Original Article

doi: 10.16926/par.2026.14.20

The impact of a preparatory camp training program on balance in young female volleyball players

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Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract: Introduction: Postural balance plays a crucial role in sports performance, particularly in young athletes during periods of intensive training. However, limited evidence exists regarding the short- and mid-term effects of intensive training camps on balance control in adolescent volleyball players. The aim of this study was to evaluate the effects of a two-week intensive volleyball training camp on postural balance parameters in young female volleyball players, assessed immediately and one month after the camp. Methods: Twenty-nine female volleyball players aged 10–15 years participated in the study. Postural balance was assessed using a Zebris posturographic platform under eyes-open (EO) and eyes-closed (EC) conditions at three time points: before the training camp (Pre), immediately after the camp (Post1), and one month after the camp (Post2). Center of pressure (COP) parameters, including sway path length and ellipse area, were analyzed. Results: Significant improvements in postural balance parameters were observed immediately after the training camp under EO conditions ($p < 0.05$). However, under EC conditions, several parameters deteriorated after the camp. One month after the camp, most parameters returned toward baseline values, indicating a partial loss of training-induced adaptations. Conclusion: An intensive volleyball training camp leads to short-term improvements in postural balance under visual control but may temporarily impair balance performance when visual input is removed. The observed decline in balance parameters one month after the camp highlights the need for continuous proprioceptive and balance-oriented training to maintain postural control adaptations in young volleyball players.

Keywords: postural balance; volleyball; training camp; youth athletes; center of pressure; proprioception

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Recevied: 23.01.2026; Accepted: 3.03.2026; Published online: 1.04.2026

Citation: Senator W, Dziuba-Slonina A. The impact of a preparatory camp training program on balance in young female volleyball players. Phys Act Rev 2026; 14(2): 46-56. doi: 10.16926/par.2026.14.20

INTRODUCTION

In today's world, the lack of spontaneous, everyday physical activity is a significant problem, particularly among young individuals [1]. Despite their education and knowledge, adolescents are not very active in their free time, often prioritizing online entertainment, such as video games, over spending time outdoors [2,3]. This shift towards a sedentary lifestyle not only impairs general fitness but also increases the risk of adverse changes in gait, falls, and poor postural stability later in life [4]. To prevent this, children should be encouraged from a young age to spend their time actively playing outside or participating in organized sports, such as dance, basketball, or volleyball [1]. In addition to physical health, such activities improve academic performance, metabolic rate, and bone mineral density [1,5,6]. Moreover, participating in regular physical activity significantly enhances the quality of life and social skills of children, helping them form lasting habits of active living [7, 8]. Despite the costs of equipment or training camps, the long-term benefits of organized sports are essential, as physical inactivity remains a serious global threat [1].

A fundamental physiological requirement of participation in such activities is postural balance: the multifaceted ability to maintain an upright body position through the continuous integration of the neuromuscular system, cognitive functions, and sensory processing [9,10]. These abilities develop from day one, starting with reflex-based functions and leading to the mastery of upright posture in infants [10]. During early school age (8 to 12 years), there is a significant progression of these abilities toward even more complex motor tasks [5]. Every movement of the human body disrupts balance by shifting the center of pressure (CoP), which must be immediately restored to prevent falling [11]. This process relies on the integration of proprioceptive information, vestibular input, and visual afferent signals [12]. Research confirms that disciplines requiring low reaction times and significant loading of the ankle joints are particularly effective in improving proprioception and postural control [13-15].

The specific demands of volleyball present a unique challenge to the postural control system, as the sport engages many body systems beneficial for a child's development [7]. It is characterized by high dynamic variability, involving frequent changes in the center of gravity and rapid multidirectional shifts [16,17]. Unlike simpler motor tasks, volleyball requires players to maintain stability while their attention is heavily divided between tracking the ball, anticipating opponents, and coordinating with teammates [18-20]. Postural control often becomes a secondary, subconscious process as cognitive resources are prioritized for tactical decisions and precise air actions, such as attacks or blocks [18,20]. Consequently, volleyball players often exhibit superior balance parameters compared to non-players, though these results can be influenced by factors such as age, sex, and performance level [18,19,21]. Furthermore, the asymmetrical nature of volleyball, dominated by unilateral actions and dominant-side loading, often leads to functional lateral imbalances [17,22]. This makes it reasonable to examine both legs and compare their balance parameters to identify sport-specific adaptations.

A significant factor in competitive sports is the preparatory training camp, which helps to improve performance through increased intensity and a focused development of motor abilities [23]. Sport camps offer a controlled environment for isolated preparation, where diet, training loads, and recovery can be strictly monitored [23,24]. While the intensification of training offers benefits like injury prevention and improved fitness [25, 26], it may also induce physical fatigue or require longer recovery times [24, 27]. Previous studies have extensively examined the impact of such camps on muscle strength, speed, and jumping parameters [23,24,28]. However, despite the established importance of postural stability in technical execution under pressure, there is a notable absence of research addressing how the intensive, day-to-day training loads typical of a volleyball camp affect balance parameters. While some studies have explored long-term balance training or sand-based exercises [15,29], the acute effect of a high-intensity training microcycle on the postural control system in young female athletes remains an unaddressed scientific gap.

Understanding whether such intensification improves subconscious stability or leads to temporary deterioration due to cumulative fatigue is crucial for optimizing youth training protocols. The aim of the study was to assess the effect of everyday training during a preparatory camp on changes in balance parameters in young female volleyball players. An additional aim was to evaluate differences in balance between the dominant and non-dominant legs of the young players. We hypothesize that balance parameters, including the size of the ellipse and the amplitude of sway, will improve after the volleyball camp compared to parameters before camp, both with eyes closed and eyes open. Our second hypothesis is that after a one-month break, balance parameters will deteriorate compared to the measurements taken immediately after the camp. The third hypothesis states that postural balance performance will be significantly better under eyes-open conditions than under eyes-closed conditions at all measurement time points.

MATERIAL AND METHODS

Participants

A total of 29 girls aged 10–15 years, practicing volleyball at the MMKS Kłodzko sports club, participated in the study. Participants were eligible if their guardians provided written informed consent for participation in the measurements and for the processing of personal data, and if they agreed to comply with the examiner's instructions. Inclusion criteria required at least six months of systematic training, conducted three times per week for 90 minutes per session. Only athletes without prior injuries or medical conditions contraindicating physical activity were included.

The mean age of the sample was 12.5 ± 0.8 years (95% CI: 12.2–12.9). The average body height was 160.4 ± 7.3 cm (95% CI: 157.7–163.2), and mean body mass was 50.1 ± 5.6 kg (95% CI: 48.0–52.2). The athletes had a mean training experience of 4.3 ± 1.2 years (95% CI: 3.7–4.8). All participants trained regularly three times per week.

The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from both the participants and their guardians. Participants were informed about the study procedures and their right to withdraw at any time. The study was approved by a local ethics committee (approval no. 8/2016).

An a priori sample size calculation was performed using G*Power 3.1 software (v. 3.1.9.2, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The expected effect size (partial eta squared, η^2) was set at 0.07, the α level at 0.05, and the statistical power ($1-\beta$) at 0.90. The required minimum sample size was 29 participants.

Research Methods

All participants were tested three times: before the preparatory camp (Pre), immediately after (Post 1), and one month after the camp (Post 2), during which they did not participate in any training. Prior to the measurements, each player was explained the measurement procedure and familiarized with the testing equipment. During each of the three sessions, four measurements were taken in random order: two with eyes open (eo) and two with eyes closed (ec), all performed in a bipedal stance.

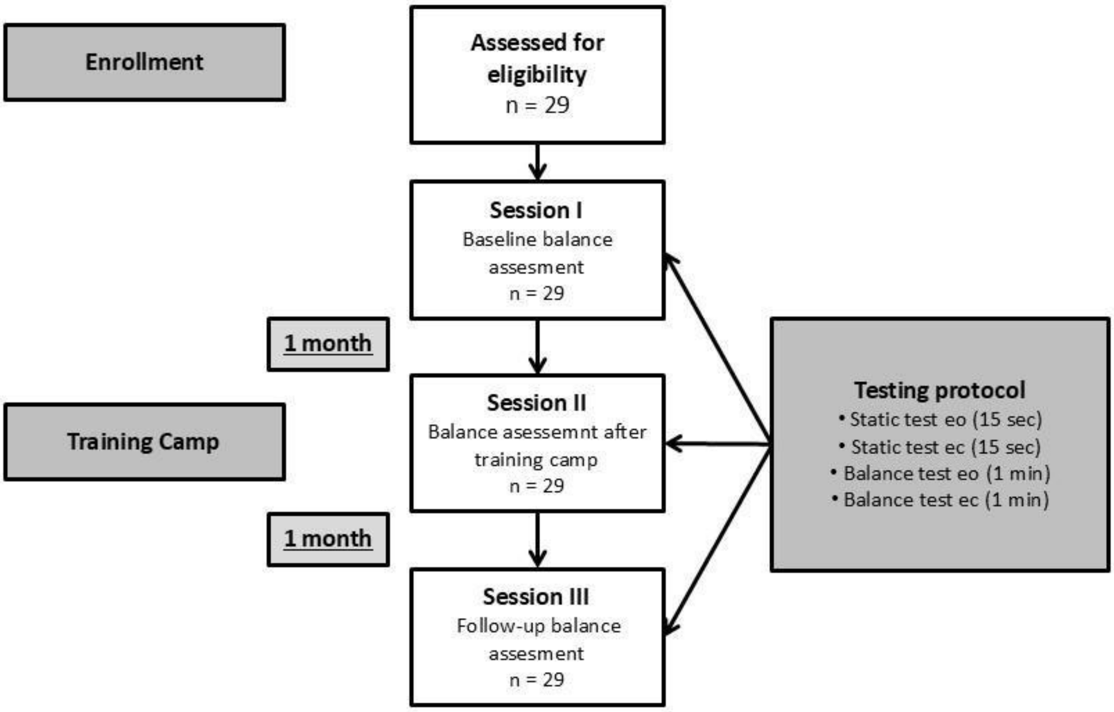

Figure1. Experimental protocol.

The first measurement was made on a day without training, in the physical education hall where the players regularly practice. The second measurement took place during the summer camp, in July on the Polish seaside. The participants stayed at the camp for 14 days. Volleyball training sessions were twice a day throughout the entire stay. Training loads were monitored and quantified by certified coaches using the session-RPE (sRPE) method to calculate the training tmpulse (TRIMP) [30]. Daily training consisted of two 90-minute sessions 180 min/day, providing a high-volume stimulus throughout the 14-day camp. Each session followed a standardized intensity protocol - general warm-up 20 min, focused on neuromuscular activation and mobility, maintaining a low intensity RPE 3–4. Specialized technical training 30 min included high-repetition drills with explosive movements jumps, lateral shuffles. Coaches maintained a 1:2 work-to-rest ratio to ensure technical precision at moderate-to-high intensity RPE 6–7. Match play 40 min high-intensity interval efforts during 2-set matches, simulating competitive demands with near-maximal bursts RPE 8–9. The total daily TRIMP score was maintained at a high level (approx. 1000–1200 units/day), ensuring a significant physiological stimulus. To isolate the effects of this training load, all participants followed a standardized diet and recovery protocol, with no additional physical activities allowed.

To assess the balance of the players we used ZEBRIS posturographic platform, which records the center of pressure (CoP) of the feet on the ground, its displacement along the sagittal and frontal axes, and also evaluates the ground reaction force. The platform operates based on a matrix of sensors that record the load on the platform. The associated FootPrint software allows for the analysis of static and dynamic load distributions and runs on Windows operating systems. An FDM-SX platform with dimensions of 550 × 400 mm was used, featuring a 400 × 300 mm sensor matrix with 1.920 sensors, a sampling frequency of 50 Hz for static measurements, and a sensor load measurement range of 1–120 N/cm^2. The platform was positioned 150 cm from the wall, and tests were conducted in an empty and quiet room. Two types of tests were conducted: Static Test and Balance Test. The duration of each test was as follows: Static eo 20 sec, rest 10 sec; Static ec 20 sec, rest 10 sec; Balance eo 1 min, rest 10 sec; Balance ec 1 min. The entire session lasted 3 minutes. In the Static test, the participant stands in the center of the platform, with the right foot on the right side and the left foot on the left side. The feet should be separated by the midline. Participants were asked to stand still, barefoot, with arms hanging freely along the torso. They were instructed to focus on a designated point in front of them, keeping the head aligned with the torso in a neutral position. Once the participant stabilized their posture, the 20-second measurement began. The results present the percentage of load on each part of the feet and indicate the more and less loaded side. First, the eo measurement was performed (20 sec), followed by a 2-minute rest, and then the same ec measurements. The Balance test assessed CoP sway during a 60-second bipedal stance, first with eo, followed by a 2-minute rest, then ec. The order of balance test in each session was randomized using an online generator (www.randomizer.org).

The following parameters were analyzed: foot load, expressed as Static L [%] – percentage load on the left lower limb; and center of pressure (CoP) displacement parameters, including MCoCx [cm] – mean CoP path along the x-axis of the platform, MCoCy [cm] – mean CoP path along the y-axis of the platform, SPL [cm] – total CoP path length during the 60-second measurement, WoE [cm] – width of the ellipse, HoE [cm] – height of the ellipse, and AoE [cm^2] – ellipse area.

Statistical Methods

Statistical analyses were performed using Statistica, version 14.1.0.4 (Cloud Software Group, Inc., Palo Alto, CA, USA). Descriptive statistics are presented as mean ± standard deviation (SD). The normality of distribution was assessed using the Shapiro–Wilk test, and homogeneity of variance was evaluated with Levene's test.

Changes in balance over time were analyzed using repeated measures analysis of variance (RM-ANOVA). If the assumption of normality was violated, the Friedman ANOVA was applied. When a significant main effect was observed, Bonferroni post-hoc tests were performed. Sphericity was examined using Mauchly's test, and Greenhouse–Geisser corrections were applied when necessary. In the case of a significant χ^2 value in the Friedman test, the Durbin–Conover post-hoc test was used.

Effect size was expressed as partial eta squared (η^2) for RM-ANOVA (small: 0.01–0.06; medium: 0.07–0.13; large: ≥ 0.14) or Kendall's W for Friedman ANOVA (small: < 0.3; moderate: 0.3–0.5; large: > 0.5).

Differences between measurements performed with eyes open and eyes closed were assessed using two-way repeated measures ANOVA. If the normality assumption was violated, the Friedman ANOVA was used. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

A total of N = 29 participants completed the balance measurements with follow up, after one month. No adverse events occurred during testing and training, and all participants completed all tests, achieving 100% adherence.

Figure 2 reflects the difference in percentage load on the left lower limb in different time points. RM-ANOVA analysis showed statistically significant difference in eo ($F(2.56) = 6.85$, $p = 0.002$, $\eta^2 = 0.19$), however no change was found in ec ($F(2.56) = 2.93$, $p = 0.06$). The Bonferroni post-hoc test showed differences between Pre to Post 1 and Post 1 to Post 2.

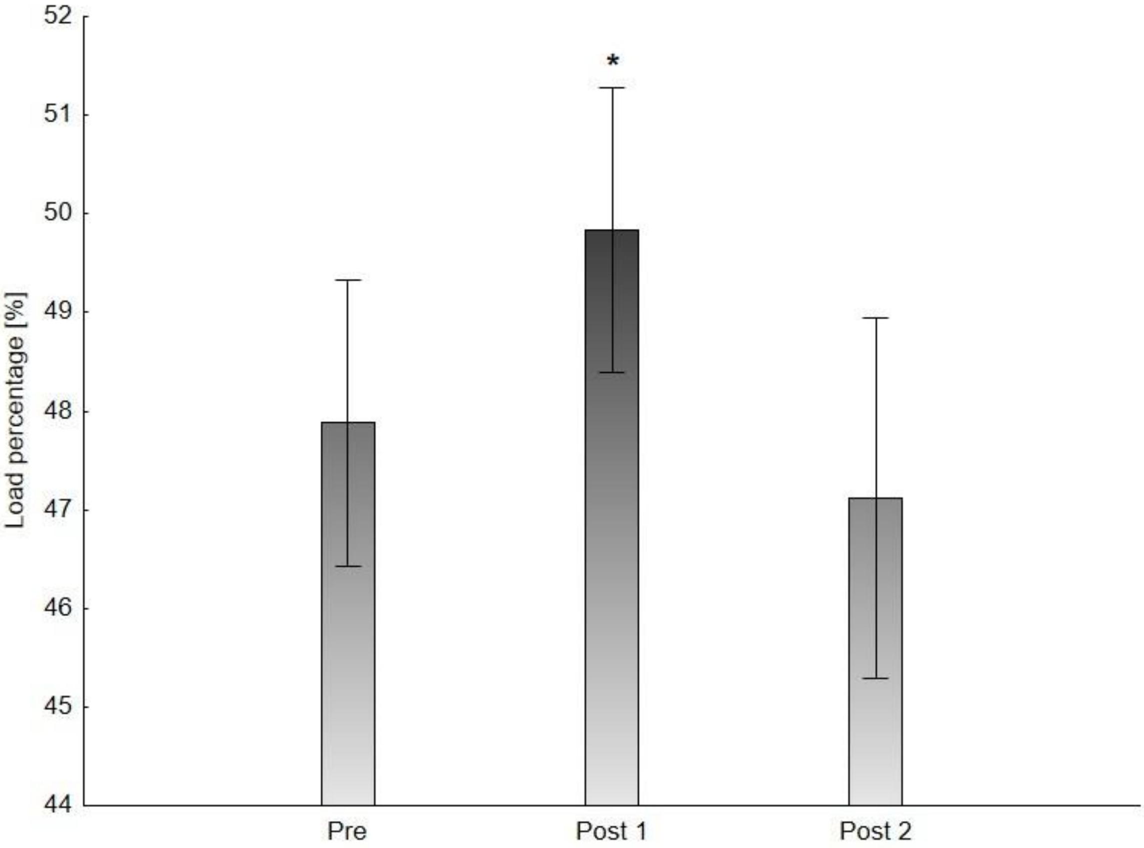

Figure 2. Comparison of percentage load on left lower limb during Static test in consecutive measurements. Pre – baseline measurement, Post 1 – measurement after training camp, Post 2 – follow up measurement after one month, *-statistically significant change.

Table 1. Comparison of Balance test results in consecutive measurements.

Variable	Pre	Post 1	Post 2	F/ χ^2	p	ES
MCoCx eo [cm]	18.13±2.27	18.55±1.92	19.03±1.86*	F=4.1	0.020	η^2=0.13
MCoCx_ec [cm]	18.05±2.79	18.47±2.48*	18.87±2.39*	χ^2=8.34	0.015	W=0.14
MCoCy_eo[cm]	24.76±1.26	24.94±1.37	24.79±1.67	F=0.29	0.750	η^2=0.01
MCoCy_ec [cm]	25.14±1.3	24.29±1.82*	24.55±2.82*	χ2=8.07	0.017	W=0.14
SPL_eo [cm]	147.35±27.99	143.63±26.51	149.87±27.43	χ2=4.2	0.120	W=0.07
SPL_ec [cm]	150.13±39.69	162.16±31.35*	160.78±37.36*	χ2=15.7	<0.001	W=0.27
WoE_eo [cm]	2.77±1.35	2.22±0.78*	2.76±1.03*~	χ2=17	<0.001	W=0.29
WoE_ec [cm]	2.68±1.19	2.85±1.25	2.87±1.25*	χ2=7.6	0.020	W=0.15
HoE_eo [cm]	4.15±1.69	4.24±2.09	5.39±1.97*~	χ2=15.1	<0.001	W=0.26
HoE_ec [cm]	4.25±1.89	4.55±1.72*	4.62±1.83	χ2=8.34	0.015	W=0.14
AoE_eo [cm^2]	9.86±8.49	7.96±5.69*	12.01±7.26*~	χ2=18.8	<0.001	W=0.32
AoE_ec [cm^2]	8.89±8.73	11.09±7.68	11.63±8.59*	χ2=10.1	0.006	W=0.17

MCoCx – mean CoP path along the x-axis of the platform, MCoCy – mean CoP path along the y-axis of the platform, SPL – total path length covered by the CoP during the 60-second measurement, WoE – width of the ellipse HoE – height of the ellipse AoE – area of the ellipse, eo – eyes open measurement, ec – eyes closed measurement *-statistically significant change compared to Pre, ~ - statistically significant change compared to Post 1

RM-ANOVA analysis showed differences in MCoCx_eo, (F(2,56) = 4.1, p = 0.02, η^2 = 0.13), however did not reveal statistically significant changes for MCoCy_eo. The Friedman ANOVA analysis revealed important changes for WoE_eo (χ2 = 17, df = 2, p = 0.0002, W = 0.29), HoE_eo (χ2 = 15.1, df = 2, p = 0,0005, 0.26) and AoE_eo, (χ2 = 18.8, df = 2, p = 0.00008, W = 0.32) but not for SPL_eo. The Bonferroni post-hoc test showed significant change MCoCx_eo between Pre and Post 2. The Durbin-Conover post-hoc analysis showed changes in Woe_eo for Post 1 compared to Pre and Post 2 compared to Post 1. Furthermore, Hoe_eo change occurred between Pre and Post 1 compared to Post 2. Finally, AoE_eo differs between Pre compared to Post 1 and Post 2 as well as Post 1 compared to Post 2.

The Friedman ANOVA analysis revealed significant differences in all eyes closed parameters, MCoCx_ec (χ2 = 8.34, df = 2, p = 0.015, W = 0,14), MCoCy_ec (χ2 = 8.07, df = 2, p = 0.017, W = 0.14) SPL_ec (χ2 = 15.7, df = 2, p = 0.0004, W = 0.27), WoE_ec (χ2 = 7.6, df = 2, p = 0.02, W = 0.15), HoE_ec (χ2 = 8.34, df = 2, p = 0.015, W = 0.14), AoE_ec (χ2 = 10.1, df = 2, p = 0.006, W = 0.17) respectively. The Durbin-Conover post-hoc analysis showed significant increase in all parameters relative to Pre, except MCoCy_ec which decreased.

Additionally based on information presented in table 1 differences between results acquired in Balance test eo and ec conditions, in different time points were analyzed. Significant changes appeared in Post 1 for MCoCy, SPL, WoE, AoE and Post 2 only for SPL, HoE. What is important, no difference was found in measurements previous to training camp (Pre).

DISCUSSION

This study evaluated the effect of training programs completed during intensive two-week training camp on balance parameters. Additionally, a follow up test after one month without any activity was performed. Moreover, assessment of differences between balance parameters in eo to ec was added. Results partially supported our first hypothesis and fully supported second and third. We showed improvements in most of the parameters in eo condition, while in ec decrease was observed. Nevertheless, in the follow up test decrease was shown for all parameters, which supports our hypothesis. The differences between eo and ec were observed after the training camp, therefore they could be the result of improvement only in balance with eo. It should be noted that the load on the lower extremities was symmetrical following the camp.

To the best of our knowledge, this is the first experimental study investigating the effect of an intensive two-week training camp on balance parameters in young female volleyball players, including follow-up evaluation. Previous volleyball research has mainly involved female players above the age of 14, particularly young adults [15,26,28]. These studies focused on interventions of varying duration [15] and analyzed programs specifically targeting balance, without examining the effects of a pre-season general conditioning camp [26, 29].

Albaladejo-Saura et al. [26] demonstrated that an 8-week injury prevention program, including stability, strength, and plyometric exercises, was effective in improving balance in young male volleyball players. These findings are consistent with ours, as the general conditioning camp implemented in our study also included stability, strength, and plyometric components. However, the difference in intervention duration should be noted. A longer intervention period is typically associated with a lower accumulation of training load within a short timeframe. Considering that the improvements observed after our training camp were not maintained one month later, a longer camp with lower acute training volume may be more favorable. Moreover, a longer duration would allow the camp to end closer to the start of the competitive season, potentially facilitating the maintenance of improvements during the season.

Similar findings were reported by Sebastia-Amat et al. [29], who implemented a 12-week balance training program. The authors observed significant improvements in balance following the intervention. However, after the cessation of the specific balance training, the measured parameters declined. These results are consistent with ours and suggest that future studies should focus on strategies to maintain training-induced improvements after the intervention period. Longitudinal observations in youth training also emphasize the importance of sustained training stimuli for maintaining adaptations [31].

To the best of our knowledge, Podstawski et al. [24] appear to be the only other researchers who have examined the effects of short, intensive training camps on motor abilities. In contrast to our findings, they did not report improvements in physical performance variables, but only changes in anthropometric characteristics. However, balance parameters were not included in their testing protocol, which limits direct comparison with our results. Nevertheless, the absence of improvement in their study may be attributed to the shorter duration of the training camp. In our study, the camp lasted two weeks, whereas in Podstawski et al. [24] it lasted only one week. Such a short duration may have been insufficient to induce meaningful adaptations, either due to inadequate training volume or excessive load not adequately distributed over time, potentially limiting recovery.

Our findings are consistent with previously reported positive effects of volleyball training on balance parameters [19]. When comparing the SPL values obtained under eyes-open (EO) conditions in our study with those reported by Rusek et al. [6], it is evident that young female volleyball players demonstrate superior postural control compared with inactive peers. Although the methodological approach used by Rusek et al. [6] differed from ours—balance was recorded for 20 seconds instead of 60 seconds—after adjusting their results proportionally for comparison, physically active females would still achieve better outcomes, with a difference exceeding 400 mm. Considering that longer testing durations may increase fatigue and reduce attentional focus, a direct comparison using identical measurement times might reveal even greater differences.

Under eyes-closed (EC) conditions, limited literature is available for direct comparison. Nikolaidou et al. [19] reported findings partially consistent with ours, showing worse balance performance under EC conditions. In our study, baseline (Pre) differences between EO and EC were observed in only one parameter. After the training camp, differences were noted in additional parameters. We interpret this as a consequence of improvements in EO conditions, likely resulting from training predominantly performed with visual input and without external perturbations or distractions. The observed deterioration under EC conditions may reflect the visually dominant nature of volleyball training. The absence of visual occlusion or proprioceptive-focused exercises during the camp may have temporarily reduced reliance on non-visual sensory input. Therefore, the changes observed in SPL, HoE, and MCoCx under EC conditions after the camp highlight the need to incorporate proprioceptive exercises and tasks performed under sensory distraction into training programs [12].

When evaluating changes in balance parameters, it is essential to distinguish between positive neuromuscular adaptations and temporary effects of acute fatigue. The significant improvements observed in most EO parameters immediately after the training camp (Post 1) likely reflect short-term, task-specific adaptations. Volleyball is a visually dominant sport, and the high daily training volume (180 minutes per day; TRIMP 1000–1200) provided a substantial stimulus for enhancing visually guided postural control. Better baseline EC results may indicate that participants were well-rested before the camp. In contrast, the intensive, high-volume training may have induced acute neuromuscular fatigue that disproportionately affected non-visual postural control mechanisms. Given the limited literature addressing acute EC balance changes in youth volleyball players, these findings should be interpreted cautiously. The temporary deterioration may represent a short-term neurophysiological adaptation to intense visual tracking demands rather than a permanent reduction in proprioceptive capacity.

The follow-up assessment conducted one month after the camp (Post 2) further illustrates this dynamic. The decline in EO performance suggests a detraining effect, whereby acute neuromuscular adaptations acquired during the camp were partially lost. Overall, the observed fluctuations in balance appear to reflect a complex interaction between rapid training-induced adaptations and transient fatigue-related suppression effects.

This study has several limitations. First, the relatively small and heterogeneous sample (age range 10–15 years) limits the generalizability of the findings. Second, the experimental protocol did not include a control group or a strictly standardized intervention, which constitutes a major limitation and restricts causal inference. The training program was based on general conditioning designed by a specialized coach rather than a strictly controlled protocol. Moreover, training intensity and volume were not analyzed in detail, which could provide valuable practical information for optimizing balance-oriented programs.

Another limitation concerns the analysis of multiple postural control parameters. Although all variables were predefined and represent distinct biomechanical aspects of balance performance, the large number of statistical tests increases the risk of type I error. No global correction across all analyzed parameters was applied; therefore, some statistically significant findings should be interpreted with caution. Future research may benefit from multivariate statistical approaches or dimensionality-reduction techniques to strengthen inference.

Finally, additional follow-up measurements at multiple time points would provide more comprehensive insight into the temporal dynamics of balance adaptations and could support more effective planning of training camps within the annual training cycle.

CONCLUSION

We conclude that an intense 2-week training camp induces short-term improvements in postural balance under eyes-open conditions, but may temporarily challenge balance control when visual input is removed. To achieve a similar effect with eyes closed, practitioners should include additional exercises that focus on eyes closed conditions. Our findings highlight that 1-month period of rest after such a program leads to a decline in or reversal of the training-induced adaptations balance parameters improvements gained during training camp. Therefore it might be beneficial to schedule such camps closer to the competitive season.

Funding Statement: This research received no external funding

Acknowledgments: We would like to thank all participants who engaged in this experiment.

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

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