

Feasibility and EMG-Based Neuromuscular Adaptations to a Kabaddi-Specific Complex Training Protocol (K-Com): A Pilot Study

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Abstract:

➤ Purpose:

This pilot study evaluated the feasibility and short-term effects of a two-week Kabaddi Complex (K-COM) training protocol on performance and neuromuscular adaptations in beginner kabaddi raiders, with the aim of informing a larger randomised controlled trial.

➤ Methods:

Eight male raiders (18–25 years) completed six sessions of paired strength and plyometric exercises (K-COM) over two weeks. Feasibility metrics included recruitment, adherence, safety, and EMG testing. Performance tests—countermovement jump (CMJ), drop jump (DJ), reactive strength index (RSI), standing broad jump (SBJ), 5 m sprint, and 505 agility—were administered pre- and post-training. Surface EMG of vastus lateralis (VL), biceps femoris (BF), and medial gastrocnemius (MGC) was recorded during CMJ, DJ, and single-leg forward jump landing (SLFJL), normalised to %MVIC, and analysed by movement phase.

➤ Results:

All athletes completed the protocol with full attendance and no injuries. Notable performance gains were observed in CMJ height (+15.8%), DJ height (+10%), SBJ distance (+11%), 5 m sprint time (1.5%), and 505 time (4.23%), while RSI showed a slight mean decrease (−2.9%). EMG data showed increased VL and BF activation in CMJ eccentric and concentric phases, and greater VL and BF pre-activation in SLFJL. DJ trials revealed increased VL activation across phases but reduced MGC activation, indicating a potential shift toward more economical landing mechanics.

➤ Conclusion:

The K-COM protocol is feasible, safe, and well-tolerated in beginner kabaddi raiders, producing short-term gains in explosive performance and favourable changes in muscle activation patterns. These results support progression to a longer trial with advanced athletes, incorporating a broader EMG muscle set and refined landing-specific tasks to improve performance profiling and injury risk prediction.

Keywords: Kabaddi, Complex Training, EMG, Injury Prevention, Pilot Study.

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I. INTRODUCTION

Kabaddi is an intermittent, high-intensity contact sport that requires repeated short bursts of maximal effort, such as sprinting, lunging, jumping, and tackling, followed by brief recovery periods. These movement patterns place substantial mechanical and neuromuscular demands on the lower limbs and trunk, particularly during high-force decelerations, single-leg landings, and quick rotational movements [1]. Recent epidemiological analyses confirm that lower-extremity injuries, including ligament sprains, muscle strains, and joint trauma, are the most prevalent in competitive kabaddi, with the knee and ankle being the most frequently affected sites [2,3]. Even though these injuries often happen after direct hits, non-contact mechanisms such as sudden changes in direction, awkward landings, or excessive rotational torque, also play an important role in the injury burden [2]. Even though kabaddi is becoming more popular, there's not much research out there on training methods or injury prevention customised to the sport. Compared to other high-intensity team sports, there's a significant gap in solid, evidence-based approaches for improving performance and keeping players safe [1,2].

Given this lack of kabaddi-specific conditioning, coaches often adapt methods from other team sports, among which contrast training (CNT) and complex training (CT) have gained attention for enhancing explosive performance [4,5]. Although these terms are sometimes used interchangeably in the literature, they differ in their sequencing and primary aims: CT typically pairs a heavy strength exercise directly with a biomechanically similar explosive exercise in a repeated sequence to promote long-term neuromuscular adaptation, whereas CNT generally performs the strength and plyometric components within the same session but in separate blocks to emphasize acute potentiation effects [4]. Post-activation phenomena explain these performance gains: classical post-activation potentiation (PAP) refers to transient, molecular-level contractile enhancement, while the broader concept of post-activation performance enhancement (PAPE) describes short-term improvements in task performance that result from a combination of neural, mechanical, and thermal factors [6]. Well-structured CT/CNT programs can acutely improve jump and sprint performance when load, rest, and exercise selection are optimised, but inter-individual variability is high. When implemented systematically over several weeks, they tend to yield moderate and reproducible improvements in jump height, sprint speed, and change-of-direction ability, though the pool of high-quality randomised controlled trials with consistent long-term follow-up remains modest and methodologically diverse [4,5]. Critically, there are no validated CT/CNT protocols made specifically for the kabaddi raider role, which demands explosive single-leg take-offs, multidirectional landings, and rotational movements. Existing kabaddi studies are typically small, non-randomised, and focused on isolated training modes such as plyometrics, ladder drills, or general strength programs [7,8,9]. This evidence gap highlights the importance of first developing and testing a sport-specific protocol for raiders before conducting a fully powered randomised controlled trial.

Explosive athletic qualities are commonly assessed using simple field tests like vertical jumps, reactive jumps, sprints, and change-of-direction drills—because they're quick to administer, cost-effective, and reliably detect training-related improvements when standardised appropriately [10]. Standard field tests measuring change-of-direction (COD) speed and agility are known to be both valid and reliable in athletic populations, provided they are administered with consistent protocols and timing systems. These tests are practical for measuring important performance skills in sports that require quick direction changes, making them suitable for tracking short-term improvements in kabaddi raiders, whose game actions involve fast acceleration and moving in different directions under pressure [11].

Surface electromyography (sEMG) is a technique that non-invasively measures muscle electrical activity linked to motor unit recruitment and firing patterns, widely used to analyse amplitude and temporal characteristics during dynamic movements [12,13]. To enable meaningful comparisons across muscles and individuals, EMG amplitudes are normalised, commonly as a percentage of maximal voluntary isometric contraction (%MVIC) or peak activity [14]. In jumping and landing tasks, muscle pre-activation is typically assessed in the 100 to 150 ms window before ground contact. This pre-activation helps prepare the muscles and tendons to absorb the impact better and keep muscular control during the landings. [15]. Phase-specific EMG analysis enables the identification of pre-activation, eccentric, and concentric phases, each reflecting unique neuromechanical demands and muscle contributions [16,17]. For example, gastrocnemius activity modulates ankle stiffness during propulsion, while coordinated quadriceps and hamstring activation governs knee stability and anterior tibial shear mitigation. Integrating EMG with kinematic data provides mechanistic insights into neuromuscular adaptations from training and their relevance to performance and injury risk [18,19,20].

While contrast and complex training match the neuromuscular demands of kabaddi, there is a lack of studies applying comprehensive EMG outcome measures specifically in kabaddi athletes. Most existing kabaddi research focuses on general performance outcomes (e.g., jump height, sprint times, agility) with few incorporating detailed EMG or biomechanical analyses. Conversely, EMG research from other sports provides validated methodological frameworks—including phase-specific windows, MVIC normalisation, and onset detection—that are directly transferable but require local feasibility testing for application in kabaddi contexts [4,17]. This gap, characterised by the lack of kabaddi-specific complex training protocols and the limited availability of EMG studies, highlights the need for pilot testing before undertaking a definitive randomised controlled trial. This study is essential to evaluate protocol feasibility (including acceptance, EMG-video synchronisation, and data processing efficiency), observe preliminary neuromuscular and performance trends, and optimise EMG outcome measures for larger-scale investigations [21].

Thus, this pilot study was designed to test the feasibility, including the EMG methods and to observe the short-term effects of the K COM Protocol, a lower limb strength and power program for kabaddi raiders, to guide future randomised controlled trials.

II. METHODS

➤ *Study Design and Participants*

This pilot study used a single-group pre-test/post-test design to evaluate the feasibility of the K-COM (Kabaddi Complex) training protocol. Eight male beginner kabaddi raiders aged 18–25 years, with 3–6 months of competitive experience, were included. Exclusion criteria were: history of lower-limb injury in the preceding 6 months, any current injury, chronic pain, neurological or musculoskeletal disorders, or participation in structured strength or plyometric training within the past month. Athletes who met the eligibility criteria and were interested in participating were recruited on a volunteer basis. The program was tested for 2 weeks with three training sessions per week. The pilot evaluated feasibility aspects, including recruitment, adherence, safety, and measurement methods.

➤ *K-COM Training Protocol (Table 1)*

The K-COM (Kabaddi Complex) training protocol was developed to enhance lower-limb explosive strength and power in kabaddi raiders, aligning with the sport’s neuromuscular demands such as sprinting, rapid deceleration, and multidirectional single-leg landings [1,2]. Exercises were selected based on established complex training literature targeting strength and plyometric pairings shown to improve athletic performance in similar populations [4,22]. Strength exercises were performed at 75–85% of one-repetition maximum (1RM), while plyometric exercises were executed with maximal effort and controlled technique. The training consisted of 3 to 5 sets, with 3 to 5 repetitions for strength exercises and 4 to 8 repetitions for plyometric exercises. Rest intervals were set at 30 to 60 seconds between exercises within each pair and 2 to 3 minutes between sets to optimise recovery and performance.

Each session began with a brief warm-up consisting of 5-7 minutes of light cardiovascular activity, followed by dynamic stretching and mobility drills that focused on the hips, knees, and ankles to prepare the joints and muscles for the training demands. Loads were adjusted to lower percentages of 1RM, as the pilot study was conducted on beginner athletes. K-COM sessions were scheduled on separate days from technical practice to ensure adequate rest and optimise performance in both types of sessions.

Table 1 K-COM Training Program–Exercise Pairing and Sessions.

Session	Exercise Pair	Strength	Plyometric
Day 1	1	Trap Bar Deadlift / Conventional Deadlift	Sledge Push / Bounding Sprint
	2	Back squat	Depth jump
Day 2	1	Bulgarian split squat	Lateral bound to vertical jump to stick landing
	2	Landmine skater squat	Lateral hurdle hops to box jump
	3	Step up	Single-leg broad jump to stick
Day 3	1	Front squat	Single-leg drop jump
	2	Nordic hamstring curl	5-meter sprint to stop

➤ *Performance and EMG Outcome Measures*

Performance outcome measures included countermovement jump (CMJ) height and drop jump (DJ) height to assess lower-limb explosive power, Reactive Strength Index (RSI) to evaluate stretch-shortening cycle efficiency and reactive strength, standing broad jump (SBJ) distance to measure horizontal lower-body power, and 5-meter sprint time and the 505 change-of-direction (COD) test to evaluate sprinting speed and agility. CMJ and DJ metrics were recorded using the My Jump Lab app, which has demonstrated strong reliability and agreement with force platforms for jump height and RSI [23]. SBJ was measured via tape, while sprint (5 m) and agility (505) times were recorded using the Photo Finish® app (Android version), which has been validated with high accuracy and reliability comparable to timing gate systems [24]. Photo Finish® was selected due to its high accuracy, portability, and cost-effectiveness, enabling practical and reliable field measurements during both pilot and main phases of the study. These field tests collectively assess explosive power, reactive ability, and COD skills critical for kabaddi performance [4,5].

$$RSI = \frac{\text{Flight Time(s)}}{\text{Ground Contact Time(s)}}$$

Surface electromyography (sEMG) was recorded during the countermovement jump (CMJ), single-leg forward jump landing (SLFJL), and drop jump (DJ) from a 45 cm box, targeting the vastus lateralis (VL), biceps femoris (BF), and medial gastrocnemius (MGC)—muscles critical for propulsion, landing mechanics, and injury prevention in kabaddi [25]. Electrode placement was according to SENIAM and CEDE guidelines, including standardised skin preparation and orientation parallel to muscle fibres [26,27]. EMG signals were sampled at ≥1000 Hz, band-pass filtered (20–450 Hz), full-wave rectified, and smoothed using a 50-ms RMS window for noise reduction and temporal precision in dynamic movements [12]. Amplitudes were normalised to percentage of maximum voluntary isometric contraction (%MVIC) from three 3–5 s trials, using the best trial for analysis [26]. RMS values were extracted for 3 phases (pre-activation, braking/eccentric, and propulsion/concentric), which were identified via frame-by-frame synchronisation of high-speed video with EMG traces to ensure accurate temporal alignment.

$$\%MVIC = \frac{EMG(task)}{MVIC} \times 100$$

(Where EMG (task) = RMS amplitude during the task
 MVIC = RMS amplitude during the maximal voluntary isometric contraction)

➤ Procedure

Participants attended one familiarisation session 48 h before baseline testing, where they practised all jump, sprint, and agility tasks and were introduced to the EMG setup. On each testing day, EMG-based assessments were performed first, consisting of the countermovement jump (CMJ), drop jump (DJ; 45 cm box), and single-leg forward jump landing (SLFJL). Jump height and reactive strength index (RSI) for CMJ and DJ were derived concurrently from these EMG trials. After a passive rest period of 10-15 min, the remaining field tests (standing broad jump, 5 m sprint, and 505 change-of-direction) were completed in a fixed order. Test sequencing and rest intervals were standardised across sessions to minimise fatigue and learning effects.

➤ Data Analysis

Descriptive statistics (mean ± SD) were calculated in Excel for all outcome measures at baseline and post-

intervention. Given the pilot nature of the study, no formal hypothesis testing was performed. Instead, within-subject percentage changes were reported to describe performance trends and assess the feasibility of the training protocol.

III. RESULTS

All eight enrolled participants completed the 2-week K-COM training protocol and all baseline and post-intervention assessments, resulting in 100% retention. No training-related injuries or adverse events were reported. Session attendance was 100%, and adherence to the prescribed exercise loads and repetitions was ≥95%.

Table 2 shows that, following 2 weeks of complex training, both countermovement jump (CMJ) and drop jump (DJ) heights increased in all 8 athletes, with mean gains of 15.8% and 10%, respectively. The standing broad jump distance also showed significant improvement across all participants, with an average increase of 11%. 5 m sprint time improved by 1.5%, while 505 agility time improved by 4.23%. The Reactive Strength Index (RSI) showed mixed outcomes, with four athletes showing slight improvement and the other four showing a decrease, leading to a small overall reduction in the group mean.

Table 2 Performance Outcomes (Pre vs Post)

Variables	Pre (Mean ± SD)	Post (Mean ± SD)	Change (%)
CMJ height (cm)	39.14 ± 7.4	45.33 ± 5.74	15.8
DJ height (cm)	35.9 ± 8.86	39.52 ± 8.87	10
RSI (drop jump)	2.06 ± 0.43	2 ± 0.5	-2.9
5m sprint (sec)	1.196 ± 0.15	1.178 ± 0.14	-1.5
505 Agility Test (sec)	2.597 ± 0.24	2.487 ± 0.18	-4.23
SBJ (m)	2.08 ± 0.45	2.31 ± 0.32	11

Note: CMJ = Countermovement Jump; DJ = Drop Jump; RSI = Reactive Strength Index; SBJ = Standing Broad Jump.

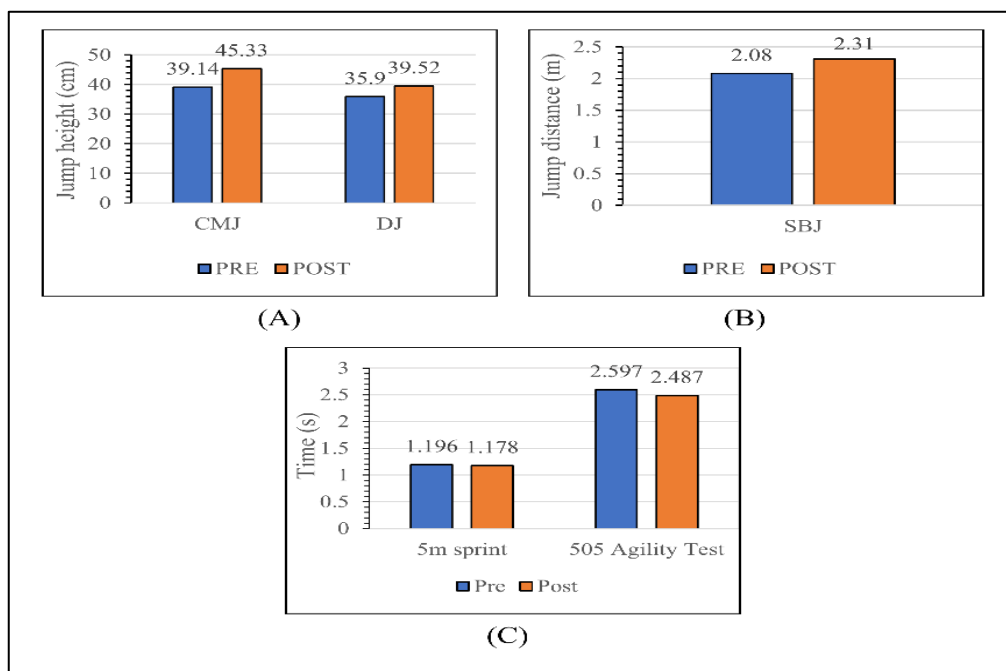


Fig 1 Pre- and Post-Intervention Changes in (A) Countermovement Jump Height and Drop Jump Height, (B) Standing Broad Jump Distance, and (C) 5 m Sprint and 505 Agility Test.

Table 3 VL and BF Activation in CMJ and SLFJL (RMS Normalised to %MVIC)

Phases	Pre (Mean ± SD)			Post (Mean ± SD)		
	VL	BF	VL:BF	VL	BF	VL:BF
Ecc (CMJ)	32.65 ± 21.4	19 ± 11.5	1.72	36.6 ± 16.2	21 ± 12.6	1.74
Con (CMJ)	91.8 ± 41.6	45 ± 20.5	2.04	136 ± 26	72.9 ± 33.7	1.87
Pre-act (SLFJL)	8.3 ± 4.4	9.2 ± 6.2	0.9	15.2 ± 8.3	17.5 ± 7.1	0.87

Note. VL = Vastus Lateralis; BF = Biceps Femoris; Ecc = Eccentric phase; Con = Concentric phase; Pre-act =Pre-activation (150 ms before IC); CMJ = Countermovement Jump; SLFJL = Single-Leg Forward Jump Landing

Table 4 Muscle Activation in Different Phases of DJ from 45 cm Box (RMS Normalised to %MVIC)

Phases	Pre (Mean ± SD)		Post (Mean ± SD)	
	VL	MGC	VL	MGC
Pre-activation (100 ms)	26 ± 18.6	77.5 ± 38.6	28.8 ± 9.9	57.5 ± 23.7
Braking	47.5 ± 30.5	92 ± 38.5	58 ± 15.3	82.3 ± 42.3
Propulsion	113 ± 63	131 ± 54	127 ± 30.5	103 ± 57

Note. VL = Vastus Lateralis; MGC=Medial Gastrocnemius; DJ=Drop jump

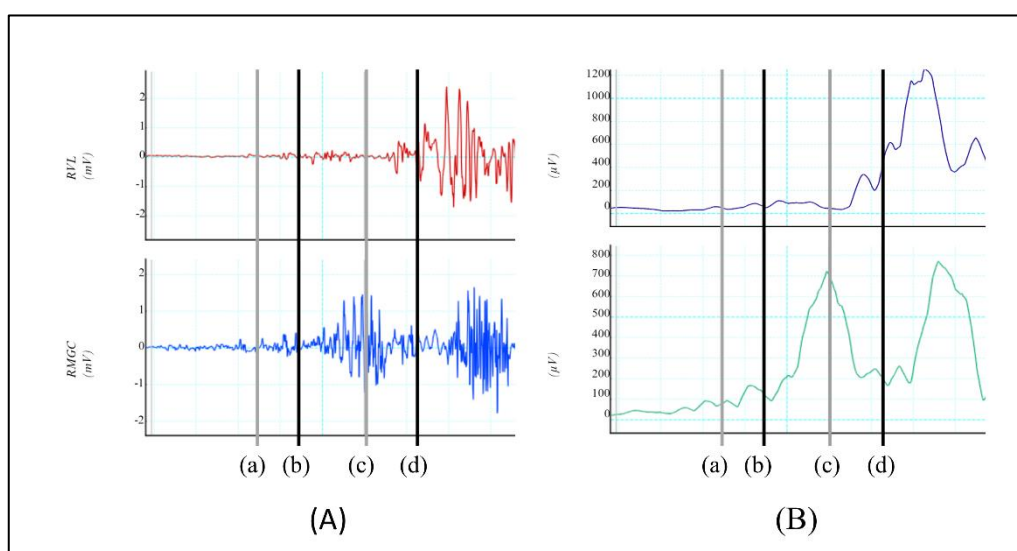


Fig 2 Representation of EMG recordings of vastus lateralis (VL) and medial gastrocnemius (MGC) during a drop jump from a 45 cm box. (a) Raw EMG signals; (b) RMS-processed EMG signals (50 ms window). Vertical lines indicate (A) 100 ms pre-initial contact (IC), (B) IC, (C) maximum knee flexion, and (D) take-off. These phases were determined via high-speed video synchronisation with EMG data.

IV. DISCUSSION

This pilot evaluated the feasibility of implementing a six-week K COM protocol by trialling its first two weeks with beginner kabaddi raiders and assessing early performance and neuromuscular changes. While this pilot focused on novices, the main trial will involve advanced or professional athletes, whose adaptations may differ due to higher baseline fitness, coordination, and technical proficiency.

As shown in Table 2 and Fig. 1, the K-COM training elicited clear gains in performance. Prior studies indicate that contrast/plyometric training in trained athletes yields moderate gains in vertical and horizontal jump performances in multi-week programs [28,29], and that beginners can exceed these improvements due to fast neural adaptation [30]. Likewise, performance in short sprint (5 m) and change-of-direction (505) tasks improved. This suggests better burst

acceleration and rapid direction change ability, key skills in kabaddi. Such enhancements fit with evidence that plyometric training typically improves sprint speed and agility in athletes [31]. Interestingly, RSI did not improve; in fact, it was slightly lower post-training. This implies athletes used longer ground contact to jump higher, emphasising force generation over quick rebound. Short-term training often yields such patterns; meta-analyses show RSI usually improves only after more sustained plyometric training [32].

Surface EMG showed that after two weeks of K-COM training, both the vastus lateralis (VL) and biceps femoris (BF) had higher activation in the CMJ's eccentric and concentric phases. Overall VL: BF ratio slightly decreased, indicating balanced co-activation rather than quadriceps dominance. VL and BF pre-activation also increased in single-leg forward jump landings (SLFJL) with an improved VL: BF ratio shown in Table 3. A balanced increase in

quadriceps and hamstring activity before landing is generally favourable for dynamic knee stability [33]. In the drop jump (Table 4), VL activation increased across all phases, which was also reflected in the improved jump height. However, MGC activation decreased across all phases, indicating reduced lower-leg stiffness, which may be counterproductive for jump performance [15]. While excessive stiffness can limit shock absorption, the post-training values in our athletes were closer to those reported in trained populations [17], suggesting a shift toward more optimal landing mechanics and improved shock absorption capacity. Recent reviews indicate that the gastrocnemius can substantially contribute to anterior tibial shear and thus ACL loading, particularly at low knee flexion angles [19]. Higher activation in pre-test during DJ could be likely because the task was new to beginners, and lower neuromuscular coordination in jump landing tasks.

V. LIMITATIONS AND FUTURE DIRECTIONS

This pilot has several limitations that should be considered when interpreting the results. First, the small sample size ($n = 8$) and the absence of a control group limit generalizability and statistical power. Second, the pilot only implemented the first two weeks of a planned six-week protocol and used beginner participants; results may not generalise to the advanced/professional athletes planned for the main trial. Third, we did not use a force plate; landing phases were identified from high-speed video, which was synchronised to EMG, so no direct kinetic measures were recorded.

Overall, the findings from this pilot indicate that even a short exposure to the K-COM protocol can produce meaningful improvements in explosive performance and positive shifts in muscle activation patterns in beginner kabaddi raiders. These early outcomes, combined with the high adherence and absence of adverse events, provide a strong rationale for proceeding to the main trial with advanced or professional kabaddi athletes. A longer intervention, broader EMG muscle set, and refined landing-specific tasks will allow for more accurate profiling of landing strategies, improved injury risk prediction, and a clearer understanding of how complex training can optimise performance in the unique demands of kabaddi.

VI. CONCLUSIONS

This pilot confirmed the K-COM protocol is feasible, safe, and well-tolerated by beginner kabaddi raiders, with full adherence and no injuries. Even over just two weeks, athletes showed measurable improvements in jump, sprint, and COD performance, alongside favourable changes in muscle activation patterns. These findings support progressing to a longer trial in advanced athletes, with refinements such as a broader EMG muscle set and sport-specific landing tasks to better evaluate K-COM's potential for enhancing performance and reducing lower-limb injury risk in kabaddi.

➤ *Conflict of Interest:*

No conflict of interest

➤ *Informed Consent:*

Informed consent was taken from all the participants.

➤ *Ethical Approval:*

Ethical approval was obtained from the university's ethical committee.

➤ *Funding:*

None

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