted onto the bow. The clicker, a small metal plate that holds the arrow to the bow, makes an audible click when the archer pulls the arrow to the final draw length just before release. Release causes acceleration of the arrow and vibration of the middle part. Thus, the accelerometer output permits determination of clicker-release times. These times were verified with the use of high speed videography.

The measuring module features programmable gain and offset, on-line help, visual data inspection as well as zoom of the display and data storage.

During the data acquisition a sound can be activated at a specified set point and in an adjustable window. This sound represents a real time feedback on whether the predefined levels are reached within the selected range or not. Different frequencies are used to distinguish 'force' and 'angle' information. Data can be recalled, viewed, compared and exported from a second software module.

SYSTEM PERFORMANCE EVALUATION

The feedback system uses up-to-date hardware and software technology. Implementation of bows with different strength and arrow length is possible. The software is flexible enough to accommodate future user requirements. The accuracy and reliability of the system was determined by using a force vs. displacement measuring device that pulls the string to draw length without applying a torque to the handle. The system is now used in the training environment of national and international caliber archers.

RESULTS AND DISCUSSION

The presented system generates reliable on-line information on performance relevant parameters:

- Forces applied to the midsection of the bow.
- Difference between the forces acting on the upper and lower part of the bow as an indication of the moment applied through ulnar and radial deviations of the bow arm wrist.
- Angle of tilt and
- two user defined channels of analog data, in this case EMG of the m. pectoralis and acceleration of the bow.

At present a longitudinal study to analyze international (Level A) and national (level B and C) caliber athletes of the DSB is under way. Due to the design of the study we can, at the moment, only report tentative and preliminary results. Continuous data collection throughout 1997 will provide an adequate basis for statistical treatment of the data. This database is a necessary prerequisite for statistically sound conclusions because of the small deviations of the measured variables and the intervening variables which make a cause-effect analysis difficult.

For each archer the scoring value and position of the 15 arrows per series on the target was recorded. The expected increase in precision and reproducibility for the members of the level B as compared to level C is observed.

M. PECTORALIS EMG

There is no relation between IEMG and the precision of the shot. Most shots are released in the time interval between two heartbeats.

FORCES ACTING ON THE BOW

In general, top level archers reproduce the wrist position very well - radial and ulnar deviations are small. However, intermittent problems occur and may cause vertical deviations of the arrow. As an example, Figure 1 and 2 show the force-time history of two shots of one archer in one series.

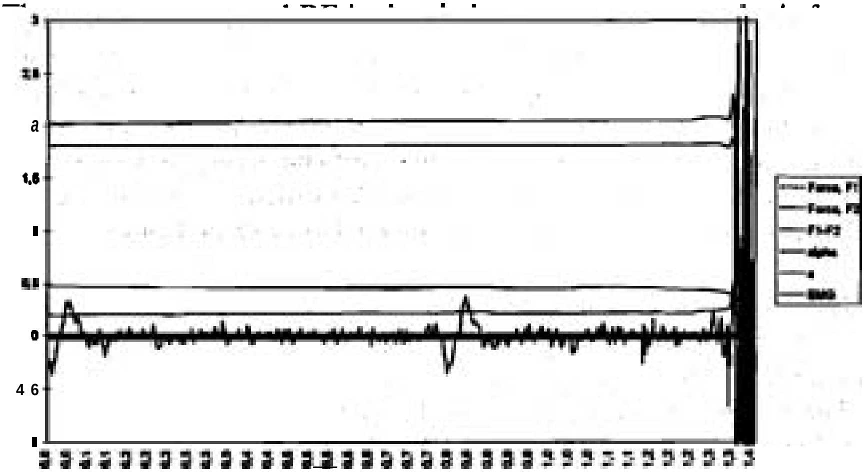

Figure 1. Normal shot for subject 'worn.'

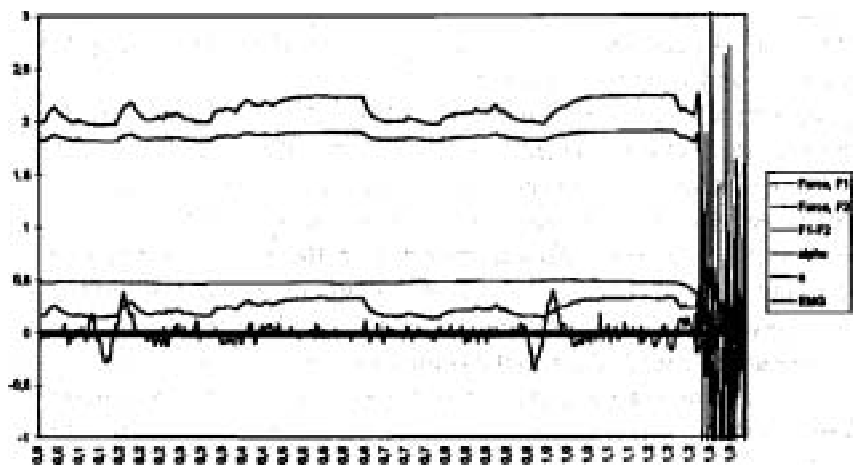

Figure 2. Subject 'worn' shooting with unstable wrist.

CLICKER - RELEASE TIME

The time interval from the instant when the clicker hits the bow to the moment of release was in a range from 160 to 210 ms. Intra-individual variability as determined by the standard deviation was very small (<10 ms). Due to the small absolute range (50 ms) of the means for all archers, a correlation between clicker-release time and performance cannot be postulated. This supports findings by Zipp (1979) who reported means from 151 to 198 ms (SD 7-11 ms) with one athlete who showed excessive variability (SD = 16 ms).

ANGLE OF TILT

Analysis of the tilt angle about an axis parallel to the arrow helps to diagnose 'wobbling,' a higher frequency fluctuation, and a low frequency drifting in pronation or supination. Figure 3 summarizes data for 15 shots of one athlete. This depicts inter-shot variability and intra-subject repeatability of the tilt angle.

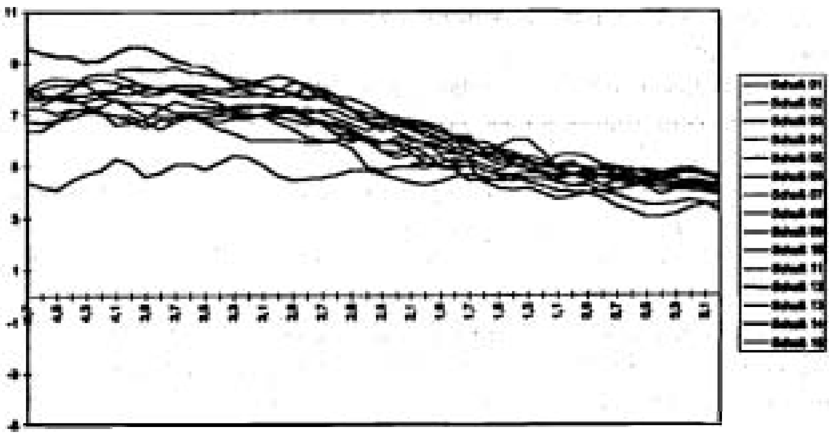

Figure 3: Comparison of the tilt angle for 15 shots of one archer with a pronounced 'drift.'

Figure 4 shows the mean tilt angle as a function of time for four archers. Archer **'-bhm'** display very little change of bow orientation, while **'-akm,' '-erm,' '-fhm'** and **'-jlm'** can be considered as 'drifters.'

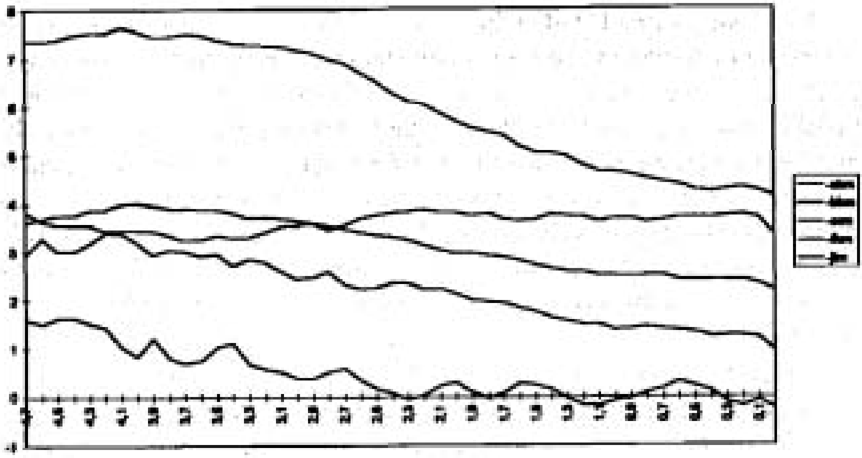

Figure 4: Comparison of mean tilt angles for five archers.

CONCLUSIONS

Archers have individual patterns of draw, anchor, aim and release. Success depends on the reproducibility of motion. Highly skilled archers have an excellent inter-shot stability concerning the measured parameters. Deviations occur intermittently and can be recorded and analyzed with the present system.

The system is a reliable and easy-to-use tool to measure performance relevant parameters in archery. It can be used to supply simultaneous feedback, to identify intermittent problems and to document the development of the athlete.

Cross-sectional and longitudinal studies from beginners up to top level athletes are needed to further confirm the diagnostic value and determine the effect of the feedback with decreasing variability on learning and stabilization of performance in archery.

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