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Dependence of the Parameters of Precision-Target Movements on the Nature of the Movements of Athletes

Vitalii Ivchenko[1], Yurii Lytvynenko[2], Alla Aloshyna[3], Nataliia Byshevets[4], Igor Grygus[5,*], Vitalii Kashuba[1], Olena Shevchuk[1], Hryhorii Byshevets[6], Leonid Yarmolinsky[1]

[1]Department of Kinesiology and Physical Culture and Sports Rehabilitation, National University of Ukraine on Physical Education and Sport, Ukraine
[2]Faculty of Health, Physical Education and Tourism, National University of Ukraine on Physical Education and Sport, Ukraine
[3]Department of Theory of Sports and Physical Culture, Faculty of Physical Education and Health, Lesya Ukrainka Volyn National University, Ukraine
[4]Department of Cybersport and Information Technology, Faculty of Coach, National University of Physical Education and Sport, Ukraine
[5]Institute of Health, National University of Water and Environmental Engineering, Ukraine
[6]Department of Theory of Sport and Physical Culture in Science of Physical Education and Sports, Faculty of Physical Education and Health, Lesya Ukrainka Volyn National University, Ukraine

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(b): *Vitalii Ivchenko, Yurii Lytvynenko, Alla Aloshyna, Nataliia Byshevets, Igor Grygus, Vitalii Kashuba, Olena Shevchuk1, Hryhorii Byshevets, Leonid Yarmolinsky (2023). Dependence of the Parameters of Precision-Target Movements on the Nature of the Movements of Athletes. International Journal of Human Movement and Sports Sciences, 11(5), 985 - 993. DOI: 10.13189/saj.2023.110506.*

Abstract Introduction: The determination and comparing the angular indicators of athletes shooting depending on the method of movement are important issues in the theory and practice of training athletes specializing in practical shooting. The aim is to establish the most effective mood of displacement and to investigate the features of angular indicators of athletes during shooting in motion. Material & Methods: Ten qualified athletes specializing in practical pistol shooting took part in the study, carried out in conditions of laboratory using the Qualisys 3D optical-electronic system of registration and analysis of human movements. Athletes made 5 attempts to hit the target with the following methods of displacement: "normal" step, "ski" step, "linear" displacement, "X-shaped" displacement, and "low" displacement. Descriptive statistics and ANOVA variance analysis (Analysis of variation) are used to analyze the obtained results. Result: It is determined that the accuracy of shooting depends statistically significantly ($p<0.05$) on the mood of displacement of an athlete. It has been proven that with a normal step displacement, the accuracy of the athlete is the lowest. When it returns, the X-shaped step assists in a notable increasing in the probability of hitting the target. Angular indicators of bio pairs torso-thigh and thigh-shin, depending on the mood of displacement of athletes specializing in practical pistol shooting, differ statistically significantly ($p<0.05$) at all moments of the walking cycle. For the carf-foot bio pair, the angular characteristics at the moments of displacement with a ski step and X-shaped displacement, low and X-shaped displacement, ski step and X-shaped displacement turn out to be the most favorable. Conclusions: The most similar in biomechanical structure of movements in the torso-thigh bio pair are low movement and ski step, in the thigh-calf bio pair – linear displacement and ski step, in the thigh-foot bio pair – ski step and X-shaped displacement, low and X-shaped displacement, low displacement and ski pitch.

Keywords Kinematic Characteristics, Technique, Motor Actions, Displacement, Method, Angular Indicators, Dispersion Analysis, Shooting

1. Introduction

It is possible to state the fact today that the development of the theory and methodology of sports takes place constantly on the basis of the design of innovative pedagogical technologies [1]. Mistakes in the technical training of athletes and the slow growth of their technical mastery negatively affect the recruitment of national teams with young, promising athletes [2]. The reasons for this situation, first of all, should be recognized as insufficient development of the theoretical basis for improving the technical preparation of athletes at all stages of long-term training [3].

Experts [2, 4, 5], for the most part, emphasize the biomechanical characteristics and parameters describing a specific sports exercise and the dimension that these indicators should have to describe the technical skill of an athlete. As is known [3, 6], it is possible to increase significantly the effectiveness of the process of teaching the techniques of the movement and qualitatively change the level of technical preparation of athletes only on the basis of accounting for the rational biomechanical parameters of motor actions being mastered.

The rapid pace of development of modern shooting sports and the growing intensity of competitive fighting on the international sports arena place increased demands for mastery of athletes [7]. The variety of exercises that the athlete performs in free style is characteristic feature of practical shooting, which distinguishes it from other types of shooting sports. Almost any exercise, in addition to high-speed loading and firing in various inconvenient positions, also requires the shooter to move quickly or fire in the replacement. Therefore, the shooter's actions have the character of precisely coordinated movements, and any mistake action causes a significant decrease in its effectiveness [8].

The question of increasing the efficiency of the system of improving shooting mastery arouses considerable interest of scientists. So far, approaches to the creation of a special training theory of practical shooting for the training of athletes have been studied [3]. The content of the means of shooting training aims at the formation of new tempo-rhythmic indicators of the executive structure of movement to consolidate the optimal image of movement during a shot has been determined, and a methodic for improving the static balance of shooters for the formation of optimal "production" in shooting with small-caliber weapons is proposed. In addition, scientists consider the issue of registration and analysis of micromovements of an athlete's hand as a platform for further improvement in pistol shooting [8].

However, information on the biokinematic features of the technique of various ways of movement of athletes specializing in practical shooting with a pistol in motion remains limited until now.

Therefore, the study of angular indicators during displacements of athletes specializing in practical pistol shooting in different moments of time will allow establishing the optimal methods of their motor actions during shooting in motion and to develop the structure and content of the technology of the formation of the technique of athletes' displacements.

The purpose of the study is to establish the most effective method of displacement and to investigate the peculiarities of the angular indicators of athletes during shooting in motion.

2. Material and Methods

Study participants. Ten qualified athletes specializing in practical pistol shooting participated in the experimental study, which was carried out in laboratory conditions using the optical-electronic system of 3D registration and analysis of human movements "Qualisys" [2, 9].

Research organization. Each athlete made five attempts of the following types of displacement: "normal" step, "ski" step, "linear" displacement, "X-shaped" displacement, and "low" displacement. During the execution of each attempt for each method of movement, the athlete made five shots at the target with the corresponding recording of the results of the shots. Athletes were guided to achieve maximum accuracy, provided they completed a series of shots in a minimum period of time. Taking into account that the phase structure of movement during shooting in motion corresponded to the structure of human walking, we determined the corresponding angular indicators at the following moments of time: separation of the left leg from the support; vertical moment; putting the left foot on the support; detachment of the right leg from the support; vertical moment; putting the right foot on the support.

2.1. Statistical Analysis

Methods of descriptive statistics, variance analysis ANOVA (Analysis of variation) were used in the study.

The application of the methods of descriptive statistics was preceded by a check of the hypothesis that the input data obeyed the normal distribution law [10]. Since the data were characterized by a normal distribution and turned out to be homogeneous, and due to the sampling of athletes of the same qualification, the average statistical indicators of the technique of displacement of athletes during shooting in motion were estimated using the average ($\bar{x}$) and standard deviation (SD). In addition, the coefficient of variation v, which varied from 1.29 to 8.90% was calculated, that is, it did not exceed 10%.

The comparative analysis of athletes specializing in practical pistol shooting, as well as the determination of the differences between their angular indicators at different moments of time depending on the method of displacement, was carried out with the help of dispersion analysis ANOVA (Analysis of variation), which allowed establishing differences between two and more groups of indicators distributed according to the normal distribution and evaluate their statistical significance at the determined level of significance [11]. Levene's test was used to examine the hypothesis of homogeneity of group variances. At the same time, in the case of the absence of a statistically significant ($p>0.05$) difference between the variances, it was evidence of the validity of the use of the parametric version of the variance analysis. Therefore, in the course of the analysis, the hypothesis H_0 was tested, that the difference between the angular characteristics of athletes during shooting, depending on the method of movement, is insignificant or is the result of coincidence. The Fisher F test, which is determined based on the values of intergroup and intragroup variances, was used for this purpose, after which its value was compared with the critical value of the F-test, taking into account that the intergroup number of degrees of freedom *df* is being calculated as the number of groups, reduced by one *(df = m - 1)*, and intra-group – as the product of the number of groups by the number of each of the groups minus one *(df = m (n-1))*. In the case when differences between several indicators at a certain point of time were tested, instead of the univariate F test, a multivariate F test (Wilks Lambda Test) was used, based on the comparison of the error covariance matrix and the between-group covariance matrix.

The check of the hypothesis about the difference between the averages of the studied indicators depending on the methods of displacement was carried out using the a posteriori Newman-Keuls test, which is characterized by sufficient power in detecting differences between groups.

The maximum acceptable probability of a type I error was 5%, i.e., the significance level α was taken to be equal to 0.05.

In the case of $p<1.0\text{-}10^{-5}$, its value was presented in the form of «p<0,05», and in other cases – in the standard form.

Statistical processing of raw data was carried out using MS Excel and Statistica 10.0 (USA, Stat Soft) computer programs [11].

2.2. Research Results

In order to determine which methods of displacement allow increasing the accuracy of the athlete and his rate of fire, in the course of the study we performed a comparative analysis of both the results of shots at the target and the spatial indicators of the displacement technique of the shooter in motion.

It was determined that the accuracy of shooting depends statistically significantly ($p<0.05$) on the method of movement of the athlete. As can be seen from the figure, when moving with a normal step, the accuracy of the athlete is the lowest, on the other hand, the X-shaped step contributes to a noticeable increase in the probability of hitting the target (Fig. 1).

At the same time, it has been proven that the accuracy of athletes differs statistically significantly ($p<0.05$) between all methods of displacement (Table 1).

Table 1. Comparison of accuracy of athletes depending on the method of displacement, score (n=50)

Methods of Displacement	Newman-Keuls criterion; approximate probabilities for posterior criteria Intergroup error MS = 30,907, df = 245				
	1 (66,01; 5,00)	2 (86,75; 4,47)	3 (80,82; 5,24)	4 (91,06; 6,81)	5 (94,47; 5,97)
1		$2 \cdot 10^{-5}$	$9 \cdot 10^{-6}$	$8 \cdot 10^{-6}$	$1{,}7 \cdot 10^{-5}$
2	$2{,}2 \cdot 10^{-5}$		$9 \cdot 10^{-6}$	0,0001	$2{,}2 \cdot 10^{-5}$
3	$9 \cdot 10^{-6}$	$9 \cdot 10^{-6}$		$2 \cdot 10^{-5}$	$8 \cdot 10^{-6}$
4	$8 \cdot 10^{-6}$	0,0001	$2 \cdot 10^{-5}$		0,00215
5	$1{,}7 \cdot 10^{-5}$	$2 \cdot 10^{-5}$	$8 \cdot 10^{-6}$	0,0022	

Note 1: ($\bar{x}$; SD), points – accuracy of shooting of athletes, depending on technique of movements; 1 – normal step; 2 – linear displacement; 3 – low displacement; 4 – ski step; 5 – X-shaped displacement; achieved significance level at pairwise comparison of shooting accuracy is presented in cells

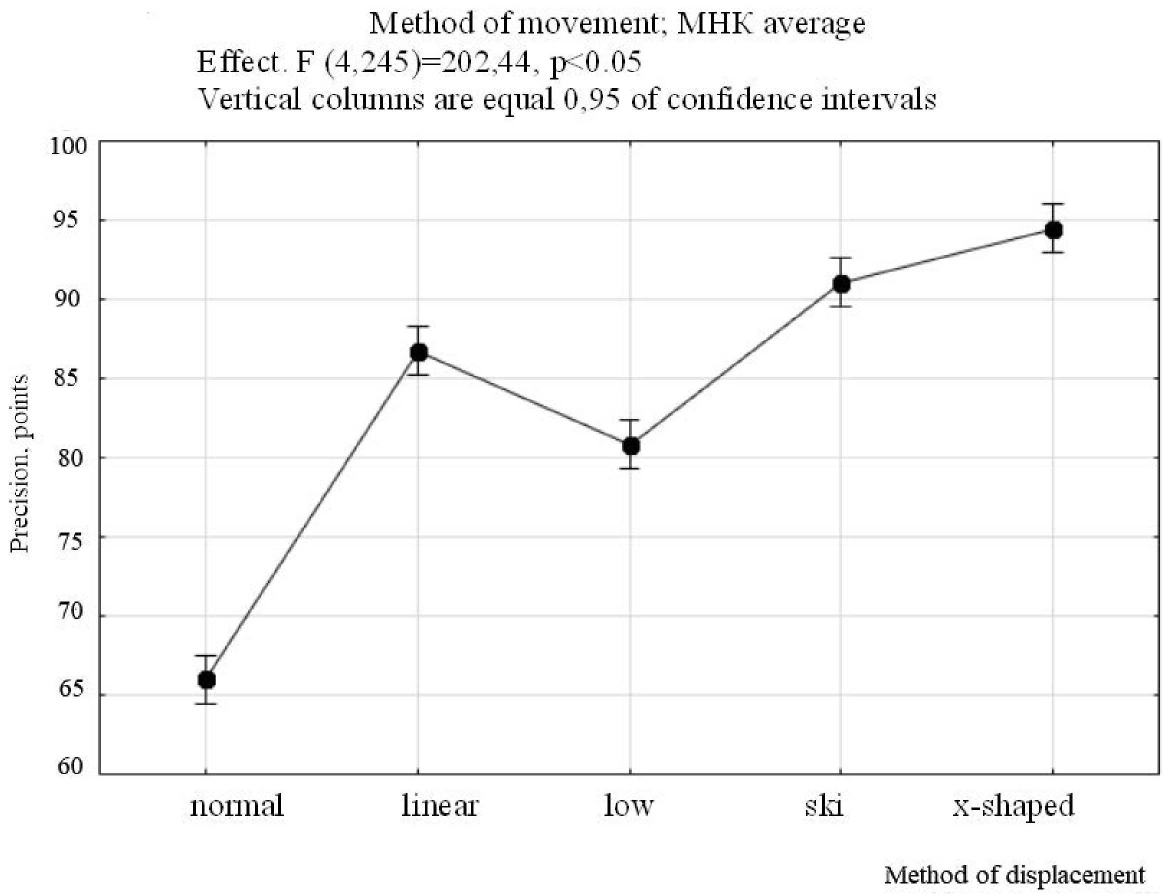

Figure 1. Dependence of shooting accuracy on the method of displacement (n=50)

Therefore, determining the biokinematic features of the technique of different methods of displacement of athletes specializing in practical pistol shooting is an important problem that will allow establishing optimal motor actions that determine the athlete's effectiveness.

Therefore, at the next stage of the research, we determined and compared the angular characteristics of athletes who specialize in practical pistol shooting, namely: the angle formed between the torso and the thigh (hip joint – right and left), thigh and calf (knee joint – right and left), calf and foot (ankle joint – right and left), the angle formed between the axis of the shoulder girdle and the girdle of the lower limbs, as well as the angle formed between the axis of the vertical and the torso (the angle of inclination of the torso).

It has been proven that for the torso-thigh biopair at different time points in the walking cycle, depending on the method of displacement, in general, statistically significant differences ($p<0.05$) are observed between all angular characteristics of athletes specializing in practical shooting (Table 2).

Analyzing the obtained results in more detailed way, we noticed that an increased angle at the moment of placing the right leg on the support, where the angle in the left hip joint is 173.14^0 ($S=5.37^0$), as well as at the moment of placing the left leg on the support for the right hip joint, where the specified angle is 173.540 (S=4.570) were specific features of displacement with a normal step. This shows that, the thigh (left and right) is not moved back in relation to the body, during displacement with a normal step at the indicated moments of time, unlike other methods of displacement.

With the help of a posteriori (pairwise) comparisons, it was determined that the angular characteristics of the torso-thigh bio pair of athletes during normal walking at all-time points in the walking cycle are statistically significantly ($p<0.05$) higher than the corresponding angles characteristic of displacement with other methods (Fig. 2).

Table 2. Comparison of the angular characteristics of the torso-thigh bio pair of athletes from practical shooting depending on the method of displacement (n=50)

Moments of time in the walking cycle	Angle	Analysis of the angular indicators of the methods of displacement by the method Least Squares -average; Wilks' Lambda =0,0024, F(48, 903,43)=71,242, p<0,05				
		F_1	p	A posteriori comparisons; df=245	R^2	F_2; df=4; p<0,05
		df=(4; 245)				
dispatch of the left leg from the support	r	0,414	0,7988	1-2; 1-3; 1-4; 1-5	0,914	650,22
	l	0,325	0,8610	1-2; 1-3; 1-4; 1-5; 2-3; 2-5; 3-5; 4-5	0,917	679,45
vertical moment	r	0,333	0,8554	all, except of 2-5	0,889	490,73
	l	0,329	0,8581	1-2; 1-3; 1-4; 1-5	0,908	606,33
placing the left foot on the support	r	1,154	0,3316	1-2; 1-3; 1-4; 1-5; 2-4; 3-4; 4-5	0,973	2233,93
	l	0,419	0,7949	all, except of 2-4	0,950	1160,46
dispatch of the right leg from the	r	0,397	0,8106	all, except of 4-5	0,911	624,57
	l	0,579	0,6780	all, except of 3-4	0,954	1259,13
vertical moment	r	0,715	0,5827	1-2; 1-3; 1-4; 1-5	0,891	500,63
	l	0,332	0,8561	all, except of 2-5 and 3-4	0,860	377,54
placing the right foot on the support	r	0,470	0,7578	all, except of 2-4 and 3-4	0,904	574,49
	l	0,267	0,8988	all, except of 2-5 and 3-4	0,873	420,04

Note 2: F1 – Levene's test for homogeneity of variances; F2 – Fisher's criterion for determining the influence of the method of displacement on the angular characteristics; R2 – the square of the multiple correlation coefficient; which indicates the proportion of variability explained by the constructed model; a posteriori comparisons – the results of pairwise comparisons according to the Newman-Keuls test, where statistically significant differences between the angles depending on the method of displacement are presented (1 – 5, see note 1); df – degrees of freedom; p – significance level reached

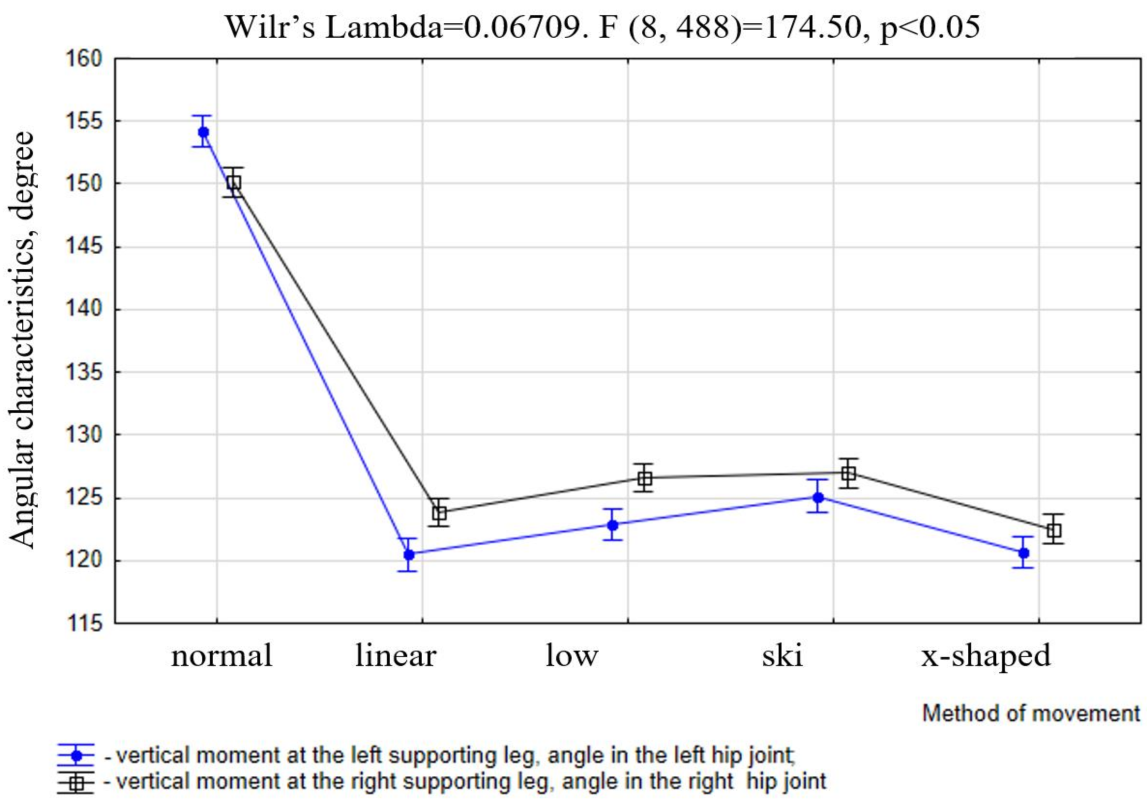

Figure 2. Comparative analysis of angular indicators at different moments of time depending on the method of displacement of athletes, where a) torso-thigh bio pair

At the same time, athletes significantly reduced the amplitude of angular movements in the hip and knee joints using other methods of displacement. Thus, considering the angular indicators for all methods of displacement except for the usual one, it was found that the maximum angular indicators of the torso-thigh bio pair were recorded at the moment of dispatching of the left leg from the support in the hip joint of the left limb, which were from 141.940 (S=4.440) with a linear step. This indicator was statistically significantly ($p<0.05$) higher than the corresponding angle recorded during the low and X-shaped displacement, however, it was not statistically significantly ($p>0.05$) different from the given angle determined during the ski step. Note that for all methods of displacement, with the exception of low displacement and ski step, where the minimum values of the angles were characteristic of the right angle at the moment of the vertical when the right limb was separated from the support, the smallest values of the angles were recorded at the moment of separation of the left leg from the support for the right hip joint. In particular, the minimum degree measure of the angle of 115.820 (S=3.120) was detected at the moment of placing the right foot on the support in the hip joint of the right limb during an X-shaped step, but the specified angle was statistically significantly ($p<0.05$) smaller than during normal displacement, and does not differ from other methods of displacement ($p>0.05$).

The smallest differences between the angular indicators of the torso-thigh bio pair were recorded when the athletes performed a low displacement and a ski step, namely, the following angles did not differ statistically significantly ($p > 0.05$): right and left angles at the moment of separation of the left leg from the support; the left corner at the moment of the vertical when the left leg was separated from the support; the left corner at the moment of separation of the right leg from the support; right and left angles at the vertical moment when the right leg is detached from the support; right and left angles at the moment of placing the right foot on the support.

Likewise, the linear displacement and the ski step were found to be similar in terms of the biomechanical structure of movements in the torso-thigh bio pair, where no statistically significant ($p>0.05$) differences were found between the angular indicators of the specified bio pair at different time points:

- ✓ right and left angles at the moment of separation of the left leg from the support;
- ✓ the left angle of the vertical moment when the left leg is separated from the support;
- ✓ the left corner at the moment of placing the left foot on the support;
- ✓ right angle at the vertical moment when the right leg is separated from the support;
- ✓ right angle at the moment of placing the right foot on the support.

In a similar way, a comparison of the angular characteristics of biopairs tight-calf and calf-foot of athletes from practical shooting at different moments of time depending on the way they moved was carried out.

The presence of statistically significant ($p<0.05$) differences between the angular characteristics of athletes from practical shooting was established depending on the method of displacement in the thigh-calf bio pair, where the maximum values of the angles also appeared to be characteristic of the usual displacement (Table 3).

Table 3. Comparison of angular characteristics of the thigh-calf bio pair of athletes from practical shooting depending on the method of displacement (n=50)

Moments of time in the walking cycle	Angle	Analysis of the angular indicators of the methods of displacement by the method Least Squares -average; Wilks' Lambda =0,0003, F(48, 903,43)=132,01, p<0,05				
		F_1	p	A posteriori comparisons; df=245	R^2	F_2; df=4; p<0,05
		df=(4; 245)				
dispatch of the left leg from the support	r	0,146	0,9649	all, except of 2-4 and 3-5	0,742	176,519
	l	0,200	0,9382	all, except of 2-4 and 3-4	0,952	1211,705
vertical moment	r	1,598	0,1755	all, except of 3-4	0,878	439,378
	l	0,273	0,8955	all, except of 2-3	0,638	107,733
placing the left foot on the support	r	1,765	0,1364	all, except of 2-4 and 3-5	0,959	1416,737
	l	2,281	0,0612	all	0,808	257,729
dispatch of the right leg from the	r	0,257	0,9055	1-2; 1-3; 1-4; 1-5; 2-3; 2-5; 3-4	0,971	2020,277
	l	0,841	0,5006	all, except of 2-4	0,929	805,851
vertical moment	r	1,591	0,1772	all, except of 2-3, 2-4 and 3-4	0,774	209,795
	l	0,534	0,7110	all, except of 2-3	0,780	217,740
placing the right foot on the support	r	0,068	0,9916	all, except of 2-4	0,647	112,175
	l	0,534	0,7107	all, except of 2-4	0,946	1079,647

Note 3: F1 – Levene's test for homogeneity of variances; F2 – Fisher's criterion for determining the influence of the method of displacement on the angular characteristics; R2 – the square of the multiple correlation coefficient; which indicates the proportion of variability explained by the constructed model; a posteriori comparisons – the results of pairwise comparisons according to the Newman-Keuls test, where statistically significant differences between the angles depending on the method of displacement are presented (1 – 5, see note 1); df – degrees of freedom; p – significance level reached

The angles in the left knee joint at the time of placing the left leg on the support differ statistically significantly (p<0.05) depending on the methods the athletes displace. Thus, during normal walking, the indicated angle is statistically significantly (p<0.05) higher than the corresponding angles during other methods of displacement; with linear displacement, the angle is statistically significantly (p<0.05) larger compared to other methods of displacement (except for the usual one); unlike other methods, with low displacement, the angle is statistically significantly (p<0.05) smaller in size; with X-shaped – the angle is statistically significantly (p<0.05) greater than with low and smaller than with ski step. At the same time, it can be asserted that the least statistically significant (p>0.05) differences were recorded during the linear displacement of the athletes and their execution of the ski step, namely, they were not detected between the following angular indicators in the walking cycles: right and left angles at the moment of dispatch of the left leg from the support; right angle when placing the left foot on the support; right and left angles at the moment of dispatch of the right leg from the support; the right angle at the vertical moment when the right leg is dispatched from the support; right and left angles when placing the left foot on the support.

As the results of the study showed, the angular characteristics of the calf-foot bio pair of athletes from practical shooting depend to a lesser extent on the method of displacement compared to other bio pairs. In particular, the value of the right angle at the time of dispatch of the right leg from the support and its vertical moment are statistically significant (p>0.05) independent of the method of displacement (Table 4).

The angular characteristics at the moments of displacement with a ski step and moving in an X-shaped way, low and X-shaped displacement, ski step with a low movement turned out to be the most successful.

Table 4. Comparison of angular characteristics of the calf-foot biopair of athletes specializing in practical shooting depending on the method of displacement (n=50)

Moments of time in the walking cycle	Angle	Analysis of the angular indicators of the methods of displacement by the method Least Squares -average; Wilks' Lambda =0,0218, F(48, 903,43)=31,97, p<0,05				
		F_1	p	A posteriori comparisons; df=245	R^2	F_2; df=4; p<0,05
		df=(4; 245)				
dispatch of the left leg from the support	r	0,63	0,6411	all, except of 2-4, 3-5 and 4-5	0,366	35,36
	l	0,40	0,8069	1-2; 1-3; 2-3; 4-5	0,246	20,00
vertical moment	r	0,40	0,8093	all, except of 4-5	0,711	150,99
	l	0,66	0,6232	1-2; 1-3; 1-4; 1-5	0,215	16,79
placing the left foot on the support	r	0,73	0,5693	all, except of 2-4	0,612	96,50
	l	1,04	0,3849	all, except of 1-3 and 2-4	0,403	41,37
dispatch of the right leg from the	r	0,98	0,4199	---------	0,013	0,80; p=0,5248
	l	1,86	0,1178	all, except of 3-4, 3-5 and 4-5	0,459	51,92
vertical moment	r	0,35	0,8455	---------	0,018	1,12; p=0,3476
	l	1,29	0,2730	all, except of 3-4, 3-5 and 4-5	0,278	23,62
placing the right = foot on the support	r	0,46	0,7625	1-4; 1-5; 2-4; 2-5; 3-4; 3-5	0,295	25,61
	l	0,88	0,4752	all	0,717	155,14

Note 4: F1 – Levene's test for homogeneity of variances; F2 – Fisher's criterion for determining the influence of the method of displacement on the angular characteristics; R2 – the square of the multiple correlation coefficient; which indicates the proportion of variability explained by the constructed model; a posteriori comparisons – the results of pairwise comparisons according to the Newman-Keuls test, where statistically significant differences between the angles depending on the method of displacement are presented (1 – 5, see note 1); df – degrees of freedom; p – significance level reached

3. Discussion

According to many experts [2, 8, 9], it is possible to formulate clear logical algorithms for the development of management decisions when designing management technologies for the formation of technical skills of athletes using mathematical tools. At the same time, the decision-making algorithm has the following form: definition of a problematic situation; formulation of the aim of the task; generation of solutions of the problem; forecasting (mathematical modeling) and evaluation of the results of the educational and training process; choosing a solution to the formulated problems; approbation of the chosen version of the decision to manage the formation of technical skills of athletes. Our research was a continuation of the scientific developments of the above-mentioned specialists and supplemented the existing developments regarding the use of mathematical tools in the evaluation of the technical skill of athletes.

Shooting belongs to technically complex sports, where the effectiveness of competitive activity mainly depends on the level of technical skill. Modern scientists are primarily focused on the study of coordination abilities and static balance of athletes specializing in shooting [8]. Instead, the question of the biokinematic features of the technique of different methods of displacement of athletes specializing in practical pistol shooting remains outside of their attention.

According to the results of the study, the method the athlete displace has statistically significant ($p<0.05$) effect on shooting accuracy. This proves the need to determine the optimal methods of displacement of the shooter during shooting on the motion [12], which requires studying the peculiarities of angular indicators when displacing athletes specializing in practical pistol shooting at different moments of time.

The study of the specific features of the displacement technique of athletes specializing in practical pistol shooting show statistically significant ($p<0.05$) differences for all angular indicators of biopairs torso-thigh and thigh-calf at different time moments in the walking cycle.

Further analysis made it possible to establish the biomechanical features of the technique. Thus, for the torso-thigh bio pair, excluding the usual movement, the maximum angle was observed during linear displacement at the moment of placing the right leg on the support in the right knee joint. Its degree measure of 156.22^0 ($S=4.29^0$) turned out to be statistically significantly ($p<0.05$) smaller than during normal displacement, but it prevailed ($p<0.05$) in magnitude similar angles recorded at low and X-shaped steps and did not differ ($p>0.05$) from the ski step. The minimum angle in the considered biopair of 83.940 (S=3.390), which was registered at the moment of dispatching of the right leg from the support in the right knee joint during the X-shaped step, was statistically significantly ($p<0.05$) smaller compared to the usual step and linear displacement.

The research made it possible to establish that, regardless of the method of displacement in the knee joints, the largest values of angular movements were recorded at the moment of placing the leg on the support (extremity performing the corresponding action). The value of the indicated angles in the right knee joint at the moment of placing the right leg on the support varied from 145.600 ($S=4.15^0$) at low to 161.83 ($S=4.00^0$) at normal movement. In the left knee joint at the time of placing the left leg on the support, the studied indicator varied from 142.440 ($S=3.05^0$) with low to 161.860 ($S=3.43^0$) with normal displacement.

Not all angular characteristics of the calf-foot biopair of athletes from practical shooting depended on the way athletes displace. In particular, the value of the right angle at the moment of dispatching of the right leg from the support and its vertical moment did not differ statistically significantly ($p>0.05$) depending on the method of displacement. For the calf-foot bio pair, the maximum value of the angle, which was 104.08^0 ($S=4.69^0$), was ascertained during the movement of the right shin joint at the moment of dispatching the right leg from the support during displacement with a ski step. However, it did not differ statistically significantly ($p>0.05$) from the specified angles for other methods of displacement. The minimum angles for all methods of displacement were recorded at the moment of placing the right leg on the support during the movement of the left ankle joint, where its minimum value of 61.57^0 ($S=2.34^0$) was found during the X-shaped displacement. It has been proven that the value of the specified angle was statistically significantly ($p<0.05$) smaller than with other methods of displacement.

The obtained results made it possible to create an idea of the structure of motor actions of athletes specializing in practical pistol shooting and to determine the optimal way of moving the shooter during shooting in motion.

4. Conclusions

Dependence of the parameters of precision-target movements on the nature of the movements of athletes is researched. A statistically significant ($p<0.05$) influence of the athlete's displacement method on shooting accuracy has been proven. It is established that when displacing with a normal step, the accuracy of the athlete is the lowest, instead, the X-shaped step contributes to a noticeable increase in the probability of hitting the target.

It is determined that the angular characteristics of biopairs torso-thigh and thigh-calf movements differ statistically significantly ($p<0.05$) for all moments of the walking cycle depending on the method of displacement. The maximum angular indicators of the torso-thigh biopair are recorded at the moment of dispatching of the left leg from the support in the hip joint of the left limb. At the same time, the specified trend is typical for all methods of displacement, except for low displacement and X-shaped step.

Regardless of the method of displacement, a characteristic feature of the angular indicators of the thigh-calf biopair is the maximum value of the angles in the knee joints at the moment of placing the leg on the support, and of the calf-foot biopair – the minimum value of the angle at the moment of placing the right leg on the support when moving the left shin joint.

The most similar in terms of the biomechanical structure of movements, where the largest number of statistically insignificant ($p>0.05$) differences are observed between the angular indicators of athletes specializing in practical pistol shooting, at different time points in the walking cycle in the torso-thigh bio-pair are low displacements and ski step, in the thigh-calf biopair – linear displacement and ski step, in the calf-foot biopair – ski step and X-shaped displacement, low and X-shaped displacement, low movement and ski step.

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