NBP JOURNAL OF CRIMINALISTICS AND LAW ŽURNAL ZA KRIMINALISTIKU I PRAVO
NBP 2020, 25(2): 29-38

Original scientific paper
Submitted: 2020-02-03
Published: 2020-10-30

doi:10.5937/nabepo25-25070

NEW POSSIBLE MULTIDIMENSIONAL MODELS FOR CLASSIFICATION OF THE BASIC LEVEL OF PISTOL SHOOTING SKILL

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Abstract: The aim of this paper was to provide a possible methodological solution for monitoring of the marksmanship training progress and evaluation of the level of shooting skill acquisition with service pistol CZ99. The second aim was the idea of development of a screening model for gender-dependent classification of the police personal, other security personnel and sport-oriented personnel in relation to their basic marksmanship skill. The research sample included a total of 83 participants (Men = 53, Women = 30) initially divided into four qualitative categories according to the personal shooting experience and shooting skill level. The applied principal component analysis has revealed a highly stable structure of the component matrix of the extracted factor. The following variables had the highest descriptive value in relation to the shooting skill in the respective samples regardless of distance: Men - an averaged value of the hit circles on the target and rounds fired, the index of efficiency considering precision and a coefficient of variation of hit circle achieved during the shooting at the target; Women - an averaged value of the hit circles on the target and rounds fired, the index of efficiency considering precision, a coefficient of variation of hit circle achieved during the shooting at the target and the index of efficiency considering accuracy. On the basis of the obtained results highly statistically significant ($p \leq 0.000$) specific multidimensional models were developed which enabled statistically significant classification of the participants relative to the pistol shooting skill classification. The accuracy of the defined equation model for estimation of shooting skill score classification was 59.7 and 61.5% for men and 68.6 and 68.0% for women in relation to the examined shooting distances of 6 and 10 m, respectively.

Keywords: shooting skill, police officer, multidimensional model, pistol shooting training.

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INTRODUCTION

Although shooting is one of the most highly developed sports, it is primarily rooted in the law enforcement and military, the structures that have obligatory and, more importantly, practical need for proficient firearms use (Vučković et al., 2008, Moon et al., 2014). It is considered that police officers are armed for their own safety and for the protection of the public (Kayihan et al., 2013). Regardless of the current incidence level of life-threatening situations (Anderson et al., 2002; Morrison & Vila, 1998), police officers must be adequately trained in order to react properly. This may require an officer to aim and fire a weapon under various conditions of psycho-physiological stress, and a failure to accurately do so can result in possible harm to the officer, suspect or general public (Muirhead et al., 2019). Also, the final act of using the gun is shooting and given that the shot needs to be as safe as possible for all parties involved, police officers must train to either improve or maintain their marksmanship skills and the acquired skill has to be continuously perfected and maintained during a professional career (Dopsaj et al., 2019). Consequently, the firearms training is an obligatory part of police officers' training that is typically organized by the agency – as specific as a standardized methodological process (Kayihan et al., 2013; Morrison & Vila, 1998; Vučković et al., 2008).

This is accomplished through the process of regular shooting training and evaluation that are considered a standard in police and law enforcement agencies worldwide (Anderson & Plecas, 2000; Kayihan et al., 2013; Silk et al., 2018). The ultimate goal of regular shooting training is to produce immediate and cumulative effects that will result in improved marksmanship and enhanced tactical efficiency (Vučković et al., 2005). As the standard-issue service weapon of the police is a handgun, it is only natural that the majority of police firearms training is geared toward handgun proficiency which encompasses two basic handgun skills: gun handling and marksmanship (Charles & Copay, 2003).

Given that marksmanship is multidimensional space consisting of different measures, the evaluation and monitoring of marksmanship performance should include different measures. The two most commonly used measures of marksmanship skill are accuracy (i.e. the extent to which the centre of the group of shots is close to the centre of the target) and precision (also referred to as consistency, i.e. the size of the group) (Johnson, 2001). One of the commonly used ways to measure accuracy is the average value of the points hit on the target, while the primary measure of shooting precision is the mean radius of the group which refers to the average of the straight-line distances between the centre of the shot group and each shot (Johnson, 2001). In addition, other measures could be used in order to gain perspective and improve the quality of information regarding the progress of the training process and the level of acquired skill. For example different indexes that can provide information regarding the degree of shooting efficiency, as well as the coefficient of variation that is defined as the ratio of the standard deviation to the mean, are commonly used in statistics to show the extent of variability of the results in relation to the group mean (Vincent, 2005).

Given the mentioned above, accurate evaluation of firearm proficiency requires the application of multivariate methods for identification of the structure of underlying measures that de-

scribe the outcome with the highest level of accuracy with classification of performance in relation to the achieved composite score (Hair et al., 1998). The aim of research was to provide a novel multidimensional methodological solution for monitoring of the marksmanship training progress applicable in practice. Further aim was to develop gender-dependent classification algorithms that would enable the accurate classification of the police or other security oriented personnel in relation to their basic marksmanship skill.

METHODS

This research could be classified as an applied scientific research. The main measurement method was field testing, while the measurement itself was conducted using a direct method.

SAMPLE

The research sample included a total of 83 adult participants (Male = 53, Female = 30) of different levels of shooting experience (5.5 ± 3.4 years). The main characteristics of males were age = 37.6 ± 12.0 years, body height = 181.7 ± 5.9 cm, body mass = 86.9 ± 9.6 kg, and body mass index = 25.76 ± 2.67 $kg \cdot m^{-2}$. The main characteristics of females were age = 24.2 ± 3.6 years, body height = 167.4 ± 5.3 cm, body mass = 61.7 ± 8.2 kg, and body mass index = 21.89 ± 2.07 $kg \cdot m^{-2}$. The overall sample was divided into four qualitative categories relative to shooting experience and shooting skill level: 1) beginners (n = 24 [29.9%]), who had no previous experience in shooting, were provided with one hour of introductory training in pistol handling; 2) intermediates (n = 23 [27.7%]), who completed the basic shooting course with a total shooting experience of three months; 3) experienced (n = 20 [24.1%]), who had completed the basic and advanced shooting course with a total shooting experience of at least one year, and 4) professionals (n = 16 [19.3%]), who had completed the basic, advanced and professional shooting course with a total shooting experience of at least two years. In relation to the total sample, 22 subjects were police officers, 8 practical shooter competitors, 20 recreational shooters and 33 the students of the Faculty of Sport and Physical Education of the University of Belgrade who voluntarily applied for the study. The research was carried out in accordance with the declaration of Helsinki and the recommendations of the guiding physicians in biomedical research involving human subjects (Williams, 2008), as well as with the ethical approval number 484-2 of the ethical board of the Faculty of Sport and Physical Education, University of Belgrade.

TESTING PROCEDURES

All testing was conducted in the closed type shooting range "Target" in Belgrade during October 2018 and May 2019, using Zastava CZ 99 standard service pistol (https://en.wikipedia.org/wiki/Zastava_CZ_99). All shootings were realized

on a Standard International Shooting Sport Federation (ISSF) 25m precision pistol shooting target from the distances of 6 and 10 m using the randomized trial method according to the procedures described earlier (Dopsaj et al., 2018, 2019). All shooting sessions were performed from the standing position (diagonal or parallel, depending on individual style of shooters) with both hands grip, using precision shooting on a standard pistol 50 x 50 cm circular target with 5 bullets per distance (6 and 10m) with no aiming period time limit. The shooting results were analysed for each shot using the custom-built software SSSE Version 1 (Kos, 2018; Kos et al., 2019).

VARIABLES

The level of shooting performance was assessed in relation to the accuracy and precision using nine variables.

Evaluation of precision:

1) AVG6m and AVG10m - Average score of the hit circles on the target and rounds fired achieved at the distance of 6 m or 10 m, expressed numerically;

2) $EFFIC_{Prec6}$ and $EFFIC_{Prec10}$ – the index of efficiency in precision, calculated as a ratio between the actual sum of points realized and the maximal hypothetic sum of points (5 x 11 = 55), expressed as a percentage value.

3) Evaluation of accuracy:

4) cV%6m and cV%10m – the coefficient of variation of hit circles achieved during the shooting (i.e. relative between-shots dispersion) calculated as standard deviation (SD)/AVG6m or 10m • 100, expressed in %;

5) $EFFIC_{Accu6}$ and $EFFIC_{Accu10}$ – the index of efficiency in accuracy, calculated as a ratio between the performed sum of hits in the target area and the number of fired bullets, expressed as a percentage value.

6) Evaluation of basic shooting skill index:

7) SSI_{6m} and SSI_{10m} – the shooting skill index, calculated as a ratio between the average value of the sum of hit circles on the target and the coefficient of variation squared, calculated for each shooting distance (SSI_{6m} = AVG6m / $cV\%6m^2$, and SSI_{10m} = AVG10m / $cV\%10m^2$).

STATISTICS

All raw data were analysed using the descriptive statistics, i.e. using mean, standard deviation (SD), the coefficient of variation (cV%), the standard error of mean (SEM), minimum and maximum (MIN and MAX). Principal component analysis was used to identify to what degree investigated variables constitute significant factors of shooting performance. The Oblimin rotation followed by the structure matrix was used to hierarchically rank the variables within the factors of each shooting distance. In this manner, the hierarchical structure of the significance of the variables in relation to each extracted factor was determined relative to the shooting distance and gender. After that, all variables that projected more than 90% on the factor were extracted as dominantly significant in defining the basic shooting skill in standing position relative to the examined shooting distance. With a new extracted set of the most discriminative basic shooting skill variables, the new factor analysis was performed in order to define the final factor structure which was necessary for calculation of the multidimensional score. This score presented the final information regarding the

overall positioning of the tested subjects in the group in relation to the examined basic shooting skill. Also, this score was defined in relation to gender for each shooting distance and represented the basic shooting skill criterion variable (Basic Shooting Skill Score - BSSS). Multiple Regression Analysis (MRA) was used in order to determine the specific equation for the evaluation of BSSS. As a final procedure, a Discriminant analysis was applied and the resulting classification was compared with the initial group classification of the participants in order to determine the predictive validity (Hair et al., 1998). The level of statistical significance was set for the probability of 95% and p-value at 0.05.

RESULTS

Table 1 shows the descriptive results of the examined variables in relation to the sample. The results for both genders have shown that the average value of the shot at the 6 m shooting distance was higher than that at 10 m, which was followed by lower variation in results at 6 m compared to 10 m. Furthermore, the $EFFIC_{prec6}$ was higher compared to $EFFIC_{prec10}$ as well as $EFFIC_{accu6}$ compared to $EFFIC_{accu10}$, which reflected in higher SSI6m than SSI10m.

Table 1. *Descriptive statistical data in relation to the shooting distance and according to gender*

			Mean	SD	SEM	Min	Max
Male	Precision	AVG6m	8.44	1.56	0.19	3.40	10.60
		$EFFIC_{Prec6}$	76.83	14.31	1.75	24.73	96.36
		AVG10m	7.03	2.09	0.34	1.20	10.20
		$EFFIC_{Prec10}$	62.70	20.96	3.36	5.09	92.73
	Accuracy	cV%6m	17.65	14.35	1.77	4.38	89.69
		$EFFIC_{Accu6}$	99.70	2.44	0.30	80.00	100.00
		cV%10m	37.14	31.80	5.09	5.08	156.49
		$EFFIC_{Accu10}$	95.38	13.35	2.14	40.00	100.00
	Index	SSI6m	12.14	14.89	1.82	0.04	53.06
		SSI_10m	4.49	7.94	1.27	0.01	34.07
Female	Precision	AVG6m	6.69	2.72	0.46	0.80	9.60
		$EFFIC_{Prec6}$	58.13	28.29	4.78	2.91	87.27
		AVG10m	5.65	2.95	0.59	1.00	9.60
		$EFFIC_{Prec10}$	46.14	31.70	6.34	2.55	87.27
	Accuracy	cV%6m	42.63	45.07	7.62	0.70	162.98
		$EFFIC_{Accu6}$	89.14	20.20	3.41	40.00	100.00
		cV%10m	69.41	67.19	13.44	5.08	223.61
		$EFFIC_{Accu10}$	76.80	28.68	5.74	20.00	100.00
	Index	SSI6m	4.69	6.29	1.06	0.00	27.69
		SSI10m	3.12	6.99	1.40	0.00	34.07

Table 2. shows the results of the Factor analysis. The amount of extracted and explained variance ranges from 71.943% for male sample for 6m shooting to 81.314% for female sample for 10m shooting.

Table 2. *Results of principal component analyses (factor analyses)*

Variables	Component Matrix			
	Male 6m	**Female 6m**	**Male 10m**	**Female 10m**
AVG	**0.958**	**0.957**	**0.966**	**0.974**
$EFFIC_{Prec}$	**0.965**	**0.974**	**0.984**	**0.980**
cV%	**-0.945**	**-0.971**	**-0.977**	**-0.962**
$EFFIC_{Accu}$	0.568	**0.907**	0.822	**0.961**
SSI	0.730	0.657	0.598	0.555
Initial Eigenvalues -Total	3.597	4.062	3.888	4.066
% of Variance	71.943	81.248	77.766	81.314

Table 3 shows the basic shooting skill model prediction equations. AVG, cV% and $EFFIC_{Prec}$ single out as the most discriminative for the measured basic shooting skill at both shooting distances in males, while AVG, cV%, $EFFIC_{Prec}$ and $EFFIC_{Accu}$ were the best predictors in females. In Table 4, the results of the Discriminant analysis are presented. At the general level, the results show that with the applied methodology and defined models, on average 68.0% shooting skill level can be successfully classified i.e. recognized.

Table 3. *Results of the Multiple Regression Analysis and the defined BSSS model prediction equations*

Gender / Distance	MRA Model Summary		ANOVA		Basic Shooting Skill Score (BSSS) prediction equations
	Adj. R^2	SEE	F	p	
Male 6m	1.000	0.003	9.65	0.000	BSSS = -6.033 + (AVG • 3.734) – (cV • 0.382) + ($EFFIC_{Prec}$ • 0.407)
Male 10m	1.000	0.003	4.19	0.000	BSSS = 20.513 + (AVG • 2.699) – (cV • 0.175) + ($EFFIC_{Prec}$ • 0.271)
Female 6m	1.000	0.003	3.02	0.000	BSSS = 15.940 - (AVG • 1.588) – (cV • 0.098) + ($EFFIC_{Prec}$ • 0.156) + ($EFFIC_{Accu}$ • 0.208)
Female 10m	1.000	0.004	1.28	0.000	BSSS = 28.569 - (AVG • 1.443) – (cV • 0.063) + ($EFFIC_{Prec}$ • 0.135) + ($EFFIC_{Accu}$ • 0.149)

Table 4. *Summary of Canonical Discriminant Functions – classification results*

Gender / Distance			Shooting Level	Predicted Group Membership				Total
Classification Success				Beginner	Intermediate	Experienced	Professional	
Male 6m	59.7% of selected original grouped cases correctly classified.	%	Beginner	**66.7**	23.8	0.0	9.5	100.0
			Intermediate	22.2	**55.6**	0.0	22.2	100.0
			Experienced	0.0	33.3	**0.0**	66.7	100.0
			Professional	0.0	15.8	0.0	**84.2**	100.0
Male 10m	61.5% of selected original grouped cases correctly classified.	%	Beginner	**44.4**	55.6	0.0	0.0	100.0
			Intermediate	13.3	**66.7**	0.0	20.0	100.0
			Experienced	0.0	25.0	**0.0**	75.0	100.0
			Professional	0.0	9.1	0.0	**90.9**	100.0
Female 6m	68.6% of selected original grouped cases correctly classified.	%	Beginner	**94.1**	0.0	5.9	0.0	100.0
			Intermediate	16.7	**16.7**	66.7	0.0	100.0
			Experienced	0.0	12.5	**87.5**	0.0	100.0
			Professional	0.0	0.0	100.0	**0.0**	100.0
Female 10m	68.0% of selected original grouped cases correctly classified.	%	Beginner	**90.0**	10.0	0.0	0.0	100.0
			Intermediate	0.0	**71.4**	0.0	28.6	100.0
			Experienced	0.0	25.0	**0.0**	75.0	100.0
			Professional	0.0	25.0	0.0	**75.0**	100.0

DISCUSSION

This study aimed to provide a novel multidimensional methodological solution for monitoring the marksmanship training progress applicable in practice and to develop gender-dependent classification algorithms for accurate classification of marksmanship skill of police or other security personnel. The main findings showed that the applied methodology differentiates the beginner and intermediate shooters from the experienced and professional shooters. The fact that it has not differentiated between the experienced shooters and professionals suggests that the structure of the used tests (standing still and aiming with unlimited time) may be insufficient to identify the difference between more experiences shooters.

The application of the principal component analysis has determined a highly stable structure of the component matrix of the extracted factor, while the highest level of saturation in description of the relevant factor regardless of distance was provided by AVG, $EFFIC_{Prec,}$ and cV% in men and AVG, $EFFIC_{Prec}$, cV%, and $EFFIC_{Accu}$ in women. The results have shown the lowest level of saturation of SSI in relation to the gender and the examined shooting distance. Consequently, it could be concluded that the discriminative value of this variable in relation to the shooting method (static position) and distance (6 and 10 m) is not satisfactory from the aspect of valid evaluation of service pistol shoot-

ing proficiency. This was further confirmed by the regression analysis as only SSI did not enter the prediction models, while other variables predicted 100% of the BSSS.

These models enabled statistically significant classification of the participants relative to the initial classification of the participants and relative to the achieved shooting proficiency when using a standard service weapon. The accuracy of classification was about 1.8% higher for 10 m distance in males and about 0.8% higher for 6 m distance in females. Note that more experienced males were all classified as professional at both shooting distances, while more experienced females were classified as experienced at 6 m and as professional at 10 m distance. In addition, the classification rate was higher at 6 m distance, which could be the reason for higher accuracy at 6 m in females. However, both male and female results indicate that the used methodology is sensitive but that more advanced shooting test should be used to differentiate between the experienced shooters by utilizing the value of this methodology to a higher degree. It should be pointed out that, when considering men, the defined models have the highest level of successful identification in the professional group that entirely consisted of the members of the police, gendarmerie and the department for the protection of persons and objects, where the classification accuracy was the highest for both shooting distances. Higher classification accuracy for the longer distance supports the notion that with the increase of test difficulty the accuracy and sensitivity may increase.

Considering the initial classification of the participants based on the shooting experience, the established model did not identify any participant as experienced but intermediate or professional for both shooting distances in males and females. However, the percentage of intermediate was lower and the percentage of professional higher at the 10 m shooting distance for males and vice versa for females. This further suggests that the novel methodology provides higher classification accuracy as it uses the actual measures of marksmanship skill rather than shooting training history.

The presented results clearly indicate that the expert classification of the service pistol marksmanship based solely on the shooting score is inadequate in relation to the overall proficiency level. It should be noted that in all 4 cases (2 distances x 2 samples) the applied analyses produced only 3 groups in relation to the shooting proficiency. Thus, it can be concluded that the application of multivariate statistical procedures and the use of composite measures enable more accurate identification of the level of marksmanship skill. The defined methodology could be used as accurate model of evaluation of marksmanship skill of police officers and security personnel. It could be developed as standardized assessment procedure that could be used in shooting training, as it would indicate what exactly the problem is (accuracy or precision), if the shooting is not at the minimal required level.

CONCLUSION

Based on the results of this research it can be concluded that highly statistically significant multidimensional models for classification of the basic level of shooting skill when using a service pistol CZ 99 have been defined. The model was defined by the application of complex statistical models based on different variables that define dimensions of shooting proficiency such as accuracy, precision, and efficiency. These models showed a good classification accuracy of relative to their shooting proficiency. Also, it has been determined that, when considering males, the defined models are the most efficient in the classification of the group of professionals, while when considering females, the most efficient classification is achieved in the group of beginners. In general, it can be concluded that in relation to the scientific methodology and for the needs of classification of the level of basic shooting skill using a service pistol CZ 99, the defined multi-dimensional models can be used with a high level of practical applicability. Moreover, the applied statistical method revealed that the used shooting tests were insufficiently complex to differentiate between the participants who were more experienced in shooting. More advanced tests could be used for this purpose in order to utilize the full potential of the defined statistical model.

REFERENCES

Anderson, G. S., Litzenberger, R., & Plecas, D. (2002). Physical Evidence of Police Officer Stress. *Policing: An International Journal of Police Strategies & Management*, *25*(2), 399–420. https://doi.org/10.1108/13639510210429437

Anderson, G. S., & Plecas, D. B. (2000). Predicting Shooting Scores from Physical Performance Data. *Policing: An International Journal of Police Strategies & Management*, *23*(4), 525–537. https://doi.org/10.1108/13639510010355611

Charles, M. T., & Copay, A. G. (2003). Acquisition of Marksmanship and Gun Handling Skills through Basic Law Enforcement Training in an American Police Department. *International Journal of Police Science & Management*, *5*(1), 16–30. https://doi.org/10.1350/ijps.5.1.16.11245

Dopsaj, M., Marković, S., Umek, A., Prebeg, G., & Kos, A. (2019). Mathematical Model of Short Distance Pistol Shooting Performance in Experienced Shooters of Both Genders. *Science, Security, Police – Journal for Criminal Justice and Law*, *24*(3). https://doi.org/10.593/nabepo24-23287

Dopsaj, M., Prebeg, G., & Kos, A. (2018). Maksimalna sila stiska šake u funkciji preciznosti i tačnosti gađanja iz službenog pištolja CZ 99: Generički modeli. *Bezbednost*, *60*(2), 30–49.

Hair, J. F., Anderson, R. E., Tatham, R., & Black, W. C. (1998). *Multivariate Data Analysis with Readings* (5th ed.). Macmillan.

Johnson, R. F. (2001). *Statistical Measures of Marksmanship* (Technical Note TN-01/2). U.S. Army Research Institute of Environmental Medicine.

Kayihan, G., Ersöz, G., Özkan, A., & Koz, M. (2013). Relationship Between Efficiency of Pistol Shooting and Selected Physical-Physiological Parameters of Police. *Policing: An International Journal of Police Strategies & Management*, *36*(4), 819–832. https://doi.org/10.1108/PIJPSM-03-2013-0034

Kos, A. (2018). *SSSE Version 1, Sensor System for Shooting Evaluation*.

Kos, A., Umek, A., Marković, S., & Dopsaj, M. (2019). Sensor System for Precision Shooting Evaluation and Real-time Biofeedback. *Procedia Computer Science*, *147*, 319–323. https://doi.org/10.1016/j.procs.2019.01.228

Mon, D., Zakynthinaki, M., Cordente, C., Barriopedro, M., & Sampedro, J. (2014). Body Sway and Performance at Competition in Male Pistol and Rifle Olympic Shooters. *Biomedical Human Kinetics*, *6*(1). https://doi.org/10.2478/bhk-2014-0010

Morrison, G. B., & Vila, B. J. (1998). Police Handgun Qualification: Practical Measure or Aimless Activity? *Policing: An International Journal of Police Strategies & Management*, *21*(3), 510–533. https://doi.org/10.1108/13639519810228804

Muirhead, H., Orr, R., Schram, B., Kornhauser, C., Holmes, R., & Dawes, J. J. (2019). The Relationship between Fitness and Marksmanship in Police Officers. *Safety*, *5*(3), 54. https://doi.org/10.3390/safety5030054

Silk, A., Savage, R., Larsen, B., & Aisbett, B. (2018). Identifying and Characterising the Physical Demands for an Australian Specialist Policing Unit. *Applied Ergonomics*, *68*, 197–203. https://doi.org/10.1016/j.apergo.2017.11.012

Vincent, W. J. (2005). *Statistics in kinesiology*. Human Kinetics.

Vučković, G., Dopsaj, M., & Dujković, P. (2005). Training for Handling Official Pistol According to International Standards. *Science, Security, Police – Journal for Criminal Justice and Law*, *10*(3), 173–194.

Vučković, G., Dopsaj, M., Radovanović, R., & Jovanović, A. (2008). Characteristics of Shooting Efficiency During a Basic Shooting Training Program Involving Police Officers of Both Sexes. *Facta Universitatis - Series: Physical Education and Sport*, *6*(2), 147–157.

Williams, J. R. (2008). The declaration of Helsinki and public health. *Bulletin of the World Health Organization*, *86*(8), 650–652.