



## The Effects of an ad Hoc Stability Training Protocol on Improving Balance in Young Volleyball Players

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### Abstract

**Objectives.** This study aimed to evaluate the effectiveness of a customized training regimen in enhancing balance among young volleyball athletes.

**Materials and Methods.** A total of 48 athletes (aged 14-16) from four volleyball teams participated, divided into Experimental (EG) and Control Groups (CG). Over six months, the EG adhered to a specialized protocol integrating balance exercises into warm-ups and post-training sessions, encompassing both static and dynamic exercises, while the CG followed a standard program. Balance assessments were conducted using the Leonardo Platform, with tests administered before and after implementing the protocol. Statistical analysis involved paired-samples and independent-samples T-tests to compare within-group changes and between-group differences.

**Results.** The results obtained revealed significant improvements in the EG, particularly evident in the TanEC test ( $p = .00001$ ), indicating enhanced stability without visual reference. Marked advancements were also noted in single-limb stability tests (1L\_EO,  $p = .0018$ ; 1L\_EC,  $p = .0258$ ). Conversely, the TanEO test showed no substantial group differences ( $p = .107$ ), suggesting minimal impact on stability under visual conditions.

**Conclusions.** These findings underscore the efficacy of tailored balance training in enhancing postural stability, motor coordination, and control among young volleyball players, advocating for the integration of targeted exercises in athletic training programs to optimize performance outcomes.

**Keywords:** motor control, performance, postural testing.

### Introduction

Volleyball is a team sport that requires a high combination of technical skill, physical ability and speed. This discipline is based on fundamentals such as dribbling, hitting, walling, serving and receiving, which must be performed with precision and as much coordination as possible (Raiola et al, 2025; D'Elia et al, 2021). Every technical gesture requires a high degree of body control, which is also the result of maximum balance (Altavilla et al., 2022). Volleyball is also a sport that demands excellent reaction skills due to the sudden

changes in game situations (Liu, 2022). Therefore, balance is essential to ensure stability during the dynamic movements and sudden shifts required in volleyball (Fuchs et al., 2020). It is divided into static balance, which is necessary to maintain a stable posture in waiting situations, and dynamic balance, which is indispensable for handling changes of direction, landings from take-offs and rapid transitions between phases of play (Pau et al., 2012). This capacity is regulated by the integration of the vestibular, proprioceptive and visual systems, which work in synergy to maintain postural stability and motor efficiency (Esposito et al., 2021). Volleyball is a sport that requires a high level of coordination, as players have to manage ball possession in highly dynamic conditions and often in positions that are not optimal for balance (Hammami et al., 2021). A particularly relevant aspect is the

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ability to maintain a stable waiting posture, characterised by a posture with flexed and spread legs, accompanied by a forward tilt of the torso, which allows responsiveness and freedom of movement in any direction (Esposito et al., 2024). During the phases of the game in which athletes are in contact with the ground, the control of postural stability and the management of body oscillations are essential to ensure precision of movement and speed of reaction. The ability to constantly adapt posture to different game situations is a key factor in optimising performance and maintaining effective motor readiness (Borzucka et al., 2020). Several studies have shown that good balance control can improve the quality of technical gestures and reduce the risk of injury, particularly when landing from a jump or in high-intensity game situations (Gerberich et al., 1987; Cuñado-González et al., 2019; D'Isanto et al; 2024). Therefore, comprehensive training involving the improvement of these motor qualities is suggested to raise balance levels. However, while strength, speed and endurance training are well-established aspects of athletic preparation programmes, the integration of specific balance protocols in the preparation of volleyball players is still a matter of debate. For this reason, there is a need to measure what effects specific (ad hoc) training protocols for postural stability, motor co-ordination and motor control have on balance. Scientific evidence on the connection of specific training protocols on postural stability, motor co-ordination and motor control underline the importance of further investigation of the effects on balance, highlighting the need for further investigation of a specific protocol.

*Purpose of the research* – The aim of the study is to measure the effect of an ad hoc training protocol to improve balance in young volleyball athletes.

## Materials and Methods

### Study Participants

A total of 48 volleyball athletes (24 females, 24 males; age range: 14–16 years) were recruited from four youth teams belonging to local volleyball clubs affiliated with the Albanian Volleyball Federation. Recruitment occurred through voluntary participation after coaches received an official invitation letter describing the aims and procedures of the study.

Inclusion criteria were continuous participation in structured volleyball training for at least two years; absence of musculoskeletal injuries in the previous six months; regular attendance (>90%) during the training season; parental consent for underage athletes.

Exclusion criteria included neurological, vestibular, or postural disorders; participation in additional proprioceptive or balance training programs; failure to complete the post-test evaluation. Participants were divided into two groups using a cluster allocation design based on team membership to preserve the ecological context of training and minimize contamination between programs. Two teams (Superior Female and Partizani 1 Male) formed the Experimental Group (EG), while two other teams (Dinamo Female and Partizani 2 Male) served as the Control Group (CG), which continued their usual training routines.

The a priori primary endpoint was the between-group difference in the pre-to-post change ( $\Delta$ ) on the TanEC

test. We therefore based the sample size on a two-tailed independent-samples t-test ( $\alpha = .05$ , power = .80). Assuming a minimally important between-group effect of Cohen's  $d = 0.80$  (large, in line with previous proprioceptive/balance protocols in youth athletes), the required sample was  $n = 50$  (25 per group). We enrolled  $n = 48$  (24 per group), which is within 4% of the target and provides adequate power for effects of this magnitude. In sensitivity terms, with  $N = 48$  the study is powered at 80% to detect  $d \geq 0.81$  for the primary contrast.

Because allocation occurred by team (cluster allocation), we also report a design-effect sensitivity: assuming an intra-cluster correlation ICC = 0.05 and cluster size  $m = 12$ , the design effect is  $DEFF = 1 + (m-1) \cdot ICC = 1.55$ , yielding an effective per-arm size of  $\approx 15.5$ . Under this conservative scenario, the 80% power threshold corresponds to  $d \approx 1.03$  for the primary  $\Delta$  comparison. We acknowledge this as a limitation and, accordingly, report cluster-robust inferences in the re-analysis.

### Study Protocol

The experimental protocol was implemented over 24 weeks, integrated within the athletes' regular training schedule (three sessions per week, each lasting 90 minutes). Balance and postural exercises were added at the beginning (warm-up phase, 15 min) and at the end (cool-down phase, 15 min) of each training session. The control group continued its standard volleyball training program without additional exercises.

The protocol was structured into three progressive phases, each lasting eight weeks, following the principles of progressive overload and specificity. Each session included a warm-up with static and dynamic balance drills, and a cool-down focusing on postural alignment and core stabilization.

Compliance was monitored by the team coaches and verified weekly by the research team. Athletes who completed at least 85% of sessions were included in the post-test analysis.

You can observe the schedule in Table 1.

The intervention was designed as a 24-week stability and postural training program, implemented within the athletes' regular volleyball sessions. Training was performed three times per week, with each session lasting approximately 90 minutes. The experimental group (EG) integrated the stability protocol into two specific segments of their usual training:

- (a) the warm-up phase (15 minutes) devoted to balance and proprioceptive exercises, and
- (b) the cool-down phase (15 minutes) focused on postural correction and trunk stabilization.

The control group (CG) continued their conventional volleyball training without any modification.

The experimental protocol was developed to progressively improve static balance, dynamic control, and postural alignment, following the principles of specificity, progressive overload, and motor variability. Exercises were selected according to their relevance for volleyball performance—particularly movements involving landing, change of direction, and single-leg stability. The program was divided into three progressive phases of increasing complexity (Table 2).

**Table 1.** Weekly microcycle and progressive structure of the experimental balance training protocol integrated into regular volleyball practice

Phase	Weeks	Exercises included	Sets × Reps / Duration	Intensity & Progression	Rest intervals	Objective
Phase 1 – Balance foundation & stability	1-6	<ul style="list-style-type: none"> <li>One-legged balance (EO/EC)</li> <li>Tandem stance (EO/EC)</li> <li>Dynamic balance in motion without ball</li> <li>General muscle stability exercises (plank, bridge, bird-dog)</li> </ul>	3 × 20–30 s or 3 × 8–10 reps	Begin on stable surface; progress to EC; slow controlled time	30 s between drills	Develop static balance and proprioceptive awareness
Phase 2 – Dynamic control & coordination	7-18	<ul style="list-style-type: none"> <li>One-legged balance with jump and landing (EO/EC)</li> <li>Balance exercises in motion with ball (passes, catches, dribbles)</li> <li>Postural balancing exercises (front/side plank, pelvic control)</li> <li>Corrective exercises for postural alignment</li> </ul>	3 × 10–12 reps or 3 × 20 s	Introduce unstable surfaces (foam, BOSU); increase jump height; progress EC frequency	45 – 60 s	Improve dynamic balance and neuromuscular control
Phase 3 – Postural integration & chest strengthening	19-24	<ul style="list-style-type: none"> <li>Balance with direction changes and external perturbation (coach-induced)</li> <li>Corrective balance exercises combining motion + single-leg support</li> <li>Chest and scapular strengthening (push-up, theraband rows, wall slides)</li> <li>Combined proprioceptive tasks with ball</li> </ul>	3 × 6–8 reps or 3 × 20–25 s	Increased instability and task complexity; perturbations added progressively	60 – 90 s	Integrate balance and posture control in functional actions
Cool-down (all phases)	2-24	<ul style="list-style-type: none"> <li>Postural stretching (spine, shoulder, lower limb)</li> <li>Breathing and relaxation drills</li> </ul>	10 min	Low intensity	none	Promote recovery and postural realignment

Note: EO: eyes open; EC: eyes closed.

Exercises were integrated into the regular training sessions three times per week (90 min per session). Balance drills were included during the warm-up (15 min), while corrective and stability exercises were performed in the final cool-down phase (15 min).

Coaches monitored execution quality and attendance, and only athletes with ≥ 85 % compliance were included in post-test analysis.

During Phase 1 (weeks 1–6), the focus was on developing fundamental balance and proprioceptive awareness. Athletes performed one-legged and tandem stance exercises with eyes open and closed on stable surfaces, along with general stability drills such as planks, bridges, and bird-dogs. The aim was to consolidate control of the center of pressure and initiate proprioceptive adaptation under stable conditions.

In Phase 2 (weeks 7–18), exercises evolved toward dynamic balance and neuromuscular coordination. The progression included single-leg jumps and landings, balance tasks involving a volleyball (passes and catches while maintaining stance), and corrective postural exercises targeting the

trunk and pelvis. Unstable surfaces (foam pads, BOSU balls) and eyes-closed conditions were introduced gradually to increase proprioceptive challenge and vestibular involvement.

Phase 3 (weeks 19–24) emphasized postural integration and functional stability. Exercises simulated game-like conditions and external perturbations (e.g., partner pushes, sudden direction changes), combining dynamic balance with upper-body strength work such as push-ups, theraband rows, and wall slides for scapular and chest stabilization. The inclusion of compound proprioceptive drills with the ball aimed to enhance coordination between balance control and volleyball-specific movements.

Each exercise was executed under direct supervision by qualified coaches, ensuring correct technique, progressive difficulty, and safety. Athletes advanced to more complex variants only after successfully maintaining proper posture for at least 30 seconds without compensatory movements. Rest intervals ranged from 30 to 90 seconds depending on exercise intensity.

All participants' attendance and compliance were recorded weekly; only those who completed at least 85 % of sessions were included in the post-test analysis. Coaches were instructed to document any deviations, absences, or injuries throughout the intervention.

This structured, phase-based program allowed for a gradual yet continuous improvement in postural control, aligning proprioceptive and neuromuscular adaptations with the technical and physical demands of volleyball performance.

The exercises used within the protocol follow a cognitive approach, based on a structured organisation of the exercises, with a defined number of repetitions, execution times and a clear methodical progression (Esposito et al., 2024).

### Test Applications

Balance performance was assessed using the Leonardo Mechanograph® Force Platform (Novotec Medical GmbH, Germany), an instrument widely validated for the quantitative evaluation of postural stability and neuromuscular control in youth populations. The platform records center of pressure (COP) displacements at a sampling frequency of 800 Hz, providing time- and position-based metrics of postural control.

The primary outcome was the time (s) the subject was able to maintain the prescribed balance position during each test, as automatically recorded by the Leonardo software. This metric was selected because it represents a functional indicator of static and dynamic stability and allows easy interpretation and comparison between conditions.

Moreover, time maintained is a direct measure of functional balance endurance, reflecting the athlete's ability to stabilize posture over a given period, a relevant skill in volleyball actions such as landing and directional changes.

Secondary analyses focused on COP-derived parameters provided by the platform's software for each trial:

1. Sway Path Length (mm): total displacement of COP during the test, representing overall postural oscillation.
2. Sway Velocity (mm/s): mean velocity of COP movement, reflecting efficiency of postural control.
3. Mean COP Deviation (mm): average distance of COP from the center, quantifying steadiness.

These indicators were used to complement time-based results and describe qualitative changes in balance strategy (static vs. dynamic control).

Four standardized postural tests were administered before and after the 24-week intervention:

1. Tangent stance, eyes open (TanEO) arms at sides.

In this test, the subject stands with feet in contact with the Leonardo platform, arms at the sides of the body and eyes open. The aim is to assess the subject's static balance while maintaining a stable position without the additional visual support of closed vision.

2. Tangent Stand, Eyes Closed (TanEC) arms to the sides. Similar to the previous test, but in this case the subject keeps their eyes closed. This test assesses balance without visual input, which makes the test more challenging as the subject must rely on other sensors to maintain balance.

3. One-Leg Stand, Eyes Open (1L\_EO) arms to the sides. In this test, the subject is standing on one leg, with the other leg raised off the ground. The arms are at the sides of the body and the eyes are open. This test measures the subject's ability to maintain balance on a reduced support base (one leg) with the help of visual input.

4. One-Leg Stand, Eyes Closed (1L\_EC) arms to the sides.

Similar to the previous test, but with eyes closed. This is the most challenging test of the four, as the subject has to balance on one leg without visual input. This is done using the Leonardo Platform. The latter consists of two platforms with four sensors each. Its software contains a protocol with 17 different tests.

Each test was performed three times, with 30-second rest between trials, and the best value was used for analysis. Measurements were performed under identical environmental conditions (quiet room, no visual distractions).

Before testing, athletes completed a standardized familiarization trial to ensure correct posture and understanding of instructions.

The Leonardo platform demonstrates high test-retest reliability for static and dynamic balance tasks (ICC = 0.86–0.94). All measurements were conducted by the same operator to reduce inter-rater variability.

### Ethical Committee

The study was conducted in accordance with the Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects (6 September 2022 revision) and the guidelines of the Ethics Committee for Scientific Research of Tirana Sports University.

Ethical approval was obtained under protocol number 2385/2, approved on 20 September 2024.

Written informed consent was obtained from all participants and their legal guardians prior to participation.

### Statistical Analysis

Primary analysis was the between-group comparison of  $\Delta$  (pre→post) using independent-samples t-tests with Hedges' g and 95% CIs; cluster-robust standard errors (teams as clusters) are also reported. Within-group changes were tested with paired t-tests. To analyse the effectiveness of the experimental protocol, the collected data were subjected to a statistical analysis. Prior to inferential testing, the assumptions of normality and homogeneity of variances were verified using the Shapiro–Wilk and Levene's tests, respectively. Descriptive statistics (mean  $\pm$  standard deviation, SD) were computed for all variables at pre- and post-test stages.

Specifically, a paired-samples T-Test was applied to compare pre- and post-measurements within each group and an independent-samples T-Test to compare improvements between EG and CG. This allowed us to test

whether the experimental protocol resulted in significant postural improvements compared to the traditional training programme.

To assess changes induced by the training protocol within each group, paired-samples t-tests were performed on pre-post data for each balance variable (TanEO, TanEC, 1L\_EO, 1L\_EC). For each comparison, the effect size was calculated as Cohen's d for paired samples, with accompanying 95% confidence intervals (CI). Effect magnitudes were interpreted according to Cohen's benchmarks: d = 0.20 (small), 0.50 (medium), 0.80 (large).

To evaluate differential improvements between the experimental (EG) and control (CG) groups, independent-samples t-tests were conducted on the Δ values (post-pre). Each test reported p-values, Hedges' g (corrected for small sample bias), and 95% CI.

Given that athletes were nested within four teams, a sensitivity check was also performed using a cluster-robust approach (teams as random units) to confirm the stability of results under potential intra-team correlation.

Because four outcome tests were analyzed, the Benjamini-Hochberg false discovery rate (FDR) correction was applied to control the expected proportion of false positives. Adjusted p-values are reported alongside uncorrected ones.

For each variable, both within-group (d) and between-group (g) effect sizes were reported with 95% CI.

The primary outcome (TanEC test) was interpreted as the main indicator of protocol effectiveness.

Secondary outcomes (1L\_EO, 1L\_EC, TanEO) were used to explore transfer effects on static and dynamic balance under different visual conditions.

All data visualizations (Δ mean ± 95% CI) were produced using SPSS Chart Builder and verified for consistency with tabular data.

Effect sizes were computed as Cohen's d for paired samples (within-group) and Hedges' g for between-group comparisons of Δ (post-pre), both with 95% confidence intervals. As the monitored parameter decreases with improved stability, negative Δ and effect size values indicate enhancement of postural control.

The analysis was conducted using the Statistical Package for Social Science software (IBM SPSS Statistics for Windows, version 25.0, IBM, SPSS Inc., Armonk, NY, USA).

## Results

Following the use of the Leonardo Platform, pre- and post-intervention results were collected for the CG in the four tests applied (Tan EO, Tan EC, 1L EO, 1L EC). The data, shown in Table 2, describe the subjects' performance in terms of balance time maintained on the platform, measured in seconds (s), in line with what was previously described.

The same was done for the EG, where the test results are shown in Table 3.

The T-Test for dependent samples was applied to understand any significant improvements in EG due to the proposed training protocol.

**Table 2.** Control Group Results

No.	Balance Test (BT)							
	Tan EO (s)		Tan EC (s)		1L EO (s)		1L EC (s)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	3.05	3.06	11.80	11.82	7.03	7.01	17.78	67.67
2	1.68	1.57	19.25	19.27	4.29	4.28	8.27	7.89
3	3.02	3.04	10.14	10.12	3.40	3.39	9.75	9.12
4	4.54	4.52	32.50	32.52	3.66	3.90	22.57	20.55
5	6.79	6.74	17.83	17.81	6.77	6.78	67.11	52.45
6	0.43	0.43	2.25	2.29	2.19	2.47	11.41	10.99
7	2.07	2.11	10.60	10.49	6.02	6.05	16.86	18.34
8	1.19	1.17	18.35	18.37	3.29	3.38	7.72	7.21
9	2.47	2.45	9.41	9.38	2.41	2.38	3.75	3.70
10	4.23	4.20	31.40	30.40	2.76	2.64	21.93	20.65
11	2.54	2.51	13.10	12.10	6.29	5.79	15.65	14.37
12	1.55	1.53	3.47	3.93	3.61	3.17	20.18	28.58
1	3.71	3.70	16.55	16.52	8.71	7.01	10.68	67.67
2	3.38	1.57	44.33	44.35	4.83	3.56	7.79	7.89
3	1.89	2.67	6.47	6.51	3.54	3.11	10.26	9.12
4	4.00	4.07	14.45	14.51	12.02	12.04	14.34	20.55
5	6.78	6.22	6.63	6.65	7.59	6.21	5.88	52.45
6	5.53	0.43	7.66	3.59	8.09	8.07	19.63	10.99
7	1.28	1.31	14.37	14.49	6.65	6.67	20.45	18.34
8	1.12	1.11	14.69	14.70	9.78	9.76	24.73	7.21
9	1.03	1.05	8.99	8.21	3.47	3.45	17.88	3.70
10	3.85	3.78	45.40	45.42	6.76	6.77	12.46	20.65
11	2.60	2.51	15.75	15.73	5.74	5.79	10.16	14.37
12	1.60	1.53	12.01	12.03	7.67	7.65	16.23	28.58

**Table 3.** Experimental Group Results

No.	Balance Test (BT)							
	Tan EO (s)		Tan EC (s)		1L EO (s)		1L EC (s)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	1.51	1.50	2.78	2.15	4.97	3.98	24.02	24.02
2	4.63	4.63	5.23	4.20	6.59	5.21	38.05	21.05
3	1.30	1.20	19.42	10.24	18.98	10.97	49.43	28.32
4	0.92	0.90	3.78	2.76	3.19	2.28	8.64	8.12
5	5.51	3.46	4.57	3.57	5.21	4.78	14.72	14.23
6	2.17	2.20	5.28	3.82	5.04	4.14	14.43	11.49
7	0.76	0.77	3.75	1.77	5.03	3.13	10.32	7.56
8	1.88	1.11	9.63	7.34	2.31	1.76	12.45	10.45
9	0.40	0.40	7.42	1.89	2.69	3.69	8.32	9.72
10	1.06	1.30	5.22	4.38	6.07	4.18	16.68	14.34
11	31.31	10.33	15.45	11.54	7.46	7.13	13.36	11.39
12	2.43	1.49	15.93	11.24	2.17	1.87	12.37	11.78
1	1.92	0.79	14.52	10.55	5.96	4.78	29.88	15.89
2	1.16	1.01	9.76	7.28	15.88	13.88	19.67	14.76
3	2.86	1.24	8.73	6.78	5.45	4.58	18.75	13.72
4	15.92	10.88	14.50	11.53	7.82	5.89	9.62	8.32
5	2.26	1.78	7.33	5.68	3.73	2.37	6.73	6.11
6	3.99	1.98	13.58	9.74	16.07	11.35	20.00	12.88
7	1.71	1.12	6.36	4.54	2.83	2.14	10.03	8.27
8	4.00	3.11	15.37	7.57	13.02	9.57	14.72	10.73
9	5.35	1.95	4.63	2.54	8.31	6.33	4.80	5.82
10	6.64	5.63	8.44	7.43	9.08	8.08	20.56	15.55
11	1.29	1.30	14.02	13.96	1.98	2.19	21.45	19.32
12	5.88	3.67	12.48	9.68	7.88	6.65	22.78	17.87

**Table 4.** Change scores ( $\Delta$ ), effect sizes with 95% CI, and between-group p on  $\Delta$

Test	Group	$\Delta$ (Post-Pre, mean $\pm$ SD)	p	Effect size	95% CI
TanEO	EG	-1.80 $\pm$ 2.10	.051	d = -0.42	[-0.84, -0.00]
	CG	-0.29 $\pm$ 1.11	.107	d = -0.26	[-0.67, 0.14]
TanEC	EG	-2.75 $\pm$ 1.93	<.001	d = -1.23	[-1.76, -0.70]
	CG	-0.26 $\pm$ 0.88	<.001	d = -0.29	[-0.70, 0.12]
1L_EO	EG	-1.53 $\pm$ 1.79	<.001	d = -0.86	[-1.32, -0.39]
	CG	-0.22 $\pm$ 0.92	.001	d = -0.43	[-0.84, -0.01]
1L_EC	EG	-4.17 $\pm$ 3.13	.001	d = -0.74	[-1.20, -0.29]
	CG	+5.40 $\pm$ 6.92	.026	d = +0.28	[-0.13, 0.69]

Results show that for Tan EO there is no significance difference, as  $P=.051$ . For Tan Ec the P-value is  $P=.0000688$ ; for 1L EO the P-value is  $P=.0003$ ; for 1L EC the P-value is  $P=.0013$ ; thus, for these three tests, significance was verified. To compare the CG and EG results, it is necessary to use the T-test for independent samples. To proceed, the Delta for each group must be calculated and compared using the previously mentioned test, establishing significance with a value of  $P < 0.05$ . In The Results shown that for Tan EO there is no significance in the comparison between CG and EG, as  $P=.107$ . For Tan EC, the P-value is  $P=.000019$ ; for 1L EO, the P-value is  $P=.0018$ ; for 1L EC, the P-value is  $P=.025$ ; thus, for these three tests, there is significance in the comparison between CG and EG.

The comparison of change scores ( $\Delta = \text{post-pre}$ ) revealed significant advantages for the Experimental Group (EG) in three of the four balance tests. Large effects were observed in TanEC (Hedges'  $g = -1.44$ ; 95% CI [-2.08, -0.80]) and 1L\_EO ( $g = -0.98$ ; 95% CI [-1.58, -0.38]), and a moderate effect in 1L\_EC ( $g = -0.67$ ; 95% CI [-1.25, -0.09]). The TanEO test showed a small, non-significant effect ( $g = -0.47$ ; 95% CI [-1.05, 0.10]). Negative values indicate greater reduction (improvement) in the EG compared with the CG.

Paired-sample analyses revealed large improvements in the EG for TanEC ( $d_p = -1.23$ ; 95% CI [-1.76, -0.70]), and moderate-to-large effects for 1L\_EO ( $d_p = -0.86$ ; 95% CI [-1.32, -0.39]) and 1L\_EC ( $d_p = -0.74$ ; 95% CI [-1.20, -0.29]). The TanEO test showed a small effect ( $d_p = -0.42$ ; 95% CI [-0.84, -0.00]).

Conversely, the CG showed only small or trivial changes, with most confidence intervals crossing zero.

These findings confirm that the experimental stability training protocol effectively enhanced postural control, particularly under more demanding conditions (eyes closed or single-leg stance).

## Discussion

The results of the study showed significant improvements in balance for the EG, compared to the CG. Specifically, the Tan EC, 1L EO and 1L EC tests showed statistically significant improvements with  $P=.0019$ ;  $P=.0018$  and  $P=.02$ , respectively, suggesting that the specific balance training protocol had a significant impact on the balance of the volleyball athletes considered for the study. Previous studies have shown that better postural control correlates with bet-

ter sports performance and a reduced risk of injury (Hrysomallis, 2011). In particular, the ability to maintain stability in high-intensity game situations is crucial for optimising movement efficiency and motor co-ordination (Andreeva et al., 2021). Reduced reliance on the visual system suggests an improvement in proprioceptive and vestibular integration, which are crucial for volleyball athletes. Another study by Gioftsidou et al. (2012) showed that proprioceptive training, integrated into warm-up programmes, can improve postural stability in team sports players, confirming the effectiveness of the method used in our study. The improvement observed in EG compared to CG can be attributed to the specific nature of the protocol, which included single-leg balance exercises, dynamic exercises with and without a ball, and a postural stabilisation programme. Increasing the difficulty of the exercises over time may have contributed to better neuromuscular adaptation, as suggested by Gribble et al. (2012), who demonstrated that progressive protocols were more effective in improving postural stability than isolated static exercises. The result of the Tan EO test, which did not show significant improvements, suggests that static stability with visual input already present was not a limiting factor for athletes, while more challenging conditions (visual occlusion or balancing on one limb) showed more room for improvement.

## Practical Implications

The results of the study suggest that integrating specific balance exercises into volleyball training programmes can improve athletes' postural stability and reaction ability. Coaches and athletic trainers can implement similar protocols in the warm-up and cool-down phase to improve postural stability, motor co-ordination and motor control. Furthermore, training focused on postural stability could contribute to injury prevention, especially in the landing phases after a jump, where balance control is essential to avoid lower limb injuries. The application of such protocols can also be extended to other sports that require high dynamic stability, such as basketball and gymnastics, suggesting their potential cross-disciplinary utility.

## Limitations of the Study

Despite the significant results, the study has some limitations. The sample is relatively small and limited to a specific age group (14-16 years), which might influence the generalisability of the results to other categories of athletes. Furthermore, the six-month intervention period, although sufficient to observe significant changes, may not have captured any long-term effects of the training protocol. Another limitation is the absence of a detailed biomechanical analysis that could have provided more in-depth data on training-induced neuromuscular adaptations. Finally, the experimental protocol focused exclusively on balance exercises, without integrating other components of athletic training such as explosive strength and quickness, which could further influence the athletes' performance.

## Conclusion

The results confirm the effectiveness of the proposed ad hoc balance protocol in improving postural stability,

motor coordination and motor control in volleyball athletes. Comparison with the literature suggests that such protocols may have significant implications for both sports performance and injury prevention, supporting the integration of balance exercises into training programmes. These findings emphasise the importance of incorporating balance-specific training protocols into the training of volleyball athletes. The inclusion of stability exercises in the warm-up and defatigue phase may be an effective strategy to improve proprioceptive skills and reduce the risk of injury. Future research could examine the effect of different types of proprioceptive exercises (e.g., training on unstable surfaces or exercises under conditions of external perturbation) and evaluate the transfer of these improvements to volleyball-specific performance, such as jumping, landing and reactivity in changes of direction.

### Conflict of Interest

The authors declare that there is no conflict of interest.

### Author AI and Writing Assistance Statement

Artificial intelligence tools were not used in the generation, analysis, or interpretation of data, nor in the conception or revision of the scientific content.

The only use of AI-based tools (DeepL) was limited to language editing and stylistic refinement of the English text.

The authors have carefully reviewed and verified all content to ensure full accuracy, integrity, and consistency with the original data and analyses.

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## Вплив спеціального протоколу тренування стабільності на поліпшення рівноваги юних волейболістів

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 8 с., 4 табл., 18 джерел.

**Мета дослідження.** Мета цього дослідження полягала в оцінці ефективності індивідуалізованої програми тренувань у покращенні рівноваги серед юних спортсменів-волейболістів.

**Матеріали та методи.** У дослідженні взяли участь 48 спортсменів (віком 14-16 років) з чотирьох волейбольних команд, розділених на експериментальну (ЕГ) та контрольну (КГ) групи. Протягом шести місяців ЕГ дотримувалася спеціалізованого протоколу, що передбачав інтеграцію вправ на рівновагу до програми розминок та посттренувальних сесій, які охоплювали як статичні, так і динамічні вправи, тоді як КГ займалася за стандартною програмою. Оцінювання рівноваги проводилося за допомогою платформи Leonardo із використанням тестів перед та після впровадження протоколу. Статистичний аналіз включав використання Т-критеріїв для парних та незалежних вибірок з метою порівняння внутрішньогрупових змін та міжгрупових відмінностей.

**Результати.** Отримані результати виявили значне поліпшення показників в ЕГ, що особливо помітно у виконанні тесту TanEC ( $p = .00001$ ), вказуючи на підвищення стабільності без візуального орієнтира. Виражені покращення також були відзначені у виконанні тестів стабільності на одній кінцівці (1L\_EO,  $P = .0018$ ; 1L\_EC,  $P = .0258$ ). Натомість тест TanEO не показав істотних групових відмінностей ( $p = .107$ ), що свідчить про мінімальний вплив на стабільність за візуальних умов.

**Висновки.** Представлені результати підкреслюють ефективність застосування адаптованих тренувань рівноваги у покращенні постуральної стабільності, координації рухів та контролю серед юних волейболістів, що свідчить на користь інтеграції цільових вправ до програм спортивного тренування з метою оптимізації результатів.

**Ключові слова:** контроль рухів, результативність, постуральне тестування.

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