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THE IMPACT OF PLANTAR OSCILLATION ON SHOOTING ACCURACY: A PRE- AND POST-TEST ANALYSIS OF CENTER OF PRESSURE IN COMPETITIVE SHOOTERS

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ABSTRACT

This study aimed to evaluate the impact of a targeted intervention on plantar oscillation in professional shooters, focusing on both medial-lateral and anterior-posterior foot movements. Thirty professional shooters participated in pre-and post-test assessments of foot oscillation using stabilometric measurements. Paired sample t-tests were conducted to compare oscillations in the left foot, right foot, and both feet combined before and after the intervention. Significant improvements were observed in medial-lateral oscillation for the right foot ($p = 0.017$) and both feet combined ($p = 0.013$), indicating enhanced lateral stability post-intervention. However, no significant changes were found in anterior-posterior movements for either foot ($p > 0.05$). These findings suggest that the intervention successfully improved lateral balance but had a limited impact on forward-backward stability. Future interventions should incorporate additional activities to target anterior-posterior control for improved overall postural stability in shooting performance.

Keywords: Plantar Oscillation; Stability; Medial-Lateral Balance; Anterior-Posterior Movement; Professional Shooters

1. INTRODUCTION

Background and Rationale

Shooting sports, which include disciplines like rifle and pistol shooting, require exceptional levels of concentration, precision, and stability. Success in these sports hinges on an athlete's ability to maintain balance and minimize postural sway, as even minor disruptions in posture can significantly impair shooting accuracy (Mononen, Viitasalo, Era, & Konttinen, 2007). Postural control is a critical factor in shooting performance, as any movement in the body, particularly in the lower extremities, can disturb the alignment between the shooter, firearm, and target. In this context, the study of plantar oscillations—measured through the center of pressure (COP)—offers valuable insights into how balance affects shooting performance.

Plantar oscillation refers to the small, continuous shifts in weight distribution across the feet, which can be quantified by monitoring the COP (Paillard & Noé, 2015). The COP represents the point on the surface of the foot where the resultant of ground reaction forces is applied. By tracking these shifts in COP, researchers can assess the stability of an individual during various tasks, including standing, walking, and shooting (Yin, et al., 2021). This study aims to explore

the relationship between plantar oscillation and shooting ability by analyzing the COP data of competitive shooters before and after training interventions. The overarching goal is to understand how improvements in postural stability might correlate with shooting accuracy.

2. THE ROLE OF BALANCE AND POSTURAL STABILITY IN SHOOTING

Balance is a fundamental aspect of athletic performance in many sports, but it holds particular significance in shooting, where precision is paramount. Athletes in shooting sports must maintain a stable posture to ensure that their weapon remains aligned with the target during the aiming and firing process. Any imbalance or excessive movement can cause deviations in the trajectory of the bullet, reducing accuracy (Era, Konttinen, & Mehto, 2000). In contrast to dynamic sports where balance recovery is essential after rapid movements, shooting sports demand a high level of static balance, where athletes need to remain as still as possible.

Postural stability, defined as the ability to maintain or restore the body's center of mass within the base of support, plays a crucial role in this process (Winter, 1995). Athletes who can reduce their postural sway—reflected by smaller and more controlled COP movements—are better able to maintain their aim and, consequently, improve their shooting accuracy (Ball et al., 2003). Numerous studies have explored the connection between postural stability and performance in various precision sports. For example, Ball et al. (2003) found that expert marksmen exhibited significantly less postural sway than novices, suggesting that experienced shooters develop superior postural control over time.

3. PLANTAR OSCILLATION AND THE CENTER OF PRESSURE

COP measurements provide a comprehensive picture of an individual's postural control by recording the location of the net force exerted by the foot on the ground during standing tasks. COP displacement, which reflects plantar oscillations, is often used to assess balance in both clinical and sports settings (Horak, Shupert, & Mirka, 1989). Smaller COP displacement indicates greater postural stability, while larger displacements are associated with greater instability (Paillard & Noé, 2015). For athletes in shooting sports, the goal is to minimize COP displacement to maintain the precision required for accurate shots.

Research has demonstrated that postural sway can be influenced by several factors, including fatigue, external environmental conditions, and training interventions (Vuillerme, Teasdale, & Nougier, 2001). Training aimed at improving balance and stability, such as proprioceptive exercises, has been shown to reduce COP displacement and improve postural control (Paillard, Noé, Rivière, & Montoya, 2006). As postural sway decreases, athletes are better able to control their movements, enhancing their performance in tasks requiring precision.

In shooting sports, COP data is particularly valuable because it offers objective measures of an athlete's balance and stability during both static and dynamic tasks. By analyzing the COP data of shooters, researchers can identify patterns of plantar oscillation that may correlate with performance outcomes, such as shooting accuracy. Studies have shown that elite shooters tend to exhibit smaller COP excursions compared to their less experienced counterparts, suggesting that balance training can have a direct impact on shooting ability (Mononen et al., 2007).

4. TRAINING AND POSTURAL CONTROL IN SHOOTERS

The relationship between postural control and shooting accuracy has led to growing interest in the development of training interventions aimed at improving balance and reducing postural sway. Research suggests that balance training can enhance postural stability and, by extension, improve performance in tasks requiring precision, such as shooting (Hrysomallis, 2011). Such training typically includes exercises that challenge an athlete's proprioceptive and vestibular systems, forcing them to make rapid adjustments to maintain balance.

One of the key training modalities used to enhance postural control is proprioceptive training, which involves exercises designed to improve the body's awareness of its position in space. Proprioception plays a critical role in maintaining balance, as it allows individuals to detect changes in body position and make rapid adjustments to prevent falls or instability (Gauchard, Vançon, & Perrin, 2001). In shooting sports, where even the slightest movement can affect performance, proprioceptive training can help athletes develop the fine motor control necessary to maintain stability during the aiming process.

In addition to proprioceptive training, athletes may also engage in balance exercises that challenge their ability to control their COP. These exercises often involve unstable surfaces, such as balance boards or foam pads, which force athletes to continuously adjust their posture to remain stable. Research has shown that such exercises can lead to significant improvements in postural control, as reflected by reductions in COP displacement (Gauchard et al., 2001). For shooters, the ability to maintain a stable COP during the aiming and firing process is critical to achieving consistent performance.

5. THE CURRENT STUDY

The current study aims to build upon the existing body of research by investigating the relationship between plantar oscillation, as measured by COP, and shooting ability in competitive shooters. Specifically, the study will analyze COP data before and after a training intervention designed to improve postural control. By examining how COP displacement changes over time, the study will provide valuable insights into the role of balance and stability in shooting performance.

In this study, we measure pre- and post-training COP in both the left and right feet, as well as in combined foot positions. These measurements will allow for a detailed analysis of plantar oscillation and its impact on shooting accuracy. Additionally, the study will explore whether certain individuals exhibit greater improvements in COP control than others, and whether these improvements are correlated with enhanced shooting performance.

In conclusion, postural control and balance are essential components of successful shooting performance. Plantar oscillation, as reflected by COP displacement, provides a valuable measure of an athlete's stability and can offer insights into their ability to maintain precision during shooting tasks. By analyzing COP data in competitive shooters, the current study seeks to deepen our understanding of how balance training can enhance shooting accuracy and performance. This research has the potential to inform future training programs for shooters, providing them with the tools they need to optimize their performance in competition.

6. METHODOLOGY

Participants

A total of 30 male competitive pistol shooters were selected for the study. The participants were aged between 18 and 25 years, with a minimum of two years of shooting experience. All participants provided informed consent before the study, which was conducted in accordance with ethical guidelines for research involving human participants.

Study Design

This study employed a pre-test and post-test experimental design to examine the effect of plantar oscillation on shooting accuracy. The center of pressure (C.O.P.) was measured at two time points: before (pre-test) and after (post-test) a standardized shooting intervention. The study aimed to compare changes in C.O.P. as an indicator of plantar oscillation and its potential impact on shooting accuracy.

Data Collection

The center of pressure (C.O.P.) was recorded using a force platform, which measured the average C.O.P. in both the left and right foot across two axes (X and Y). The platform captured data in millimeters (mm) for the following positions:

- Left X: Medial-lateral C.O.P. position for the left foot.
- Left Y: Anterior-posterior C.O.P. position for the left foot.
- Right X: Medial-lateral C.O.P. position for the right foot.
- Right Y: Anterior-posterior C.O.P. position for the right foot.
- Both X: Combined medial-lateral C.O.P. position for both feet.
- Both Y: Combined anterior-posterior C.O.P. position for both feet.

C.O.P. data were collected before (pre-test) and after (post-test) a shooting session. Each participant completed 10 standardized shots using their regular shooting stance, and C.O.P. was recorded for each attempt. The post-test measurements were taken immediately following the shooting intervention.

Shooting Intervention

Participants were required to shoot at a target positioned at a standard competition distance of 10 meters. Each participant performed 10 shots during the session. No adjustments or alterations to the participants' stance or technique were made during the shooting trials. The shooting accuracy was recorded as the ability to hit the target, but the primary focus of analysis was on plantar oscillation as measured by C.O.P.

Data Analysis

The C.O.P. values from both the pre- and post-test phases were compared using descriptive statistics to observe changes in plantar oscillation. Data for each participant were averaged across their 10 shots for both pre-test and post-test conditions. Paired t-tests were conducted to assess the statistical significance of differences between pre-test and post-test C.O.P. measurements for each foot (left and right) and for both feet combined.

Outcome Measures

The main outcome measures were changes in the C.O.P. for the left and right feet in both the X (medial-lateral) and Y (anterior-posterior) directions, as well as the combined C.O.P. values for both feet. These changes were analyzed to determine if there was a correlation between plantar oscillation and shooting performance.

Statistical Analysis

Data were analyzed using SPSS (version 22). The level of significance was set at $p < 0.05$. Descriptive statistics such as means and standard deviations were calculated for pre- and post-test C.O.P. values. Paired t-tests were used to determine whether the intervention had a significant effect on C.O.P. values. The results were presented in terms of mean differences and significance levels, highlighting any notable changes in plantar oscillation patterns.

7. RESULTS

Table 1 The Descriptive statistics of the variables

Descriptive Statistics				
Variable	N	Mean	Std. Error	Std. Deviation
Left foot Medial-Lateral Pre-test	30	-0.01	0.08767	0.48019
Left foot Anterior-Posterior Pre-test	30	-1.3467	0.68061	3.72788
Right foot Medial-Lateral Pre-test	30	-0.1367	0.10322	0.56537
Right foot Anterior-Posterior Pre-test	30	0.49	0.42506	2.32814
Both feet Medial-Lateral Pre-test	30	1.58	0.39358	2.15573
Both feet Anterior-Posterior Pre-test	30	-0.5433	0.46458	2.54459
Left foot Medial-Lateral Post-test	30	0.0333	0.04944	0.2708
Left foot Anterior-Posterior Post-test	30	-0.9833	0.40149	2.19907
Right foot Medial-Lateral Post-test	30	0.01	0.05149	0.28205
Right foot Anterior-Posterior Post-test	30	0.4133	0.23232	1.27245
Both feet Medial-Lateral Post-test	30	1.1667	0.27963	1.53158
Both feet Anterior-Posterior Post-test	30	-0.4	0.31106	1.70375
Valid N (listwise)	30			

Table 1 presents the descriptive statistics of plantar oscillation data measured in two conditions (Pre-test and Post-test) for three foot positions: Left foot, Right foot, and Both feet, across Medial-Lateral (X plane) and Anterior-Posterior (Y plane) directions.

Key Findings:

Left Foot Medial-Lateral Movement:

- Pre-test: The mean value was -0.01, with a standard deviation of 0.48019.
- Post-test: After intervention, the mean shifted slightly to 0.0333, with a reduced standard deviation of 0.2708, suggesting a decrease in variability of plantar oscillation.

Left Foot Anterior-Posterior Movement:

- Pre-test: The mean was -1.3467 with a high standard deviation (3.72788), indicating considerable variation in movement.
- Post-test: The mean improved to -0.9833, and the standard deviation decreased to 2.19907, suggesting a reduction in the oscillation and an improvement in control.

Right Foot Medial-Lateral Movement:

- Pre-test: The mean was -0.1367, and the standard deviation was 0.56537.
- Post-test: The mean shifted to a more neutral 0.01, with a decreased standard deviation of 0.28205, indicating better control in this plane after the intervention.

Right Foot Anterior-Posterior Movement:

- Pre-test: The mean was 0.49, with a standard deviation of 2.32814.
- Post-test: The mean decreased slightly to 0.4133, while the variability reduced (standard deviation of 1.27245), indicating some improvement in oscillation control.

Both Feet Medial-Lateral Movement:

- Pre-test: The mean was 1.58, indicating a notable lateral shift, with a standard deviation of 2.15573.
- Post-test: The mean reduced to 1.1667, with a standard deviation of 1.53158, implying reduced lateral movement and less variability post-intervention.

Both Feet Anterior-Posterior Movement:

- Pre-test: The mean was -0.5433, with a standard deviation of 2.54459.
- Post-test: The mean moved to -0.4, with a lower standard deviation of 1.70375, suggesting a small improvement in movement control along the anterior-posterior axis.

The intervention seems to have positively affected plantar oscillation, as evidenced by reduced variability (standard deviation) in most of the foot positions and movement planes post-intervention. After the intervention, these changes indicate better stability and control of foot movements in the X and Y planes.

Table 2: Paired sample test of the variables

Paired Samples Test									
Paired Differences		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				Sig. (2-tailed)
					Lower	Upper			
Pair 1	Left foot Medial-Lateral Pre-test - Left foot Medial-Lateral Post-test	-.04333	.25554	.04665	-.13875	.05209	-.929	29	.361
Pair 2	Left foot Anterior-Posterior Pre-test -	-.36333	1.68574	.30777	-.99280	.26613	-1.181	29	.247

	Left foot Anterior-Posterior Post-test								
Pair 3	Right foot Medial-Lateral Pre-test - Right foot Medial-Lateral Post-test	-.14667	.31811	.05808	-.26545	-.02788	-2.525	29	.017
Pair 4	Right foot Anterior-Posterior Pre-test - Right foot Anterior-Posterior Post-test	.07667	1.30296	.23789	-.40987	.56320	.322	29	.750
Pair 5	Both feet Medial-Lateral Pre-test - Both feet Medial-Lateral Post-test	.41333	.85045	.15527	.09577	.73090	2.662	29	.013
Pair 6	Both feet Anterior-Posterior Pre-test - Both feet Anterior-Posterior Post-test	-.14333	1.11809	.20413	-.56084	.27417	-.702	29	.488

Table 2 presents the paired sample test results, comparing the pre-test and post-test measures of plantar oscillation in different foot positions and movement directions. This test assesses whether there are significant differences between the pre-test and post-test values for each variable.

Key Findings:

Left Foot Medial-Lateral Movement (Pair 1):

- The mean difference between the pre-test and post-test was -0.04333.
- The t-value was -0.929 with a p-value of 0.361, which is greater than the 0.05 threshold. Therefore, there is no significant difference in medial-lateral movement of the left foot before and after the intervention.

Left Foot Anterior-Posterior Movement (Pair 2):

- The mean difference was -0.36333.
- The t-value was -1.181, with a p-value of 0.247. This indicates no significant difference in anterior-posterior movement of the left foot between the pre-test and post-test.

Right Foot Medial-Lateral Movement (Pair 3):

- The mean difference was -0.14667.
- The t-value was -2.525 with a p-value of 0.017, which is less than 0.05. This indicates a significant reduction in the medial-lateral movement of the right foot post-intervention, suggesting improved stability in this direction.

Right Foot Anterior-Posterior Movement (Pair 4):

- The mean difference was 0.07667.
- The t-value was 0.322 with a p-value of 0.750, indicating no significant difference in anterior-posterior movement of the right foot before and after the intervention.

Both Feet Medial-Lateral Movement (Pair 5):

- The mean difference was 0.41333.
- The t-value was 2.662 with a p-value of 0.013, indicating a significant change in medial-lateral movement of both feet. This suggests that there was a notable improvement in stability in this plane post-intervention.

Both Feet Anterior-Posterior Movement (Pair 6):

- The mean difference was -0.14333.
- The t-value was -0.702 with a p-value of 0.488, indicating no significant difference in anterior-posterior movement for both feet before and after the intervention.

Out of the six paired comparisons, two show statistically significant changes after the intervention:

- Right foot Medial-Lateral movement (Pair 3) showed significant improvement.
- Both feet Medial-Lateral movement (Pair 5) also showed significant improvement.

The rest of the comparisons did not show significant differences, suggesting that the intervention had more pronounced effects on Medial-Lateral movements than on Anterior-Posterior movements.

8. DISCUSSION

The purpose of this study was to evaluate the impact of an intervention on plantar oscillation in professional shooters by comparing pre-test and post-test data for various foot movement variables. The study investigated the medial-lateral and anterior-posterior oscillations of the left foot, right foot, and both feet combined. The results provide insight into how balance and stability, critical components of shooting accuracy, may be influenced by targeted interventions.

Medial-Lateral Oscillation:

A significant reduction in the medial-lateral oscillation was observed for both the right foot and both feet combined post-intervention ($p = 0.017$ and $p = 0.013$, respectively). This indicates improved balance and stability in the lateral plane, suggesting that the intervention successfully enhanced stability in these aspects. Improved stability in medial-lateral movement is critical in shooting sports as it ensures greater control over body movements, reducing unnecessary swaying during shooting.

However, the left foot's medial-lateral movement did not show a significant change ($p = 0.361$), which could indicate that the intervention had less effect on the left foot or that more time may be needed to develop stability in this region.

Anterior-Posterior Oscillation:

The anterior-posterior oscillations of both feet, as well as each foot individually, did not show significant differences after the intervention (p-values ranged from 0.247 to 0.750). This lack of significant change suggests that the intervention did not markedly affect forward-backward stability in this group of shooters. Since anterior-posterior stability is also crucial for maintaining proper posture in shooting, future interventions may need to incorporate more specific activities targeting this movement plane.

These findings are in line with prior research, which emphasizes the importance of postural control in shooting performance. Improvements in medial-lateral stability may contribute to more controlled and precise movements, enhancing overall shooting accuracy. However, anterior-posterior movements may require more focused interventions to see similar improvements.

9. CONCLUSION

This study aimed to assess the impact of a targeted intervention on plantar oscillation in professional shooters by analyzing the pre-test and post-test differences in medial-lateral and anterior-posterior foot movements. Based on the findings:

- Medial-Lateral Movements: The intervention significantly improved medial-lateral stability, particularly for the right foot and when both feet were considered together, indicating a positive impact on lateral balance. These changes are likely beneficial for reducing side-to-side swaying during shooting, potentially improving accuracy.
- Anterior-Posterior Movements: No significant changes were observed in anterior-posterior stability across the left foot, right foot, or both feet. This suggests that the current intervention may not have been as effective in addressing forward-backward postural control, and further adjustments may be needed to enhance stability in this dimension.

In summary, while the intervention successfully improved lateral stability, further research is required to optimize anterior-posterior control, which is equally important for precision in shooting sports. Future studies should focus on integrating exercises or techniques that specifically target anterior-posterior stability, along with examining the long-term effects of such interventions on shooting performance.

Implications for Practice

- Coaches and trainers of professional shooters should incorporate balance exercises focusing on medial-lateral stability, as this dimension has been shown to improve post-intervention.
- Future interventions may need to integrate additional activities to address anterior-posterior stability, which remains a critical aspect of maintaining proper posture during shooting.

CONFLICT OF INTERESTS

None.

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