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Original scientific paper
UDC 799.3.091.4:577.3–055.2
Received September 26, 1985

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INFLUENCE OF POSTURAL STABILITY ON SPORT SHOOTING PERFORMANCE

Sport shooting / Shooting posture, stability / Posture stability / Women

On a sample of women shooters of international level, an experimental investigation of the influence of measured postural stability on shooting performance, has been carried out.
Results are discussed in terms of visual, and equilibrium sensitive receptor systems and locomotor effector system function during shooting, with respect to skill acquisition and muscular fatigue progression.

1. INTRODUCTION

In sport rifle shooting one can distinguish three basic postures – lying, on knees and standing. This last one leads generally to the worst results, among causes being the instability of the shooter-rifle system. This is the consequence of high position of the body's center of gravity and relatively small body suport area, defined by two closely positioned feets. The vertical projection of rifle falls out of this area, causing aditional correction of the shooter's posture, which becomes asymetric and unnatural. Maintaining such a posture requires high ability of regulation of fixation muscles. The character of body's pendulum-like behavior is a result of the level of efficacy of vestibulo-cerebellar postural automatism supported by fixation mechanism of the visual analyzer. It is important to underline that the posture of top class shooters is modified by twisting in such a way as to realize maximal support of the body by bones and ligaments only, with minimal activation of postural muscle groups, specially knee fixators (5).

To study man's postural stability, in maintaining motionless upright position, one can use the simplest physical model of the body in the form of an inverted pendulum. Such a system can rotate only around the ankles in sagittal plane and so posesses only one degree of freedom. Using this very simple representation of human body Nashner (citation after Stockwell and co.) developed a detailed control model of the function of sensory systems being a part of postural control. Gurfinkel (Gurfinkel 1973) described dynamics of the correponding body sway. Since, however, during this motionless body posture, movements occur, besides in ankles, in other joint systems also, a more precise insight into the mechanisms of posture control requires an introduction of the more complex biomechanical models consisting of two, three and more segments. In Stockwell and co. and Koozekanani and co. 1980, the four-segment model (feet, lower legs, upper legs and upper part of the body consisting of trunk, head and upper extremities) is used. It is still relatively simple, at least in comparison with those usually used in studies of dynamics of various movements. In these works a quantitative description of dynamics of the body sway, directed to estimation of functioning of mechanisms for mantainance of static equilibrium, is given.

From the biomechanical point of view, it is clear that postural stability will be inversely proportioned to the distance between the vertical projection of the position of centre of gravity of the shooter-rifle system and the point of action of ground reaction force vector.

Physiological mechanisms of control and regulation of posture, specially during shooting, are not simple. Numerous innate and learned reflex mechanisms decisively influence the shooting result, at the same time taking part in building the dynamic stereotype enabling completely automatic control, i.e. regulation of effective fixation of the shooter-rifle system. The basis for effective fixation of the system, however, could be find in intramuscular and intermuscular coordination with perfected spatial and temporal excitation and inhibition of postural fixators, rifle fixators and shooting agonists.

That means that the progressing in posture stability in beginer to the master is the result of development of neuronal processes during the specific training. In such a way developed body stability is one of the basic condition of shooting perfection.

If, among measuring devices, we have only a force platform on the disposal – as it has been the case in this investigation – it is not possible to provide an exact estimation of body stability. It is possible to follow the variations of the centre of pressure only partially, through monitoring continuous changes in amplitudes of horizontal components of ground reaction force signals (following instantaneous values as a function of time).

The aim of this investigation was to determine the variability of the stability of the body in women shooters of various competitive levels and its relation with shooting results, using standard rifle.

3. MATERIAL AND METHODS

3.1. Subjects

Experiment was carried out on the sample of seven rifle shooters, women, of the regional and national level. General data on participants are shown in Table 1. All of them have just went through the period of competition.

3.2. Measurement procedure and measurement variables

Measurement has taken place in the Biomechanics laboratory at the Faculty of Physical Education in Zagreb, in normal experimental conditions. Each participant has performed, in her own tempo, ten shots with the target 10 m apart. All of them have used the same rifle. While aiming and shooting they stood on the force platform enabling measurement and registration of horizontal components of ground reaction force; $F_x(t)$ (forward--backward direction) and $F_y(t)$ (left-right direction). Considerably small platform dimensions, 40 x 40 cm, have disturbed in a certain way the optimal shooting posture in some particioants — marked by * in Table 1. Force component signals measured are registred as continuous curves on a paper strip chart.

As a criterion of postural stability, *maximal total deviation (i.e. maximum — minimum value) of the amplitude of ground reaction force during the 10 seconds period preceding shooting (expressed in Newtons)* has been chosen. This criterion was applied separately for $F_x(t)$ and $F_y(t)$ components, being marked by F_x and F_y, respectively, for each shot. The time period of 10 seconds was chosen because this is the characteristic period of maximal concentration of a typical (average) rifle shooter prior to shooting.

For the evaluation of shooting performance the raw shooting results (0—10) were used. (There were alltogether 7 x 10 = 70 shots).

3.3. Data processing

Processing of measured data has been done on the microcomputer Apple II, being a part of the biomechanical measurement system described in Medved, 1984. Processing included the calculation of basic parameters (arithmetic mean, standard deviation, range) of all variables and calculation of linear regression between force variables as predictors and shooting results as criterion.

5. RESULTS AND DISCUSSION

Visual analysis of shots on the targets used reveals that each participant showed relatively well grouped shots (with could have been expected considering high shooting quality of the sample of rifle shooters chosen), located, in general, in the right lower quadrant. All shots of a particular subject are reasonably well grouped at a distance more or less apart form the target center. Th.. quality of shots guarantees, in a certain way, that situation conditions during measurement have been adequate and therefore have enabled the accumulation of reliable data.

Table 2 contains the results of 10 shots, for each individual subject (arithmetic mean, standard deviation and coefficient of variation). As could have been expected, with the exception of the subject No. 5 who missed all the shots, worse results are accompanied by larger dispersion, whereas the most successful subject has the smallest coefficient of variation.

Horizontal force component signals have shown the following: deviations of the transverzal component $F_y(t)$ (left-right) of the ground reaction force from the neutral position are minimal, practically equal to zero. The sagital component of ground reaction force $F_x(t)$ (forward-backward) has shown, meanwhile, remarkable differences in different subjects, as well as in several trials of the same subject, whereas this last phenomenon was signifficantly less expressed than the former. So, it can be said that there exists a certain „typical'' signal $F_x(t)$ for each shooter.

Table 3 shows mean values and standard deviations of F_x for each individual participant.

In the whole $F_x(t)$ signal space the smallest deviation amounted to zero and the highest to 20, 1 N. Mean value was 5.7 and standard deviation 3.9 N.

Linear regression between the sagital force component displacement F_x and shooting results, for the whole trial space, was calculated. The diagram on Figure 2 shows the regression line between these variables, having correlation coefficient of 0,58.

From the mechanical point of view, our results (lying in agreement with those of Žilina and co., 1981). show without doubt that higher body center of mass displacements are accompanied by worse results. One has to take into account, however, that all shooters have used the same rifle and that they didn't have the information on individual scores and therefore couldn't make correction in aiming. This, at the same time, indicates the need for collaboration between researchers and Shooting association, aiming at further research in this area, accentuated by the fact that the work presented here is the first of that type in SFR Yugoslavia.

Table 1. — GENERAL DATA ON PARTICIPANTS

Subject No.	Age (years)	Height (cm)	Mass of the bod-rifle system (N)	Duration of sports training (years)
1*	17	168	738	5
2*	19	161	649	7
3*	18	169	598	6
4	21	170	674	8
5	23	168	670	8
6	35	158	611	25
7*	26	170	725	11

* Considerable amount of disturbance of the optimal posture caused by small platform dimensions

Table 2. – SHOOTING RESULTS FOR INDIVIDUAL PARTICIPANTS

Subject No.	Shooting results — shots		
	arith. mean	stand. dev.	coeff. of var. (%of mean value)
1	2.2	1.23	56
2	4.2	1.23	29
3	5.5	1.90	22
4	5.4	1.17	22
5	0	—	—
6	6.6	1.08	16
7	8.9	0.57	6

REFERENCES

1. Gurfinkel, E.V.: Physical foundations of stabilography, Agressologie 1973, 14, C, 9–14.
2. Juriev, A.A.: Pulevaja sportivnaja strelba, Fizkultura i sport, Moskva, 1973.
3. Koozekanani, S.H., C.W. Stockwell, R.B. McGhee i Firoozmad F.: On the role of dynamic models in quantitative posturography, IEEE Transactions on Biomedical Engineering, Vol. BME – 27, No. 10, 1980.
4. Medved, V.: Biomehanički mjerni sistem, Zbornik 29. Skupa JUREMA, VI Savjetovanje o mjerenju, Plitvice, 1984, 43–46.
5. Sportsko streljaštvo, Narodna knjiga, Beograd, 1974.
6. Stockwell, C.W., S. H. Koozekannani and K. Barin: A physical model of human postural dynamics, Annals New York Academy of Sciences.
7. Žilina, M.Ja., A.A. Šamanov, A.V. Aktov: Ocenka tehniki strelbi iz vintovki s pomoščju tehničeskih sredstvov, Teorija i praktika fizičeskoj kul'tury, No. 11. 12–14, 1981.

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Originalni znanstveni članak
UDC 799.3.091.4:577.3–055.2
Primljeno 26. 9. 1985.

UTJECAJ STABILNOSTI POLOŽAJA TIJELA NA REZULTATE U GAĐANJU

Izlažu se osnovne karakteristike biomehaničkog modeliranja čovjekove posturalne dinamike. Izvode se kriteriji procjene pokreta posturalnog njihanja, temeljeni na signalima sile reakcije podloge.

Na uzorku ženskih strijelaca međunarodnog nivoa provedeno je eksperimentalno ispitivanje utjecaja mjerene posturalne stabilnosti na točnost gađanja. Obrada podataka obuhvatila je izračunavanje osnovne statistike parametara posturalnih gibanja, kao i linealne regresije među njima.

Rezultati se diskutiraju u kontekstu funkcioniranja vizuelnog receptorskog sustava i sustava receptora za osjet ravnoteže, u odnosu na usvajanje vještine i nastupanje mišićnog zamora.

Daljnja istraživanja u ovome interdisciplinarnom području trebala bi obuhvatiti, među ostalim, povezivanje fizioloških i biomehaničkih aspekata funkcije sistema, čemu bi pridonijelo korištenje površinske elektromiografije.

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ВЛИЯНИЕ СТАБИЛЬНОСТИ ПОЛОЖЕНИЯ ТЕЛА НА РЕЗУЛЬТАТЫ В СТРЕЛЬБЕ

Приводятся основные характеристики биомеханического формирования динамики туловища у человека. Определяются параметры оценки колебаний туловищ, которые зависят от размеров силы, вызванной реакцией на опору.

В выборке, состоящей из стрелков женского пола международного уровня, проведено экспериментальное исследование влияния стабильности туловища на точность прицеливания. В результате исследования получены основные статистические данные о параметрах движения туловища, а также – линеарная регрессия между ними.

Результаты анализа рассматриваются в рамках функционирования зрительного анализатора и механизмов равновесия, а также – с точки зрения утомляемости мышец и ловкости спортсменок.

Дальнейшие исследования в этой области должны охватить, между прочим, взаимоотышения физиологических и биомеханических аспектов рассматриваемой системы, при чем необходимо использовать метод поверхностной электромиографии.