GAZİANTEP ÜNİVERSİTESİ
Spor Bilimleri Dergisi

Cilt / Vol: 8, Sayı / Issue: 4
December / Aralık, 2023
ISSN: 2536-5339

Does Skill Level Affect Plantar Pressure Distribution in Air Pistol Shooters?

Selda YILMAZ[1] Gülçin GÜLER*[1] Deniz ŞİMŞEK[1]

[1]Eskişehir Technical University, Faculty of Sport Science, *ESKİŞEHİR*

DOI: 10.31680/gaunjss.1366822

Orijinal Makale / Original Article

Geliş Tarihi / Received: 26.09.2023 **Kabul Tarihi / Accepted:** 29.10.2023 **Yayın Tarihi / Published:** 26.12.2023

Abstract

In order to achieve optimal shooting performance, athletes need to make postural stability adjustments at an optimal level. The aim of this study was to investigate plantar pressure distributions of shooters during shooting performance. Twelve air pistol shooters (Elite, n=6; Novice, n=6) volunteered to participate in the study. Plantar pressure assessments [total foot, forefoot, midfoot, and hind foot maximal force (MF)(N), peak pressure (PP)(kPa), and mean pressure (MP)(kPa) during 10 shots were examined using the PEDAR® insole system. It was found that right total foot MF, MP and hind foot PP values of the novice group were higher than elite group. In left foot, elite group's left total foot, forefoot and hind foot PP; left forefoot MF and MP values were higher than novice group's ($p < .05$). The elite group's left total foot MF and hind foot PP values were higher from the right foot and also right forefoot and midfoot MF, and MP and right midfoot PP values were higher from the left foot. In novice group, right total, forefoot and midfoot PP, MP, forefoot, midfoot and hind foot MF values were significantly higher than left foot ($p<.05$). Finally, elite shooters transferred their body weight to left hind foot and right forefoot during shots, resulting in higher scores, while novices actively used their right total foot and had significantly lower scores compared to the elite group. Coaches should incorporate athlete-specific postural stability exercises in training programs to teach athletes to distribute their body weights more evenly between both feet.

Keywords: Shooting, plantar pressure, postural balance, postural stability

* **Sorumlu Yazar:** Gülçin GÜLER **E-mail:**gguler@eskisehir.edu.tr

Giriş

Shooting is a static sport that requires a high level of focus and coordination along with physical fitness (Hawkins & Sefton, 2011; Herpin et al., 2010; Stambolieva et al., 2015). Performance in shooting is affected by various factors such as stability of hold (Pellegrini & Schena, 2005; Reinkemeier & Bühlmann, 2013), postural control (Aalto et al., 1990; Era et al., 1996), experience and training (Goonetilleke et al., 2009), breathing rhythm, visual focus ability, and hand-eye coordination. When examining the technical factors that affect performance, it has been noted that the ability to stabilize the pistol plays a crucial role (Pellegrini & Schena, 2005; Reinkemeier & Bühlmann, 2013). In air pistol shooting, maximum control of body movements by the shooter is necessary for the maximum stabilization of the pistol. It has been suggested that the ability to balance the pistol and, therefore, performance is controlled by the center of pressure (COP) movements of the body (Ball et al., 2003). Furthermore, there is a consensus in the scientific literature and among expert coaches that better postural balance leads to higher performance levels (Aalto et al., 1990; Konttinen et al., 1998; Herpin et al., 2010; Reinkemeier & Bühlmann, 2013).

Physical fitness and postural control are essential to maintain a consistent static stance until the end of the competition (Era et al., 1996; Viitasalo et al., 2001; Mononen et al., 2007). To achieve a good shooting performance, the athlete must make postural stability adjustments at an optimal level (Hawkins & Sefton, 2011). Any medio-lateral or anterior-posterior sway of the body during the shooting could negatively affect the athlete's performance. Therefore, even the slightest change in posture could result in a change in the shooting score. In shooting sports, controlling oscillations and maintaining a stable posture are utmost important (Sağıroğlu et al., 2016; Era et al., 1996; Ball et al., 2003). In a study by Goonetilleke et al. (2009), it was stated that optimal shooting performance in shooting is largely associated with the combination of the shooter's postural control at the moment of releasing the trigger and rifle stabilization. When studies on postural balance and stability in the literature were examined, it was seen that postural balance differentiated elite and novice shooters and that elite shooters had better postural stability than novice shooters (Era et al., 1996; Ihalainen et al., 2016; Mon et al., 2014; Aalto et al., 1990). Although there are studies conducted on shooters in which body sway is evaluated with a force platform (Ihalainen et al., 2016; Sağıroğlu et al., 2016; Hawkins & Sefton, 2011), there are limited studies evaluating plantar pressure. In the plantar pressure studies, the

differences in plantar pressure distributions with and without shoes (Kim, 2019) and the plantar pressure of the pistol shooters (Chadefaux et al., 2020) were investigated. No study has been found in the literature that evaluates in detail the plantar pressure distributions exhibited by air pistol shooters with different skill levels during shooting performance. Therefore, the current study aimed to examine the plantar pressure strategies exhibited by elite and novice air pistol shooters during shooting, focusing on (i) skill level and (ii) comparison between the left and right foot.

Materials and methods

Participants

The study included 12 air pistol athletes [Elite Group (n=6): body weight = 78.67 (kg) ± 4.89, height = 176.33 ± 5.68 (cm), BMI = 25.32 ± 1.59 (kg/m2), age = 25.5 ± 12.08 (years), years of experience = 8.66 ± 5.61, shooting score = 9.22 ± 0.76; Novice Group (n=6): body weight = 83.83 ± 19.79 (kg), height = 168.00 ± 5.51 (cm), BMI = 29.68 ± 6.81 (kg/m2), age = 19.83 ± 10.94 (years), years of experience = 1.5 ± 0.55, shooting score = 7.97 ± 1.43] who volunteered to participate. The inclusion criteria for participants were determined similarly to the study by Ortega and Wang (2018). Elite athletes were selected from among national team shooters, while novices were selected from athletes with less than two years of experience. Participants with any physical illness or injury during the 2020-2021 season were excluded from the study. Before the experimental study, participants were informed and signed a voluntary participation form. Necessary permission was obtained from the Eskişehir Technical University Scientific Research and Publication Ethics Board (Protocol No: 55779) to conduct the study.

Data collection

Plantar pressure

Plantar pressure measurements of the athletes were recorded using the PEDAR® insole system (Novel Gmbh, Munich, Germany), which has a thickness of 2.6 mm and contains 99 sensors with a sampling rate of 100Hz. Plantar pressure values were recorded for all athletes during 10 shots. The foot was masked in 8 different areas: (1) left total foot, (2) left forefoot, (3) left midfoot, (4) left hind foot, (5) right total foot, (6) right forefoot, (7) right midfoot, (8) right hind foot. Mean pressure [MP (kPa)], maximal force [MF (N)], and peak pressure [PP (kPa)] values were recorded.

Weight and height

The participants' body weights (kg) were measured by Tanita Leicester and their heights (m) were measured by Seca (Seca, Vogel & Halke, Hamburg). Body Mass Index (BMI) values were calculated by dividing the body weight (kg) by the square of the height (m^2).

Shooting scores

Each athlete performed 10 shots, and their shooting scores were recorded using the SIUS Ascor SA951, which is an ISSF-approved electronic shooting system.

Measurement protocol

Before starting the experimental study, the participants were asked to warm up specific to their branch. Following the warm-up process, athletes' insoles were selected according to their shoe sizes, and the insoles were placed in their own shoes. Athletes performed 10 shots and used their own equipment in accordance with ISSF rules during the shooting (ISSF, 2022). Plantar pressure distributions of all athletes were recorded during the 10 shots.

Data analysis

Mean pressure, maximal force, and peak pressure values for the left total foot, left forefoot, left midfoot, left hind foot, right total foot, right forefoot, right midfoot, and right hind foot regions were recorded for all athletes during the 10 shots. Plantar pressure data were analyzed using the Pedar analysis system (Novel Projects® & Novel Scientific®, Munich, Germany).

Statistical analysis

The data were presented as mean and standard deviation. Before statistical analysis, the normality of the data was tested using the Kolmogorov-Smirnov test. Mann-Whitney U test was used for between-group and within-group comparisons of the right and left feet. IBM SPSS Statistics software (SPSS 26.0. IBM Corp., Armonk, NY, USA) was used for the mathematical calculations. The level of significance was set at $p < 0.05$.

Results

The descriptive data of elite and novice shooters are presented in Table 1; between-group comparisons of plantar pressure for the left and right feet are provided in Tables 2 and 3, while within-group comparisons of plantar pressure for the right and left feet are presented in Tables 4 and 5.

Table 1. Descriptive Data of Elite and Novice Shooters

	Weight (kg)	Height (cm)	BMI (kg/m2)	Age (years)	Years of Exp.	Shoot.Scr.
Elite Group	78.67 ± 4.89	176.33 ± 5.68	25.32 ± 1.59	25.5 ± 12.08	8.66 ± 5.61	9.22 ± .76
Novice Group	83.83 ± 19.79	168.00 ± 5.51	29.68 ± 6.81	19.83 ± 10.94	1.5 ± 0.55	7.97 ± 1.43

There was no difference in weight and BMI between the groups (p>.05). It was found that the shooting scores of the elite group were significantly higher than the novice group (p<0.001)

Table 2. Between-Group Plantar Pressure Distributions for the Left Foot

		Elite Group (n=60 shots)		Novice Group (n=60 shots)		Z score	p
		Mean	sd.	Mean	sd.		
TOTAL FOOT	MF(N)	283.43	76.16	250.67	98.63	-.558	.557
	PP(kPa)	69.84	17.41	57.59	13.30	-3.406	**.001***
	MP (kPa)	16.89	4.74	15.39	5.70	-.310	.757
FORE FOOT	MF (N)	62.27	33.85	46.64	23.06	-2.498	**.012***
	PP(kPa)	43.88	14.75	35.20	9.68	-3.183	**.001***
	MP (kPa)	8.73	4.21	7.11	4.34	-2.433	**.015***
MID FOOT	MF (N)	51.51	44.03	64.02	50.67	-1.317	.188
	PP (kPa)	38.79	16.91	36.23	11.19	-1.165	.244
	MP (kPa)	10.04	9.62	11.45	7.74	-1.821	.069
HIND FOOT	MF (N)	130.42	57.91	131.46	59.29	-.236	.813
	PP (kPa)	61.08	21.44	52.65	16.50	-2.609	**.009***
	MP (kPa)	30.96	12.82	31.32	13.37	-.094	.925

When examining the plantar pressure values for the left foot between the groups, it was found that the elite group had significantly higher total foot, forefoot, hind foot PP, forefoot MF, and MP values compared to the novice group (p < .05).

Table 3. Between-Group Plantar Pressure Distributions for the Right Foot

		Elite Group (n=60 shots)		Novice Group (n=60 shots)		Z score	p
		Mean	sd.	Mean	sd.		
TOTAL FOOT	MF(N)	261.16	56.74	303.65	93.62	-2.661	**.008***
	PP(kPa)	71.64	16.64	71.67	21.27	-.152	.879
	MP (kPa)	15.72	2.50	19.07	5.91	-3.081	**.002***
FORE FOOT	MF (N)	84.21	28.08	79.23	37.13	-.499	.618
	PP(kPa)	44.55	9.34	44.69	16.43	-1.023	.306
	MP (kPa)	11.81	3.06	12.01	5.71	-.362	.717
MID FOOT	MF (N)	79.17	44.19	96.12	59.41	-1.176	.240
	PP (kPa)	55.39	32.09	48.27	16.33	-.042	.967
	MP (kPa)	14.79	9.37	17.77	8.69	-1.842	.065
HIND FOOT	MF (N)	142.36	55.10	150.93	57.72	-.877	.381
	PP (kPa)	53.54	11.20	63.25	24.87	-2.199	**.028***
	MP (kPa)	32.26	11.54	35.75	14.96	-1.107	.268

When examining the plantar pressure values for the right foot between the groups, it was found that the novice group had significantly higher right total foot MF, MP, and hind foot PP values compared to the elite group ($p < .05$).

Table 4. Comparison of the Novice Group's Left and Right Foot

		Novice Left Foot (n=60 shots)		Novice Right Foot (n=60 shots)			
		Mean	**sd.**	**Mean**	**sd.**	**Z score**	**p**
TOTAL FOOT	**MF(N)**	250.67	98.63	303.65	93.62	-1.727	.084
	PP(kPa)	57.59	13.30	71.67	21.27	-4.199	**.000***
	MP (kPa)	15.39	5.70	19.07	5.91	-2.724	**.006***
FORE FOOT	**MF (N)**	46.64	23.06	79.23	37.13	-4.844	**.000***
	PP(kPa)	35.20	9.68	44.69	16.43	-3.212	**.001***
	MP (kPa)	7.11	4.34	12.01	5.71	-4.577	**.000***
MID FOOT	**MF (N)**	64.02	50.67	96.12	59.41	-2.761	**.006***
	PP (kPa)	36.23	11.19	48.27	16.33	-4.031	**.000***
	MP (kPa)	11.45	7.74	17.77	8.69	-3.322	**.001***
HIND FOOT	**MF (N)**	131.46	59.29	150.93	57.72	-2.309	**.021***
	PP (kPa)	52.65	16.50	63.25	24.87	-1.907	.057
	MP (kPa)	31.32	13.37	35.75	14.96	-1.491	.136

MF: Maximal Force; PP: Peak Pressure; MP: Mean Pressure

In the novice group, all values except right total foot MF, hind foot PP, and MP were higher than those in the corresponding regions of the left foot ($p < .05$).

Table 5. Comparison of the Elite Group's Right and Left Foot

		Elite Left Foot (n=60 shots)		Elite Right Foot (n=60 shots)			
		Mean	**Sd.**	**Mean**	**Sd.**	**Z score**	**p**
TOTAL FOOT	**MF(N)**	283.43	76.16	261.16	56.74	-2.131	**.033***
	PP(kPa)	69.84	17.41	71.64	16.64	-.924	.356
	MP (kPa)	16.89	4.74	15.72	2.50	-.215	.830
FORE FOOT	**MF (N)**	62.27	33.85	84.21	28.08	-3.921	**.000***
	PP(kPa)	43.88	14.75	44.55	9.34	-.241	.809
	MP (kPa)	8.73	4.21	11.81	3.06	-4.792	**.000***
MID FOOT	**MF (N)**	51.51	44.03	79.17	44.19	-3.910	**.000***
	PP (kPa)	38.79	16.91	55.39	32.09	-3.385	**.001***
	MP (kPa)	10.04	9.62	14.79	9.37	-4.157	**.000***
HIND FOOT	**MF (N)**	130.42	57.91	142.36	55.10	-1.165	.244
	PP (kPa)	61.08	21.44	53.54	11.20	-2.152	**.031***
	MP (kPa)	30.96	12.82	32.26	11.54	-.404	.686

MF: Maximal force; PP: Peak Pressure; MP: Mean Pressure

It was observed in the elite group that, left total foot MF and hind foot PP values were higher than those of the right foot. Additionally, right forefoot, midfoot MF, and MP values, along with right midfoot PP values, were higher than those of the left foot ($p < .05$).

Discussion and conclusion

In the present study, it was aimed to evaluate the plantar pressure strategies exhibited by elite and novice air pistol shooters during shooting performance. It was found that the elite group had higher values for left total foot, forefoot, hind foot PP, forefoot MF, and MP compared to the novice group. Also, it was determined that the right total foot MF, MP and hind foot PP values of the novice group were higher than the elite group. In other words, the left foot parameters of the elite group were higher than those of the novice group. This difference may be attributed to the fact that the elite group could transfer balanced their body weight between both feet, while the novice group may have transferred more of their body weight to the right foot. When examining postural stability studies conducted with shooters in the literature, it has been stated that elite shooters have better postural stability compared to novices (Konttinen et al., 1999; Era et al., 1996; Ju & Kim, 2004; Mon et al., 2014; Ihalainen et al., 2016). According to the results of the current study, similar to the literature, it is believed that elite shooters adjusted postural balance better.

The elite group's right forefoot, midfoot MF and MP, and right midfoot PP values, and the novice group's right total foot, forefoot and midfoot PP, MP, forefoot, midfoot and hind foot MF values were found to be significantly higher than these parts of the left foot. In both groups, higher pressure was exhibited in these regions of the right foot. Additionally, unlike the novice group, the elite group had higher values for left total foot MF and hind foot PP compared to the right foot. Chadefaux et al. (2020), stated that shooters transferred more of their body weight to the right foot, possibly due to holding the pistol with the right hand. In the current study, similar to Chadefaux et al. (2020), it was observed that more pressure was exerted on the right foot in both groups, possibly because the pistol was held in the right hand. It is thought that this may be due to the transfer of body weight to the right side since the pistol is in the right hand.

When all the findings are considered collectively, it was seen that pressure differences in the foot regions were greater in the novice group compared to the elite group, and these differences originated entirely from the right foot regions. Although differences were detected in some parameters of the elite group in both the right and left feet, it was observed that they transferred their body weight to both feet more balanced compared to the novice group. However, a literature review revealed no studies using a plantar pressure analysis system to investigate how shooters distribute

their body weight to different regions of the feet. Therefore, more studies are needed on the plantar pressure in shooters.

The main limitation of this study were the small number of shots and participants, and also the foot arch structure was not included in the study. In future studies, the number of participants can be increased and the relationship between athletes' foot arch structures and plantar pressure distributions can be evaluated. This study suggests that coaches could enhance their training programs by incorporating different load transfer strategies, such as shifting the load to the left hindfoot and right forefoot, to increase the performance of novice shooters.

References

Aalto, H., Pyykkö, I., Ilmarinen, R., Kähkönen, E., & Starck, J. (1990). Postural stability in shooters. Orl, 52(4), 232-238.

Ball, K., Best, R., & Wrigley, T. (2003). Body sway, aim point fluctuation and performance in rifle shooters: inter-and intra-individual analysis. Journal of sports sciences, 21(7), 559-566.

Chadefaux, D., Valdes-Tamayo, L., Moreno Flores, R., Poulet, Y., Herrera Altamira, G., Hybois, S., ... & Thoreux, P. (2020). A preliminary study of stability in elite and novice 10 meter air pistol shooters. Computer Methods in Biomechanics and Biomedical Engineering, 23(sup1), S61-S62.

Era, P., Konttinen, N., Mehto, P., Saarela, P., & Lyytinen, H. (1996). Postural stability and skilled performance—a study on top-level and naive rifle shooters. Journal of biomechanics, 29(3), 301-306.

Goonetilleke, R. S., Hoffmann, E. R., & Lau, W. C. (2009). Pistol shooting accuracy as dependent on experience, eyes being opened and available viewing time. Applied ergonomics, 40(3), 500-508.

Hawkins, R. N., & Sefton, J. M. (2011). Effects of stance width on performance and postural stability in national-standard pistol shooters. Journal of sports sciences, 29(13), 1381-1387.

Herpin, G., Gauchard, G. C., Lion, A., Collet, P., Keller, D., & Perrin, P. P. (2010). Sensorimotor specificities in balance control of expert fencers and pistol shooters. Journal of electromyography and kinesiology, 20(1), 162-169.

Ihalainen, S., Kuitunen, S., Mononen, K., & Linnamo, V. (2016). Determinants of elite-level air rifle shooting performance. Scandinavian journal of medicine & science in sports, 26(3), 266-274.

ISSF. (2023). General Technical Rules. https://www.issfsports.org/theissf/rules_and_regulations/general_technical_rules.ashx (Erişim tarihi: 23.09.2023)

Joo, D. Y., & Kim, M. G. (2004). Effect of the physical stability of players of air-gun in aiming shooting. Korea sport research, 15(2), 551-566.

Kim, S. E. (2019). The influence of shoe on posture and performance of rifle shooters-a comparative study. Int. J. Eng. Res. Technol, 12, 1205-1209.

Konttinen, N., Lyytinen, H., & Era, P. (1999). Brain slow potentials and postural sway behavior during sharpshooting performance. Journal of motor behavior, 31(1), 11-20.

Konttinen, N., Lyytinen, H., Viitasalo, J., Iilo Nttin En, N. K., Lyytin En, H. I., & Ka Viitasalo, J. K. (1998). Preparatory heart rate patterns in competitive rifle shooting. Journal of Sports Sciences, 16(3), 235–242.

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).

Mononen, K., Konttinen, N., Viitasalo, J., & Era, P. (2007). Relationships between postural balance, rifle stability and shooting accuracy among novice rifle shooters. Scandinavian journal of medicine & science in sports, 17(2), 180-185.

Ortega, E., & Wang, C. J. K. (2018). Pre-performance physiological state: Heart rate variability as a predictor of shooting performance. Applied psychophysiology and biofeedback, 43, 75-85.

Pellegrini, B., & Schena, F. (2005). Characterization of arm-gun movement during air pistol aiming phase. Journal of sports medicine and physical fitness, 45(4), 467.

Reinkemeier, H., & Bühlmann, G. (2013). Pistol Shooting-the Olympic Disciplines: Technique, Training, Tactics, Psychology, Guns. Verlag MEC.

Sağıroğlu, İ., Erdoğan, M., Ada, M., Kamuk, U., & Ateş, O. (2016). Ateşli ve havalı silahlar atıcılarında postural statik denge ve vücut kütle indeksi arasındaki ilişkinin araştırılması. İstanbul Üniversitesi Spor Bilimleri Dergisi, 6(1), 33-40.

Stambolieva, K., Otzetov, M., Petrova, D., Ikonomov, R., & Gatev, P. (2015). Postural stability during static upright stance in archers. In Posture, Balance and the

Brain International Workshop Proceedings (pp. 29-35). Sofia, Bulgaria: Procon Ltd.

Viitasalo, J. T., Era, P., Konttinen, N., Mononen, H., Mononen, K., & Norvapalo, K. (2001). Effects of 12-week shooting training and mode of feedback on shooting scores among novice shooters. Scandinavian journal of medicine & science in sports, 11(6), 362-368.