A MEASUREMENT CHAIN APPLICABLE IN THE BIOMECHANICS OF SHOOTING SPORTS

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INTRODUCTION

In contrast to most sport activities Shooting Sports require the absence of movement to achieve the best performance. Coaches and training books (Rifle Marksmanship Guide, U.S. Army 1979) stress the importance of body stability in shooting position for successful results. Despite the Physiological or Biomechanical factors that could deteriorate the performance, the elite athletes exhibit a surprisingly high degree of precision. For example, in air-rifle shooting from the standing position, the angular error to obtain a hit of "ten" must be no worse than 56" (0.016§) of arc (Zatsiorsky and Aktov, 1990). The world record in this modality is 600 points, meaning that in 60 cases out of 60, the error was less than the value said above. This data show the development of a very fine control over the quasi-static motor patterns of shooting sports. In the field of Sports Biomechanics a variety of measurement techniques have been used to evaluate the movement patterns and the stability of the shooter-gun system. Gianikellis et al. (1992), have presented a method for Kinematic analysis of shooting sports based on the use of Sonic Digitizing to evaluate the postural consistency as well as the spatial orientation of the rifle. In this study, some improvements were introduced for this cost-effective, time-efficient and accurate technique to evaluate postural consistency in shooting sports during the aiming process.

METHODOLOGY

The measurement of the three-dimensional coordinates of superficial landmarks that define the body segments is necessary to describe the relative positions and orientations of body segments (Posture) as well as the displacements of the Centre of Pressure (CP) on the horizontal plane as an integrator of the postural sway. To this purpose the measurement chain (Fig. 1) consists of a Sonic Digitizer, a strain-gauge Force Platform (DINASCAN) and a microphone sensor on the barrel of the rifle (not confused with the microphones of the Sonic Digitizer). Sonic Digitizing consists in converting information respect to the 3-d coordinates of body landmarks to digital values, using the properties of sound's propagation. The system works counting the time required for the ultra sound waves, from the sequentially fired emitters, to reach the four microphones (three are enough). Cognizant the speed of the sound in still air (343.8 m/sec, 20§C), the time is converted in distance to every one of the four microphones (there is the possibility of temperature compensation).

In the field of Biomechanics, during the last years, there is an augmented interest in the application of this technique (Engin and Peindl, 1984; Hsiao and Keyserling, 1990; Worringham, 1991; Steffny and Schumpe, 1991; Seuser et al., 1992; Charteris et al., 1994; Herriots and Barret, 1994).

The system presented here involves the SAC GP8-3D Sonic Digitizer with 16 ultrasound (60 KHz) emitters, four microphone sensors fixed on a rigid frame that receive the ultrasound waves of every sequentially fired emitter, the Multiplexer unit with 16 channels and the Control unit connected with a Personal Computer by means of a Parallel Interface Card (PIO12) for high data rate throughput in ASCII packed binary format. Remote control operation permits PC to command the system to fire emitters by depressing a key or by software programming. The program can also select the emitters to be used, the sampling rate, point or string firing modes and the number of fires for every emitter.

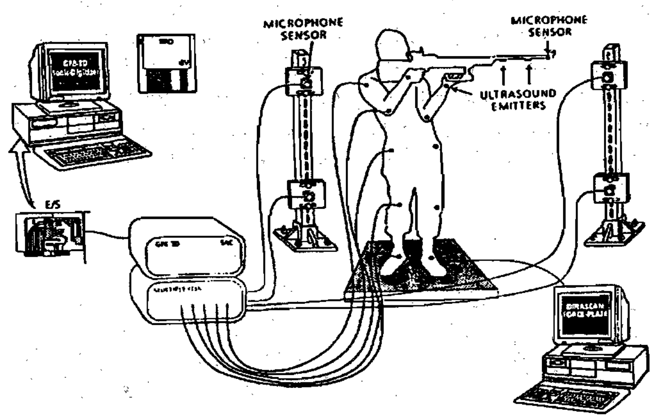

Fig. 1. The measurement chain set up.

Nominal resolution is 0.1 mm and the calculated standard deviation for stationary emitters was 0.1 mm. The sampling rate is 66.6 Hz **(66.6/number** of emitters to be used) in an active volume of two metres side cube. This sampling rate of about 7 Hz per emitter (9 emitters) seems to be enough to avoid aliasing for this kind of motor patterns. We have calculated that more than a 95% of the cumulative **periodogram** (Energy of the signal) is contained up to the 2.5 Hz of the spectrum frequency (Fig. 2).

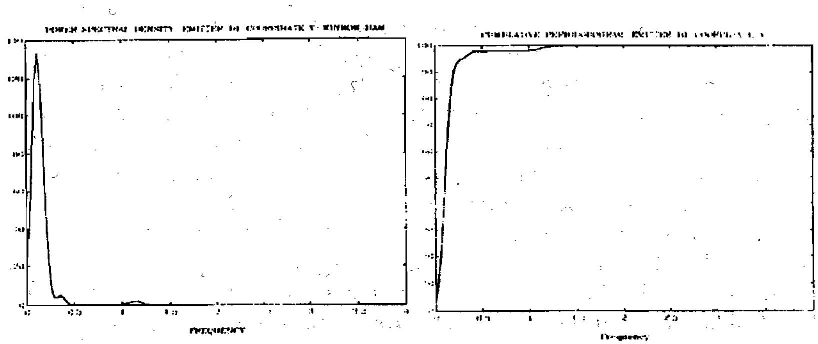

Fig. 2. Spectral parameters for the tip of the rifle.

In the calibration procedure it is used a Digital caliper **18E** with resolution 0.01 mm and measuring range 500 mm. It is carried out knowing the position of at least three points (emitters) into the working volume to calculate the position of the four microphones by means of an iterative process of optimization (Newton-Raphson). Now calibration is not a such cumbersome work because we do not need the four microphones on the same plane. Once the position of the four microphones is known, the algorithm of calibration calculates (using the file of calibration) the spatial coordinates of every emitter. In the files of data registered in the memory of the PC. there is information respect to the emitter, its four distances to the microphone sensors. the instants of the emitter's sequential firing and the instant of the triggering of the rifle (microphone sensor on the rifle) to analyse the time interval we are interested. Next the 3-d coordinates of the emitters are calculated using the data of the calibration file. Given that the Sonic Digitizer is a multiplexing system there is the need of some kind of interpolation of the data to obtain th coordinates at the same instant of time, and, some kind of smoothing eliminating part of the contaminating high frequency "noise" before differentiation, This subroutine package (Woltring, 1986), for smoothing and differentiation, is based on the natural B-Spline functions according to the true predicted Mean-Squared Error criterion of Craven and Wahnba (1979). Therefore, it is possible to obtain the derivatives of the paths of the markers. (Fig. 3).

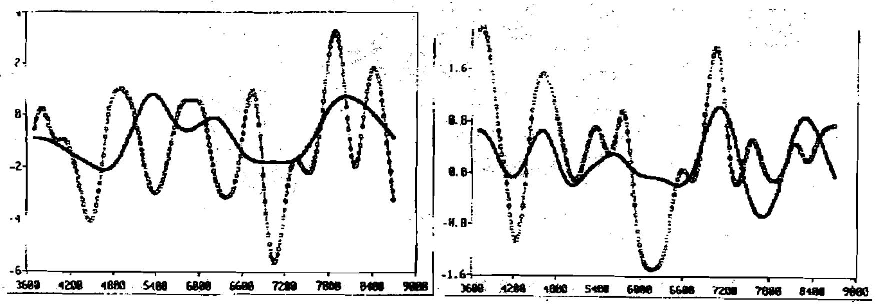

Fig. 3. Velocities in the Y and Z directions of the tip of the rifle (empty squares) and a landmark on the upper trunk (filled squares).

The measurement chain involves a strain gauge Force Platform (DINASCAN-IBV) synchronized with the Sonic Digitizer to study the body sway of the shooter during the aiming process. Strain gauges are highly linear sensors and their application to shooting sports measurements is particularly appropriate due to their good behaviour at low frequencies. The force-plate contains four octagonal force transducers that provide high sensitivity. Eight strain gauges are attached to each transducer, four of them sensitive to vertical load and the other four sensitive to transversal load. Two complete Wheatstone bridges are thus configured for each force direction for temperature compensation. Strain gage layout on the octagonal sensors has been optimized through Finite Element Modelling (FEM) to minimize crosstalk effects between both force directions. Besides, the design of the transducers includes joints for mechanical uncoupling. Specialized analog-to-digital electronics is provided for signal conditioning and data acquisition. The electronic card consists of an analog multiplexor, a precision instrumentation amplifier. a 12-bit analog-to-digital converter and a communication interface connecting to a personal computer. The software has been specifically developed at IBV for data acquisition and processing. The sampling rate is up to 1000 Hz for a single force-plate and 500 for two plates. For Stabilometric studies in shooting sports we use only one platform in a sampling rate of 100 Hz. Given that the error in the position of the (CP) is ii 2 mm, the following parameters can be obtained: Forward maximum sway, lateral maximum sway, mean sway area, mean velocity of the centre of pressure and mean sway frequency (Fig. 4).

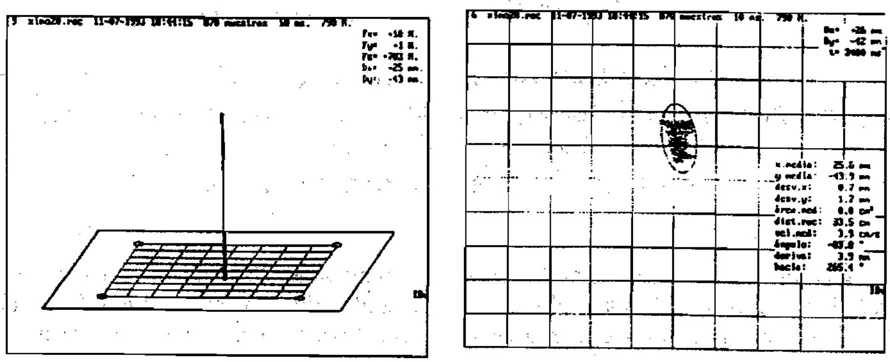

Fig. 4. Stabilometric evaluation with DINASCAN Force Plate.

CONCLUSIONS

The measurement chain presented here, enables us to carry out Biomechanical studies of the motor patterns in the shooting sports, based on the recording of the 3-d coordinates of superficial landmarks that define the body segments. Also, the displacements of the Centre of Pressure (CP) on the horizontal plane as an integrator of the postural sway.

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