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Balance Training and Shooting Performance: The Role of Load and the Unstable Surface

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Abstract: Considering the significance of postural balance in shooting ability, and consequently soldiers' occupational performance and survivability, it is of importance to promote the use of balance training programs to improve shooters' efficiency. This study explored how a balance training program affects shooting performance. Twenty participants were divided into two equal groups. They all performed 60 shots in a shooting simulator while standing. The participants went through this process twice, before and after a 4-week balance training program. The shooting was done under four different conditions: without load on a stable surface, with load on a stable surface, without load on an unstable surface, and with load on an unstable surface. The training program had a significant impact on the experimental group, improving their balance by 76 ± 9% ($p < 0.01$). Additionally, in the experimental group, shooting score increased by 47% and the % center of gravity by 20% ($p < 0.01$). The stability of the shots, measured by holding time in the target, doubled from 2.2 to 4.5 seconds ($p < 0.01$). These improvements were more pronounced when participants had a load and/or were on an unstable surface. In conclusion, a balance training program can be beneficial for improving shooting performance.

Keywords: postural sway; shooting ability; external load; military environment; uneven terrain

1. Introduction

A crucial aspect in evaluating shooting proficiency lies in maintaining good postural balance, which significantly influences both body sway and rifle stability [1,2] and consequently affects soldiers' occupational performance. A decline in postural balance has been associated with reduced aiming accuracy and shorter target holding time, both of which are correlated with lower shooting performance [3]. In a military context, soldiers' wellness and ability to survive can be at stake because of the consequences of a poor shooting skill. The significance of postural balance in facilitating accurate shooting is reinforced by the observation that proficient rifle shooters show reduced body sway amplitudes during both bipedal standing [4] and shooting [5,6], in contrast to novice shooters.

Factors within the military environment, such as the transportation of additional weight in backpacks and traversing uneven terrain, can adversely affect soldiers' postural balance [1,5], consequently impacting their shooting performance and survivability. The presence of a backpack and the uneven terrain leads to changes in muscle activation patterns required to maintain an upright stance, thus modifying the proprioceptive feedback of the nervous system and postural sway [7,8]. Importantly, the implementation of proprioceptive intervention programs holds the potential to enhance the static postural balance of soldiers on unstable surfaces [9].

Therefore, it is recommended to prioritize the development of postural balance, especially for young soldiers and novices engaged in specialized training exercises that require precise body and rifle stabilization [1,5]. Considering the importance of postural balance in shooting performance, it is advisable to promote the use of supplementary balance training programs to improve shooters' postural abilities [1,5,10]. The aim of this study was to examine the effects of a balance training program on shooting performance in novice soldiers. Including a backpack carriage and unstable surface in the study was crucial, as these conditions frequently appear and negatively impact soldiers' balance and occupational performance and wellness during military activities.

2. Materials and Methods

2.1. Participants

19 male and 1 female cadets aged 18 ± 3 y from the Hellenic Army Academy were involved in the research. None of the participants had shooting experience for over 2 years. After being informed verbally and in writing about the research process, participants consent in writing to their participation in it. The Educational Council of the Hellenic Army Academy have approved the conduct of the study.

2.2. Experimental procedures

All participants underwent an initial assessment of their anthropometric characteristics. Then, they split into two groups: the control group (n = 10) followed the typical school program, and the experimental group (n = 10) participated in a 4-week training program.

The rifle shooting test comprising 3 sets of 10 shots from a standing position was conducted before (Pre) and after (Post) the training program. Assessments were carried out on both stable (onB) and unstable (offB) surface. The offB was made using two foaming balance beams. Participants had to stand on them and balance in a bipedal position. The shootings occurred in two additional scenarios. In one scenario, the participants were dressed in combat gear and equipment (L). In the other scenario, they were dressed in athletic attire (noL). Each participant executed the aforementioned procedure (all four conditions) twice before the training program and twice after the training program, on separate days. It is worth noting that the intra-class correlation between the trials was significant in both groups (ICC = 0.85-0.91, $p < 0.01$), and no significant differences were observed between the two trials. As a result, the shooting data from both days were merged.

All measurements were conducted between 2 p.m. and 5 p.m. at the Hellenic Army Academy, in a temperature-controlled room (25-26 ^{o}C) with consistent humidity levels (35-45%). Over the course of the first two visits, participants became familiar with shooting under all conditions (onB-L, offB-L, onB-noL, offB-noL) and with the balance test with, or without load.

A training program was conducted before and after the assessments. The purpose of the program was to improve balance and neuromuscular coordination (see the detailed training program in a following section).

2.3. Balance assessment

Postural balance evaluation was performed by one-foot test on a wooden surface (50 cm wide, 20 cm height) at baseline and immediately after the completion of the 4-week training program. The participant placed one-third of the one foot on the board and then raised and bended the other leg in the knee joint and tried to maintain a single-limb stance for as long as possible. The hands were free to perform balancing moves. Three attempts were made for each leg with a break of 30 sec between them. The commencement of each trial was started by the participant at their convenience, with the examiner responsible for timekeeping. If the test participant failed to maintain balance in the first three seconds, the trial was repeated. Balance performance was evaluated by calculating the average time for the 6 attempts.

The participants underwent 12 trials, with 6 attempts conducted while wearing combat gear and equipment, and the other 6 while wearing athletic attire. Preceding the commencement of the test, the examiner conducted a demonstration, and the participant underwent a familiarization trial for each leg, with or without combat gear and equipment.

2.4. Training characteristics

The duration of the training program was four weeks, with a frequency of three sessions per week. 11 training sessions was conducted on average. The duration and the level of difficulty of the program was increased by going from simpler to more complex exercises and by affecting visual information (exercises with closed eyes) in order for the participants to have continuous progress.

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For the execution of the intervention program, instruments such as bosu balls, mini trampolines, wobble boards, and balance beams were used. Each training session consisted 3 sets of 4 balance exercises: a) standing on mini trampoline with one leg stance with or without vision b) balancing with 2 feet on a wobble board, c) high knee skipping on bosu, d) walking on foaming balance beam.

The sessions were conducted as circular training that lasted for a duration of 14-36 minutes. Between sets, there was a rest period of 2 minutes. Each exercise lasted 30 seconds the first week, 45 seconds the next 2 weeks and 60 seconds the last week. The exercise to rest ratio was 1:1. A trainer supervised all sessions, providing initial and continuous instructions, and monitoring exercise and resting time.

2.5. Analytical methods and equipment

Body height measurements were conducted in a standing position with a height gauge (Seca 206; Seca, Hamburg, Germany), and the measurement of body mass was conducted with an electronic precision scale (Seca 813; Seca, Hamburg, Germany).

The combat gear was comprised the combat boots, combat vest with a load equal to the weight of the personal ammunitions (approximately 5 kg), a rucksack and a M4A1 rifle. The average weight of the equipment was 22,5 ± 1,7 kg and represented the 30% of the participant's body weight.

A shooting simulator (Noptel ST 2000, Noptel Oy, Oulu, Finland) was used to evaluate shooting ability. The simulator consists of a laser transmitter, an optical glass laser sensitive receiver with an associated paper aiming target, which is a 2.3-cm-diameter circular target located 5 m away. This target simulates a 46-cm-diameter target at 100 m, which is similar to the standard 49-cm-wide, 100-m military silhouette man [11]. The shooting simulator was fixed to the barrel of an M4A1 airsoft carbine rifle. This weapon is used by the armed forces for training and has the same look, feel, and features (dimensions and weight), as the real U.S. Army M4A1. The airsoft M4A1 carbine rifle with CO_2 magazines produces realistic noise and feeling during recoil. Participants were given the directive to shoot as quickly and precisely as possible.

The variables analyzed with the Noptel software included: (a) the SCORE (arbitrary units, AU), (b) the % Center of Gravity (COG) of shots around a specific point, which is not necessarily the center of the target. The higher the percentage, the higher the COG; (c) the deviation (in cm) of shots in relation to the horizontal (Xdev) and the vertical (Ydev) axes. The shorter the distance, the smaller the deviation; (d) the holding period (Hold) which is the time in seconds before shooting, during which the laser was held firmly within the holding limits. These limits were determined by three points in which it was considered that the shooting rings were made around them: the center of the target, the center of gravity of the laser at the time of holding (COG not for the shots, but for the course of the shooting laser) and the point of the shot itself; (e) the interval time in seconds between shots (Interval) and (f) Relative Triggering Value (RTV; arbitrary units, AU), shows the 'cleanness' of triggering. A smaller RTV means that the motion of the laser during shooting time is smaller compared to the motion of the laser during the holding period. The parameters (b) to (f) across the 10 shots had an average value.

2.6. Statistical Analyses

Statistical analyses were performed using Statistica 10.0 (StatSoft, Inc., Tulsa, OK, USA). A general linear model (GLM) with repeated measures and a Bonferonni post-hoc comparison was performed. For all analyses, we checked data sphericity with the Mauchly test. Under no circumstances was there a violation of sphericity, therefore the Greinhouse-Geisser correction was not used. We calculated the partial effect size η^2 as a measure of the magnitude of the effect, which takes values between 0 and 1: 0.02 = small, 0.13 = moderate, and > 0.26 = large effect size. Possible correlations between measured variables were explored via calculating the Pearson product-moment correlation coefficient (r) for nondirectional tests (two-tailed). A regression analysis was conducted using the SCORE as the dependent variable and balance time together with HOLD as the independent variables. From regression analysis, R squared and the level of significance were

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calculated. All data are presented as mean ± SD, unless otherwise showed. We set the significance level at $p \leq 0.05$.

3. Results

3.1. Balance

Load affected negatively balance $F(1,18) = 37$, $p < 0.01$, $\eta^2 = 0.70$, but similarly in EXP and CON (interaction effect: $F(1,18) = 0.07$, $p = 0.9$).

The training program improved balance by 77 ± 8% in no load and by 75 ± 11% in with load conditions in EXP, with no differences in CON [interaction effect: $F(1,18) = 26$, $p < 0.01$, $\eta^2 = 0.62$] (Figure 1).

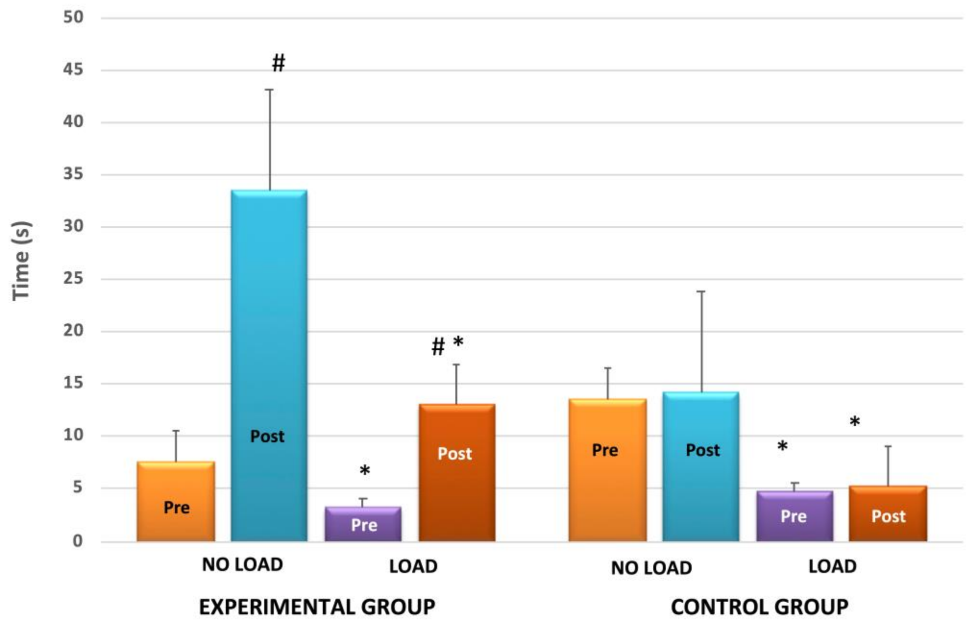

Figure 1. The time in balance test before (PRE) and after (POST) the training period without (NO LOAD) and with load (LOAD), for the experimental (left panel) and control (right panel) groups. The values represent the mean of three trials for each foot, each separated by 30 sec of rest. The plotted values show the mean ± SD. * Significantly different form the respective NO LOAD condition, $p < 0.01$; # Significantly different from the respective PRE condition, $p < 0.01$.

3.2. Shooting performace

In all conditions, the baseline values of shooting variables did not exhibit any significant differences between the experimental and control group [$F(1,18)$ from 0.25 to 0.70, $p > 0.05$].

The shooting SCORE exhibited an increase following training for EXP and maintained a similar level for CON [interaction effect: $F(1,18) = 15$, $p = 0.01$, $\eta^2 = 0.60$] (Figure 2). The results indicated a percentage increase in SCORE of 34%, 40%, 48%, and 66% for onB-noL, onB-L, offB-noL, and offB-L, respectively for EXP, with minor changes ranging from 2% to 6% observed for CON.

Moreover, a significant rise in COG was noted post-EXP training compared to CON, along with a notable interaction effect [$F(1,18) = 8.9$, $p < 0.01$, $\eta^2 = 0.58$], as shown in Figure 3. The EXP exhibited a percentage surge of 13%, 22%, 19%, and 28% for onB-noL, onB-L, offB-noL, and offB-L, correspondingly, whereas CON experienced minor changes ranging from -1% to 8%.

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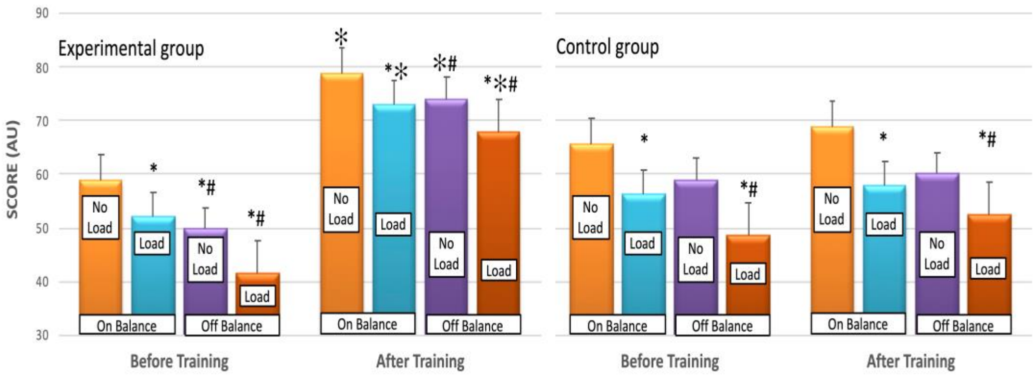
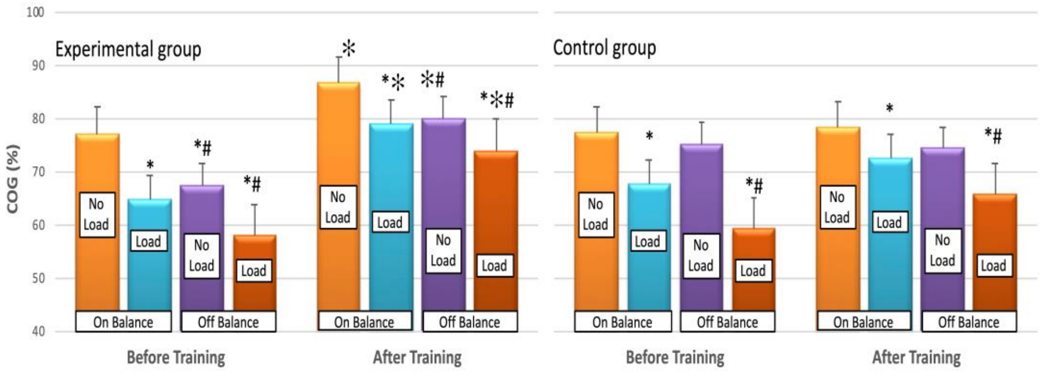


(a) (b)

Figure 2. The SCORE before (left panel) and after (right panel) the training period without (No Load) and with load (Load), for the experimental (a) and control (b) groups. The values represent the mean of six trials of 10 shots. The plotted values show the mean ± SE. * significant differences from the respective no load condition; # significant differences from the respective on balance condition; ⁎ significant differences from the respective condition before training, $p < 0.01$.



(a) (b)

Figure 3. The COG (%) before (left panel) and after (right panel) the training period without (No Load) and with load (Load), for the experimental (a) and control (b) groups. The values represent the mean of six trials of 10 shots. The plotted values show the mean ± SE. * significant differences from the respective no load condition; # significant differences from the respective on balance condition. ⁎ significant differences from the respective condition before training, $p < 0.01$.

Table 1 displays the shooting parameters following the completion of the training program. The load and unstable surface had a negative impact on all shooting parameters (Table 1 and Table S1). However, only HOLD, X-dev and Y-dev were modified following the training program. In particular, the HOLD improved after the balance training program across all conditions, with a notably greater improvement in conditions involving load (Table 1). Moreover, the training program resulted in similar and significant reductions in X-dev and Y-dev across all conditions. A significant correlation between balance and SCORE (r values ranged from 0.45 to 0.67, $p < 0.05$), as well as with X-dev and Y-dev (r values ranged from 0.42 to 0.58, $p < 0.05$) was noted. Additionally, the combination of balance time and HOLD in a regression model [$F(2,13) = 4.13$, $p < 0.05$] yields an explanatory power of 40% for SCORE variance.

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Table 1. The changes in shooting parameters after the balance training program (values after training minus values before training) for the control and experimental group, on balance on both stable (onB) and unstable (offB) surfaces in either athletic attire (noL) or combat gear and equipment (L).

	onB-noL	onB-L	offB-noL	offB-L
CONTROL GROUP				
Hold (s)	0,52	0,86	0,28	0,38
Xdev (cm)	-0,18	-0,24	0,29	-0,09
Ydev (cm)	-0,22	-0,27	0,19	-0,29
Interval (s)	0,79	2,05	1,59	1,31
RTV (AU)	-0,01	0,03	-0,02	-0,03
EXPERIMENTAL GROUP				
Hold (s)	1,84#	2,84#*	1,87#	2,67#*
Xdev (cm)	-0,46#	-0,78#	-0,62#	-0,62#
Ydev (cm)	-1,00#	-1,00#	-0,94#	-0,95#
Interval (s)	0,81	-0,28	0,78	1,54
RTV (AU)	-0,07	-0,11	-0,13	-0,07

significant differences after the training program, $p < 0.01$; * significant differences compared to no load conditions, $p < 0.01$.

4. Discussion

A significant increase in postural balance was observed following a 4-week program focused on proprioception training. This improvement was concurrent with a significant enhancement in shooting accuracy, as demonstrated by improvements in both score and center of gravity of the shots, as well as in rifle stability, as shown by holding time and deviation in both the horizontal and vertical axes. As such, the training program exerted a more pronounced influence in situations involving military equipment and on unstable surfaces.

4.1. Proprioception training and postural balance

During the evaluation of nine commonly performed military tasks across various military services globally, it was determined that postural balance ability represents a crucial skill-related fitness component [12]. The implementation of proprioception training programs aiming to enhance the ability to maintain postural balance by transmitting joint position information to the neuromuscular control centers of the central nervous system [13]. Research has demonstrated that a proprioceptive intervention program enhanced the postural balance of combat soldiers when standing on unstable surfaces. Specifically, the soldiers' ability to balance on a bosu ball significantly improved, particularly when doing so with their eyes closed [9]. The analysis of previous data reveals a connection between proprioceptive training and postural balance in both healthy adults and young athletes [14,15]. The current study has corroborated the findings of prior research and observed that these enhancements, although of lesser magnitude, remain evident when military equipment is integrated. The question of whether the implementation of the balance training program with participants wearing the equipment would result in a more pronounced effect on balance enhancement in specific military activities, needs to be addressed.

4.2. Postural balance and shooting performance

Maintaining proper postural balance is crucial for successful shooting, as it directly and indirectly affects rifle stability [1]. Previous studies by Mononen et al. [1] and Era et al. [5] have shown that reduced body sway and minimal rifle movement are correlated with improved shooting accuracy and score. According to Ihalainen et al. [10], maintaining postural balance in the anteroposterior direction is essential for stability while holding the rifle. Enhancing postural balance in this direction leads to improved rifle stability. Holding and aiming play a significant role in shooting performance, explaining 36.3% of the variance in this performance [2]. Furthermore, postural balance and gun barrel stability can differentiate between high-scoring and low-scoring shots [6,16]. Consistent with these findings, we reported an enhanced shooting accuracy and increased rifle stability following a training program designed to enhance balance. The notable correlations between SCORE and balance, coupled with the considerable proportion of the observed variance in SCORE that can be attributed to balance and holding time, amplify these observations. In other studies, the combination of a balance training program with either vibration [17] or respiratory muscle training [18] in rifle athletes demonstrated an enhancement in shooting performance. Nevertheless, these studies were unable to discern the exclusive impact of balance training on the reported outcome.

As far as we know, this study is the first to demonstrate the combined effect of external load and an unstable surface on shooting performance. The unstable ground and the load carried affects negatively the postural stability and consequently shooting performance. We observed that participants who carried the external load while standing on an unstable surface exhibited poorer shooting scores and a lower %COG. Several studies have showed the adverse effects of soldier load on postural sway [7] and shooting accuracy [19]. Specifically, the act of walking on uneven surfaces has a considerable influence on postural stability [20]. Furthermore, Gil-Cosano et al. [19] documented a 30% decline in shooting score when soldiers wore a backpack (19.5 ± 2.4 kg, equivalent to 24.2 ± 3.4% of their body weight).

The present study showed that shooting performance, under all conditions, was improved as a result of the balance training program. It is important to note that the beneficial effect of balance training on shooting was more pronounced when both the rucksack and unstable ground were included in the shooting tests. Specifically, after the training period, the percentage increase in SCORE and %COG was twice as high compared to the increase observed in the condition without load and on a stable surface. Considering the significance of postural balance in shooting performance and survivability within military contexts, it is recommended to prioritize training on postural balance for achieving optimal standing positions and rifle stability. This is especially crucial for novice soldiers and in military settings to promote occupational wellness and performance.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Table S1.

Author Contributions: Conceptualization, Stylianos Kounalakis; Data curation, Anastasios Karagiannis and Ioannis Kostoulas; Formal analysis, Ioannis Kostoulas; Investigation, Anastasios Karagiannis and Ioannis Kostoulas; Methodology, Stylianos Kounalakis, Anastasios Karagiannis and Ioannis Kostoulas; Supervision, Stylianos Kounalakis; Visualization, Anastasios Karagiannis; Writing – original draft, Stylianos Kounalakis and Ioannis Kostoulas; Writing – review & editing, Stylianos Kounalakis.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and had the approval of Hellenic Army Academy for studies involving humans.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not publicly available due to privacy and ethical concerns.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Mononen, K.; Konttinen, N.; Viitasalo, J.; Era, P. Relationships between Postural Balance, Rifle Stability and Shooting Accuracy among Novice Rifle Shooters. *Scandinavian Med Sci Sports* **2007**, *17*, 180–185, doi:10.1111/j.1600-0838.2006.00549.x.

2. Lang, D.; Zhou, A. Determinants of Shooting Performance in Elite Air Rifle Shooters. *Sports Biomechanics* **2022**, 1–11, doi:10.1080/14763141.2022.2055627.
3. Köykkä, M.; Ihalainen, S.; Linnamo, V.; Ruotsalainen, K.; Häkkinen, K.; Laaksonen, M.S. Aiming Strategy Affects Performance-related Factors in Biathlon Standing Shooting. *Scandinavian Med Sci Sports* **2021**, *31*, 573–585, doi:10.1111/sms.13864.
4. Niinimaa, V.; McAvoy, T. Influence of Exercise on Body Sway in the Standing Rifle Shooting Position. *Can J Appl Sport Sci* **1983**, *8*, 30–33.
5. Era, P.; Konttinen, N.; Mehto, P.; Saarela, P.; Lyytinen, H. Postural Stability and Skilled Performance—A Study on Top-Level and Naive Rifle Shooters. *Journal of Biomechanics* **1996**, *29*, 301–306, doi:10.1016/0021-9290(95)00066-6.
6. Konttinen, N.; Lyytinen, H.; Era, P. Brain Slow Potentials and Postural Sway Behavior During Sharpshooting Performance. *Journal of Motor Behavior* **1999**, *31*, 11–20, doi:10.1080/00222899909601888.
7. Heller, M.F.; Challis, J.H.; Sharkey, N.A. Changes in Postural Sway as a Consequence of Wearing a Military Backpack. *Gait & Posture* **2009**, *30*, 115–117, doi:10.1016/j.gaitpost.2009.02.015.
8. Kavounoudias, A.; Gilhodes, J.-C.; Roll, R.; Roll, J.-P. From Balance Regulation to Body Orientation: Two Goals for Muscle Proprioceptive Information Processing? *Experimental Brain Research* **1999**, *124*, 80–88, doi:10.1007/s002210050602.
9. Funk, S.; Jacob, T.; Ben-Dov, D.; Yanovich, E.; Tirosh, O.; Steinberg, N. A Balance and Proprioception Intervention Programme to Enhance Combat Performance in Military Personnel. *J R Army Med Corps* **2018**, *164*, 52–57, doi:10.1136/jramc-2017-000809.
10. Ihalainen, S.; Kuitunen, S.; Mononen, K.; Linnamo, V. Determinants of Elite-level Air Rifle Shooting Performance. *Scandinavian Med Sci Sports* **2016**, *26*, 266–274, doi:10.1111/sms.12440.
11. Kostoulas, I.D.; Kounalakis, S.N.; Toubekis, A.G.; Karagiannis, A.; Kaniadakis, A.; Mavraganis, D.; Karatrantou, K.; Gerodimos, V. The Effect of Wet Conditions and Surface Combat Swimming on Shooting. *Military Medicine* **2023**, *188*, e235–e241, doi:10.1093/milmed/usab277.
12. Nindl, B.C.; Alvar, B.A.; R. Dudley, J.; Favre, M.W.; Martin, G.J.; Sharp, M.A.; Warr, B.J.; Stephenson, M.D.; Kraemer, W.J. Executive Summary From the National Strength and Conditioning Association's Second Blue Ribbon Panel on Military Physical Readiness: Military Physical Performance Testing. *Journal of Strength and Conditioning Research* **2015**, *29*, S216–S220, doi:10.1519/JSC.0000000000001037.
13. Hrysomallis, C. Balance Ability and Athletic Performance: *Sports Medicine* **2011**, *41*, 221–232, doi:10.2165/11538560-000000000-00000.
14. Mitrousis, I.; Bourdas, D.I.; Kounalakis, S.; Bekris, E.; Mitrotasios, M.; Kostopoulos, N.; Ktistakis, I.E.; Zacharakis, E. The Effect of a Balance Training Program on the Balance and Technical Skills of Adolescent Soccer Players. *jsportscimed* **2023**, 645–657, doi:10.52082/jssm.2023.645.
15. Cuğ, M.; Duncan, A.; Wikstrom, E. Comparative Effects of Different Balance-Training–Progression Styles on Postural Control and Ankle Force Production: A Randomized Controlled Trial. *Journal of Athletic Training* **2016**, *51*, 101–110, doi:10.4085/1062-6050-51.2.08.
16. Mononen, K.; Viitasalo, J.T.; Era, P.; Konttinen, N. Optoelectronic Measures in the Analysis of Running Target Shooting. *Scandinavian Med Sci Sports* **2003**, *13*, 200–207, doi:10.1034/j.1600-0838.2003.00130.x.
17. Hung, M.-H.; Lin, K.-C.; Wu, C.-C.; Juang, J.-H.; Lin, Y.-Y.; Chang, C.-Y. Effects of Complex Functional Strength Training on Balance and Shooting Performance of Rifle Shooters. *Applied Sciences* **2021**, *11*, 6143, doi:10.3390/app11136143.
18. Park, H.-K.; Kim, D.-W.; Kim, T.-H. Improvements of Shooting Performance in Adolescent Air Rifle Athletes After 6-Week Balance and Respiration Training Programs. *Journal of Sport Rehabilitation* **2019**, *28*, 552–557, doi:10.1123/jsr.2017-0386.
19. Gil-Cosano, J.J.; Orantes-Gonzalez, E.; Heredia-Jimenez, J. Effect of Carrying Different Military Equipment during a Fatigue Test on Shooting Performance. *European Journal of Sport Science* **2019**, *19*, 186–191, doi:10.1080/17461391.2018.1502359.
20. Wang, J.; Gillette, J.C. Carrying Asymmetric Loads While Walking on an Uneven Surface. *Gait & Posture* **2018**, *65*, 39–44, doi:10.1016/j.gaitpost.2018.06.173.