A Six-Week Dynamic Stretching Warm-Up Protocol Enhances Dynamic Balance but Not Sprint and Agility Performance in Adolescent Male Volleyball Players

by

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This study aimed to investigate the long-term effects of a six-week dynamic stretching warm-up protocol on sprint performance, agility, and dynamic balance in adolescent volleyball athletes. Thirty male volleyball players, aged 16 to 17 years, were randomly assigned to an experimental group (n = 14) performing dynamic stretching or a control group (n = 16) undertaking a conventional warm-up without stretching. The intervention lasted 6 weeks and comprised 5 sessions each week. Evaluations performed prior to and after the intervention included a 5-m-sprint test, a modified T-test for agility, and a Y-Balance-test for dynamic balance. The results indicated a significant interaction between time and the group ($p < 0.01$, η_p^2: 0.32–0.47 [large]) only in the Y-balance test in the anterior and posterolateral directions. The experimental group demonstrated a significant improvement in dynamic balance compared to the control group in both the anterior ($p = 0.018$, $d = 1.15$ [large]) and posterolateral ($p = 0.001$, $d = 1.72$ [large]) directions of the Y-balance test. No significant improvements in agility performance were seen ($p = 0.469$, $\eta_p^2 = 0.03$ [small]). Sprint performance declined in both groups, demonstrating a significant main effect of time ($p < 0.001$, $\eta_p^2 = 0.59$ [large]), whereas no significant group effect was seen ($p = 0.086$, $\eta_p^2 = 0.16$ [large]). Therefore, a six-week dynamic stretching warm-up exercise program enhanced teenage male volleyball players' dynamic balance significantly, particularly in the front and posterolateral directions. The training intervention decreased short-distance (5 m) sprint performance and did not improve agility. Although dynamic stretching can improve some aspects of neuromuscular control, the findings suggest that it should be paired with sport-specific training to optimize overall volleyball performance and injury prevention techniques.

***Keywords**: flexibility; neuromuscular control; proprioception; range of motion; warm-up protocols; youth athletics*

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Introduction

Volleyball is a high-intensity, intermittent activity that necessitates a complex combination of physical traits, including explosive strength, agility, speed, and dynamic balance, all essential for optimal performance and injury prevention (Keoliya et al., 2024). For young athletes, especially those in the cadet category (16–17 years), enhancing performance while reducing injury risk is essential (Jayanthi et al., 2019). The warm-up procedure is essential for acclimating athletes to the physical requirements of volleyball; yet, the most effective components and techniques are still under investigation and discussion (Weldon et al., 2021).

Dynamic stretching, characterized by intentional movements over a joint's complete range of motion, has recently been recognized as a potentially superior alternative to static stretching for pre-activity preparation (Behm et al., 2023; Çabuk et al., 2026). This shift is supported by research suggesting that dynamic stretching might enhance muscular performance, improve coordination, and possibly reduce injury risk (Behm et al., 2023). However, the long-term effects of incorporating dynamic stretching into warm-up routines, particularly for adolescent volleyball players, remain little studied.

Not only are sprint performance, agility, and dynamic balance essential elements of volleyball mastery, but also major determinants of injury risk reduction and general athletic development enhancement in young players (Keoliya et al., 2024). Many volleyball motions, including approaching the net for a spike or moving to defend against an opponent's attack, depend on fast covering of short distances (Zahálka et al., 2017). In volleyball, where players must constantly modify their position in response to the ball and opponent movements, agility defined as the ability to change direction quickly and efficiently is crucial (Chuang et al., 2022). Often disregarded but equally crucial, dynamic equilibrium underlies many volleyball-specific abilities and might help prevent injuries (Keoliya et al., 2024).

Acute effects of dynamic stretching on several performance criteria in athletes have been investigated recently. For young U-17 male soccer players, Ltifi et al. (2023) indicated that dynamic stretching enhanced sprint performance and agility. In adolescent handball players, Zmijewski et al. (2020) also noted improved agility performance following dynamic stretching. These researches, however, mostly concentrated on acute impacts, hence lacking data of the long-term changes possible with regular application of dynamic stretching techniques.

There has been limited study on the correlation between dynamic stretching and balance, particularly in volleyball-specific contexts. Following a comprehensive analysis, Behm et al. (2023) proposed that dynamic stretching could enhance proprioception and balance. Nevertheless, research focused on sports, particularly this including volleyball players, is limited. The necessity for equilibrium in volleyball performance and injury prevention underscores the importance of this area of research (Weldon et al., 2021).

Due to their rapid physical and neurological development, characterized by heightened neuroplasticity and potential for training-induced adaptations, adolescent athletes represent a unique population for research (Brown et al., 2017). Training programs during this pivotal period may exert substantial and enduring effects on athletic performance and injury susceptibility (Dong et al., 2023). Consequently, understanding the impact of specific warm-up protocols on adolescent volleyball athletes is essential for both immediate performance and long-term physical growth.

Prior investigations into warm-up tactics in volleyball have predominantly focused on adult demographics or examined solely acute effects (Behm et al., 2023). A dynamic warm-up improved vertical jump performance in collegiate volleyball players compared to a static stretching regimen (Esteban-García et al., 2024). Nevertheless, particularly for younger athletes, the long-term ramifications and potential adaptations arising from the habitual application of such methods mostly remain uncharted.

The Y-balance test is a reliable and accurate tool for evaluating dynamic balance, neuromuscular control, and identifying possible injury risk in athletes, especially in multidirectional sports like volleyball (Plisky et al., 2021). Its multi-directional nature makes it especially useful for volleyball, as players must maintain balance while navigating across numerous planes (Borzucka et al., 2024).

Incorporating this test into volleyball-specific research allows for a more in-depth evaluation of the neuromuscular control components of performance that may be altered by warm-up routines.

Extensive research in this domain is essential due to the scarcity of longitudinal studies examining the effects of dynamic stretching on various performance metrics in adolescent volleyball players. Furthermore, earlier studies have shown that neuromuscular adaptations develop within 4–8 weeks of continuous training stimuli; consequently, a 6-week program offers a reasonable mix between promoting adaptation and preserving practical relevance in real-world training contexts (Borzucka et al., 2024; Plisky et al., 2021). The present study aimed to address this gap by exploring the long-term effects (6 weeks) of a warm-up protocol incorporating dynamic stretching exercises on sprint performance (5 m), agility (a modified T-test), and dynamic balance (a Y-balance test) in adolescent volleyball players.

Methods

Participants

G*power software (version 3.1.9.6; Kiel University, Kiel, Germany) was used to calculate the minimum required sample size (Kang, 2021). A sample size of 28 participants would be sufficient to detect significant differences (effect size $f = 0.55$, $\alpha = 0.05$) with an actual power of 80%. Therefore, thirty male cadet volleyball players, aged 16 to 17, were recruited from two Tunisian clubs: the Olympic Club of Kélibia and the Sporting Eagle of Haouaria. Table 1 presents basic characteristics of participants randomly allocated to a dynamic stretching group (DS, $n = 14$) or a control group (CONT, $n = 16$). All participants had a minimum of five years of volleyball experience and engaged in training five times weekly for two hours. Their routine training program frequently encompassed technical skill enhancement, tactical exercises, and volleyball-specific physical conditioning. The physical training intervention of this study aimed to enhance players' fitness levels via a combination of aerobic activities, strength training, and sport-specific exercises. Training sessions were generally conducted in the late afternoon from 6 p.m. to 8 p.m. to mitigate the effects of circadian variations on performance.

The eligibility criteria were regular participation in team training sessions, absence of lower extremity injuries in the preceding six months, and no known neuromuscular disorders. Any acute illness or injury that transpired during the study period was classified as an exclusion criterion. Prior to participation, all athletes and their legal guardians provided informed consent after thoroughly reviewing the study protocol, potential risks, and benefits. The study adhered to the Declaration of Helsinki, and the local ethics committee of the High Institute of Sports and Physical Education of Kef, University of Jendouba, Kef, Tunisia (approval code: IRB-C-0010/2024; approval date: 23 September 2024). Due to the nature of the intervention, participants' blinding was not feasible; however, the outcome assessors were blinded to the group allocation during all performance measurements to minimize detection bias (Ferrante di Ruffano & Deeks, 2015). Additionally, the data analyst was kept blinded to the group assignment during initial analysis. This study complied with the ethical standards of exercise science research (Guelmami et al., 2024).

Measures

Adherence to the intervention protocol was monitored through attendance records maintained by research assistants supervising each session. Participants were required to attend at least 85% of the scheduled sessions (minimum 25 of the 30 sessions) to be included in the final analysis. All included participants met this criterion, with attendance rates of 96.7 ± 2.5% in the dynamic stretching group and 95.8 ± 3.1% in the control group. Daily compliance with the prescribed protocol was ensured through direct supervision and standardized training logs, with no significant deviations reported. Performance assessments were conducted at baseline (pre-test) and after the six-week intervention period (post-test), with all tests performed at the same time of day (6 p.m.) to minimize circadian variations in performance (Youngstedt et al., 2022).

All agility and sprint tests were conducted on the same indoor volleyball court with a professional-grade synthetic PVC surface (Gerflor Taraflex Sport M Plus, Villeurbanne, France) used for regular volleyball training and competition. This surface, featuring 35% shock absorption and coefficient of friction of 80–110 according to the EN 14904 standard, was selected to optimize ecological validity by replicating the exact playing conditions experienced during volleyball competition. The surface was thoroughly cleaned before testing, and participants wore the same court-specific footwear for all assessments to eliminate potential confounding effects of variable surfaces or footwear interactions. All tests were performed in indoor sports facilities under standardized conditions (temperature: 22–24°C, relative humidity: 50–60%). Environmental conditions were monitored using calibrated equipment (Kestrel 5400 Heat Stress Tracker, Nielsen-Kellerman, Boothwyn, PA, USA) before and during each testing session, with no significant variations observed between pre- and post-intervention assessments (temperature difference: 0.7 ± 0.3°C; humidity difference: 2.5 ± 1.2%). Participants were instructed to refrain from strenuous physical activity for 48 hours prior to testing, maintain their usual dietary habits throughout the study period, and wear the same footwear for all testing sessions. Compliance with pre-testing instructions was verified through standardized 24-h recall questionnaires administered before each testing session. These questionnaires documented physical activity, sleep patterns, and nutritional intake. Additionally, participants maintained activity logs throughout the study period that were reviewed by research staff prior to each testing session.

Information on each participant's body height, mass and fat content was collected using a wall-mounted stadiometer (Easy Glide Stadiometer; Perspective Enterprises, Portage, MI, USA) and an electronic scale (Life Source Model UC-321P, made by A and D Company, Tokyo, Japan), respectively. All performance tests were administered by the same two examiners with extensive experience in sports performance assessment. The primary examiner conducted all measurements while the secondary examiner verified proper execution and recorded data. Inter-rater reliability was established prior to the study through pilot testing with 10 volleyball players (not included in the main study), yielding excellent agreement (ICC > 0.90) for all outcome measures. Additionally, standardized written protocols and measurement checklists were utilized to ensure procedural consistency across all testing sessions.

The testing battery consisted of a 5-m sprint test, a modified T-test for agility, and a Y-balance test for dynamic balance. These tests were chosen based on their established reliability and validity in assessing key performance variables in volleyball players (Fessi et al., 2016; Iglesias-Caamaño et al., 2022).

Sprint Performance

The 5-m sprint test, which assesses explosive speed crucial for volleyball-specific actions, was conducted using electronic timing gates (Microgate, Bolzano, Italy) positioned at the start and the 5-m mark. The 5-m sprint test was specifically selected based on time-motion analysis of volleyball match play, which demonstrated that most on-court displacements occurred over distances of 3–5 m (Nikolaidis et al., 2015). These short accelerative movements are crucial for volleyball performance, particularly during defensive actions and approach movements preceding attacks. While longer sprint distances (10–20 m) have been used in volleyball testing, the 5-m distance better isolates the initial acceleration phase most relevant to volleyball-specific movement patterns (Nikolaidis et al., 2015). Additionally, this distance minimizes the potential confounding effect of maximum velocity capacity, focusing instead on the neuromuscular factors most likely to be influenced by a stretching intervention (Haugen et al., 2019). Participants began from a standing start, with the front foot placed 30 cm behind the first timing gate (Andrašić et al., 2021). The electronic timing system (Microgate Witty Gate, Bolzano, Italy) utilized infrared photocells positioned at hip height to standardize the measurement point across participants of different statures (Haugen et al., 2019). The system was automatically triggered when participants crossed the first timing gate, eliminating manual start error. To minimize false starts, participants were required to maintain a stationary position for 3 s before initiating movement, verified by the absence of pressure-pad sensor activation. A consistent starting position was enforced through floor markings and verbal commands standardized across all testing sessions. The decision to use the fastest time rather than an average for sprint and agility analyses followed established methodological precedents in team sport testing (Al Haddad et al., 2015). This approach allowed to capture peak neuromuscular performance capability, which represents the most relevant metric for explosive actions in volleyball. Best-trial analysis demonstrates superior sensitivity to training-induced changes compared to average scores, particularly in high-level athletes who typically perform more consistently across trials (Comfort et al., 2014). Additionally, utilizing peak performance measures better reflects the maximum capabilities that would be expressed during critical match situations, enhancing the ecological validity of our findings (Al Haddad et al., 2015). Three maximal effort trials were performed with standardized 2-min rest intervals between attempts to minimize fatigue effects while maintaining physiological readiness and the fastest recorded time was used for further analysis.

Agility Test

The modified T-test was employed to assess multi-directional agility, a key component of volleyball performance that requires rapid changes in direction and the body position (Sassi et al., 2009). The test involves forward, lateral, and backward running in a T-shaped pattern. Timing gates were placed at the start/finish line. Prior to testing, detailed verbal instructions and visual demonstrations of the modified T-test were provided to all participants by the same experienced examiner. The test pattern was physically marked on the court with colored tape to ensure clear visualization of the movement path. Participants were instructed to follow the T-shaped pattern by (1) sprinting forward 9.14 m to the centre cone, (2) side-shuffling 4.57 m to the right without crossing feet, (3) side-shuffling 9.14 m to the far-left cone, (4) side-shuffling 4.57 m back to the centre cone, and (5) sprinting to the starting line. A standardized demonstration was performed before the participants' first attempt, and verification questions were asked to confirm understanding of the protocol (Sassi et al., 2009). All directional changes during the modified T-test were standardized according to established protocols (Sassi et al., 2009). Specifically, 180° turns were performed at each cone with the participants inside foot planted firmly at a consistent distance (30 cm) from the cone. Left-to-right and right-to-left transitions required participants to maintain a sideways shuffling technique without crossing feet, with hips and shoulders consistently oriented laterally to the direction of movement. This standardization minimized technique-based variability in performance, as lateral movement mechanics significantly impact agility test outcomes (Spiteri et al., 2014). To ensure measurement validity, strict criteria were established for acceptable trial execution. Trials were immediately terminated and repeated following a minimum of the three-minute recovery period if participants: (1) crossed their feet during lateral movements, (2) failed to touch the designated cone, (3) changed direction before reaching the prescribed marker, (4) failed to maintain the proper body position during lateral movements, or (5) experienced a slip or a fall. The number of invalid trials was recorded (mean: 0.6 ± 0.7 per participant), with no significant difference between groups ($p = 0.814$). Participants performed three trials with 3 min of recovery between attempts, the duration shown to allow adequate ATP-PC system replenishment while minimizing learning effects between trials (Bishop et al., 2011). The best time was used for statistical analysis to capture peak agility performance potential (Sassi et al., 2009).

Dynamic Balance Test

Dynamic balance was evaluated using the Y-balance test, following the protocol described by Alkhathami (2023). Participants stood on their dominant leg while reaching as far as possible with the free leg in three directions: anterior, posteromedial, and posterolateral. The maximum reach distance in each direction was recorded. Three trials were performed for each direction, with the average used for analysis as recommended by Plisky et al. (2009). Composite scores were calculated as the sum of the three reach distances divided by three times the limb length, expressed as a percentage, providing a normalized measure of multi-directional dynamic balance (Lu et al., 2022).

The dynamic stretching exercises (Table 2) were selected based on established protocols validated in team sport athletes (Fletcher, 2010; Sheppard et al., 2009) and specifically tailored to address the muscle groups most active in volleyball performance. These exercises systematically target the gluteal, hamstring, adductor, quadriceps, and gastrocnemius muscle groups, which are critical for jumping, lateral movements, and rapid direction changes common in volleyball (Sheppard et al., 2009). This selection aligned with current recommendations for dynamic preparation specific to volleyball's movement demands (Krističević et al., 2016). The control group's warm-up comprised 5 min of light running, 5 min of walking (instead of stretching exercises), and 10 min of volleyball-specific exercises. The volleyball-specific drills (10 min) were identical for both groups, consisting of standardized technical exercises focused on passing, setting, attacking, and defensive movements typical of volleyball practice. These drills were designed and supervised by the same coaching staff for both groups to ensure consistency and followed a structured progression from fundamental skills to more game-like situations. The content and intensity of these drills were documented daily to verify equivalence between groups (Lidor & Ziv, 2010). The control group performed a warm-up without stretching but with time-matched low-intensity walking to isolate the specific effects of dynamic stretching while controlling for total warm-up duration and activity exposure. This design served as an active control condition rather than a placebo, following established experimental protocols in stretching research (Behm et al., 2023; Chaabene et al., 2019). Heart rate monitoring during both protocols confirmed comparable physiological demands between groups during the initial jogging phase (DS: 130 ± 8 bpm; CONT: 132 ± 7 bpm) and the final volleyball-specific phase (DS: 148 ± 10 bpm; CONT: 145 ± 11 bpm), with the only significant difference occurring during the experimental phase (dynamic stretching: 136 ± 9 bpm vs. walking: 115 ± 8 bpm; $p < 0.001$). This methodological approach enabled precise attribution of observed effects to the dynamic stretching protocol rather than confounding variables like total exercise duration or generalized activity exposure (Opplert and Babault, 2018). The control condition still incorporated elements of a practical warm-up (jogging and sport-specific drills) to maintain ecological validity while controlling for the independent variable.

Both treatments were provided five times weekly for six weeks, directly prior to regular training sessions. The dynamic stretching protocol was supervised by two physical trainers who demonstrated each exercise, provided verbal cues for proper execution, and monitored technique throughout all sessions. Intensity was standardized using verbal instructions to maintain controlled movement through the full range of motion without ballistic movements (Fletcher, 2010). Protocol fidelity was ensured through weekly team meetings to review implementation, standardized instruction scripts, and periodic cross-verification between supervisors. A checklist of critical exercise components was completed for each session to document adherence to protocol specifications.

Design and Procedures

This study investigated the impact of a 6-week dynamic stretching warm-up regimen on performance indicators in adolescent male volleyball players through a randomized controlled trial with parallel groups. Participants were randomly assigned to an experimental group (n = 14, dynamic stretching) or a control group (n = 16, no stretching) via a computer-generated sequence. Baseline measurements were completed one week prior to the intervention, and post-intervention evaluations were performed at the conclusion of the six-week program. The complete process is illustrated in the CONSORT flow diagram (Figure 1). This unbalanced distribution resulted from the simple randomization procedure using a computer-generated sequence, which can produce chance imbalances in group sizes while maintaining the unpredictability of treatment assignments. No participants dropped out during the randomization process. To minimize learning effects, all participants attended two familiarization sessions in the week preceding baseline testing. This protocol was implemented based on previous research demonstrating that two familiarization sessions are optimal for achieving measurement stability in performance tests, particularly for the Y-balance test and agility measures in adolescent athletes (Plisky et al., 2021). That study indicated that reliability significantly improved after the second practice session, with minimal additional benefit from further familiarization. The first session involved anthropometric measurements and medical screening. During the second session, players were acquainted with the dynamic stretching exercises and testing procedures for sprint performance, agility, and dynamic balance.

Intervention Protocol

During the six-week intervention, both groups adhered to their standard volleyball training regimens; the sole distinction was the warm-up protocol. The control group engaged in a warm-up without stretching, while the experimental group performed dynamic stretching.

The dynamic stretching protocol comprised 5 min of light jogging, 10 min of dynamic stretching exercises (Table 2), and 10 min of volleyball-specific drills. The dynamic stretching exercises aimed to engage essential muscle groups utilized in volleyball-specific movements, with each stretch lasting 30 s and performed twice. The dynamic stretching protocol duration (30 s, performed twice for each exercise) was established based on meta-analyses indicating optimal neuromuscular responses with 30–60 s of dynamic stretching per muscle group (Chaabene et al., 2019). This duration provides sufficient stimulus for acute improvements in range of motion while avoiding potential fatigue effects associated with prolonged dynamic stretching. The dual repetition approach allowed adequate neuromuscular preparation while maintaining efficient warm-up duration suitable for practical implementation in team sport settings.

Statistical Analysis

The analysis was conducted utilizing SPSS version 28.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was employed to assess normality of distribution, whereas the Levene's test was utilized to evaluate homogeneity of variance. Descriptive statistics were expressed as means ± standard deviation (SD). The within-subjects variable was time (pre-test vs. post-test), and the between-subjects variable was group (experimental vs. control), employed in a two-way repeated measure analysis of variance (ANOVA) to assess the intervention's effects. When the assumption of sphericity was violated, Greenhouse-Geisser corrections were applied. Effect sizes were computed via partial eta squared (η_p^2) and categorized as small (0.01–0.05), medium (0.06–0.13), or large (≥ 0.14) (Cohen, 2013). Upon discovering significant interactions, post-hoc pairwise comparisons were conducted utilizing Bonferroni-adjusted *t*-tests. Cohen's *d* was computed to assess the extent of between-group changes, utilizing values of 0.2, 0.5, and 0.8, which corresponded to small, medium, and large effects, respectively (Cohen, 2013). The percentage changes between the pre-test and post-test were computed using the formula ([post-test value − pre-test value] / pre-test value) x 100. Independent samples *t*-tests facilitated the comparison of percentage changes between groups. Test-retest reliability was assessed using intraclass correlation coefficients (ICC, model 3,1) and 95% confidence intervals. ICC scores were categorized as bad (< 0.40), fair (0.40–0.59), good (0.60–0.74), or excellent (> 0.75) (Koo & Li, 2016). The standard error of measurement (SEM) and the coefficient of variation (CV) exhibited total dependability. For all statistical analyses, the significance level was established at $p < 0.05$.

Results

Test Reliability Analysis

All tests employed in this study demonstrated good to excellent relative inter-session reliability, with ICC ranging from 0.70 to 0.94, except for the 5-m sprint test which exhibited low inter-session reliability (ICC = 0.27) (Table 3). Absolute reliability was generally good, as evidenced by SEM values below 5% and the CV less than 10% for most tests. However, the 5-m sprint test showed lower absolute reliability (SEM > 5%).

Inter-trial reliability was robust across all tests, with ICC values ranging from 0.77 to 0.99, indicating good to excellent reliability. Absolute reliability measures further supported this finding, with SEM values consistently below 5% and CV values under 10% (Table 4).

Agility Performance

Two-way repeated measures ANOVA (group × time) revealed no significant interaction between factors ($F = 0.55$, $p = 0.469$, $\eta_p^2 = 0.03$ [*small*], $\omega = 0.11$) for the modified T-test. This indicates that the 6-week dynamic stretching (DS) warm-up protocol did not significantly improve agility performance compared to the control (CONT) group (Table 5). The percentage change in agility performance showed no significant differences between DS and CONT groups ($p = 0.459$, $d = 0.33$ [*small*]) (Figure 2).

Sprint Performance

For the 5-m sprint test, two-way repeated measures ANOVA revealed a significant main effect of time (F = 25.43, p < 0.001, η_P^2 = 0.59 [*large*], ω = 1.00), but no significant group effect (F = 3.30, p = 0.086, η_P^2 = 0.16 [*large*], ω = 0.41) (Table 5). Pairwise comparisons indicated a decline in 5-m sprint performance for both DS (p = 0.017) and CONT (p = 0.19) groups following the 6-week intervention. The percentage change in sprint performance did not differ significantly between groups (p = 0.101, d = 0.78 [*moderate*]) (Figure 2).

Dynamic Balance Performance

For the Y-balance test considering the anterior direction, a significant interaction between the group and time was observed (F = 8.41, p = 0.010, η_P^2 = 0.32 [*large*], ω = 0.87) (Table 5). The DS group demonstrated significant improvement after the 6-week intervention (p = 0.004) and outperformed the CONT group at T1 (p = 0.001).

With regard to the posteromedial direction, analysis revealed a significant main effect of time (F = 13.68, p < 0.002, η_P^2 = 0.13 [*medium*], ω = 0.35), but no significant group effect (F = 3.91, p = 0.064, η_P^2 = 0.18 [*large*], ω = 0.47). The DS group showed significant improvement from T0 to T1 (p = 0.001) and performed better than the CONT group at T1 (p = 0.024).

Taking into account the posterolateral direction, significant main effects were observed for time (F = 7.38, p = 0.014, η_P^2 = 0.92 [*large*], ω = 0.73) and the group (F = 6.77, p = 0.018, η_P^2 = 0.27 [*large*], ω = 0.96), along with a significant interaction (F = 15.84, p = 0.001, η_P^2 = 0.47 [*large*], ω = 0.96) (Table 5). The DS group demonstrated significant improvement from T0 to T1 (p < 0.001) and outperformed the CONT group at T1 (p = 0.001).

Between-group comparisons of percentage changes (Figure 4) revealed significant differences in the anterior and posterolateral direction (p = 0.018, d = 1.14 [*moderate*] and p = 0.001, d = 1.72 [*large*], respectively), while no significant difference in the posteromedial direction (p = 0.205, d = 0.57 [*small*]).

Table 1. The characteristics of the participants: the experimental group (n = 14) and the control group (n = 16)*.

Variables	Age (years)	Body Mass (kg)	Body Height (m)	LLL (m)	BF (%)
DS	16.64 ± 0.50	72.27 ± 8.47	1.86 ± 0.08	1.12 ± 0.06	11.94 ± 3.20
CONT	16.31 ± 0.48	67.49 ± 6.18	1.81 ± 0.05	1.11 ± 0.04	11.46 ± 2.66

DS = experimental group; CONT = control group; LLL = lower limb length; BF = body fat,
** values are expressed as mean ± SD*

Table 2. Active dynamic stretching exercises.

Muscle groups	Stretching Exercises
Gluteus	Walk forward with knee raises up to the chest, trunk straight.
Hamstrings	Walk with kicks forward, the knee is kept in full extension, the foot is kept in a neutral position.
Adductors	Walk forward with lateral elevation of the knee, the leg is bent at 90° “hedge crossing position”.
Quadriceps	Walk forward with heels on your buttocks.
Gastrocnemius	Walk forward with rolling feet. Raise the body as high as possible on the tip of the toe while keeping the trunk straight.

Table 3. Indices of relative and absolute inter-session reliability of the 5-m sprint, the modified T-test, the anterior Y-balance test, the posteromedial Y-balance test and the posterolateral Y-balance test (n = 13).

Variables	Mean ± SD		ICC (95%CI)	CV%	SEM (%)
	Trial 1	Test 2			
Agility test (s)	5.63 ± 0.30	5.58 ± 0.24	0.70 (0.26–0.60)	3.81	0.12 (2.09)
5-m sprint (s)	1.03 ± 0.07	1.05 ± 0.05	0.27 (−1.39–0.77)	7.36	0.07 (6.29)
Anterior Y-balance test (m)	0.78 ± 0.07	0.79 ± 0.07	0.87 (0.57–0.96)	6.30	0.02 (2.27)
Posteromedial Y-balance test (m)	1.15 ± 0.09	1.12 ± 0.08	0.87 (0.58–0.96)	5.05	0.02 (1.82)
Posterolateral Y-balance test (m)	1.16 ± 0.08	1.15 ± 0.10	0.94 (0.80–0.98)	3.80	0.01 (0.93)

ICC = intraclass correlation coefficient; CV = coefficient of variation; SEM = standard error of measurement

Table 4. The relative and absolute intra-session reliability indices of the 5-m sprint test, the modified T-test, the anterior Y-balance test, the posteromedial Y-balance test and the posterolateral Y-balance test (n = 13).

Variables	Mean ± SD		ICC (95%CI)	CV%	SEM (%)
	Trial 1	Test 2			
Modified T-test (s)	5.76 ± 0.30	5.72 ± 0.30	0.88 (0.61–0.96)	3.45	0.07 (1.20)
5-m sprint (s)	1.09 ± 0.07	1.07 ± 0.06	0.77 (0.24–0.93)	4.94	0.03 (2.37)
Anterior Y-balance test (m)	0.75 ± 0.07	0.78 ± 0.07	0.99 (0.96–0.99)	2.06	0.002 (0.21)
Posteromedial Y-balance test (m)	1.12 ± 0.09	1.14 ± 0.09	0.97 (0.89–0.99)	2.98	0.01 (0.52)
Posterolateral Y-balance test (m)	1.13 ± 0.08	1.15 ± 0.10	0.98 (0.93–0.99)	2.25	0.004 (0.32)

ICC = intraclass correlation coefficient; CV = coefficient of variation; SEM = standard error of measurement

Table 5. The results of the 5-m sprint, the modified T-test, the anterior Y-balance test, the posteromedial Y-balance test and the posterolateral Y-balance test at two measurement points: before (T0) and after (T1) the intervention (pre- and post-test).

		DS (n = 14)	CONT (n = 16)	Main Effects		Interactions
				Time	Group	Time × Group
Modified T-test (s)	T0	6.02 ± 0.35	5.96 ± 0.43	F = 1.98 $p = 0.177$	F = 0.01 $p = 0.935$	F = 0.55 $p = 0.469$
	T1	5.87 ± 0.24	6.09 ± 0.39	$\eta^2_p = 0.10$ *ώ = 0.27*	$\eta^2_p = 0.01$ *ώ = 0.05*	$\eta^2_p = 0.03$ *ώ = 0.11*
5-m sprint (s)	T0	0.88 ± 0.05 [a]	0.89 ± 0.07 [a]	F = 25.43 $p < 0.001$	F = 1.75 $p = 0.203$	F = 3.30 $p = 0.086$
	T1	0.94 ± 0.08	0.99 ± 0.07	$\eta^2_p = 0.59$ *ώ = 1.00*	$\eta^2_p = 0.09$ *ώ = 0.24*	$\eta^2_p = 0.16$ *ώ = 0.41*
Anterior Y-balance test (m)	T0	0.72 ± 0.05 [a]	0.73 ± 0.09	F = 2.13 $p = 0.162$	F = 3.48 $p = 0.078$	F = 8.41 $p = 0.010$
	T1	0.80 ± 0.06b	0.70 ± 0.04	$\eta^2_p = 0.11$ *ώ = 0.28*	$\eta^2_p = 0.16$ *ώ = 0.42*	$\eta^2_p = 0.32$ *ώ = 0.78*
Posteromedial Y-balance test (m)	T0	1.07 ± 0.10 [a]	1.02 ± 0.10	F = 13.68 $p = 0.002$	F = 3.91 $p = 0.064$	F = 2.78 $p = 0.113$
	T1	1.14 ± 0.11 [b]	1.02 ± 0.08	$\eta^2_p = 0.13$ *ώ = 0.35*	$\eta^2_p = 0.18$ *ώ = 0.47*	$\eta^2_p = 0.13$ *ώ = 0.35*
Posterolateral Y-balance test (m)	T0	1.07 ± 0.10 [a]	1.04 ± 0.06	F = 7.38 $p = 0.014$	F = 6.77 $p = 0.018$	F = 15.84 $p = 0.001$
	T1	1.19 ± 0.09b	1.02 ± 0.07	$\eta^2_p = 0.29$ *ώ = 0.73*	$\eta^2_p = 0.27$ *ώ = 0.96*	$\eta^2_p = 0.47$ *ώ =0.96*

DS = experimental group; CONT = control group; T0 = before the intervention; T1 = after the intervention; η_p^2 = effect size; ώ = statistical power; [a] significant difference ($p < 0.05$) before and after the intervention; [b] significant difference ($p < 0.05$) between the experimental and the control group

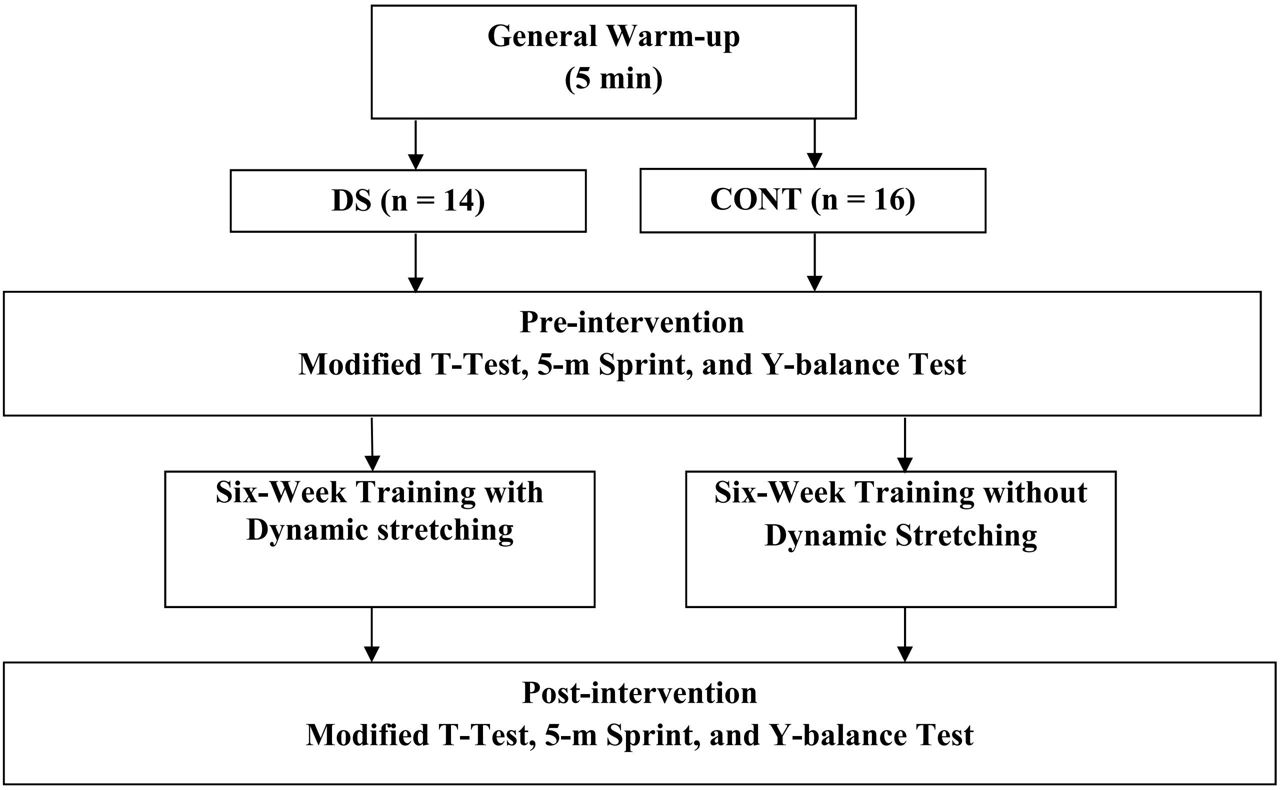

Figure 1. Experimental protocol.
DS = experimental group; CONT = control group

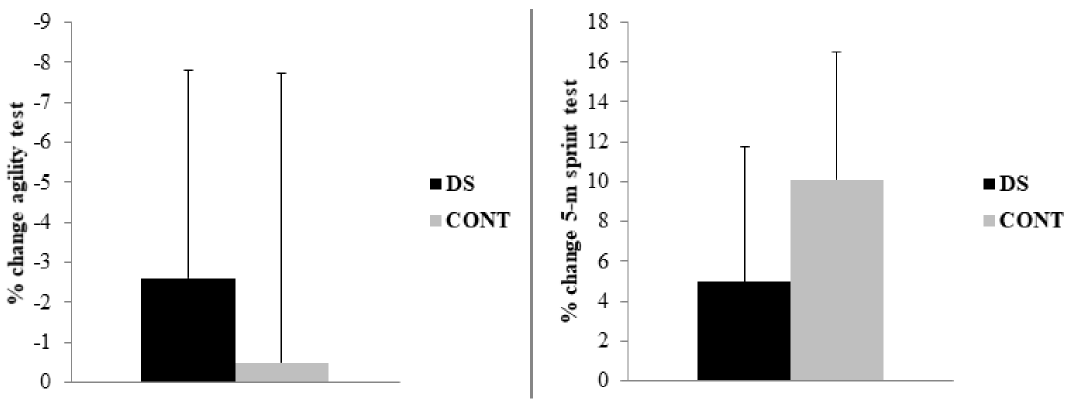

Figure 2. Comparison of pre- and post-intervention percentages of change in agility and 5-m sprint performance between the experimental (DS) and the control group (CONT).

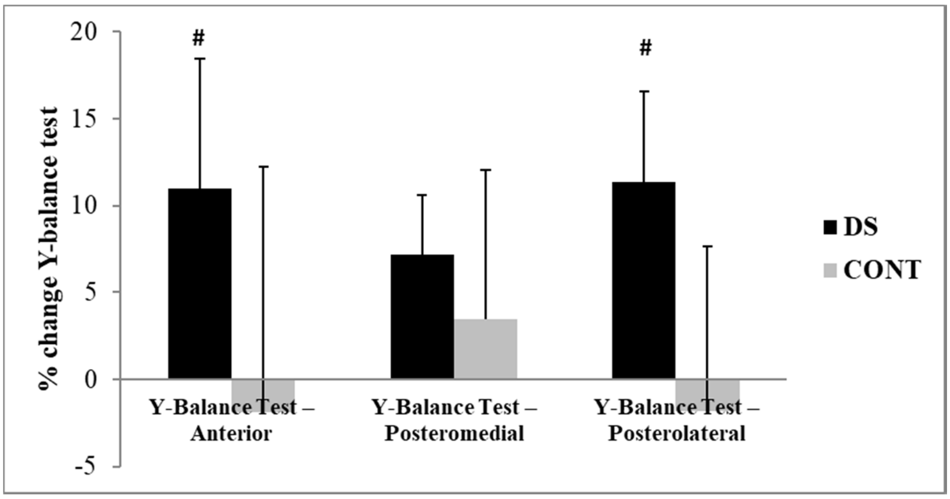

Figure 3. Comparison of the percentages of change in the performance of the Y-balance test in the three directions, between the experimental (DS) and the control group (CONT), before and after six weeks of the intervention.
#: significant differences ($p < 0.05$) between the experimental and the control group

Discussion

This randomized controlled trial sought to address a critical knowledge deficiency regarding the long-term effects of interventions in young athletes by examining the influence of a 6-week dynamic stretching warm-up protocol on sprint performance, agility, and dynamic balance in adolescent male volleyball players. Our data revealed a complex link between these performance indicators and the intervention; sprint and agility performance exhibited no change, whereas dynamic balance, especially in the anterior and posterolateral directions, showed significant improvements. The specific improvement in balance, without corresponding enhancements in sprinting and agility performance, illustrates the complex nature of neuromuscular responses to dynamic stretching methods.

The Y-balance test results revealed that our intervention led to a quite significant improvement in dynamic balance. The experimental group (DS) showed very significant improvement in all three directions (anterior, posteromedial, and posterolateral) after the 6-week dynamic stretching intervention. These results confirm earlier research on the favorable effects of dynamic stretching on proprioception and neuromuscular control (Heil et al., 2020; Iwata et al., 2019), hence improving knowledge about this particular population of teenage volleyball players.

The mentioned improvements in dynamic balance especially apply to volleyball players since the nature of the game is defined by frequent jumps, landings, and quick directional changes. Improved dynamic balance may help improve postural control, therefore lowering the risk of lower extremity injuries (Heil et al., 2020). Moreover, the noted enhancements in dynamic balance may result in improved on-court performance, especially in tasks necessitating stability during fast movements and directional shifts, which are frequent in volleyball (Hrysomallis, 2007). Hrysomallis (2007) observed that greater balancing skill correlated with a reduced incidence of ankle injuries in team sports, such as volleyball.

The processes behind these balance improvements most certainly involve improved proprioceptive acuity and muscle activation patterns (Kröger and Watkins, 2021). Dynamic stretching increases Golgi tendon organ activity and muscle spindle sensitivity, therefore improving joint position sensation and kinesthetic awareness (Kröger and Watkins, 2021). Furthermore, the repetitive qualities of dynamic stretching workouts could have improved motor unit recruitment and inter-muscular synchronization, thereby enabling more effective postural control strategies (Kröger & Watkins, 2021).

The anterior and posterolateral routes exhibited more substantial alterations than the posteromedial direction. This distinctive response may be ascribed to the particular movement patterns emphasized in volleyball, which predominantly involve anterior and lateral motions rather than posteromedial movements (Vittala et al., 2021). The dynamic stretching exercise did not markedly enhance 5-m sprint performance or agility, as assessed by the modified T-test, contradicting our initial hypothesis and certain previous studies (Behm et al., 2023; Borzucka et al., 2024). This emphasizes the need of a thorough knowledge of stretching consequences in environments related to sports. These results are contradictory to earlier studies showing that dynamic stretching improved sprint and agility performance in team sports (Behm et al., 2023; Borzucka et al., 2024). The specificity principle in training adaptations could help clarify the difference between improved balance and unaltered sprint and agility performance (Borzucka et al., 2024; Zemková et al., 2025). Dynamic stretching studies have revealed various post-stretch responses including no significant effects (Saw et al., 2015), enhanced performance (Behm et al., 2023), and damage to the extended limb (Chaouachi et al., 2010). Our results support those of Ltifi et al. (2023) who observed no significant improvement in sprint performance or change-of-direction speed among youth male handball players after a 4-week dynamic stretching program.

The diverse physiological demands of the applied tests elucidated the differences in balance and sprint performance. While sprint tests require maximal power and explosive strength, the submaximal Y-balance test is more targeted at proprioceptive and vestibular systems (Ibrahim et al., 2025; Paradisis et al., 2014). This duality indicates that dynamic stretching may enhance neuromuscular control systems without markedly diminishing high-velocity force production capacities. In contrast, the dynamic stretching exercises we executed might not have delivered adequate specific loading to induce alterations in sprint and agility performance. According to Qiu et al. (2023), alterations in these variables may need more focused, high-intensity training stimuli that closely reflect the demands of particular activities. Moreover, although adequate to elicit modifications in dynamic balance, the 6-week intervention duration may have been not sufficient to substantially enhance sprint and agility performance. To this end, longer intervention duration may be required to exhibit substantial alterations (Lu et al., 2022). Conversely, although pertinent to volleyball-specific movements, the 5-m sprint test may lack the sensitivity to identify subtle variations in acceleration capability. The effect of stretching intensity specifically, maximal or discomfort-level stretching vs. submaximal static stretching on subsequent performance remains a contentious issue in the literature (Bryant et al., 2023).

Our participants maintained their regular volleyball practice during the study period. The requirements of sport-specific training, particularly in elite athletes, may have hindered possible adaptations from the dynamic stretching regimen (Keoliya et al., 2024). The substantial standard deviations in response to the intervention indicated that individual characteristics, including the training background, genetic predisposition, and baseline fitness levels, may have affected the outcomes (Chmelo et al., 2015). These findings underscore the challenges in formulating suitable warm-up protocols for youth athletes and the necessity for further research to determine the ideal variables for enhancing various aspects of sports performance. Future research ought to encompass a more extensive array of assessments, incorporating volleyball-specific performance indicators, to comprehensively elucidate the practical ramifications of dynamic stretching protocols in this demographic.

Finally, we need to acknowledge some limitations of the present study. Indeed, the six-week intervention duration might have been not sufficient to demonstrate significant differences in performance measures. There is a need of longitudinal research to evaluate potential delayed impacts on various performance indicators. Other performance criteria such as jump height, power output, and sport-specific skills could allow to better understand how such an intervention influenced general volleyball performance. Future studies could include a wider range of performance measures and physiological indicators to generate a more complete knowledge of the effects of prolonged dynamic stretching interventions, even while concentrating on specific performance outcomes including sprinting, agility, and dynamic balance.

Conclusions

The findings of this study indicate that a 6-week dynamic stretching warm-up regimen can markedly enhance the dynamic balance of youth male volleyball athletes. Despite the absence of notable improvements in sprint or agility performance, the enhancement in dynamic balance holds substantial implications for injury prevention and general athletic development within this population.

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