***Journal of Sport Biomechanics***

 ***(P-ISSN: 2476-4906) (E-ISSN: 2476-5937)***

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**Effects of an Integrated Balance and Muscle Tension Control Training Program on Kinematic Variables and Defensive Accuracy in Volleyball Players**

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# Abstract

**Objective**: This study aims to investigate the impact of integrated training on kinematics variables and defensive accuracy in volleyball, focusing on enhancing balance and muscle tension control through proprioceptive neuromuscular facilitation (PNF) exercises. **Methods**: The sample consisted of 14 male volleyball athletes from the first volleyball league of Al-Jaish Sports Club were divided into experimental (n=7) and control group (n=7). In the pre- and post-intervention periods, dynamic balance, muscle tension control and kinematic variables (during a lateral reaching task) as well as defensive performance accuracy upon fatigue onset of recoil laser strikes were assessed. Exposure The intervention program was carried out for six weeks, and the following measuring tools were used to assess performance, Y-Balance Test as well as sEMG and kinematic variables using Kinovea. **Results**: Compared with the control- group, individuals in the experimental- group demonstrated significantly improved performance at balance (Y-Balance Test, Cohen's d = 1.42), muscle activity and tension control (sEMG, Cohen's d = 1.38) and defensive ability accuracy (Cohen's d = 1.60). Kinematic variables revealed moderate to large enhancements in knee, hip, shoulder, elbow ankle and trunk angles where effect size ranged from 1.03 to 1.49 (Cohen's d). Control group, as expected, showed mild changes in all studied variables. **Conclusion**: The combined training program enhanced volleyball players’ biomechanical efficiency and defensive performance, highlighting its potential to boost performance, reduce injury risk, and improve coaching effectiveness.

# Keywords

Muscle Balance, Muscle Tension Control, Proprioceptive Neuromuscular Facilitation (PNF), Defensive Performance in Volleyball.

# Introduction

Volleyball is an intermittent, high-intensity sport that involves a unique mix of strength, agility, coordination and precise neuromuscular control. In addition, the capacity to remain centered and regulate muscle tension are crucial attributes of defensive performance which depend largely on the ability of a player to perform movements with respect to maintaining good body balance over unstable conditions such as blocking, receiving or high-speed cross step (1). These qualities are also influential in sporting accomplishment and have a major contribution to the prevention of injury (2).

Balance is closely related to several physical components of athletic stability, including faster reaction times, optimal movement efficiency, and better injury prevention (3,4). Equally important is the ability to modulate muscle tension, balancing forceful contractions with necessary relaxation during execution. This helps maintain maximal technique while minimizing exhaustion from explosive exertions (5). Previous studies proved that PNF and balance exercises create an improvement of neuromuscular coordination and joint stability (3,6).

In addition to balance, the regulation of muscle tension is a fundamental component of athletic performance, particularly in sports requiring rapid and repeated defensive actions such as volleyball. Muscle tension control refers to the athlete’s ability to modulate contraction and relaxation levels in specific muscle groups according to task demands (7). Effective tension regulation enhances motor coordination, supports energy efficiency, and prevents unnecessary co-contractions that may limit movement speed or increase fatigue (8). Moreover, inadequate muscle tension control has been associated with an increased risk of overuse injuries and reduced technical accuracy in high-intensity sports (9).

Several approaches have been proposed to improve muscle tension regulation, including proprioceptive neuromuscular facilitation (PNF), relaxation techniques, and combined strength–flexibility programs. These interventions have demonstrated positive effects on neuromuscular efficiency, movement fluidity, and the coordination between agonist and antagonist muscles during complex, sport-specific actions (10,11). Despite this evidence, most research has investigated these methods in isolation, and little is known about their combined effect with balance training on defensive performance in volleyball.

While the benefits of balance training and muscle tension control have been explored independently, there is a notable gap in research examining their combined impact within an integrated training framework, particularly in the context of volleyball. Existing studies tend to isolate these variables—either focusing on proprioceptive training to improve lower-limb control and defensive performance (12,13), or exploring the effects of Muscle tension programs on flexibility and neuromuscular efficiency (14). However, these segmented approaches fail to account for the potential synergistic effects that may arise when both balance and Muscle tension are trained simultaneously. Furthermore, few studies have examined how such integration influences kinematic variables—including the knee, hip, shoulder, elbow, ankle, and trunk—and their relationship to defensive skill accuracy (15).

Despite the recognized importance of balance training and muscle tension control in improving athletic performance, current research in volleyball has predominantly examined these components in isolation. Balance-focused programs have been shown to enhance proprioception, stability, and joint control, while interventions targeting muscle tension regulation contribute to improved neuromuscular efficiency and reduced fatigue. However, little evidence exists regarding their combined effect as part of an integrated training program. Furthermore, few studies have systematically investigated how such integration may influence sport-specific kinematic variables—such as hip, knee, ankle, shoulder, and trunk movements—and their direct relationship to defensive accuracy in volleyball. This lack of integrated evidence creates a gap in the literature, highlighting the need for a structured program that unifies these two training dimensions and evaluates their synergistic impact on both biomechanical efficiency and defensive performance outcomes. The novelty of this research lies in its dual-focus approach, combining proprioceptive balance exercises with targeted muscle tension control techniques. This integrated method directly measures their effects on sport-specific defensive performance. By providing empirical evidence of the biomechanical and performance benefits of this integrated approach, the study offers a new, evidence-based model for conditioning programs in volleyball that could also be adapted to other dynamic, high-intensity sports.

# Materials and Methods

## **Research Design**

The experimental group performed a combined training program, while the control group maintained its physical activity routine (two parallel groups). To determine the effects of the intervention, pre- and post-tests were conducted based on measures of dynamic balance, lower-limb muscle activation (as indicated by sEMG), kinematics variables, and defensive skill accuracy. The age, height, weight and training experience of the participants were recorded as baseline measurements before intervention to provide group equivalence.

## **Participants**

The sample consisted of fourteen male first-division volleyball players from Al-Jaish Sports Club, purposively selected to ensure homogeneity in competitive level and training background. All participants signed informed consent forms after receiving a full explanation of the study’s aims, procedures, and potential risks and benefits.

A priori sample size estimation was conducted using G\*Power software based on an expected medium effect size (f = 0.25), an alpha level of 0.05, and a desired power of 0.80 for repeated-measures ANOVA with two groups and two measurement points. The analysis indicated that a minimum of 24 participants would be required to achieve adequate statistical power. However, due to the fact that the club roster included only 14 players, the sample size could not be expanded. This limitation may restrict the generalizability of the results to other teams or competitive levels. Nevertheless, the use of reliable and validated measurement tools ensured robust findings within the specific context of the available sample.

An integrated training program was utilized by the experimental group (n = 7) while control group participants (n = 7) continued with standard training. As showed in **Table 1**, there were no significant between-group differences when comparing age, height, weight and training experience at the baseline measurement level reflecting their equivalence before the intervention period.

### **Table 1. Baseline Characteristics and Equivalence Between Experimental and Control Groups**

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Experimental Group (n=7) | Control Group (n=7) | p-value |
| Age (years) | 23.8 ± 2.5 | 24.1 ± 2.3 | 0.80 |
| Height (cm) | 180.5 ± 4.0 | 179.8 ± 4.3 | 0.72 |
| Weight (kg) | 74.2 ± 3.8 | 73.9 ± 4.1 | 0.85 |
| Experience (years) | 4.3 ± 1.2 | 4.4 ± 1.1 | 0.90 |
| \*: significant at p<0.05 |

## **Equipment and Measurement Tools**

Dynamic balance was assessed using the Lower-Quarter Y-Balance Test (YBT), performed with standardized stance and three reach directions: anterior, posteromedial, and posterolateral. Reach distances were normalized to limb length using the formula (reach distance / leg length × 100). Following a familiarization session, For the Lower-Quarter Y-Balance Test (YBT), each participant performed three successful trials per limb and per reach direction. Invalid attempts, such as lifting the stance foot or using hand support, were repeated. The YBT has demonstrated high reliability (ICC ≈ 0.85–0.93) and strong validity for use in athletic populations (Plisky et al., 2006). In this study, the scores for the dominant and non-dominant limbs were calculated and presented separately in the table to provide detailed insights into limb-specific balance performance and improvements following the integrated training program. The composite score for each limb was computed by averaging the three reach directions (16).

Lower-limb muscle activation was assessed using wireless surface electromyography (sEMG), targeting specific muscles within the quadriceps, hamstrings, and gastrocnemius groups: Rectus Femoris (RF), Biceps Femoris (BF), and Medial Gastrocnemius (MG), respectively. These muscles were selected due to their key role in postural stability, lateral defensive movements, and jump-landing tasks in volleyball. EMG signals were normalized to each participant’s maximum voluntary isometric contraction (MVIC), measured according to SENIAM guidelines, to allow meaningful comparisons between participants and to express muscle activity relative to maximal capacity (%MVIC). Muscle activity was recorded continuously throughout the entire defensive task, and Root Mean Square (RMS) values were calculated both over the full task duration and at peak contraction points. This approach provides a comprehensive assessment of muscle tension control, reflecting the athletes’ ability to dynamically modulate muscle activation during functional sport-specific movements (17). The evaluations were done on the dominant and non-dominant portions of the body. These muscles were chosen as they play an important role in balance control, and protective movements such as jumping, landing and lateral movements in volleyball (18). We selected the dominant side since aspects of muscle strength differ between sides (within individuals), and we aimed to examine primary muscle activation during athletic actions on one side, while including the non-dominant side in order to detect differences in muscle activation. Specifically, for the dynamic movement phase data were collected on surface electromyographic (EMG) measures obtained during defensive tasks involving jumps to block and lateral defensive maneuvers. These tasks were specifically chosen due to the high degree of muscle activation required and tailoring data collection during these movements allows for detailed examination of muscle behavior under stress in game-related situations. Skin preparation involved shaving, light abrasion, and cleaning with alcohol. Electrodes were placed in accordance with SENIAM guidelines (19), with an inter-electrode distance of approximately 20 mm and alignment parallel to muscle fibers. Data were sampled at ≥1000 Hz, band-pass filtered between 20–450 Hz, with a 50 Hz notch filter to remove mains interference, then rectified and smoothed using a root mean square (RMS) window of 50 ms.

Kinematic variables, including knee, hip, shoulder, elbow, ankle, and trunk angles, were captured using high-speed video cameras (120 fps) positioned on tripods 5–8 meters away and perpendicular to the plane of motion. A total of ten reflective markers were placed on key anatomical landmarks: anterior and posterior superior iliac spines (ASIS and PSIS) for pelvis tracking, greater trochanter for hip motion, lateral epicondyle of the knee for knee movement, lateral malleolus for ankle movement, acromion process for shoulder kinematics, lateral epicondyle of the elbow for elbow motion, and the C7 vertebra for trunk monitoring.

In this study, joint angles were specifically analyzed during the take-off, flight, and landing phases of defensive skill tasks, as well as during lateral movements associated with blocking and ball redirection. Each participant performed three successful trials per task, and the angles were measured for each trial. The mean values of these trials were used for statistical analysis to ensure reliability and reduce the influence of outliers. This approach allowed for a detailed assessment of the kinematic adaptations resulting from the integrated training program.

Anatomical landmarks were used to establish reference frames for the definition of joint angles to ensure accurate measurement. Joint angles were defined relative to the physiological alignment of body segments—for example, the knee angle was calculated between the thigh and shank, and the elbow angle between the upper arm and forearm. A calibration frame with metered markers provided a pixel-to-metric scale for precise measurements.

For each joint, the specific anatomical plane was clearly accounted for: knee flexion/extension was measured in the sagittal plane, hip abduction/adduction in the frontal plane, shoulder flexion/extension in the sagittal plane, shoulder abduction/adduction in the frontal plane, elbow flexion/extension in the sagittal plane, ankle dorsiflexion/plantarflexion in the sagittal plane, and trunk lateral flexion/rotation in the frontal and transverse planes, respectively.

This method ensures that joint angles were accurately and reliably assessed for all subjects and that the motion of each joint was analyzed according to its primary physiological plane of movement.

 A calibration frame with metered markers was used to establish the pixel-to-metric scale. To reduce parallax, camera optical axes were aligned with the movement plane, and lighting conditions were kept constant. Motion analysis was performed using Kinovea software (versions 0.8x/0.9x), which has demonstrated high inter- and intra-rater reliability and good agreement with three-dimensional motion capture systems. Kinematic data were filtered using a low-pass Butterworth filter with a cutoff frequency of 6 Hz to reduce high-frequency noise from marker tracking and small tremors. The filtering process ensures smoother joint angle curves and more accurate representation of actual biomechanical movements. Joint angles were calculated after filtering to minimize the effect of measurement artifacts and to allow precise assessment of changes in knee, hip, shoulder, elbow, ankle, and trunk angles during defensive tasks (20–23).

## **Procedure**

Before the formal testing, all participants attended a structured familiarization session to ensure full understanding of testing protocols and to minimize learning effects. The session included a detailed demonstration of the Lower-Quarter Y-Balance Test (YBT) and the defensive skill tasks, followed by supervised practice. During this phase, correct body positioning, movement execution, and task-specific rules were explained, and participants received feedback to correct deviations from standardized procedures.

Each training/testing session lasted approximately 2 hours per participant. The experimental group performed a six-week integrated training program combining balance exercises on unstable surfaces, proprioceptive neuromuscular facilitation (PNF) stretching, and muscle tension control drills.

In the integrated training program, muscle tension control was addressed through structured drills aimed at improving athletes’ ability to alternate between contraction and relaxation during sport-specific actions. Progressive muscle relaxation techniques were employed, where players deliberately contracted and released major muscle groups of the lower limbs, trunk, and shoulders in timed cycles. This method has been shown to enhance neuromuscular awareness and reduce unnecessary co-contractions during performance (24). Additionally, proprioceptive neuromuscular facilitation (PNF) stretching with contract–relax sequences was included to optimize the coordination between agonist and antagonist muscles, thereby improving the efficiency of force application and movement fluidity (25). Controlled breathing strategies were also integrated, as diaphragmatic breathing combined with postural stabilization has been demonstrated to regulate muscle tension, improve trunk stability, and delay the onset of fatigue in high-intensity tasks (26). These elements were progressively incorporated into defensive stances, blocking simulations, and lateral shuffles, enabling players to practice tension modulation under conditions resembling actual match demands. Each session allocated approximately 10–15 minutes for muscle tension control exercises within the two-hour training block, with gradual progression in intensity and complexity across the six-week program.

 Training intensity was gradually increased based on perceived exertion (RPE scale 6–8 out of 10) and monitored by the coaching staff. The control group maintained their regular volleyball training routine, which consisted of standard skill and conditioning drills at similar duration but without specific balance or muscle tension interventions.

For the Y-Balance Test (YBT), each participant performed three trials per leg in three directions (anterior, posteromedial, posterolateral). Both the dominant and non-dominant legs were assessed to provide a complete profile of lower-limb balance and asymmetry. Dominance was determined by asking participants which leg they preferred to use when kicking a ball. The mean score of the three trials for each leg was calculated separately for analysis. In addition, the composite score for each participant was obtained by averaging the normalized reach distances of the dominant and non-dominant legs, following standardized protocols (27). Rest intervals of 60–90 seconds were provided between trials to minimize fatigue. Among the 14 participants, 9 were right-foot dominant and 5 were left-foot dominant, ensuring representation of both foot-dominance types in the sample.

Kinematic analysis was conducted during defensive volleyball tasks that simulated game conditions. The tasks included jumping, blocking, and lateral movements, performed without the ball to focus on movement mechanics. The net height was set at standard men’s regulation height (2.43 m). Each defensive movement was performed three times, and the average of the three trials was used for analysis. Kinematic data were collected from the moment of initiation of the lateral or vertical movement until landing, ensuring capture of the entire action sequence.

Defensive performance accuracy in volleyball was operationally defined as the degree to which players executed defensive movements in accordance with established technical criteria, including correct foot placement, trunk alignment, arm positioning, and the effective redirection of the simulated ball trajectory. Accuracy was therefore not limited to the outcome of the movement but also encompassed the quality and precision of motor execution during defensive actions. This approach aligns with previous definitions of performance accuracy in sport, where accuracy is described as the extent to which an observed performance matches a desired target or technical model (28,29). Within volleyball specifically, performance accuracy has been linked to the athlete’s ability to position the body efficiently in space and to control kinematic patterns that support successful defensive responses (30). Accordingly, in this study, defensive accuracy was scored based on predefined criteria evaluated from video analysis, emphasizing both the biomechanical quality of execution and the success of defensive outcomes.

All testing took place on the same indoor volleyball court with standard lighting conditions. Participants wore their regular court shoes and attire to replicate typical training conditions. Testing sessions were scheduled within the same two-hour window in the late afternoon to reduce circadian variation effects. Video recordings for kinematic analysis were conducted from fixed camera positions, stored securely, and anonymized. Analysts digitizing joint angles in Kinovea were blinded to group allocation and testing phase. Quality control was ensured by re-digitizing 20% of trials to calculate intra- and inter-rater reliability.

## **Data Analysis**

All statistical analyses were performed using SPSS (ver. 26). Paired t-tests were used to compare pre- and post-test scores within each group, while independent t-tests were used to compare post-test differences between the experimental and control groups. Cohen’s d was calculated to determine the effect size of the intervention.

The primary variables analyzed included: dynamic balance (YBT composite score), muscle activation (RMS sEMG), kinematics variables (knee, hip, shoulder, elbow, ankle, and trunk angles), and defensive skill accuracy.

# Results

The results presented in the two tables illustrate the effects of the integrated training program on physical performance and biomechanical variables in the experimental group compared to the control group. **Table 2** shows that the experimental group demonstrated significant improvements across all measured variables—balance (YBT score), muscle tension control (sEMG), and defensive performance accuracy—with p values below 0.05 and large effect sizes (Cohen’s d > 1.3). In contrast, the control group showed no significant changes, except for a moderate improvement in muscle tension control. **Table 3** indicates that the experimental group exhibited notable and significant changes in key joint angles (knee, hip, shoulder, elbow, ankle, and trunk) following the intervention, with medium to large effect sizes. The control group, however, displayed no substantial changes in kinematics variables. **Figure 1** illustrates pre test and post test comparisons of balance (YBT score), muscle tension control (sEMG units), and defensive performance accuracy (%) for the experimental group and control groups. The experimental group shows marked improvements in all three variables after the intervention, with noticeable increases from pre- to post-test, whereas the control group exhibits minimal changes, indicating the effectiveness of the integrated training program. **Figure 2** shows the comparison of kinematic variables between the experimental and control groups in the pre- and post-training test. The figure shows that most joints (e.g. knee, shoulder, elbow, trunk) experienced a significant from pretest to posttest in the experimental group, while the changes in the control group remained less pronounced or almost constant, indicating the effect of training on improving the angles of some joints.

### Table 2. Pre- and Post-Training Comparison of Balance, Muscle Tension Control, and Defensive Performance Accuracy

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variable | Group | Pre-Test (Mean ± SD) | Post-Test (Mean ± SD) | t-value | p-value | Cohen’s d |
| Balance (YBT score) | Experimental | 21.5 ± 2.1 | 24.8 ± 2.5 | 3.67 | 0.005\* | 1.42 |
| Control | 21.3 ± 2.3 | 21.5 ± 2.1 | 0.33 | 0.75 | 0.14 |
| Muscle Tension Control (sEMG units) | Experimental | 63.5 ± 5.4 | 80.5 ± 6.2 | 5.31 | 0.002\* | 1.38 |
| Control | 63.3 ± 5.0 | 70.3 ± 5.8 | 2.58 | 0.03\* | 0.87 |
| Defensive Performance Accuracy (%) | Experimental | 70.5 ± 5.4 | 85.2 ± 4.6 | 6.13 | 0.001\* | 1.60 |
| Control | 71.2 ± 6.1 | 74.8 ± 5.8 | 1.56 | 0.09 | 0.61 |
| \*: significant at p<0.05Note: YBT = Y-Balance Test; sEMG = surface electromyography. p-values from paired t-tests within groups. Cohen’s d indicates effect size: 0.2 = small, 0.5 = medium, ≥0.8 = large. |

### Table 3. Pre- and Post-Training Comparison of Kinematic variables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variable | Group | Pre-Test (Mean ± SD) | Post-Test (Mean ± SD) | t-value | p-value | Cohen’s d |
| Knee Angle (°) | Experimental | 135.0 ± 5.3 | 133.4 ± 4.8 | 3.33 | 0.012\* | 1.39 |
| Control | 134.9 ± 5.0 | 134.7 ± 4.5 | 0.33 | 0.85 | 0.14 |
| Hip Angle (°) | Experimental | 42.0 ± 2.1 | 39.5 ± 2.0 | 2.50 | 0.030\* | 1.09 |
| Control | 41.8 ± 2.3 | 41.7 ± 2.2 | 0.50 | 0.62 | 0.28 |
| Shoulder Angle (°) | Experimental | 92.0 ± 2.8 | 88.0 ± 2.6 | 3.08 | 0.020\* | 1.49 |
| Control | 91.8 ± 2.9 | 89.2 ± 2.7 | 1.44 | 0.17 | 0.79 |
| Elbow Angle (°) | Experimental | 160.0 ± 5.1 | 155.0 ± 4.8 | 2.78 | 0.025\* | 1.15 |
| Control | 160.5 ± 4.7 | 159.8 ± 4.9 | 1.56 | 0.10 | 0.75 |
| Ankle Angle (°) | Experimental | 20.0 ± 2.1 | 18.0 ± 1.9 | 2.22 | 0.040\* | 1.03 |
| Control | 19.8 ± 2.0 | 19.5 ± 2.1 | 0.78 | 0.46 | 0.18 |
| Trunk Angle (°) | Experimental | 30.0 ± 3.2 | 28.0 ± 3.1 | 2.50 | 0.035\* | 0.93 |
| Control | 29.8 ± 3.1 | 29.4 ± 3.2 | 1.22 | 0.25 | 0.42 |
| \*: significant at p<0.05Note: All joint angles measured in degrees (°) using 2-D motion analysis in Kinovea. Positive changes indicate improved biomechanical positioning. p-values from paired t-tests within groups; Cohen’s d interpreted. |



### Figure 1: Comparison of Balance, Muscle Tension Control, and Defensive Performance Accuracy



### **Figure 2**: Comparison of Kinematic variables

# Discussion

The results strongly support the research hypothesis, showing that the experimental group experienced significant improvements in balance, muscle tension control, defensive performance accuracy, and kinematic variables, while the control group exhibited minimal or no changes. These findings indicate that the integrated training program effectively enhances both neuromuscular coordination and biomechanical efficiency in volleyball players.

With regard to the first objective—improving balance—the experimental group showed clear improvements, supporting the idea that proprioceptive and unstable-surface training effectively enhances athletes’ balance. These findings are consistent with previous research (1,2) that highlight the role of balance training in reducing injury risk and improving performance.

The integration of balance and muscle tension control training has been shown to enhance defensive performance in volleyball players. Duchene et al. (2023) found that core stability and knee joint loading during change of direction are influenced by sidestepping expertise, which is related to balance and neuromuscular control. Their study suggests that improved core stability can lead to more efficient movement patterns and reduced injury risk, aligning with the findings of this study that demonstrate significant improvements in kinematic variables and defensive performance accuracy following integrated training (31).

Studies in sports such as basketball and soccer have also demonstrated that proprioceptive training and muscle tension control improve movement efficiency and defensive performance (32,33).This study contributes to these findings by showing the combined effects of both training elements specifically in volleyball.

Studies show that balanced and managing tension build stronger defenders in basically any game. Yılmaz (2024) also noted that training balance improves dynamic neuromuscular control among athletes, resulting in better orthoveric economy and reducing the risk of injuries (34). Likewise, a study from basketball with a similar protocol showed an improvement at passing and shooting and dynamic balance skills leading to better overall performance (35). The best in defense will benefit from improved explosive power, agility and dribbling abilities with football-specific balance training (36). These results are in agreement with ours, as changes in postural adjustments were observed only after a period of combined balance and cocontraction training.

The second objective, improving muscle tension control, is also supported by Table 2, where the experimental group demonstrated a significant increase in sEMG-measured control. These findings confirm that PNF stretching and relaxation drills are effective in enhancing neuromuscular modulation during high-intensity actions, consistent with prior research (5).

The third objective, optimizing kinematic variables, is addressed in Table 3, which shows statistically significant improvements across all measured joint angles (knee, hip, shoulder, elbow, ankle, trunk). For example, knee angle improved with a large effect size, reflecting more efficient lower-limb mechanics. Similar patterns were observed in upper-body joints, such as the shoulder, which are crucial for maintaining proper defensive posture. These biomechanical changes support the hypothesis that integrated training can enhance movement efficiency and reduce injury risk (13).

Improvements in knee and hip angles, particularly during defensive maneuvers such as blocking or diving, contribute to enhanced body alignment and force absorption, crucial for preventing knee and lower-back injuries (37).

Furthermore, the biomechanical implications of integrated training are supported by recent research in robotics and musculoskeletal modeling. Kawaharazuka et al. (2024) proposed a method for learning balance control in musculoskeletal humanoids by considering changes in body state, joint angles, and muscle tension. This approach highlights the importance of dynamic muscle control and joint alignment in maintaining balance, which is directly applicable to athletic performance. Their findings underscore the relevance of muscle tension control in optimizing movement efficiency and preventing injury, paralleling the outcomes observed in this study (31).

The fourth objective, improving defensive performance accuracy, is clearly confirmed in Table 2, where the experimental group achieved the highest effect size. This indicates that integrating balance and Muscle tension training has a direct and substantial impact on sport-specific skills, such as anticipating and responding to opponent attacks. These results expand on earlier isolated findings by showing that a combined intervention yields even greater performance gains (38).

The integrated training program not only enhances defensive performance but also contributes to overall athletic development, improving movement efficiency in both offensive and defensive phases of the game (39).

Overall, the results from Table 2 and Table 3 collectively confirm the research hypothesis: a structured, integrated balance and muscle tension control program significantly outperforms standard training in enhancing both biomechanical efficiency and defensive skill performance in volleyball players.

The significant improvements observed in Table 2 and Table 3 have direct and valuable applications in volleyball training practice. The marked gains in balance and muscle tension control (Table 2) indicate that integrating unstable-surface training, proprioceptive drills, and PNF-based muscle relaxation techniques into regular training can substantially improve postural balance and neuromuscular efficiency. Such enhancements enable players to maintain optimal positioning during rapid directional changes and high-pressure defensive situations.

The exercises incorporated in the integrated training program—unstable-surface training, proprioceptive drills, and PNF-based muscle relaxation techniques—are directly relevant to the study’s interventions. Unstable-surface training was employed to challenge dynamic balance during lateral and defensive volleyball movements, enhancing postural stability under game-specific conditions. Proprioceptive drills targeted joint position sense and reactive stability, improving movement efficiency and coordination during defensive tasks. PNF-based muscle relaxation techniques were applied before and after training sessions to optimize neuromuscular modulation, reduce excessive muscle tension, and allow controlled execution of high-intensity movements. Collectively, these exercises formed a cohesive program designed to improve both kinematic efficiency and defensive accuracy, directly aligning with the study’s primary objectives (40).

Furthermore, the improvements in kinematic variables (Table 3)—particularly in the knee, hip, and shoulder—highlight the importance of targeted biomechanical optimization. Coaches can use video-based motion analysis tools (e.g., Kinovea) to identify and correct suboptimal joint positions, ensuring that technical skills are performed with maximum efficiency and reduced injury risk.

The increase in defensive performance accuracy (Table 2), the largest effect observed in this study, underscores the competitive advantage of integrating these training methods. Drills that simulate real match conditions, combined with balance and muscle tension control exercises, can improve reaction speed, anticipation, and technical precision in defensive actions.

In practical terms, adopting the integrated training model tested in this study could lead to, Enhanced on-court agility and balance under competitive pressure, Reduced injury risk through improved joint alignment and neuromuscular control, and Improved match performance, especially in defensive roles, where quick, accurate responses are crucial.

By systematically applying the methods validated by the outcomes in Table 2 and Table 3, volleyball coaches and strength & conditioning specialists can develop more comprehensive training programs that address both biomechanical efficiency and sport-specific skill execution.

Both Table 2 and Table 3 highlight the effectiveness of the integrated training program in improving balance, muscle tension control, defensive skill accuracy, and several kinematic variables. The experimental group showed significant improvements across all variables, with large effect sizes, while the control group showed minimal to no significant changes. These findings suggest that the training program had a substantial impact on both the athletes' physical mechanics and performance outcomes, supporting previous research on the benefits of integrated training programs for athletes (2,41).

# Conclusions

The integrated program combining balance training with muscle tension control significantly improved balance, neuromuscular control, kinematics variables, and defensive accuracy in first-division volleyball players, with clear practical and statistical significance. Enhancements in joint angles suggest potential for both performance gains and injury prevention. Overall, the findings support adopting such integrated methods over standard training to optimize biomechanics and sport-specific defensive skills.

# Recommendations

This study recommends integrating balance training on unstable surfaces and proprioceptive drills into volleyball players’ weekly programs to enhance postural balance and reactive control. Proprioceptive neuromuscular facilitation (PNF) stretching and relaxation techniques should be applied before and after high-intensity sessions to optimize neuromuscular modulation and reduce muscle stiffness. Regular use of motion analysis tools, such as Kinovea, is advised to monitor kinematics variables and improve defensive posture, thereby lowering injury risk. Defensive drills should simulate real match conditions, incorporating balance and tension control elements to boost accuracy and reaction speed. Extending the program across an entire competitive season is suggested, along with further large-scale, multi-team studies to confirm these findings.

# Limitations

This study’s findings are limited by the small sample size (n = 14) from a single club, which may restrict generalizability. The intervention was confined to a short period, with no assessment of long-term effects, and training occurred in controlled indoor conditions. Individual factors such as recovery rate, diet, and sleep were not considered. Additionally, performance was measured only before and after the program, without intermediate assessments to track progress. Future research should involve larger, more diverse samples, longer interventions, and periodic evaluations to better capture performance changes over time.

# Acknowledgements

I am thankful to all who contributed to the success of this study. We thank the individuals for their time and commitment. Special thanks to all staff members at the University of Baghdad, College of Physical Education and Sports Sciences, for their invaluable help along this research work. The author is grateful to the research team for their technical proficiency and support in data collection and analysis.

# Ethical Approval

The study was approved by the Institutional Review Board (IRB) of College at the College of Physical Education and Sport Sciences / University of Baghdad (Approval Code: IRB-PESS-2025-02). All participants provided written informed consent. All procedures adhered to the Declaration of Helsinki and protected the confidentially and anonymity of subjects.

# Funding

No funding was received for this study. The research was self-funded by the authors.

# Authors’ Contributions

Moneer Fadel Ali Hassan: Conceptualized and designed the study, collected data, conducted statistical analysis, and wrote the initial draft of the manuscript,Omar Waleed Abdulkareem: Provided guidance on study design, supervised data collection, reviewed the manuscript, and contributed to the final revisions.

# Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

# Use of Artificial Intelligence

No artificial intelligence tools, were used in the writing or analysis process of this manuscript.

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