A PROCEDURE FOR DETERMINING TWO 'POSTURAL INSTABILITY' FACTORS THAT INFLUENCE ON THE PERFORMANCE IN RIFLE-SHOOTING

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The purpose of this study is to analyze the individual rifle-shooting sport technique of an international level shooter defining the factors of mechanical instability that have negative effects on the performance. Kinematic and stabilometric data were registered by means of a sonic digitiser synchronised with a force platform. Postural stability has been evaluated for ten intervals of the last five seconds of the aiming time. Multivariate analysis techniques allowed to identify two factors of 'postural instability' that explain the 78.8% of the total variability. Namely, 'instability of the segment pelvis during the 7^{th} interval of the aiming time' and 'instability of the structure that form the rifle and the supporting it upper trunk during the final second of the aiming line'. The results provide objective information respect to the motor patterns in the rifle-shooting justifying the proposed theoretical model for the identification of the postural stability and its influence on the performance.

KEY WORDS: Biomechanics, shooting sports, postural stability.

INTRODUCTION: According to many trainers and athletes, postural consistency is one of the most important factors that determine performance in shooting sports. Thus the main problem of sport technique consists in the elimination of degrees of freedom in the joints maintaining the relative position and orientation of the body segments. In rifle-shooting, while shooters try the align their eye with the rifle and the target, they adopt an uncomfortable posture characterized by a pronounced extension with simultaneous lateral bend and slight twist of the trunk respect to the pelvis. This posture is consequence of shooter's attempt to pass all mechanical load across the passive structures and elements of the locomotor system avoiding the intervention of the muscles that control the joints. Experimental data proved that this posture is mechanically unstable because of the influence of the gravity, the mechanical properties of the locomotor system and specially of the viscoelastic properties of muscles and of the complex control processes during aiming. In spite of the importance of the postural consistency most biomechanical studies contributed to obtain information only respect to the kinematics of the rifle or of the whole system by means of stabilometric analyses (Iskra et al.,1988; Larue et al., 1989; Mason et al., 1990; Zatsiorsky and Aktov 1990; Era et al. 1995). However it is very important to analyze the geometry of the shooter-rifle system as emerges from the interactions of its parts and to evaluate the relationship of its geometry with performance. Responding to this demand a validated mechanical model has been developed providing information about the geometry of the rifle-shooting motor patterns and proving the coupled motions that take place during aiming (Gianikellis et al., 1998). Continuing this work the main purpose of this study is to analyze the individual rifle-shooting sport technique of an international level shooter defining the factors of mechanical instability that have negative effects on the performance.

METHOD: A high level shooter performed 60 shots with an air-rifle from the distance of 10m in competition's simulated conditions (score 7.81 ± 1.38). Kinematic and stabilometric data were registered by means of a measurement chain integrated by a Sonic Digitizer (SAC GP8-3D) with sampling rate 7.4 Hz per emitter, accuracy .054, precision of the reconstructed coordinates .115 mm and spatio-temporal resolution 70.7 $\sqrt{Hz}\ mm^{-1}$ all evaluated according to a standard protocol, a strain-gauge force platform (DINASCAN) sampling at 100 Hz with precision $\pm$ 2 mm respect to the coordinates of the center of pressure and a microphone of variable gain fixed on the rifle to detect the instant of the shot (Gianikellis et al., 1994). The microphone is connected to the Control Unit of the Sonic

Digitiser and so an 'S' symbol is appearing in the data files indicating the instant of shot. In this way we can analyze position - time data for the final five seconds of aiming time. Position-time 'data smoothing' carried out by quintic splines using the package 'Generalized Cross-Validatory Spline', according to the 'true predicted mean - squared error' criterion, given the automatic identification of the markers (w_i = 1) and the known precision of the spatial coordinates (σ^2). A validated mechanical model was developed, considering six degrees of freedom for every segment, to describe three-dimensional linear and rotational displacements of the rifle, upper trunk and pelvis (Gianikellis et al., 1998). The calculated random errors respect to the kinematic parameters were less than 4.5%. After data treatment and calculation of the kinematic parameters the period of the last five seconds of the aiming time was divided in ten intervals of 500 ms. In these intervals several stability variables were calculated enabling the evaluation of shooting technique and its relation with the performance. These stability variables were, for all intervals of the aiming time and all segments:

1. Range of linear and rotational movement in three dimensions.
2. The RMS of all calculated parameters.
3. The length of the trajectory of every landmark.
4. The orientation of the ellipse that define by the 2D coordinates of the geometrical centres
5. The components and the module of the linear velocities of the geometrical centers.

Once defined the variables of the study, a multivariate analysis has been done to identify the 'postural instability factors' that influence on the performance in the given experimental conditions.

RESULTS: Correlation analysis respect to all study variables in all intervals allowed to know the relationships among all stability parameters of the shooter-rifle system, as well as to identify a reduced number of variables negatively correlated with the performance ($p<.028$ - $p<.0004$). The results confirm the interactions between parts in the shooter-rifle system and the continuous regulation of shooters posture during aiming. Also, postural stability seems to be very important during the last two seconds of the aiming (intervals 7^{th} to 10^{th}). All body segments instability parameters are negatively correlated with the performance and the most significant correlationships ($p<.0004$ - $.005$) were for the instability parameters of the pelvis during the 7^{th} interval where the shooter starts to press the trigger. Even if clearly, postural instability in this period is harmful for the performance we can not compare these findings with the similar ones of other investigations because of the lack of information. However it appears logical to think that oscillations in the lower part of the system are transmitted to the upper parts with a time delay. Finally, it is worth to mention that the results in this study do not confirm any correlation between the score and the stability of the rifle's orientation (Zatsiorky and Aktov, 1992).

The factor analysis allowed to obtain a reduced number of mechanically identifiable factors not correlated each other that influence on the performance, in the cited experimental conditions. Two levels of performance were established considering the score on the target as the criterion of the technique's quality. The good level was for scores higher than 7 and the poor level for the other shots. In this way 2 factors of "postural instability" have been identified explaining the 78.8% of the total variability. The first one gives information about the 'instability of the segment pelvis during the 7^{th} interval of the aiming time' and the second one gives information about the 'instability of the structure that form the rifle and the supporting it upper trunk during the final second of the aiming line'. The fact that these two factors are not correlated justified the theoretical model of this study respect to the evaluation of the performance by means of the postural stability parameters. The carried out ANOVA process confirmed that both factors affect significantly the performance ($p_1<.0000$; $p_2<.0076$).

CONCLUSION: The results of this study provide relevant and objective information respect to the motor patterns in the rifle-shooting justifying the here proposed theoretical model and allowing the identification of the nature of the postural instability and its influence on the performance. Given that scoring is consequence of the dynamic interactions of the system's parts the shooter and his trainer have to look for aiming techniques reducing all undesired oscillations and making possible the stabilization of the body segments and specially of the pelvis during the last two seconds of the aiming.

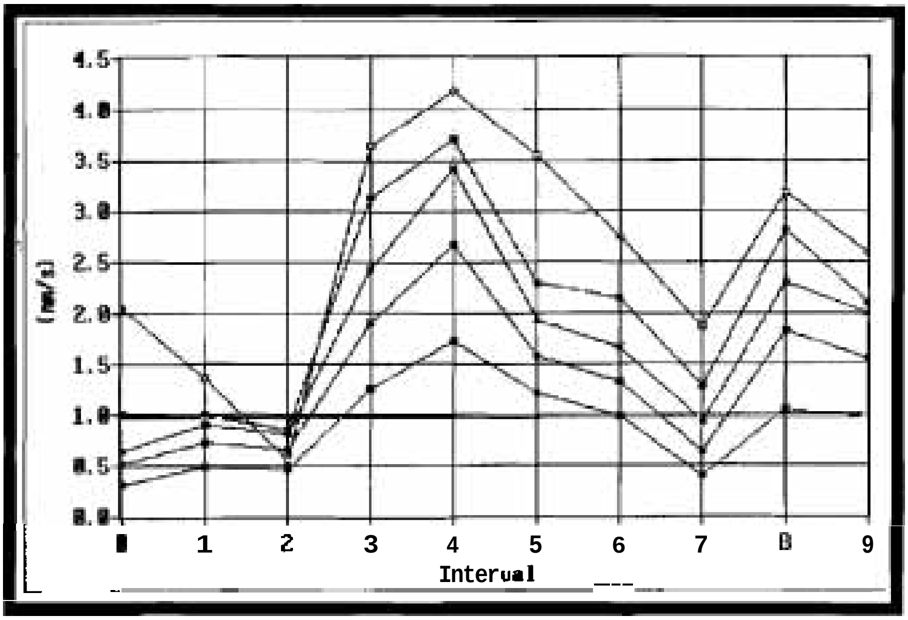

Figure 1 - Representation of the mean values, over the sixty shots, of the velocity of different markers of the shooter-rifle system in the ten intervals of the aiming time.

REFERENCES:

Era, P. et al. (1995). Postural stability in good and poor trials in rifle - shooting. A study on top level and naive shooters. In, K. Hakkinen, K.L. Keskinen, P.V. Komi, A. Mero, (Eds.), Proceedings of *XVth* Congress of the International Society of Biomechanics, 252 - 253. Jyvaskyla. Finland.

Gianikellis, K.; Dura, J.V.; Hoyos, J.V. (1994). A measurement chain applicable in the Biomechanics of shooting sports. In A. Barabas & Gy. Fabian (Eds.), Proceedings of the *XIIth International* Symposium on Biomechanics in Sports 266 - 269. Budapest. Hungary.

Gianikellis, K.; Dura, J.V.; Hoyos, J.V. (1996). 3-D Biomechanical analysis of the motor patterns observed during the 10 m rifle - shooting modality. In J. Abrantes (ed.) Proceedings of the *XIVth* International Symposium on Biomechanics in Sports, 217 - 219. Madeira. Portugal.

Gianikellis, K,; Maynar, M; Dura, J.V. (1998). A mechanical model for measuring in three dimensions the small amplitude coupled motion that characterizes motor patterns in shooting activities. In H.J. Riehle & M.M. Vieten (Eds.) Proceedings of the *XVIth* International Symposium on Biomechanics in Sports, 330 - 333. Konstanz. Germany.

Iskra, L.; Gajewski, J.; Wit, A. (1988). Spectral analysis of shooter-gun system. In G. Groot, A.P. Holander, P.A. Huijing, G.J. Ingen Schenau (Eds.). In *Biomechanics XI* - B, (Ed. by de Groot, G.; Holander, A.P.; Huijing, P.A.; Ingen Schenau, G.J.), 913 - 919. Amsterdam Free University Press, Netherlands.

Larue, J. et al. (1989). Stabilite en tir: influence de l'expertise en biathlon et en tir a la carabine. ***Canadian Journal of Sport Sciences, 14,*** 1, 38 - 45.

Mason, B.R.; Cowan, L.F.; Gonczol, T. (1990). Factors affecting accuracy in pistol shooting. ***Excel,*** 6, 4, 2 - 6.

Zatsiorsky, V.M.; Aktov, A.V. (1990). Biomechanics of highly precise movements: the aiming process in Air Rifle shooting. ***Journal o Biomechanics,*** 23, suppl. l, 35 - 41.