MATHEMATICAL MODEL OF SHORT DISTANCE PISTOL SHOOTING PERFORMANCE IN EXPERIENCED SHOOTERS OF BOTH GENDER

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Abstract: The aim of this paper is to determine the mathematical model of relation of accuracy and precision when shooting from a pistol Zastava CZ 99 in relation to gender and short target distance. The research included 49 participants (Men = 27, Women = 22). The testing was carried out using precision shooting from CZ 99 pistol on a Standard ISSF 25 m precision pistol target at a 6, 10 and 15 m distance (5 rounds per distance). The level of performance was evaluated in relation to accuracy and precision in the function of target distance. For the sample of men, the shooting accuracy was 76.98, 62.70 and 50.61%, while for the sample of women it was 60.32, 51.03 and 37.29% for the shooting distance of 6, 10 and 15 m respectively. The precision level was 8.52, 7.01 and 5.59 points (i.e. circles) for men and 6.63, 5.61 and 4.24 points for women respectively. The defined dependency models accuracy-distance and precision-distance have shown that for men the efficiency of shooting in relation to accuracy is decreasing 2.91%, i.e. 0.32 circles, while for women the accuracy decreases 2.57%, i.e. 0.27 circles, for every meter of increase in distance.

Keywords: CZ 99, pistol shooting, police officers, accuracy, precision.

INTRODUCTION

Olympic shooting, including the discipline of precision shooting, is a part of one of the most competitive and highly developed sports in the system of Olympic sports (Mon, Zakynthinaki, Cordente, Barriopedro, Sampedro, 2014). On the other hand, shooting a weapon is a very important and highly popular skill and it is used for sport and recreation purposes among the civilian population and professionally in military and law enforcement sector (Kayihan, Ersöz, Özkan, Koz, 2013).

In relation to military and police skills, the use of a firearm, i.e. service weapon belongs to the category of specific (motor) skills (Vučković, Dopsaj, Radovanović, Aleksandar, 2008; Silk, Savage, Larsen, Aisbett, 2018; Donner & Popovich, 2019). Both military and police personnel have a legal right to use a service weapon, but before earning such a right they have to complete the adequate training (Morrison & Vila, 1998; Kešetović, 2005). The training process is mostly organized through police specific standardized methodical process and represents one of the most important parts of police training (Morrison & Vila, 1998; Vučković, Dopsaj, Dujković, 2005; Kayihan et al., 2013; Silk et al., 2018). The proficiency for effective use of the service pistol is one of the important skills that have to be continuously perfected and maintained during a professional career. This is accomplished through the process of regular shooting training which is considered a standard in police and law enforcement agencies worldwide (Anderson & Plecas, 2000; Vučković et al., 2005; Kayihan et al., 2013; Silk et al., 2018).

Professionally important police and/or military skills, including the use of a standard service weapon, are a part of the phenomenology of research of multidimensional area which, based on previous research, consists of: physical, psychological, neurocognitive, biomechanical and technical sub-areas, and is a constant subject of scientific interest in relation to sport and police (Mason, Cowan, Bond, 1989; Anderson & Plecas, 2000; Vučković et al., 2008; Goonetilleke, Hoffman, Lau, 2009; Kayihan et al., 2013; Moon et al., 2014; Dopsaj, Prebeg, Kos, 2018; Kos, Umek, Marković, Dopsaj, 2019; Donner & Popovich, 2019). However, to date, there is no research that considers the accuracy and precision of shooting from a service pistol in relation to shooting distance. In other words, there is no data, nor model indicators, regarding changes in accuracy and precision in relation to the distance in optimal aiming conditions.

In accordance with the aforementioned deficiency of relevant data in the available scientific literature, the primary aim of this paper is to determine the mathematical model of relationship of accuracy and precision of shooting a pistol Zastava CZ 99 in standardized shooting conditions in relation to target distance and gender. In addition to defining the model characteristics of relations accuracy-distance and precision-distance, the obtained results can be used to control the efficiency and quality of the training programs and applied shooting training sessions, for the purposes of development of sport science in terms of shooting education programs, practical shooting, and in relation to forensic science and judicial medicine (Bresson & Franck, 2009; Brown, Tandy, Wulf, Young, 2013; Kos et al., 2019).

METHODS

This research can be classified in the category of applied research. The main measurement method that was used was field testing, while in relation to the type of measurement the direct method was used. In terms of the process of obtaining new knowledge, an analytical approach was used with total induction, and the method of mathematical statistics was used for the calculation of the analysed data.

SUBJECT SAMPLE

This research included a total of 49 participants (Men = 27, Women = 22) experienced pistol shooters (Shooting Experience = 6.2 ± 3.7 years), with the following basic characteristics: Men – Age = 34.5 ± 12.2 years, Body Height = 183.2 ± 5.6 cm, Body Mass = 85.9 ± 10.8 kg, BMI = 25.58 ± 2.73 kg•m^{-2}; Women – Age = 23.3 ± 4.4 years, Body Height = 167.7 ± 5.6 cm, Body Mass = 61.4 ± 8.7 kg, BMI = 21.74 ± 2.00 kg•m^{-2}.

VARIABLES

All measurements were performed using Zastava CZ 99 service pistol in the "Target" closed type shooting range in Belgrade. All shootings were realized on a Standard ISSF 25 m precision pistol target from the distances of 6, 10 and 15 m using the randomized method. All shootings were performed in the standing position using precision shooting on a circular target with 5 rounds per distance. The shooting performance was recorded for each shot using specialized software SSSE Version 1 (Kos, 2018; Kos et al., 2019). The level of shooting performance was evaluated in relation to accuracy and precision.

For the purposes of evaluation of accuracy the following 3 variables were used:

1) A_6m – calculated as a ratio between the maximal hypothetic sum of points (5 x 11 = 55) and the actual sum of points realized from the distance of 6 m, expressed as a percentage value;

2) A_10m – calculated as a ratio between the maximal hypothetic sum of points (5 x 11 = 55) and the actual sum of points realized from the distance of 10 m, expressed as a percentage value;

3) A_15m – calculated as a ratio between the maximal hypothetic sum of points (5 x 11 = 55) and the actual sum of points realized from the distance of 15 m, expressed as a percentage value;

For the purpose of evaluation of precision the following 3 variables were used:

1) P_6m – calculated as a ratio between the sum of hit circles on the target and rounds fired, achieved at the distance of 6 m, expressed numerically;

2) P_10m – calculated as a ratio between the sum of hit circles on the target and rounds fired, achieved at the distance of 10 m, expressed numerically;

3) P_15m – calculated as a ratio between the sum of hit circles on the target and rounds fired, achieved at the distance of 15 m, expressed numerically;

STATISTICS

All results were processed using basic descriptive statistics and the parameters of central tendency (Mean) and data dispersion (SD, % cV, absolute and relative SEM, and Confidence intervals) were calculated from the data. The normality of the distribution of the data was calculated using the nonparametric Kolmogorov-Smirnov test (KS-Z). Differences in relation to accuracy and precision achieved at different shooting distances were determined by the application of multivariate (MANOVA) and univariate (ANOVA) statistical analysis. The paired differences were determined using the Bonferroni test. The trend changes of dependent (accuracy and precision) in relation to independent (distance) variables were defined by the application of linear regression analysis. The level of statistical significance was defined for the probability of 95%, i.e. value p = 0.05 (Hair, Anderson, Tatham, Black, 1998).

RESULTS

Table 1 shows the descriptive results of the examined variables in relation to gender and shooting distance. Table 2 shows all the results of MANOVA and ANOVA of the examined variables in relation to gender.

Table 1. *Descriptive results of the examined variables in relation to the gender of the participants*

		Males (N=27)			Females (N=22)		
Accuracy		**6 m**	**10 m**	**15 m**	**6 m**	**10 m**	**15 m**
Mean		76.98	62.70	50.61*	60.32	51.03	37.29[#]
SD		17.96	22.47	27.57	23.55	24.24	28.35
cV%		23.33	35.84	54.48	39.04	47.50	76.03
Std. Error (Aps.)		3.46	4.32	5.31	5.02	5.19	6.04
Std. Error (Rel.)		4.49	6.89	10.49	8.32	10.17	16.20
95% CIM	LB	69.88	53.81	39.70	49.88	40.24	24.72
	UB	84.09	71.59	61.51	70.76	61.82	49.86
Min		32.73	10.91	1.81	18.18	12.73	1.82
Max		96.36	92.73	89.09	87.27	87.27	80.00
Precision		**6 m**	**10 m**	**15 m**	**6 m**	**10 m**	**15 m**
Mean		8.52	7.01	5.59[¥]	6.63	5.61	4.24[§]
SD		1.90	2.44	2.99	2.59	2.68	3.01
cV%		22.30	34.81	53.49	39.06	47.77	70.99
Std. Error (Aps.)		0.36	0.47	0.58	0.55	0.57	0.64
Std. Error (Rel.)		4.23	6.70	10.38	8.30	10.16	15.09
95% CIM	LB	7.57	6.05	4.64	5.46	4.43	3.06
	UB	9.47	7.96	6.54	7.81	6.79	5.42
Min		3.6	1.2	0.2	2.0	1.4	0.2
Max		10.6	10.2	9.8	9.6	9.6	8.8

95% CIM – 95% Confidence Interval for Mean; LB – Lower Bound; UP – Upper Bound; **Accuracy:** Males 6m vs 15m, * p =0.000; Females 6m vs 15m, [#] p =0.012; **Precision:** Males 6m vs 15m, [¥] p =0.000; Females 6m vs 15m, [§] p =0.017;

Table 3 shows the model values of shooting accuracy and precision for different distances in relation to gender, synthesized based on the defined dependency models. Figures 1 and 2 show the defined models of accuracy and precision in the function of shooting distance and in relation to the gender of participants.
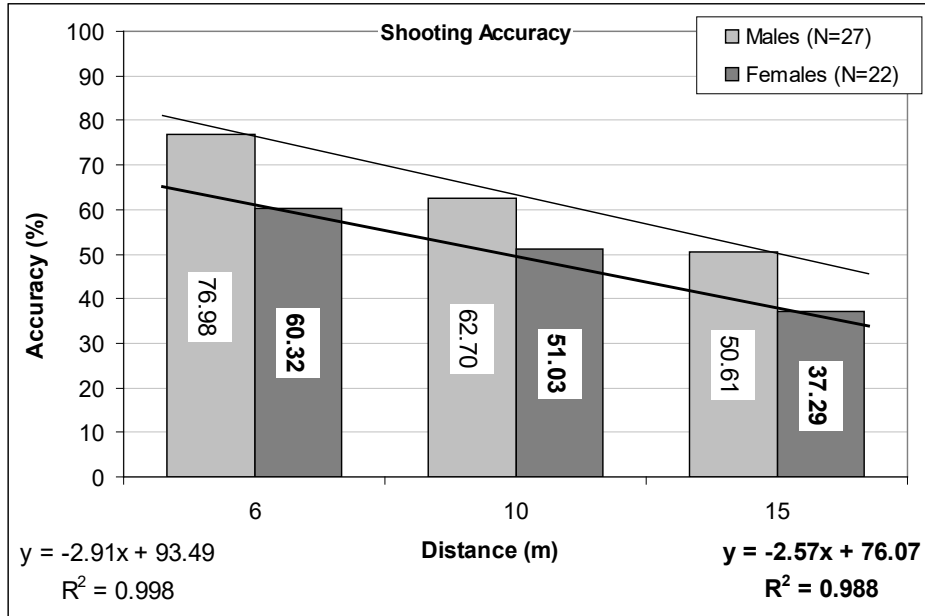

Figure 1. *The defined model of accuracy in the function of shooting distance in relation to the gender of the participants*
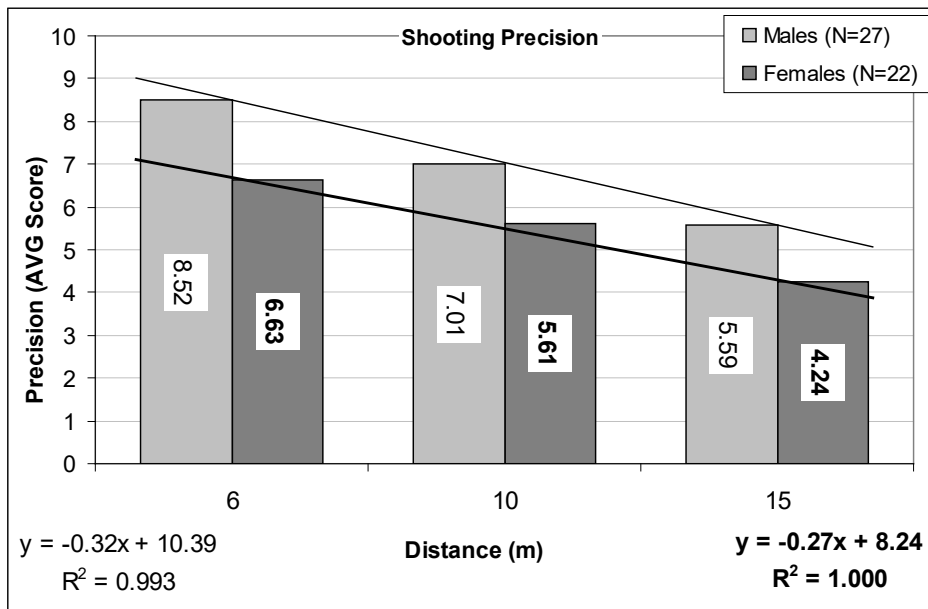

Figure 2. *The defined model of precision in the function of shooting distance and in relation to the gender of the participants*

Table 2. *The results of the MANOVA and ANOVA of the examined variables in relation to the gender of the participants*

Multivariate Tests

Effect -			Value	F	Hypothes. df	Error df	Sig.	Partial Eta²	Observed Power
Between	Gender - Accuracy	Wilks' Lambda	.820	3.30	3.00	45.0	.029	.180	.715
	Gender - Precision	Wilks' Lambda	.911	6.82	2.00	140.0	.001	.089	.915

ANOVA – Gender Univariate Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	F	Sig.	Partial Eta²	Observed Power
Between Gender	m6_Accuracy	3366.9	1	7.899	.007	.144	.786
	m10_ Accuracy	1650.4	1	3.607	.088	.061	.400
	m15_ Accuracy	2150.8	1	2.758	.103	.055	.370
	m6_Precision	3.51	1	5.273	.026	.101	.614
	m10_ Precision	2.25	1	2.140	.150	.044	.299
	m15_ Precision	0.18	1	0.303	.585	.006	.084

ANOVA – Distance Univariate Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	F	Sig.	Partial Eta²	Observed Power
Between Distance	Accuracy_Male	9414.8	2	8.893	.000	.186	.968
	Accuracy_Female	5908.1	2	4.543	.014	.126	.754
	Precision_Male	115.9	2	9.393	.000	.194	.975
	Precision_Female	63.4	2	4.142	.020	.116	.712

Table 3. *The results of the model values of shooting accuracy and precision from different shooting distances in relation to the gender of the participants*

Distance (m)	Accuracy Male	Accuracy Female	Precision Male	Precision Female	Distance (m)	Accuracy Male	Accuracy Female	Precision Male	Precision Female
1	90.6	73.5	10.1	8.0	17	44.0	32.4	5.0	3.7
2	87.7	70.9	9.8	7.7	18	41.1	29.8	4.6	3.4
3	84.8	68.4	9.4	7.4	19	38.2	27.2	4.3	3.1
4	81.9	65.8	9.1	7.2	20	35.3	24.7	4.0	2.8
5	78.9	63.2	8.8	6.9	21	32.4	22.1	3.7	2.6
6	76.0	60.7	8.5	6.6	22	29.5	19.5	3.4	2.3
7	73.1	58.1	8.2	6.4	23	26.6	17.0	3.0	2.0
8	70.2	55.5	7.8	6.1	24	23.7	14.4	2.7	1.8
9	67.3	52.9	7.5	5.8	25	20.7	11.8	2.4	1.5
10	64.4	50.4	7.2	5.5	26	17.8	9.3	2.1	1.2
11	61.5	47.8	6.9	5.3	27	14.9	6.7	1.8	0.9
12	58.6	45.2	6.6	5.0	28	12.0	4.1	1.4	0.7
13	55.7	42.7	6.2	4.7	29	9.1	1.5	1.1	0.4
14	52.8	40.1	5.9	4.5	30	6.2		0.8	0.1
15	49.8	37.5	5.6	4.2	31	3.3		0.5	
16	46.9	35.0	5.3	3.9	32	0.4		0.2	

DISCUSSION

In relation to the demands of professional qualification, the efficiency of the use of a service weapon is one of the most important training courses in police training. It was determined that some sort of service weapon (pistol, semi-automatic or a stun gun) is used in as many as 35-50% of all cases of official engagement of the police, i.e. in ¾ of all situations in relation to the use of all available technical and tactical means of coercion used by the police in Australia (Silk et al., 2018). Based on the results of this research it can be argued that for the male sample accuracy of shooting from Zastava CZ 99 service pistol was 76.98, 62.70 and 50.61% for the distances of 6, 10 and 15 m respectively. For the female sample accuracy was at the level of 60.32, 51.03 and 37.29% of the hypothetical maximal result for the same distances respectively (Table 1).

It was determined (Table 2) that the shooting performance, i.e. accuracy and precision, is statistically significantly different at the general level for the tested distances in relation to gender (Wilks' Lambda = 0.820, p = 0.029, Wilks' Lambda = 0.911, p = 0.001, respectively). The difference between male and female participants is accounting for 18.0%, that is 8.9% of the common variance (Partial η^2 = 0.180 and 0.089), while the strength of the analysis was at the level of 71.5% and 91.5% probability (Observed Power = 0.715 and 0.915).

In relation to the difference in shooting performance in men and women in relation to accuracy at the same distance, a statistically significant difference was determined only at the 6 m distance (Table 2, m6_Accuracy, p = 0.007), while there were no statistically significant differences at the distances of 10 and 15 m (Table 2). In other words, the tested men and women shot from the standard service pistol Zastava CZ 99 on a statistically significantly different level of performance in relation to accuracy. It can be concluded that the tested men are dominant only at the shorter shooting distance of 6 m, and potentially at 10 m (p = 0.088, i.e. the difference is at the 91.2% probability), while for the 15 m distance, there are no differences (Table 2).

For the defined model of the trend of accuracy change in the function of the shooting distance, the following dependency was determined: y = - 2.91x + 93.49 for men and y = - 2.57x + 76.07 for women (Figure 1). The presented model predicted the probability of maximal shooting accuracy at the smallest theoretical distance, i.e. 1 m, which is at the level of 93.49% for the male sample and 76.07% for the female sample. Also, the model defined that with each meter of shooting distance the shooting accuracy is reduced by 2.91 and 2.57% for the male and female samples, respectively (Figure 1). Application of the model defined the theoretical limit for the utilization of the mentioned firearm with the 95% probability. For the accuracy, the maximal hypothetical distance of practical utilization of the service pistol is 32 m for men and 29 m for women (Table 3).

In relation to the shooting precision, based on the obtained results, it can be argued that for the tested sample of men it was at the level of 8.52, 7.01 and 5.59 points for the distances of 6, 10 and 15 m, respectively, while for the tested sample of women it was at the level of 6.63, 5.61 and 4.24 points, i.e. circles, for the same distances (Table 1, Figure 1).

Based on the coefficient of variation (cV%) as a measure of homogeneity of the data, it can be argued that the tested subsamples in relation to shooting performance had the characteristics of a homogeneous group for the 6 m distance, acceptable homogeneity for the distance of 10 and 15 m for the male sample, and 10 m for the female sample, while for the female sample at the 15 m distance a very low level of homogeneity (cV% = 70.99%) was determined. In other words, the given task was proportionally easy for all participants at a 6 m and 10 m shooting distance, as well as at the 15 m distance for men, while at the same distance it proved to be in the category of difficult tasks for the examined sample of women.

Regarding the shooting performance in relation to precision, a statistically significant difference between men and women has been established only for the 6 m distance (Table 2, m6_Precission, p = 0.026), while for 10 and 15 m distances the difference was not significant. In other words, the tested men shot from the standard service pistol Zastava CZ 99 on a statistically significantly different level of performance compared to women only at the shortest shooting distance of 6 m, while for 10 and 15 m they did not (Table 2).

For the defined model of trend change of precision in the function of shooting distance the following function was determined: y = - 0.32x + 10.39 for men, and y = - 0.27x + 8.24 for women (Graph 2). The model determined the probability of maximal shooting precision at the smallest theoretical distance, i.e. 1 m, which is at the level of 10.39 and 8.24 circles for men and women, respectively. Also, the model defined that with each meter of shooting distance the shooting precision is reduced by 0.32 and 0.27 circles for men and women, respectively (Figure 2).

Dependency matrix of precision in relation to the shooting distance synthesized based on the model has shown that (with 95% probability) the maximal distance of precise utilization of the standard service pistol Zastava CZ 99 is 32 m for men and 30 m for women (Table 3).

One of the possible explanations for the statistically significant differences in accuracy and precision as measures of shooting performance using a standard service pistol at a 6 m shooting distance between men and women can be related to gender-based differences in upper extremity strength.

It was determined that maximal handgrip strength, as an overall indicator of hand strength, statistically significantly influences accuracy (19.3%) and precision (13.4%) in the situation of precision shooting from a standard service pistol Zastava CZ 99 at the aforementioned distance (Dopsaj et al., 2018).

As men are nearly 2 times stronger (Marković et al., 2018[b]) and have a higher level of explosiveness, i.e. rate of force development (RFD) (Marković et al., 2018[a]) and the 6 m distance is a relatively small distance from the aiming point to the target, it is most probable that persons with stronger hands, i.e. men, can use this strength advantage to compensate for the aiming and triggering errors. Also, as men and women used the same weapon, i.e. a weapon with the same weight, the weight of the pistol was a smaller relative load for men compared to women, thus making the weapon manipulation an easier physical task for men (Anderson & Plecas, 2000). However, aiming and triggering are dominant elements of positive performance at

longer shooting distances, i.e. 10 and 15 m, (Mon et al., 2014), which is the most probable reason for the fact that physical advantage in terms of higher strength and explosiveness of hand and arm in men and women is minimized in relation to differences in shooting accuracy and precision. At this point, there is no precise explanation why a statistically significant difference was not found for the examined parameters of efficiency of shooting performance between men and women in relation to longer shooting distances of 10 and 15 m. The most probable explanation is multidimensional and includes a specific combination of cognitive, physical, psychological, anatomical, morphological, biomechanical and other factors, in terms of differences and similarities that influence the similar efficiency of men and women when shooting at the 10 and 15 m distance (Mason et al., 1989; Anderson & Plecas, 2000; Goonetilleke et al., 2009; Kayihan et al., 2013; Miller & Halpern, 2014).

CONCLUSION

Based on the results of this research it can be argued that for the tested group of men, for the task of precision shooting from the pistol Zastava CZ 99, the accuracy was 76.98, 62.70 and 50.61% for the shooting distance of 6, 10 and 15 m, respectively. The shooting accuracy of the tested group of women was 60.32, 51.03 and 37.29% of the hypothetical maximal result at the same distances, respectively. In relation to the shooting precision, it was determined that the precision level was 8.52, 7.01 and 5.59 points (i.e. circles) for the male and 6.63, 5.61 and 4.24 points for the female sample, respectively. In relation to the gender-based differences in terms of shooting performance, it was determined that men and women have statistically significantly different accuracy and precision only for the 6 m shooting distance, while for longer distances, i.e. 10 and 15 m, there are no differences.

The defined model of accuracy in the function of target distance has determined that the hypothetical probability of maximal shooting accuracy at the smallest theoretical distance, i.e. 1 m distance, was at the level of 93.49% and 76.07% for men and women, respectively. With every meter of distance from the target, the shooting efficiency is reduced by 2.91% in men and 2.57% in women. Also, it was determined that the maximal possible hypothetical distance of shooting efficiency in terms of accuracy was 32 m for men and 29 m for women in the tested sample.

For the defined model in terms of the relation of changes in shooting precision in the function of shooting distance, it was determined that the hypothetical probability of maximal shooting precision at the smallest theoretical distance, i.e. 1 m distance, was at the level of 10.39 circles for men and 8.24 circles for women. With every meter of increased distance from the target, the shooting precision is reduced by 0.32 circles in men and 0.27 circles in women. Also, it was determined that the maximal possible hypothetical distance of shooting efficiency in terms of precision was 32 m for men and 30 m for women.

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