

Enhancing Kinetic and Neuromuscular Benefits Via Plyometric Training on Key Performance Metrics in University-level Kabaddi Players: A Randomized Controlled Trial

Thirulogachandar Gunasekar¹, C. V. Senthil Nathan²,
P. Senthil³, V. H. Hema⁴

Corresponding Author: **G. Thirulogachandar**

¹Orchid Id: 0000-0003-4214-8946

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Abstract:

Background: Agility, reaction time, and postural control are essential performance determinants in Kabaddi, a high-intensity intermittent sport demanding rapid directional changes, reflex responses, and stability during dynamic contact. Although traditional strength and agility drills are common, plyometric training may induce more significant neuromuscular adaptation.

Methods: A randomized controlled trial was conducted with 40 male Kabaddi players aged 18–25 years, who were randomly assigned to two groups ($n = 20$ each). Group A underwent an 8-week plyometric training protocol, whereas Group B performed traditional agility and conditioning drills matched for frequency and duration. Agility was assessed using the Modified T-Drill Test, reaction time was measured using a digital reaction trainer sensor, and postural control was evaluated using a force plate system to analyze center-of-pressure (COP) sway. Pre- and post-intervention measurements were compared within and between groups using paired and unpaired t -tests.

Results: Plyometric training produced greater improvements in agility (-2.8 ± 0.5 s vs -1.5 ± 0.6 s, $p < 0.01$), reaction time (-78 ± 22 ms vs -44 ± 17 ms, $p < 0.01$), and postural stability (COP sway reduction -18.2% vs -9.6% , $p < 0.05$).

Conclusion: The 8-week plyometric program significantly enhanced agility, reaction speed, and postural control compared to traditional training. Plyometric drills integrating explosive lower-limb power and reactive balance stimuli can be effectively incorporated in Kabaddi performance conditioning.

Keywords: Plyometric training, Kabaddi, Agility, Force plate system, Reaction time.

Introduction:

Kabaddi is a contact-based sport involving rapid acceleration, directional change, and stability management during offensive and defensive maneuvers^(1,3). Kabaddi is a game that blends gymnastics, rugby, wrestling, and judo. Catching, holding, locking, and jumping are crucial body motions in this game, therefore having favorable anthropometric and physiological traits can help you perform better in competition.⁽⁴⁾ Individual performance depends on physical attributes such as strength, agility, reaction time, and postural control. Players who can quickly respond to opponent movement while maintaining balance have a higher probability of successful raid or defense execution⁽²⁾.

Traditional Kabaddi training emphasizes general conditioning, running drills, and jump squats, which improve endurance and basic coordination but may not sufficiently target rapid stretch-shortening adaptations^(3, 5). Plyometric training, which involves explosive movements like bounding, hopping, and depth jumping, enhances neuromuscular reactivity via increased muscle spindle sensitivity, tendon stiffness, and motor unit synchronization^(2, 6, 7).

Reaction time, essential for instantaneous movement response, can be objectively quantified through digital trainer sensors that measure initiation latency in milliseconds. To succeed in contests, volleyball players must maximize their physical performance while enhancing their technical and tactical aspects. In volleyball, speed, movement velocity, and quick reaction times are crucial for success.⁽⁸⁾ In sports, quick reflexes and nimble movements are closely related and constantly interact to successfully carry out acts.⁽⁹⁾ Acceleration and directional quickness are measured using standardized tests, such as the Modified T-Drill Test ^(10,12). A force plate can be used to quantify postural control, which reflects proprioceptive and vestibular efficiency, to analyze center-of-pressure displacement and stability.⁽¹¹⁾

This randomized trial compared the efficacy of plyometric and traditional training methods in improving agility, reaction time, and postural control in male Kabaddi players across an 8-week intervention.

Methodology:

A randomized controlled trial is scheduled to take place from April 2025 to October 2025. The study involves forty-eight players, aged between 18 and 25, who have a body mass index (BMI) of 18.4 kg/m², stand 163 cm tall, weigh 49 kg, have a visceral fat level of 2.5, and a resting metabolic rate of 1284 kcal/day. These participants were selected from Dr. M.G.R. Educational and Research Institute and university-level teams. They participated in an 8-week program, which included plyometric and traditional training focused on improving agility, reaction time, and postural

control in male university Kabaddi players, conducted three times a week. By the end of the study, 40 participants had completed the training regimen, while eight withdrew.

Participants were required to have at least two years of competitive Kabaddi experience and no lower limb injuries in the six months leading up to the study. Those with neurological or vestibular disorders, neurological, psychiatric, or binocular vision disorders, a history of migraines, epilepsy, or other conditions impacting visual or motor skills, musculoskeletal imbalances, and those who attended less than 80% of the intervention were not included in the study.

Sample size determination: The necessary sample size for the two-group pre–post design was determined using a paired t-test (two-sided $\alpha = 0.05$, power = 80%). **Study design:** Between-group pre–post (paired t-test), Power ($1 - \beta$): 80% $\rightarrow Z_{1-\beta}=1-\beta =0.84$, Expected mean difference (Δ): 0.4632 seconds (COP pre vs post), assumed pre–post correlation (r): 0.5, standard deviation of differences (SD), Calculated minimum sample size: 21 participants, Adjustment for 10% dropout: $21 / (1 - 0.10) \approx 24$ participants. **Final target:** 24 participants. The sample size calculation indicated that at least 24 participants were needed to achieve 80% power (two-sided $\alpha = 0.05$). To enhance precision and account for possible dropouts, forty-eight male kabaddi players were recruited; 40 players completed the intervention and were included in the final analysis. A total of forty-eight participants were necessary to identify a statistically significant difference before and after training, based on 80% power, a 5% significance level (two-sided), and an anticipated risk difference of 30%. Sample size was calculated using Open Epi, Version 3.01⁽¹²⁾. Descriptive statistics summarized the baseline characteristics. Paired t-tests assessed within-group changes, and independent t-tests evaluated pre- and post-training differences. Statistical significance was set at $p < 0.05$. Analyses were conducted using SPSS v26.

Ethical Consideration:

The institutional ethics committee has reviewed and discussed in detail the study, and clearing all queries raised in the meeting, the committee has granted ethical clearance for the study (No.04/2025/D/PHYSIO/IRB/2025-2026). Prior to participating in the study, the participants and their parents provided signed and informed consent after being made aware of the project and the accompanying written information paper.

Procedures and Intervention

The study's initial stage involved obtaining all necessary ethical clearances and establishing the essential infrastructure and equipment. Preliminary eye examinations were carried out to identify eligible participants. Before testing started, each individual provided written informed consent. Baseline

data, including physical and ocular parameters, were collected using standardized forms. Body composition was assessed with an OMRON Bioelectrical Impedance Analyzer (BIA), which calculates body fat, muscle mass, and metabolic rate through electrical impedance. As per the study protocol, all participants engaged in a 10-minute warmup consisting of jogging and dynamic stretching of the upper and lower limbs, as well as trunk muscles (12, 24). This was followed by 5 minutes of static stretching. Rest periods between sets lasted 90 seconds. Participants in the experimental group participated in a 15–30-minute session and completed an eight-week structured plyometric training program focused on explosive lower-limb movements, with progressive overload applied throughout. Group B adhered to a traditional training routine that included running drills, static stretching, and basic strength exercises like squats, lunges, and push-ups. Both interventions were matched in terms of frequency, duration, and intensity, with sessions held three times a week under professional supervision to ensure consistency across groups.

Outcome measures were evaluated at two points: prior to the pre-test (week 0) and following the post-test (week 8) of the intervention. Agility was assessed using the Modified T-Drill Test ⁽¹²⁾, with the time taken to complete the test recorded in seconds via a digital stopwatch. Reaction time was gauged using a device comprising wireless, Bluetooth-enabled LED pods managed by the ReactionX mobile application ^(12, 13, 24), with results in milliseconds. Postural control was determined by examining center-of-pressure sway in both anterior-posterior and medial-lateral directions, utilizing the BTrackS (Balance Tracking System V4). The Balance Assessor is a portable, cost-effective, and validated force plate system that employs sensors and software to objectively measure postural sway and center of pressure (COP) for balance evaluation. The portable force plate captures the mean total sway path (in millimeters). All participants adhered to this training regimen three times a week for eight weeks, alongside their usual kabaddi training. Post-intervention evaluations were carried out using the same testing protocol and equipment as at baseline to ensure measurement consistency. During the primary training phase, participants who completed the training engaged in structured plyometric and traditional exercises to activate both the neuromotor and visual processing systems.

Modified T-Drill Test:

The Modified T-Drill Test was conducted according to the procedure outlined by Sassi et al. (2009) & Jothi et al.^(7,12). Participants started the test behind line A and sprinted at full speed to cone B, which was located 5 meters ahead. Upon reaching the 30 cm high cone B, they tapped its top with their right hand. From there, they performed a lateral shuffle to cone C, situated 2.5 meters to the left of cone B, while keeping a forward-facing stance and

ensuring their feet did not cross. At cone C, they tapped the top with their left hand, shuffled 5 meters to the right to cone D, tapped it, and then shuffled back to cone B, tapping it again with their right hand. To finish the sequence, participants backpedaled as quickly as possible to the original starting line A. Each participant completed three trials, with a three-minute rest period between each attempt. The fastest time recorded from the three trials was used for the final analysis.

Reaction time test

Participants then positioned themselves in a ready stance with knees flexed at 15-20°, hands resting at waist level, and gaze fixed on a central target 2 meters ahead to mimic peripheral vision demands during kabaddi raids. The ReactionX mobile application in Focus Mode randomized illumination across pods (500 ms per light, 2-5 s variable interstimulus intervals, 30 trials total: 5 per pod), emphasizing sustained attention with progressive difficulty (adaptive ISI shortening after 80% accuracy). On illumination, the participants tapped the activated pod with the ipsilateral hand within 2 s, prohibiting foot displacement or trunk rotation exceeding 15°. Missed taps, errors, or responses >2 s incurred penalties, with feet fixed to emphasize isolated upper-limb visuomotor reaction. This setup optimized the measurement of sport-relevant response latency and accuracy.

Result:

Table 1 shows the participants' demographic characteristics in terms of age, height, weight, fat mass, and muscle mass.

Table 2 shows both groups showed statistically significant improvements in agility and reaction time post-intervention. However, the plyometric group demonstrated superior gains across all variables. The mean agility time decreased by 2.8 seconds in the plyometric group compared to 1.5 seconds in the control. Reaction time improved by 78 ms in plyometric training, almost double that seen with traditional exercises. Additionally, the reduction in center-of-pressure sway was higher among plyometric participants, indicating enhanced dynamic postural stability.

Table 1. Demographic Characteristics of the Participants.

Groups	Age	Height (cm)	Weight (kg)	Fat mass (%)	Muscle-mass (%)
Participants	19.87±2.03	164.51±10.02	59.42±9.74	15.51±5.63	38.73±2.41

Table 2. Pre-test and Post-test for Agility, Reaction Time and Centre of Pressure (COP) for Both Groups.

Variable	Group (n=20)	Pre-test Mean \pm SD	Post-test Mean \pm SD	Mean Difference	p-value (within)	p-value (between groups)
Agility (s)	Plyometric	17.2 \pm 1.1	14.4 \pm 0.9	-2.8 \pm 0.5	0.001	0.004
Agility (s)	Traditional	17.1 \pm 1.0	15.6 \pm 0.8	-1.5 \pm 0.6	0.02	0.006
Reaction Time (ms)	Plyometric	312 \pm 33	234 \pm 28	-78 \pm 22	0.001	0.003
Reaction Time (ms)	Traditional	308 \pm 31	264 \pm 33	-44 \pm 17	0.04	0.006
COP Sway (mm)	Plyometric	102 \pm 18	83 \pm 14	-18.2%	0.003	0.02
COP Sway (mm)	Traditional	101 \pm 19	91 \pm 15	-9.6%	0.045	0.005

Discussion

In this RCT, male university Kabaddi players' agility, reaction time, and postural control were compared between regular conditioning and an eight-week plyometric training program. According to Čaprić et al. (14,24), plyometric training produced significantly greater improvements across all performance parameters, confirming its superior efficacy in enhancing neuromuscular and sensorimotor functions crucial to Kabaddi performance. Thirulogachandar Gunasekar et al. (10) and Huang, Hsuan, et al. (13), in this study, have shown that the improvement in agility can be attributed to the enhanced rate of force development and neuromuscular coordination induced by the repeated stretch-shortening cycle (SSC) actions characteristic of plyometric exercises. These movements increase muscle spindle sensitivity, tendon stiffness, and motor unit synchronization, enabling quicker and more powerful transitions between eccentric and concentric contractions (16). The rapid stretch during eccentric loading activates the myotatic reflex, which augments subsequent concentric force generation, improving the efficiency of movement required for quick directional changes and acceleration during gameplay(17). The reaction time improvements observed in the plyometric group are linked to faster neural

transmission and more efficient motor unit recruitment facilitated by adaptive changes in the central and peripheral nervous systems⁽¹⁸⁾. The repetitive exposure to external stimuli during explosive drills enhances motor cortex responsiveness and synaptic efficiency, thereby reducing sensory-to-motor processing latency. This neural adaptation enables quicker initiation of movement responses to unpredictable game stimuli, such as advances in raids and tackles⁽¹⁹⁾. The improvements in postural control, as evidenced by reduced center-of-pressure sway, can be explained by proprioceptive and vestibular adaptations resulting from repeated jumps, landings, and single-leg stabilization tasks inherent in plyometric routines⁽²⁰⁾. These exercises stimulate joint mechanoreceptors, improving afferent feedback to the central nervous system and facilitating better integration of sensory information for balance regulation⁽²¹⁾. Enhanced activation of deep stabilizing muscles, such as the gluteus medius and core musculature, further contributes to dynamic stability and injury prevention during rapid multidirectional movements⁽²²⁾. In comparison, traditional training lacks the reactive and elastic components of plyometric movements, limiting neuromuscular activation intensity and sensory adaptation potential⁽²³⁾. Despite a modest sample size and short intervention period, the current findings substantiate the role of plyometric training as a superior conditioning strategy for optimizing agility, neural responsiveness, and postural stability in Kabaddi players. Future studies employing electromyographic, kinematic, and neurophysiological assessments are warranted to further delineate the biomechanical and neural mechanisms underlying these performance enhancements.

Conclusion

Eight weeks of structured plyometric training significantly improved agility, reaction time, and postural control in Kabaddi players compared with traditional training methods. Incorporating structured plyometric exercises into sports conditioning protocols is recommended to optimize neuromuscular performance and reactive stability in high-intensity Kabaddi contexts.

Limitations of the Study

Although the intervention demonstrated positive outcomes, its effectiveness in improving kabaddi-specific dribbling skills was limited in this study. The study did not evaluate the retention or long-term consistency of improvements observed post-intervention. Additionally, the motion sensor device was not examined and warrants further investigation.

The study excluded paediatric and adolescent populations, limiting the generalizability of findings to younger age groups. Gender-specific responses, particularly among female athletes, were not evaluated. The

sample was restricted to male kabaddi players; therefore, findings may not be generalizable to athletes from other sports, such as volleyball or cricket.

Conflict of interest

The authors state that none of the work described in this study may have been influenced by any known conflicting financial interests or personal ties.

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Affiliation:

¹ Assistant Professor, Research Scholar, Faculty of Physiotherapy, Dr. M. G. R. Educational and Research Institute, Chennai, 600077, India.

² Professor, Principal, Faculty of Physiotherapy, Dr. M. G. R. Educational and Research Institute, Chennai, 600077, India

³ Professor and Dean, Vels School of Physiotherapy, Vels Institute of Science Technology and Advanced Studies (VISTAS), Periyapalayam Campus, Manjankaranai Village, Uthukkottai Taluk, Tiruvallur District, Tamil Nadu 601102, India

⁴ Professor, Principal, Faculty of Nursing, Dr. M. G. R. Educational and Research Institute, A.C.S. Medical College and Hospital, Chennai, 600077, India

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