STABILOMETRY APPLIED ON THE ANALYSIS OF INDIVIDUAL TECHNIQUE IN THE AIR - RIFLE SHOOTING

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The main problem of sport technique in shooting sports is to maintain the body segments as stable as possible. Experimental data proved that shooters adopt a mechanically unstable posture as consequence of the interactions among body segments. Stabilometric analysis, by means of force plates, allows the evaluation of postural stability, measuring displacements of the center of pressure (COP). In this study the postural stability of a high level air - rifle shooter and its relationship with performance has been evaluated. The results confirmed that it is possible to obtain relevant information with respect to shooter's technique, given that, the shooter displayed a trend to achieve better shots trying to intercept the center of the target with moving the whole body – rifle system forwards ($p<.000$; $r = -.445$).

KEY WORDS: biomechanics, stabilometry, rifle shooting

INTRODUCTION: It is well known that elite shooters and archers display high levels of precision. In air - rifle shooting, for instance, the angular error to obtain a hit of "ten" must be no worse than 0.016º (Zatsiorsky and Aktov, 1990). The same error regarding the torsion angle of the bow, from the distance of 30 m in archery, should not exceed the value of 0.2º (Pekalski, 1990). Even if there is no answer, up to now, to the question “how the vertical posture is maintained and how it is related to voluntary limb movements” trainers, athletes and training books, consider postural stability as one of the most important factors that influence performance. Postural stability in aiming is considered as the consequence of the gravity’s interaction with the mechanical properties of the locomotor system and the control process. Shooters and archers try to make their posture more consistent and reproducible passing the mechanical loads across the passive structures and elements of the locomotor system to limit muscular intervention. Kinematic experimental data in rifle shooting exemplified very slow and small amplitude interactive movements of the body segments resulting to a mechanically unstable posture. Also, the identification of two "postural instability factors" significantly correlated to the performance allowed for considering postural stability as a very relevant question to obtain good scores (Gianikellis et al., 1999). However other researchers used force plates to evaluate postural stability in shooting sports measuring displacements of the Center of Pressure (COP) (Niinimaa and Mc Avoy, 1983; Larue et al. 1989; Mason and Pelgrim, 1986; Mason et al., 1990; Era, et al., 1995; Wu et al., 1997; Norvapalo et al., 1997; Viitasalo et al.; 1997). COP is defined as the point of application of the resultant of the external forces applied to the support area. Its variability, with respect to time expresses the neuromuscular answer to the instantaneous position of the Body's Centre of Gravity in order to maintain upright posture. Stabilometric analysis is performed on the basis of descriptive statistics, ranges and areas of COP migration, velocities of COP migration, length of path travelled by the COP, transfer functions, spectral characteristics, autocorrelation and autoregression analysis, time - to - contact measures, evolutionary spectral analysis, fractal dimensions, phase plane analysis and Crassberger - Procacia coefficients developed to study dimensionality of chaotic processes. In all cited methods it is assumed that the COP migration is random. However, recent research findings on the prolonged unconstrained standing justify the opposite idea characterising COP displacement patterns as: i) fast, step-like displacement of the average position of COP from one region to another (shifting), ii) fast large displacement and returning of COP to approximately the same position (fidgeting), and, iii) slow, continuous displacement of the average position of COP that quantifies a trend (drifting) (Duarte and Zatsiorsky, 1999). The main purpose of this work is to analyse the individual rifle – shooting technique of an international level shooter characterising and evaluating his postural stability by means of COP displacements as an integrator of postural sway on the horizontal plane determining the influence, if any, of his postural control quality on the performance obtained on the target.

METHODS: An elite shooter performed, in competitive conditions, 60 shots with air – rifle from the distance of 10m obtaining a good score (7.81 ± 1.38). COP displacements on the horizontal plane registered using a strain - gauge force plate (DINASCAN 600M) at a sampling rate of 100 Hz (natural frequency > 400 Hz) (Fig. 1). An error analysis procedure, applying static loads on different points of its surface, yielded a precision of ± 1mm with respect to the co -ordinates of COP. Strain gauges are highly linear sensors and their application to shooting sports measurements is particularly appropriate due to their good behaviour at low frequencies. A microphone sensor fixed on the rifle and synchronised with the force plate enables to detect the triggering instant in order to analyse the last five seconds of aiming time up to triggering.

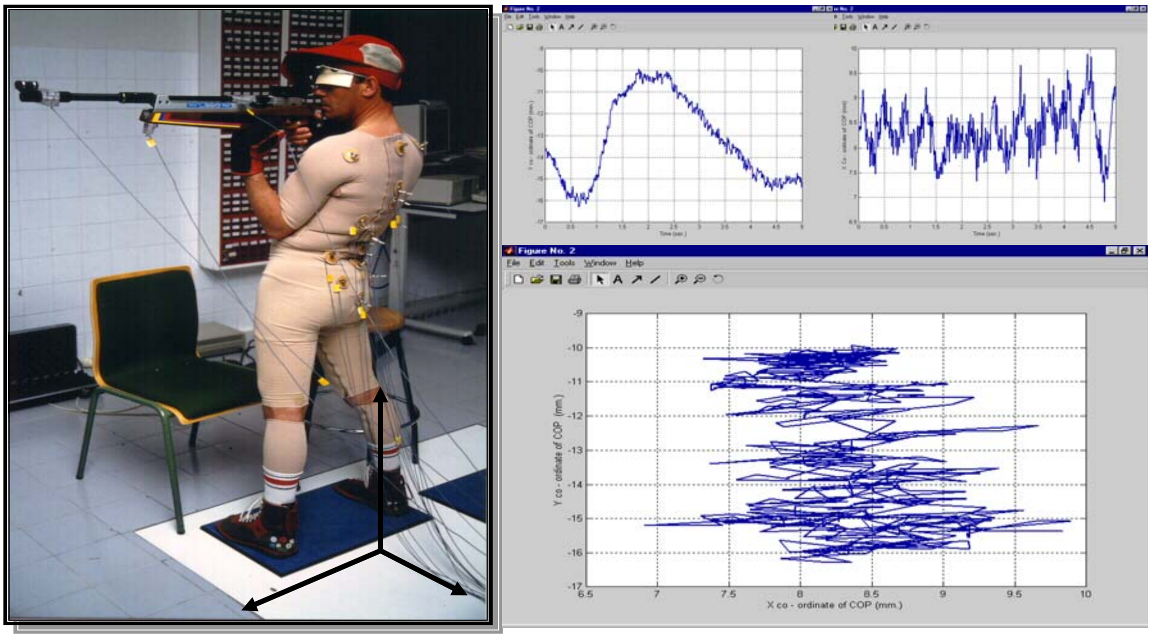

Figure 1 - Experimental set up and representation of the resultant COP trajectory with its components in the (X) and (Y) directions.

The processing of the information referred to COP migration and the calculation and representation of all study parameters took place in MATLAB environment where data are exported in ASCII files. Data "smoothing" to eliminate part of the high frequency "noise" carried out with quintic splines according to the "True Predicted Mean-squared Error" criterion using the package "Generalized Cross-Validatory Spline" (Woltring, 1986). After data treatment the period of the last five seconds of the aiming time was divided in ten intervals (500 ms). Then different variables were calculated to evaluate the shooter´s postural stability in each interval, namely, the total range of movement, and the RMS of the COP, the length of COP trajectory, the average velocity and acceleration and the range of velocity and acceleration (Fig. 2). Finally, the slope of the straight line of best fit for the last five seconds of aiming was calculated by means of Pearson´s correlation coefficient.

RESULTS AND DISCUSSION: One of the most interesting findings was that all information with respect to COP migration in the direction of the target (X) was lacking validity because of the precision of the force plate. Then whatever the force plate is measuring, during aiming, in (X) direction is just "white noise" (Fig. 1). Consequently only data referred to (Y) direction have been analysed (Fig. 2). Descriptive statistics allow a quite clear idea with respect to COP migration. The reader can observe (table 1) the statistics of the ranges of position, velocity and acceleration of COP during the last five seconds of the aiming. Also data confirmed that the whole system is moved as a block, given that COP trajectories are in phase with those of landmarks on the body (Fig. 2). With respect to the calculated variables for intervals 1 -10, the results confirm that the average value of the COP velocity has the same trend with velocities in the same direction of the other body segments (Fig. 2).

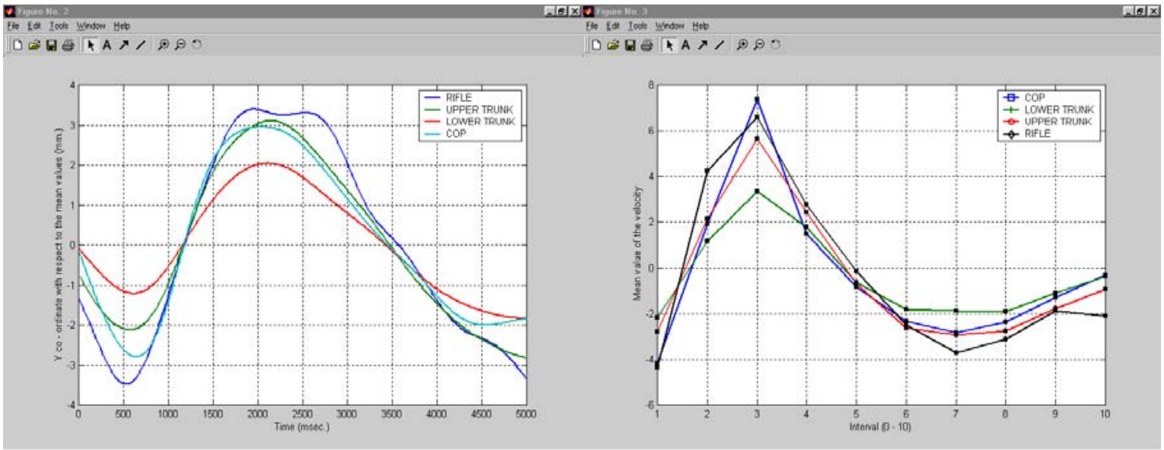

Figure 2 - Evolution of the (Y) co - ordinate of the COP and body segments (left) and the mean values of their velocity for the intervals 1 – 10 (right).

Table 1 Mean Values of the Range of Kinematic Variables of the COP During the Last Five Seconds of the Aiming

	N	Min.	Max.	Mean		SD
Range of movement of COP (mm) (Y) co – ordinate	60	2,03	12,09	5,2951	,2592	2,0079
Length of COP trajectory (mm) (Y) co – ordinate	60	71,41	110,44	82,7587	,9471	7,3360
Range of COP velocity (mm/s) (Y) co – ordinate	60	,13	26,51	16,0403	,6068	4,7005
Range of COP acceleration (mm/s^2) (Y) co – ordinate	60	,02	241,04	142,6806	5,3287	41,275

Concerning the slope of the best fit line of the (Y) co – ordinate with respect to aiming time, data displayed a trend of better shots when COP is moving in the anterior direction with respect to shooter's medial – lateral axis (negative Pearson's coefficient). Finally the results confirm a statistically significant correlation ($p<.000$; $r = -.445$) between the slope of the straight line of best fit of (Y) co - ordinate of the COP for the last five seconds of aiming and the performance obtaining on the target. This means that a shooter has to try to intercept the center of the target moving the whole body – rifle system forwards rather than backwards. This finding suggest that a shooter's control quality is dependent on the direction of the COP migration.

CONCLUSION: The results of this study provide relevant and objective information with respect to the postural stability and individual aiming technique of a high level rifle – shooter once a statistically significant correlation between COP migration patterns and performance has been established.

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