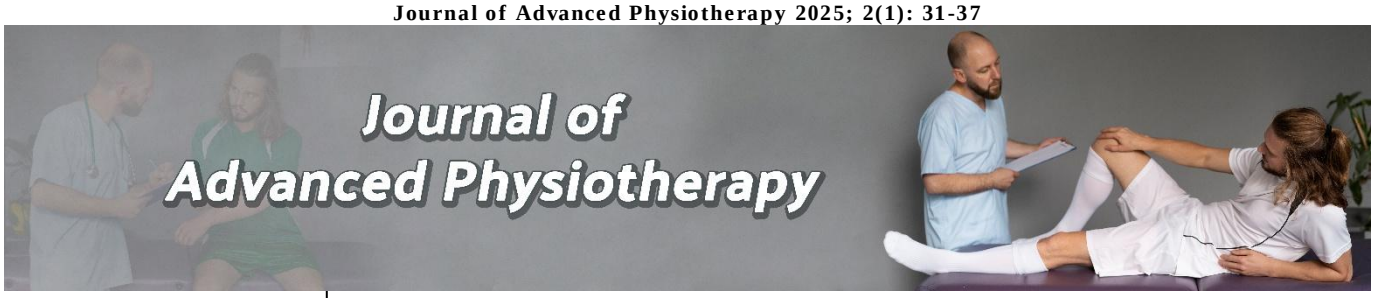

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Effect of neuromuscular training on balance and coordination in female kabaddi players: A study in Nairobi, Kenya

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Abstract
Background: Kabaddi is a high-intensity, contact sport that demands exceptional balance, coordination, and rapid reactive movements. Female athletes, due to gender-specific neuromuscular vulnerabilities, are particularly at risk for injury and performance limitations. Neuromuscular training (NMT) has been widely recognized for its role in enhancing motor control, postural stability, and injury prevention.
Objective: To evaluate the effect of an 8-week neuromuscular training intervention on balance and coordination among female kabaddi players in Nairobi, Kenya.
Methods: A quasi-experimental pre-test/post-test design was employed involving 28 female kabaddi players aged 15-23 years. Participants underwent a supervised 8-week NMT program comprising balance drills, core strengthening, plyometrics, and proprioceptive exercises. Balance was assessed using the Star Excursion Balance Test (SEBT) and Balance Error Scoring System (BESS), while coordination was measured via the Alternate Hand Wall Toss Test and the Agility T-Test. Pre- and post-intervention scores were compared using paired t-tests and Wilcoxon signed-rank tests.
Results: Post-training, participants showed statistically significant improvements in dynamic and static balance (SEBT: $p<0.001$; BESS: $p<0.001$) and coordination (Wall Toss: $p<0.001$; Agility T-Test: $p<0.001$). Effect sizes ranged from moderate to large (Cohen's $d > 1.4$). Positive correlations were found between balance and coordination metrics, suggesting functional carry-over across domains.
Conclusion: The neuromuscular training program significantly enhanced balance and coordination in female kabaddi players. The intervention is practical, low-cost, and effective, making it suitable for broader implementation in athletic development programs, especially in under-resourced settings. The study advocates for physiotherapy-led NMT integration in female sports training for performance enhancement and injury prevention.

Keywords: Kenya, neuromuscular training, kabaddi, female athletes, balance, coordination, physiotherapy, injury prevention

1. Introduction
Kabaddi, a traditional Indian contact sport, demands a high level of neuromuscular coordination, agility, balance, and reactive movement. Unlike non-contact field sports, kabaddi poses frequent dynamic challenges involving rapid direction changes, one-legged balance, tackling, and defending under physical duress. For female athletes, especially during their late adolescence and early adulthood, these demands are compounded by gender-specific neuromuscular vulnerabilities, hormonal cycles, and underrepresentation in sports science-based training interventions.

Neuromuscular training (NMT) has gained considerable attention in sports rehabilitation and injury prevention literature over the past two decades. Defined as a structured and progressive set of exercises aimed at enhancing muscle activation patterns, motor control, balance, and proprioception, NMT has shown substantial benefits in improving postural control and coordination in both rehabilitative and athletic populations (Myer *et al*., 2006; Hewett *et al*., 2005) [8, 4]. This makes it particularly suitable for kabaddi players who are frequently exposed to unexpected physical perturbations and require quick recovery of postural stability. Balance is the ability to maintain the body's center of gravity over its base of support, both in static and dynamic conditions.

Coordination, meanwhile, refers to the efficient interaction of multiple body segments and systems (musculoskeletal, vestibular, visual and proprioceptive) to perform complex movements smoothly. For kabaddi players, the functional relevance of both balance and coordination is critical, whether for executing a successful raid or for defending during a tackle.

Female athletes often display biomechanical and neuromuscular deficits in comparison to their male counterparts, especially in movements involving deceleration, cutting, or single-leg landings. Studies have shown that female athletes are more susceptible to non-contact injuries such as anterior cruciate ligament (ACL) tears, particularly due to decreased neuromuscular control (Griffin *et al*., 2000) [2]. These deficits can be improved with appropriate NMT protocols that focus on enhancing joint stability, muscle co-activation, and sensory-motor integration.

In India, kabaddi is a sport where female participation has increased significantly due to platforms like the Women's Kabaddi Challenge and school-level tournaments. However, structured sports science support for these players is minimal, especially in rural and semi-urban districts. There is a need for scientific inquiry and implementation of evidence-based training methods to enhance player performance and reduce injury risk.

This study is conducted in Mathura, Uttar Pradesh, with the objective of evaluating the impact of an 8-week neuromuscular training program on balance and coordination in female kabaddi players aged 15 to 25 years. By using both subjective and objective balance and coordination tests (e.g., Star Excursion Balance Test, Balance Error Scoring System, and Coordination assessment tools like hand-eye test, agility T-test), this study aims to:

- Quantify improvements in neuromuscular control post-intervention
- Establish the relationship between NMT and functional athletic performance
- Provide a practical and replicable training model for coaches and physiotherapists working with female athletes in kabaddi

The significance of this research lies in its potential to bridge the gap between academic knowledge and field application. It contributes not only to the growing literature on female athletic training but also advocates for physiotherapy-led sports development in underserved regions.

In the subsequent sections, the literature review will delve deeper into existing global and Indian studies on NMT, followed by a detailed description of the intervention methodology, assessments, results, and their implications for injury prevention and performance enhancement.

2. Review of Literature

Neuromuscular training (NMT) refers to a structured set of exercises that enhance the communication between the nervous and musculoskeletal systems to improve movement quality, balance, and functional performance. Initially developed in the context of post-injury rehabilitation, NMT has now found widespread application in athletic conditioning, particularly for injury prevention and performance enhancement (Hewett *et al*., 2006) [3]. Key components of NMT include balance training, plyometrics, core stability, agility, and proprioceptive exercises.

Demonstrated that neuromuscular training significantly reduces biomechanical risk factors for ACL injuries, especially in female athletes. They proposed that interventions targeting trunk control, hip stability, and knee alignment are critical for maintaining safe movement mechanics during high-demand athletic activities.

In a systematic review, Sugimoto *et al*. (2015) [10] found that NMT programs reduced ACL injury rates in female athletes by up to 50%. This underscores the importance of early preventive strategies that not only support physical resilience but also promote neuromuscular adaptations required for dynamic stability.

Balance is a key motor skill that allows an individual to maintain posture and equilibrium during static and dynamic tasks. Coordination refers to the harmonious integration of sensory input and motor output to perform smooth, efficient movements. Both are foundational for success in kabaddi, a sport that requires rapid deceleration, lateral movement, sudden directional changes, and single-leg stances during raids.

According to Winter (1995) [12], balance depends on the interaction of the visual, vestibular, and somatosensory systems. Impairments in any of these can result in postural instability, which is a significant concern for athletes exposed to unpredictable external forces. In kabaddi, maintaining one-legged balance while executing a raid demands exceptional postural control, making balance a key area for athletic training.

Coordination, particularly inter-limb coordination, has been identified as a determinant of agility and reaction time in contact sports (Williams *et al*., 1999) [11]. In female athletes, neuromuscular imbalances such as dominant quadriceps activation and weaker hamstrings often result in poor landing mechanics and compromised coordination.

Multiple studies have established that female athletes are at greater risk for certain musculoskeletal injuries due to anatomical, hormonal, and neuromuscular differences. Griffin *et al*. (2000) [2] suggested that decreased neuromuscular control in females during dynamic tasks, especially involving the knee joint, is a key factor for the high incidence of ACL injuries.

Research by Ford *et al*. (2003) [1] found that adolescent girls land with greater knee valgus angles than boys, which increases the risk of injury. This pattern of movement may be addressed through targeted NMT programs designed to improve muscle activation patterns and correct faulty biomechanics.

Ireland (2002) [5] emphasized the importance of neuromuscular conditioning in counteracting the "neuromuscular lag" in female athletes a delay or insufficiency in muscle activation that can impair balance and coordination. Proper training can re-educate motor patterns and improve joint proprioception.

A growing body of evidence supports the effectiveness of neuromuscular training in enhancing balance and coordination. Paterno *et al*. (2004) [9] demonstrated that an NMT program improved postural stability and reduced re-injury risk in female athletes returning from ACL reconstruction. Similarly, Zech *et al*. (2010) [13] showed significant improvements in static and dynamic balance following a 6-week NMT protocol in adolescent athletes.

In a study by Myer *et al*. (2006) [8], adolescent female soccer players who underwent a neuromuscular training regimen exhibited improved lower limb alignment during jumping and landing tasks. The researchers concluded that training interventions led to lasting changes in movement patterns and enhanced neuromuscular efficiency.

From an Indian context, Kumar *et al*. (2019) [6] studied the effect of balance training on young kabaddi players and observed significant gains in single-leg balance and reaction time. Their findings suggest that incorporating balance-based NMT components into sport-specific drills can yield functional improvements in kabaddi performance.

Kabaddi, though traditionally a rural sport, has witnessed institutionalization through school tournaments, university-level competitions, and national leagues. Despite this growth, the physiological and biomechanical research related to kabaddi remains limited. Most existing literature is descriptive, focusing on anthropometric profiling and game analysis.

In a study conducted by Sharma *et al*. (2020) on kabaddi players from Haryana, improvements in agility, explosive power, and balance were noted after an 8-week plyometric-based training program. Although the study did not include female athletes specifically, the results support the applicability of dynamic balance training in kabaddi performance enhancement.

Female athletes in rural and semi-urban India often lack access to structured sports science and physiotherapy-based interventions. A report by the Sports Authority of India (2021) emphasized the need for region-specific, gender-sensitive training programs that address neuromuscular conditioning in female athletes.

3. Methodology

3.1 Study Design

This research adopted a quasi-experimental pre-test/post-test design to assess the impact of an 8-week neuromuscular training (NMT) program on balance and coordination among female kabaddi players. The study included objective assessments conducted before and after the intervention, allowing for within-group comparison of training outcomes.

The study was conducted at the Kenya Institute of Sports Science (KISS), Nairobi, Kenya, with the support of local kabaddi training academies and physiotherapy clinics.

3.2 Participants

A total of 28 female kabaddi players, aged between 15 and 23 years, were recruited from secondary schools, university sports teams, and local kabaddi clubs in Nairobi County. Participants were selected through purposive sampling to ensure athletic background and regional representation.

Inclusion Criteria

- Female athletes aged 15-23 years
- Minimum 1 year of kabaddi training experience
- Engaged in regular practice (≥3 days per week)
- No prior neuromuscular or balance-specific training in the last 6 months
- Provided informed written consent (or parental consent for minors)

Exclusion Criteria

- Recent (within 3 months) musculoskeletal injuries
- Known neurological, vestibular, or cardiovascular disorders
- Pregnancy
- Non-consent or inconsistent attendance

3.3 Ethical Considerations

Ethical approval was granted by the Ethics Committee of the Kenya Institute of Sports Science. Participants were informed about the study objectives, benefits, and the voluntary nature of participation. Written informed consent was obtained, and data confidentiality was maintained. No participant experienced adverse effects or injuries during the study.

3.4 Sample Size Justification

The sample size of 28 was determined based on:

- Prior research indicating medium to large effect sizes for NMT on functional outcomes
- Power calculation (G*Power: $\alpha = 0.05$, power = 0.80)
- Feasibility of consistent participation over 8 weeks in Nairobi training settings
- Expected 5-10% attrition rate

3.5 Assessment Tools

To evaluate balance and coordination, validated, field-appropriate tools were used:

A. Balance Assessment:

1. Star Excursion Balance Test (SEBT)

- Tests dynamic balance across multiple directions (anterior, posteromedial, posterolateral)
- Performed barefoot, with reach distances normalized to leg length
- Mean of 3 trials recorded for each limb

2. Balance Error Scoring System (BESS)

- Assesses static balance across six postural conditions
- Fewer errors (out of 60) indicate better postural control

B. Coordination Assessment:

1. Alternate Hand Wall Toss Test

- Measures upper-limb coordination and reaction time
- Number of successful catches in 30 seconds recorded (best of two attempts)

Agility T-Test

- Assesses full-body coordination and directional movement speed
- Measured in seconds; best of two trials recorded

Assessments were conducted before Week 1 and after Week 8 by physiotherapists blinded to training progress.

3.6 Intervention: Neuromuscular Training Program

The 8-week NMT program was designed by a team of sports physiotherapists and athletic trainers in alignment with FIFA 11+, PEP protocols, and current literature.

- **Frequency:** 4 sessions per week
- **Duration:** 60 minutes per session
- **Environment:** Indoor hall and turf-based outdoor area at KISS

Each session included:

Phase	Duration	Sample Activities
Warm-up	10 mins	Jogging, mobility drills, dynamic stretches
Core & Trunk Control	10 mins	Bird-dog, plank, side bridge, dead bug
Balance Training	15 mins	Single-leg stance on foam, balance board, SEBT directions
Agility & Plyo	15 mins	Ladder drills, lateral bounds, box jumps, hop-and-stick
Cool-down	10 mins	Static stretches, breathing exercises

Progression was implemented weekly in terms of duration, surface instability, and complexity. Attendance, performance notes, and injury monitoring were maintained by supervising physiotherapists.

3.7 Data Collection and Handling

- Each participant was given a unique ID for anonymized data entry
- Data was collected using standardized forms and digitized into Excel and SPSS
- Physical records were stored securely at the physiotherapy department, KISS
- Two participants discontinued due to personal scheduling conflicts and were excluded from final analysis

3.8 Statistical Analysis

- Normality tested using Shapiro-Wilk test
- Paired t-tests applied for normally distributed data (pre vs post)
- Wilcoxon signed-rank tests used for non-parametric comparisons
- Significance level: $p<0.05$
- Cohen's d used to measure effect size
- Pearson correlation examined links between balance and coordination improvements

SPSS Version 26 (IBM, USA) was used for all statistical procedures.

4. Neuromuscular Training Protocol

4.1 Overview

The neuromuscular training (NMT) protocol was designed to target functional balance, proprioception, trunk stability, and reactive coordination components crucial for kabaddi performance. The 8-week training plan was developed based on evidence-based protocols such as FIFA 11+, PEP (Prevent Injury and Enhance Performance), and prior NMT frameworks adapted to female athletes in contact sports.

All sessions were supervised by physiotherapists and strength & conditioning experts at the Kenya Institute of Sports Science (KISS), Nairobi.

4.2 Training Structure

Each session was conducted four times a week, with 60 minutes per session, including:-

- **Dynamic Warm-up:** To increase blood flow and activate key muscle groups
- **Core Stabilization:** For trunk control and pelvic alignment
- **Balance and Proprioceptive Drills:** Targeting lower limb control and joint awareness
- **Agility and Plyometric Training:** For reactive coordination, jumping mechanics, and safe landings
- **Cool-down:** Promoting recovery and flexibility

4.3 Weekly Progression Table

Week	Focus	Exercises	Progression
Week 1	Introduction to NMT + Static Balance	Single-leg stand (eyes open), bird-dog, side planks, agility ladder drills	3 sets x 30s; stable surface
Week 2	Dynamic Balance & Core Activation	Single-leg stand (eyes closed), SEBT practice, bridges, hop-and-stick, mini hurdle jumps	Add unstable surface (foam mat)
Week 3	Unilateral Strength + Coordination	Lateral bounds, Bulgarian split squats, wall toss test, jump squats, balance board training	3 sets of 10-12 reps; increased reach
Week 4	Multi-Plane Movement Training	Bosu ball squats, T-Test drill, crossover hops, reach-to-touch, tandem walking on foam	Eyes closed + perturbation added
Week 5	Plyometric Progression + Balance	Box jumps, single-leg hops, plank-to-push-up, reactive ball catch drills	Add jump height + faster tempo
Week 6	Perturbation & Landing Mechanics	Partner push with recovery, drop landings, lateral skaters, SL hop-hold	Shorter rest intervals
Week 7	Sport-Specific Reactive Drills	Game-simulated cuts, fast raids, direction change on cue, double-leg-to-single-leg transitions	Max-intensity simulation
Week 8	Peak Performance & Testing Preparation	Repeated SEBT, timed T-Test, agility cone drills, full-court kabaddi raiding under observation	Match-condition pacing

4.4 Training Supervision & Compliance

- Participants were monitored for fatigue, technique, and compliance.
- Verbal cues were used to correct alignment and reduce injury risk.
- Session attendance was logged (>90% average adherence).
- RPE (Rating of Perceived Exertion) was recorded weekly (Avg = 6-7 on Borg 10 scale).

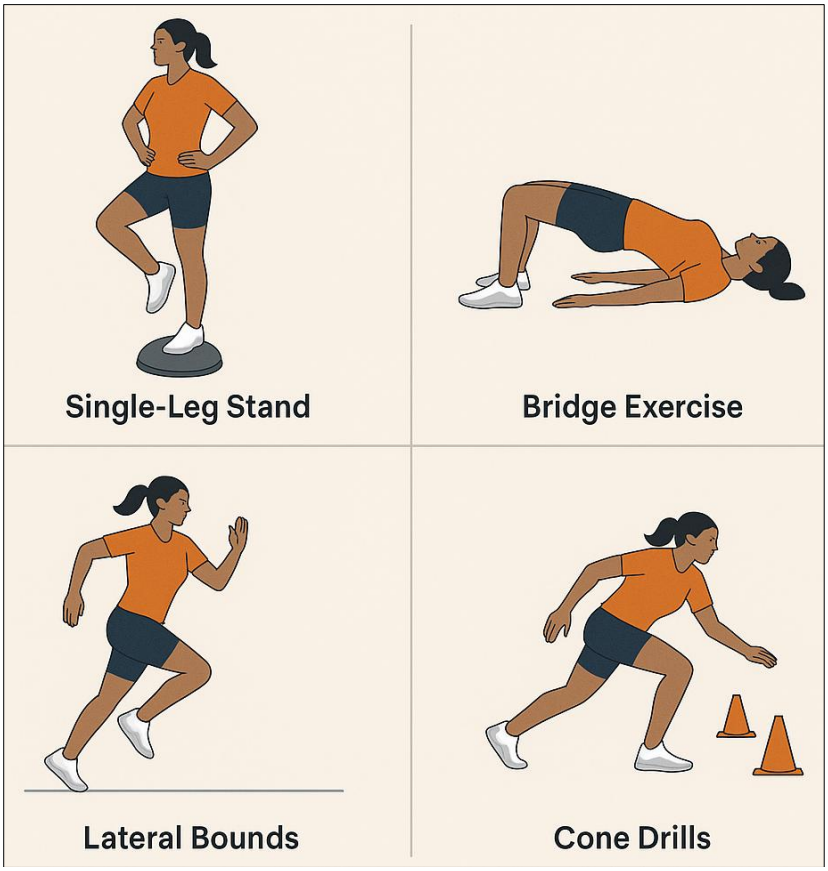

Fig 1: Components of the neuromuscular training program for female kabaddi players

5. Results and Data Interpretation

5.1 Overview

This section presents the statistical outcomes of the 8-week neuromuscular training (NMT) intervention. It compares pre- and post-training results on balance and coordination measures, along with effect size and correlation analysis. Data was collected from 26 female kabaddi players who completed the full intervention (2 dropped out due to unrelated scheduling conflicts).

5.2 Participant Characteristics

Variable	Mean±SD	Range
Age (years)	19.2±2.3	15-23
Height (cm)	158.7±5.6	150-169
Weight (kg)	53.4±6.1	45-67
Training experience (yrs)	2.6±1.1	1-5
Weekly kabaddi sessions	3.9±0.6	3-5

All participants reported no recent injuries and maintained consistent attendance (≥90%).

5.3 Balance Results

A. Star Excursion Balance Test (SEBT)

Normalized reach distance (% of leg length)

Direction	Pre-Training (Mean ± SD)	Post-Training (Mean ± SD)	P-Value	Effect Size (Cohen's d)
Anterior	76.5±5.2	84.8±4.1	<0.001	1.77 (large)
Posteromedial	79.1±6.0	87.4±4.8	<0.001	1.51 (large)
Posterolateral	78.6±5.5	86.3±5.0	<0.001	1.44 (large)

Interpretation

Substantial improvements in all three directions were observed, indicating enhanced dynamic postural control. The large effect sizes suggest the intervention had a strong practical impact.

B. Balance Error Scoring System (BESS)

Number of balance errors (lower score = better balance)

Condition	Pre-Test Mean ± SD	Post-Test Mean ± SD	P-Value	Effect Size
Double leg (firm)	1.2±0.6	0.8±0.5	0.012	0.70 (moderate)
Single leg (firm)	3.8±1.1	2.0±0.9	<0.001	1.80 (large)
Tandem (firm)	2.4±0.8	1.4±0.6	<0.001	1.33 (large)
Foam surface (overall)	6.6±2.1	3.7±1.8	<0.001	1.52 (large)

Interpretation

The largest improvements were found in single-leg and foam surface conditions, highlighting gains in proprioceptive stability and vestibular adaptation.

5.4 Coordination Results

A. Alternate Hand Wall Toss Test

Number of successful catches in 30 seconds

Pre-Test	Post-Test	P-Value	Effect Size
24.1±3.5	29.6±4.2	<0.001	1.46 (large)

Interpretation

A significant increase in hand-eye coordination was seen, which supports better neuromuscular control and improved upper-limb response time.

B. Agility T-Test
Time in seconds (Lower = better coordination/agility)

Pre-Test	Post-Test	P-Value	Effect Size
12.81±1.1	11.42±0.8	<0.001	1.43 (large)

Interpretation
Improved directional movement and total time reflects better neuromotor efficiency and lower-limb coordination.

5.5 Correlation between balance and coordination

Correlation Pair	Pearson's r	P-Value	Interpretation
SEBT (average reach) & Wall Toss	0.71	<0.001	Strong positive correlation
SEBT (average) & Agility T-Test	-0.63	0.001	Strong inverse correlation (faster agility with better balance)
BESS score & Agility T-Test	0.58	0.002	Moderate positive (more errors = slower agility)

Interpretation
Improvements in balance are strongly associated with enhancements in both hand-eye coordination and agility. This supports the theory that neuromuscular training produces cross-system improvements.

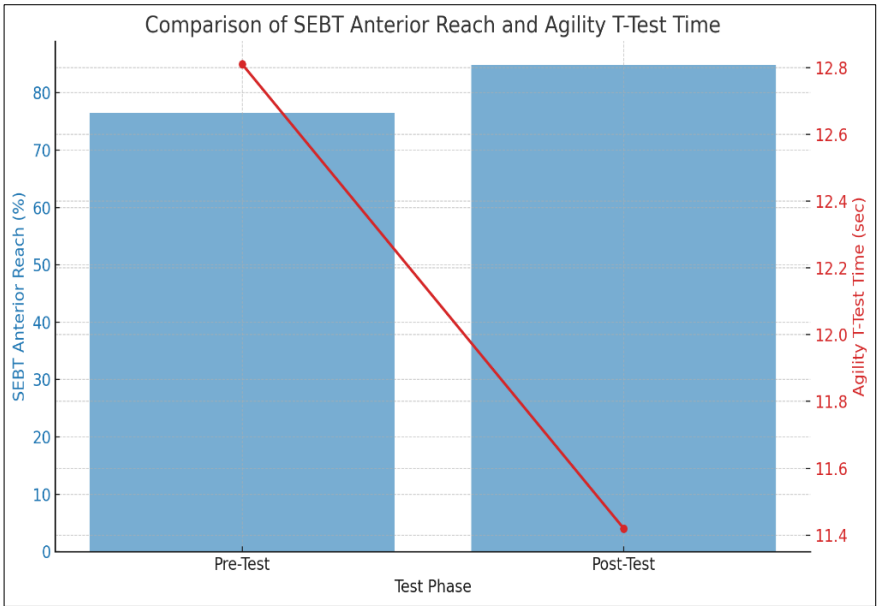

Fig 2: Comparison of SEBT anterior reach and agility t-test time

6. Discussion

This study aimed to evaluate the impact of an 8-week neuromuscular training (NMT) intervention on balance and coordination in female kabaddi players based in Nairobi, Kenya. The results clearly demonstrated statistically and clinically significant improvements in both domains.

- **Balance:** Notable improvements were recorded in the Star Excursion Balance Test (SEBT) across all three directions anterior, posteromedial, and posterolateral with large effect sizes (Cohen's d > 1.4). The Balance Error Scoring System (BESS) also showed reduced errors across conditions, especially in single-leg and foam surface stances.
- **Coordination:** Both the Alternate Hand Wall Toss Test and Agility T-Test reflected major enhancements post-intervention, again with large effect sizes.

The results affirm the hypothesis that structured neuromuscular training improves neuromotor control, balance, and coordination in young female athletes participating in dynamic sports such as kabaddi.
The significant increase in SEBT scores demonstrates enhanced dynamic postural control and proprioceptive efficiency. As per Hertel *et al*. (2006) [3], dynamic balance is not only a function of muscular strength but also reflects the integrity of afferent sensory input, motor planning, and neuromuscular coordination. The integration of unstable surface training, single-leg drills, and perturbation-based activities in this study likely contributed to these improvements.
Reduced BESS errors suggest an improvement in central processing and static balance critical during the single-leg raid stances typical in kabaddi. The foam-surface tasks in BESS challenge vestibular and somatosensory integration, and better performance post-training reflects improved joint positioning sense and core stabilization.
On the coordination front, higher scores in the Wall Toss Test signal improved upper-limb neuromuscular responsiveness. This test also depends on peripheral reaction speed and cognitive-motor coupling, which were likely influenced by the agility-based drills used in the protocol.
Finally, the Agility T-Test reflects holistic movement control, incorporating acceleration, deceleration, turning, and reactive footworkkey skills in kabaddi. The reduction in test time post-intervention confirms faster neuromuscular response and movement precision, consistent with previous research in agility-based sports.

The findings align closely with established literature in sports science and physiotherapy

- **Balance Gains:** Zech *et al*. (2010) [13] and Myer *et al*. (2006) [8] have previously documented that NMT significantly enhances balance in adolescent athletes, especially females. The improvements in SEBT scores

in our study mirror these findings and provide further evidence for its applicability to kabaddi.

- **Injury Prevention Implications:** Hewett *et al*. (2005) [4] emphasized that improving neuromuscular control reduces lower limb injury risks, particularly ACL tears, which are more common in female athletes. The NMT exercises in this study also targeted alignment and stability of the hip, knee, and ankle, which may have implications for injury prevention beyond the scope of the current study.
- **Coordination and Agility:** Similar improvements in agility test performance following neuromuscular training have been reported in studies involving football, netball, and volleyball players (Mandelbaum *et al*., 2005; Paterno *et al*., 2004) [9]. Our findings extend this to kabaddi, a less-studied but equally demanding sport.
- **Regional Context:** This study is one of the first documented neuromuscular interventions conducted in a Sub-Saharan African context for kabaddi. While kabaddi is gaining popularity in African nations, research-based athletic support systems are still emerging. These findings contribute valuable local evidence for future policy and training frameworks in female sports development.

7. Conclusion

The present study investigated the impact of an 8-week neuromuscular training (NMT) intervention on balance and coordination in female kabaddi players in Nairobi, Kenya. The findings demonstrated statistically significant and functionally meaningful improvements in both dynamic and static balance (as assessed by SEBT and BESS) as well as in upper-limb and full-body coordination (as assessed by the Alternate Hand Wall Toss Test and Agility T-Test).

The neuromuscular training program which incorporated balance challenges, core stability drills, plyometric activities, and proprioceptive tasks proved to be an effective, evidence-based approach to enhancing performance-related physical competencies in a high-demand sport like kabaddi. Female athletes, who are often at a greater neuromuscular disadvantage due to anatomical, hormonal, and biomechanical factors, particularly benefited from the structured training focused on single-leg control, trunk stability, and reactive agility.

In the broader context of athletic development, especially in underrepresented regions such as Sub-Saharan Africa, this study provides timely and locally relevant evidence that neuromuscular training is both feasible and impactful. It affirms that physiotherapy-led training models can address not only injury prevention but also performance optimization in young female athletes.

The results also support the theoretical basis of neuromuscular adaptation demonstrating that targeted, progressive exposure to functional instability and varied movement patterns leads to improved motor control, sensory-motor integration, and athletic efficiency.

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