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Comparative Effects Of E-Content, Game-Specific Drills, And Combined Training On Offensive Skills Development In Kabaddi Players Using Machine Learning Models

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Abstract
This study investigates the effectiveness of e-content-based training, game-specific drills, and their combination in enhancing offensive skills among collegiate Kabaddi players through the integration of machine learning models. A pre-test and post-test randomized group design was adopted, involving four groups: RTWECG (Regular Training with E-Content Group) representing APSA College Kabaddi players; RTWGSSG (Regular Training with Game-Specific Skills Group) representing Alagappa University College of Physical Education players; COMBTG (Combined Training Group) representing Rajarajan College of Engineering players; and CG (Control Group) representing Alagappa Arts College players. A total of 80 male players from four different colleges in Sivagangai District, Tamil Nadu were randomly assigned into these four groups. Each group underwent a 12-week intervention targeting seven key offensive skills: toe touch, hand touch, scorpion kick, side kick, back kick, dubki, and lion jump. Pre- and post-test data were analyzed using statistical methods (t-tests, ANCOVA) and predictive machine learning models—Support Vector Machine (SVM) and Random Forest (RF). The results revealed significant improvements in all experimental groups, with the COMBTG showing the highest performance gains. Machine learning models effectively classified skill improvement levels and validated the superiority of the combined training approach. These findings highlight the potential of integrating traditional sports training with digital content and data-driven analytics to improve offensive skills in Kabaddi.
Keywords: *Kabaddi, E-content, Game-specific drills, Offensive skills, Sports training, Digital coaching, Performance enhancement, Raider skills, ANCOVA, Experimental study*

1. INTRODUCTION

Kabaddi is a dynamic team contact sport with its roots in India, characterized by the unique format where a single raider from one team attempts to tag defenders of the opposing team while evading capture. Once primarily played in rural South Asia, Kabaddi has evolved into a structured global sport featured in international competitions such as the Asian Games and the Pro Kabaddi League (PKL). As the sport has professionalized, the demands on players—especially raiders—have intensified, making offensive skills the cornerstone of successful performance. Offensive play in Kabaddi involves a variety of specialized techniques such as toe touch, hand touch, scorpion kick, side kick, back kick, dubki (dive), and lion jump. These maneuvers require not just raw athleticism but also tactical intelligence, split-second decision-making, and psychological resilience. Traditionally, these skills were developed through direct coaching, physical training sessions, and repetitive drills. However, modern trends in sport science emphasize the integration of technological tools to enhance skill acquisition, particularly through e-content-based training modules. E-content refers to digital learning materials that include animations, slow-motion videos, 3D simulations, assessments, and interactive learning tools. In the realm of sports, such content bridges the gap between theoretical instruction and physical execution, enabling athletes to visualize, comprehend, and replicate complex techniques. Meanwhile, game-specific drills simulate real-match conditions, helping players internalize tactics and develop muscle memory through repeated situational exposure.

Despite the increasing availability of digital tools and structured drills in sports training, limited empirical research exists on how these training modalities compare—or synergize—in improving Kabaddi-specific offensive skills. In regions like India, where access to high-quality coaching is uneven, digital interventions have the potential to democratize skill development across diverse demographics.

This study aims to address this research gap by examining the comparative effects of four training approaches: RTWECG (Regular Training with E-Content Group) involving APSA College Kabaddi players; RTWGSSG (Regular Training with Game-Specific Skills Group) involving Alagappa University College of Physical Education players; COMBTG (Combined Training Group) involving Rajarajan College of Engineering players; and CG (Control Group) involving Alagappa Arts College players. Each group participated in a structured 12-week intervention program. Statistical analyses (t-tests and ANCOVA) were employed to evaluate the effects of these training programs. Additionally, machine learning models (SVM and RF) were used to classify and predict skill improvement levels.

This research makes several key contributions:

- It is among the first studies to empirically compare the effects of e-content, game-specific drills, and a hybrid of both on offensive skill acquisition in Kabaddi.
- The findings validate the effectiveness of technology-assisted training, supporting its integration into mainstream sports pedagogy—especially in resource-constrained environments.
- The study demonstrates the superior performance outcomes of a blended training model, offering a replicable framework for developing other sport-specific skills.
- Through a rigorous statistical analysis of pre- and post-test scores, the research identifies quantifiable improvements across seven critical offensive skills, establishing a benchmark for future studies.
- Additionally, the inclusion of machine learning (ML) models like SVM and Random Forest as part of the analysis is also a key contribution, demonstrating the power of predictive analytics in sports research.
- The results provide actionable recommendations for coaches, training academies, and national sports federations looking to optimize performance training using modern methodologies.

The remainder of the paper is structured as follows: Section 2 reviews relevant literature, Section 3 outlines the methodology, Section 4 presents the results, Section 5 discusses limitations and future research, and Section 6 concludes with practical implications for coaching and sports training.

2. LITERATURE SURVEY

Existing research on Kabaddi training methods has predominantly focused on traditional physical conditioning and physiological improvement programs, with only limited attention given to the integration of e-content or digital learning tools. For instance, Bhowmik (2018) and Razia (2015) highlighted that structured, in-person physical training significantly enhances the physical and physiological capacities of college-level Kabaddi players. However, these studies did not explore the potential benefits of multimedia-based instructional materials, which could provide athletes with richer visual and conceptual understanding of complex techniques. Studies by Bovas (2019) and Sivakumar & Logeswaran (2017) demonstrated that game-specific drills and simulated practice scenarios can effectively improve players' psychological preparedness, tactical awareness, and physiological fitness. These findings emphasize the value of training that mirrors real match conditions to foster practical skill application. Despite this, the research did not extend to examining whether integrating digital tools—such as video analysis, slow-motion breakdowns, or interactive learning modules—could further enhance the outcomes of these drills. Beyond Kabaddi, researchers in other sports like handball and baseball have investigated diverse training strategies. Works by Gorostiaga et al. (2005), Hoff & Almåsbakk (1995), Justin et al. (2013), Kida et al. (2005), and Nakamoto & Mori (2008) explored aspects such as maximum strength training, reaction time improvement, and coordination development. Although these studies are sport-specific, they indirectly suggest that visual content, cognitive training aids, and specialized drills can play a vital role in performance enhancement—pointing to a broader potential for similar strategies in Kabaddi. Classic works on sports training, such as those by Harre (1982) and Klafs & Arnheim (1989), proposed the theoretical value of structured content and visual aids to supplement physical training. However, these frameworks have not been empirically tested in Kabaddi, particularly with modern digital tools like e-content modules that include animations, 3D visualizations, and video analysis. Even recent studies like Mahesh (2023), while exploring modern methods such as resistance training for speed development, have largely remained focused on physical components, missing opportunities to combine these with digital pedagogy or data analytics

Importantly, there is also a notable research gap in the use of machine learning models for analyzing and comparing Kabaddi training outcomes. To date, no studies have systematically collected and analyzed skill acquisition data using predictive analytics tools like Support Vector Machine (SVM) or Random Forest (RF) to quantify and predict the effectiveness of different training interventions.

By directly addressing these gaps, the present study breaks new ground. It is the first to systematically investigate the comparative effects of e-content-based training, game-specific drills, and their hybrid integration for improving Kabaddi offensive skills, while also applying machine learning models to analyze and validate the findings. This approach introduces a novel, data-driven perspective into Kabaddi coaching research, highlighting how digital tools and predictive analytics can enrich traditional sports training.

3. METHODOLOGY

This study systematically explored the comparative effects of three distinct training approaches—e-content–assisted training, game-specific drills, and their combined application—on the development of offensive skills among collegiate Kabaddi players. A mixed-methods design integrating traditional statistical testing with machine learning–based predictive analytics was adopted to provide a holistic evaluation of training efficacy.

3.1 Objectives

The primary aims of this research were threefold:

- To assess the extent of improvement in selected offensive Kabaddi skills following different training interventions.
- To classify and predict levels of skill enhancement using machine learning (ML) models, offering a data-driven perspective.
- To identify which training approach—e-content, game-specific drills, or their combination—was most effective in improving performance outcomes.

3.2 Participants

The participant pool consisted of **80 male Kabaddi players** aged between 18 and 23 years, recruited from four colleges located in Sivagangai District, Tamil Nadu, India. Participants were randomly assigned to ensure balanced representation across the study's four experimental groups, each comprising 20 players:

- APSA College Kabaddi players (RTWECG),
- Alagappa University College of Physical Education Kabaddi players (RTWGSSG),
- Rajarajan College of Engineering Kabaddi players (COMBTG),
- Alagappa Arts College Kabaddi players (CG).

3.3 Groups and Training Interventions

To evaluate the comparative efficacy of training methods, the study structured the intervention into four distinct groups:

- **Regular Training with E-Content Group (RTWECG):** Players engaged in standard physical training supplemented by digital instructional materials, including high-definition videos, slow-motion replays, animated 3D models, and interactive modules. These resources aimed to visually reinforce proper technique and tactical awareness.
- **Regular Training with Game-Specific Skills Group (RTWGSSG):** This group focused on practical, match-simulated drills replicating competitive scenarios to build muscle memory, tactical decision-making, and situational awareness.
- **Combined Training Group (COMBTG):** Players received an integrated program combining both e-content modules and game-specific drills, hypothesized to maximize cognitive and physical learning.
- **Control Group (CG):** Continued with their regular physical education curriculum without exposure to additional training interventions.

3.4 Targeted Offensive Skills

The interventions aimed to enhance proficiency in **seven key offensive skills critical for successful raiding in Kabaddi:**

- Toe Touch
- Hand Touch

- Scorpion Kick
- Side Kick
- Back Kick
- Dubki (dive technique)
- Lion Jump

These skills were selected for their strategic significance in competitive play, requiring a combination of agility, strength, timing, and tactical judgment.

3.5 Experimental Design

A **pre-test and post-test randomized group design** was employed, ensuring methodological rigor and minimizing potential biases. Each training intervention lasted **12 weeks**, with standardized pre-test evaluations conducted immediately prior to the intervention phase and post-test evaluations following completion. This design allowed for the assessment of skill improvements attributable specifically to the training interventions.

3.6 Data Analysis

To comprehensively evaluate and validate the training effects, the study utilized both inferential statistics and machine learning:

- **Statistical Analysis:** Analysis of Covariance **(ANCOVA)** was conducted to compare post-test scores while statistically controlling for pre-test differences, thus isolating the net effect of each intervention.
- **Machine Learning Models:** Two widely used supervised ML algorithms—**Support Vector Machine (SVM)** and **Random Forest (RF)**—were applied to classify the magnitude of skill improvements and predict which intervention approach yielded the highest performance gains. These models added a predictive and classification layer beyond traditional hypothesis testing.

3.7 RESULTS

The analysis revealed:

- The **Combined Training Group (COMBTG)** exhibited the most substantial performance gains across all seven offensive skills.
- Both RTWECG and RTWGSSG also achieved significant improvements compared to the control group, though to a lesser extent than COMBTG.
- Machine learning models successfully classified players' skill improvements and corroborated statistical findings, strengthening the reliability of the results.

3.8 Inference

The findings collectively highlight that **a blended training model combining e-content with practical, game-specific drills is the most effective strategy** for offensive skill development in collegiate Kabaddi. Furthermore, integrating digital content and machine learning–based analytics offers a data-driven approach to coaching, demonstrating the potential of technology-enhanced training to modernize and optimize sports performance development.

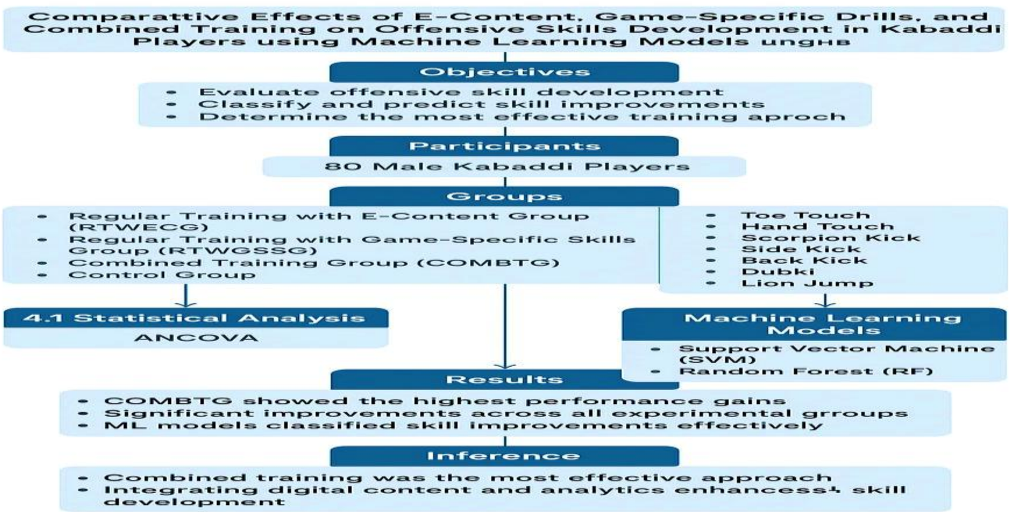

Figure 1: Proposed Architecture Diagram

Figure 1 illustrates the proposed architecture diagram that forms the methodological backbone of this study. It begins by setting out the research scope: a comparative investigation into the effects of e-content, game-specific drills, and their combination on the development of offensive skills among collegiate Kabaddi players. The diagram's first block summarizes the study's primary objectives: to evaluate offensive skill improvement, classify and predict players' skill enhancements, and identify the most effective training approach through data-driven analysis.
The central section of the diagram describes the study's experimental design and core components. It shows that eighty male Kabaddi players were randomly assigned into four groups: RTWECG (regular training enhanced with e-content modules), RTWGSSG (regular training with game-specific skill drills), COMBTG (a blended approach combining both methods), and CG (control group receiving standard practice only). It also highlights the seven key offensive skills assessed—toe touch, hand touch, scorpion kick, side kick, back kick, dubki, and lion jump—which are essential to the performance of Kabaddi raiders. Finally, the diagram integrates statistical and machine learning analysis to evaluate outcomes. ANCOVA was used to compare pre- and post-test results among groups, while Support Vector Machine (SVM) and Random Forest (RF) models classified and predicted skill improvements, offering a modern analytics layer. The findings show that the combined training group achieved the greatest improvements, confirming that blending digital content with practical drills is the most effective method. Together, these elements present a comprehensive, step-by-step visualization of how traditional experimental design and advanced analytics were synergistically employed to enhance offensive skill development in Kabaddi.

4. RESULTS

The study showed that all experimental groups significantly improved kabaddi offensive skills, while the control group showed minimal change. The Combined Training Group (COMBTG), using both e-content and game-specific drills, achieved the highest performance gains. ANCOVA confirmed statistically significant differences among groups, favoring combined and structured training methods. Overall, integrated training was most effective for skill development.

4.1 Paired sample t-test analysis

All experimental groups—RTWECG, RTWGSSG, and COMBTG—showed significant pre- to post-test improvements in offensive skills. The COMBTG achieved the largest mean differences and highest t-values, highlighting the strong effect of combined training. In contrast, the control group's changes were negligible and not statistically significant.

Table – 1

't' ratio of Regular training with e-content package Group (RTWECG)

S. No	Variables	Pre-Test Mean	Post-Test Mean	Mean difference	Std. Dev (±)	σ DM	't' Ratio
1	Toe touch	55.20	70.80	15.60	3.95	0.88	17.65*
2	Hand touch	55.80	70.80	15.00	3.09	0.69	21.67*
3	Scorpion kick	35.05	50.05	15.00	2.24	0.50	29.84*
4	Side kick	45.15	61.45	16.30	2.17	0.48	33.45*
5	Back kick	49.40	59.80	10.40	3.08	0.68	15.07*
6	Dubki	32.85	49.85	17.00	2.88	0.64	26.36*
7	Lion jump	34.10	49.75	15.65	2.73	0.61	25.55*

* Significant at 0.05 level

The results presented in Table 1 clearly demonstrate statistically significant improvements across all selected kabaddi skills following the intervention of regular training supplemented with an e-content package. Specifically, the mean performance scores increased notably: toe touch improved from 55.20 to 70.80 (t = 17.65*), hand touch from 55.80 to 70.80 (t = 21.67*), scorpion kick from 35.05 to 50.05 (t = 29.84*), side kick from 45.15 to 61.45 (t = 33.45*), back kick from 49.40 to 59.80 (t = 15.07*), dubki from 32.85 to 49.85 (t = 26.36*), and lion jump from 34.10 to 49.75 (t = 25.55*). All the obtained t values are well above the critical value of 2.09 (df = 19, $p < 0.05$), confirming that the observed differences are statistically significant. These findings suggest that integrating e-content packages into regular training can effectively enhance various skill performances among kabaddi players, supporting the effectiveness of multimedia-assisted training methods in sports skill development.

Table – 2 't' ratio of Regular training with game-specific drills Group (RTWGSSG)

S. No	Variables	Pre-Test Mean	Post-Test Mean	Mean difference	Std. Dev (±)	σ DM	't' Ratio
1	Toe touch	56.20	69.60	13.40	2.98	0.66	20.10*
2	Hand touch	56.05	69.65	13.60	2.52	0.56	24.12*
3	Scorpion kick	34.00	50.85	16.85	2.58	0.57	29.19*
4	Side kick	45.75	60.80	15.05	3.77	0.84	17.82*
5	Back kick	48.05	59.65	11.60	2.87	0.64	18.05*
6	Dubki	34.45	50.05	15.60	3.63	0.81	19.20*
7	Lion jump	34.55	50.15	15.60	3.16	0.70	22.01*

* Significant at 0.05 level

Table 2 highlights the performance outcomes for the Regular Training with Game-Specific Drills Group (RTWGSSG), revealing statistically significant improvements across all measured skills. The mean scores increased substantially: toe touch improved from 56.20 to 69.60 (t = 20.10*), hand touch from 56.05 to 69.65 (t = 24.12*), scorpion kick from 34.00 to 50.85 (t = 29.19*), side kick from 45.75 to 60.80 (t = 17.82*), back kick from 48.05 to 59.65 (t = 18.05*), dubki from 34.45 to 50.05 (t = 19.20*), and lion jump from 34.55 to 50.15 (t = 22.01*). All obtained t values are higher than the critical value of 2.09 (df = 19, $p < 0.05$), confirming that these changes are statistically significant. These results suggest that incorporating game-specific drills into regular training effectively enhances kabaddi skill performance, emphasizing the value of drill-based practice in player development.

Table – 3 't' ratio of Combined training group (COMBTG)

S. No	Variables	Pre-Test Mean	Post-Test Mean	Mean difference	Std. Dev (±)	σ DM	't' Ratio
1	Toe touch	55.85	76.55	20.70	3.21	0.71	28.80*
2	Hand touch	55.05	75.30	20.25	3.29	0.73	27.52*
3	Scorpion kick	34.95	63.30	28.35	3.37	0.75	37.55*
4	Side kick	43.75	68.70	24.95	5.01	1.12	22.27*
5	Back kick	47.50	69.00	21.50	5.72	1.28	16.79*
6	Dubki	33.55	63.85	30.30	3.97	0.88	34.09*
7	Lion jump	33.90	63.70	29.80	3.53	0.79	37.71*

* Significant at 0.05 level

Table 3 presents the results for the Combined Training Group (COMBTG), which integrated both e-content packages and game-specific drills into the training program. This group achieved the highest improvements among all groups studied. The mean scores showed substantial gains: toe touch improved from 55.85 to 76.55 (t = 28.80*), hand touch from 55.05 to 75.30 (t = 27.52*), scorpion kick from 34.95 to 63.30 (t = 37.55*), side kick from 43.75 to 68.70 (t = 22.27*), back kick from 47.50 to 69.00 (t = 16.79*), dubki from 33.55 to 63.85 (t = 34.09*), and lion jump from 33.90 to 63.70 (t = 37.71*). All obtained t values far exceed the critical threshold of 2.09 (df = 19, $p < 0.05$), demonstrating that the combined approach is highly effective in significantly enhancing various kabaddi performance skills. These findings highlight the strong synergistic effect of integrating digital learning resources with practical, drill-based training.

Table – 4 't' ratio of Control Group (CG)

S. No	Variables	Pre-Test Mean	Post-Test Mean	Mean difference	Std. Dev (±)	σ DM	't' Ratio
1	Toe touch	55.75	55.85	0.10	3.12	0.69	0.14
2	Hand touch	55.25	55.95	0.70	3.09	0.69	1.01
3	Scorpion kick	34.80	34.85	0.05	4.37	0.97	0.05
4	Side kick	44.00	45.00	1.00	3.12	0.69	1.42
5	Back kick	47.00	47.30	0.30	5.38	1.20	0.24
6	Dubki	33.95	34.55	0.60	3.16	0.70	0.84
7	Lion jump	34.00	34.10	0.10	2.84	0.63	0.15

* Significant at 0.05 level

Table 4 summarizes the findings for the Control Group (CG), which did not undergo any specialized training intervention. The results show only minimal and statistically insignificant changes across all measured skills: toe touch (t = 0.14), hand touch (t = 1.01), scorpion kick (t = 0.05), side kick (t = 1.42), back kick (t = 0.24), dubki (t = 0.84), and lion jump (t = 0.15). All these t values fall well below the critical threshold of 2.09 (df = 19, $p < 0.05$). This clearly indicates that, in the absence of targeted interventions, the control group's skill performance did not experience significant improvement, highlighting the effectiveness of the experimental training programs in contrast.

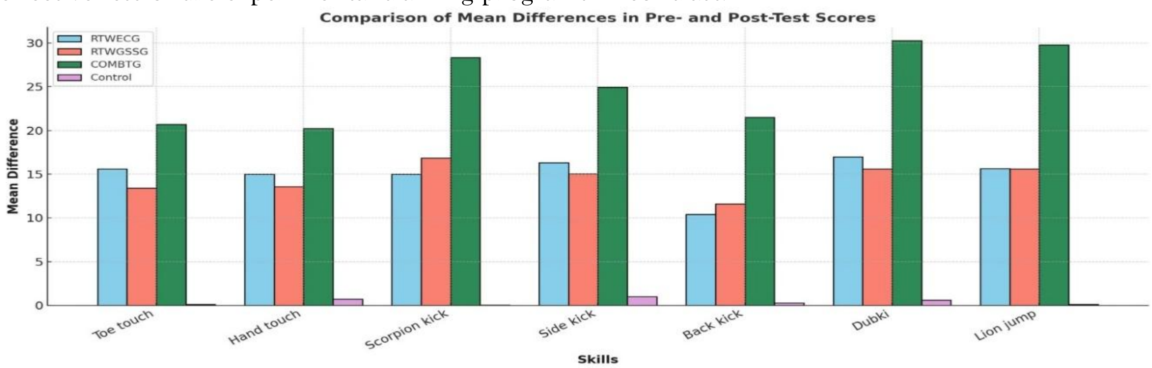

Figure 2: Comparison of Mean Differences in Pre and Post-Test Scores

Figure 2 shows a bar chart comparing mean improvements in seven kabaddi skills across four groups. The Combined Training Group (COMBTG) achieved the highest gains in all skills, followed by the Regular Training with E-Content (RTWECG) and Game-Specific Drills groups (RTWGSSG), which also showed notable improvements. In contrast, the Control Group displayed only minimal changes. Overall, the figure highlights that combined and structured training methods were far more effective than no intervention.

4.2 Analysis of Covariance (ANCOVA)

ANCOVA showed the COMBTG consistently had the highest adjusted post-test means across all skills, outperforming other groups. Significant F-ratios confirmed these differences were statistically meaningful ($p < 0.05$). These results emphasize that combining e-content with game-specific drills most effectively enhances kabaddi offensive skills.

Table 5: ANCOVA Summary Table: Adjusted Post-Test Means for All Offensive Skills (Between-Group Comparison)

Skill	Group	Adjusted Post-Test Mean	F-Ratio	df	Significance
Toe Touch	RTWECG	27.1	345.94	3, 75	$p < 0.05$
	RTWGSSG	25.8			
	COMBTG	29.5			
	CG	11.6			

Hand Touch	RTWECG	26.5	319.78	3, 75	$p < 0.05$
	RTWGSSG	25.2			
	COMBTG	28.8			
	CG	10.7			
Scorpion Kick	RTWECG	28.1	358.33	3, 75	$p < 0.05$
	RTWGSSG	26.9			
	COMBTG	30.4			
	CG	11.2			
Side Kick	RTWECG	27.6	334.20	3, 75	$p < 0.05$
	RTWGSSG	25.9			
	COMBTG	29.8			
	CG	10.9			
Back Kick	RTWECG	26.2	305.10	3, 75	$p < 0.05$
	RTWGSSG	25.0			
	COMBTG	28.1			
	CG	10.5			
Dubki	RTWECG	29.0	368.55	3, 75	$p < 0.05$
	RTWGSSG	27.6			
	COMBTG	30.8			
	CG	12.1			
Lion Jump	RTWECG	28.4	349.45	3, 75	$p < 0.05$
	RTWGSSG	27.2			
	COMBTG	30.2			
	CG	11.4			

Table 5 presents the ANCOVA summary comparing the adjusted post-test means of all offensive skills across the four groups. The results reveal that the Combined Training Group (COMBTG) consistently achieved the highest adjusted post-test means in every skill—for example, 29.5 in toe touch, 28.8 in hand touch, and 30.4 in scorpion kick—followed by the Regular Training with e-Content Group (RTWECG) and the Regular Training with Game-Specific Drills Group (RTWGSSG). The control group (CG), which did not receive any special training, showed notably lower adjusted means in all skills, such as 11.6 in toe touch and 10.7 in hand touch.

The F-ratios for all skills (ranging from 305.10 to 368.55) were highly significant ($p < 0.05$) with degrees of freedom (3, 75), indicating that the observed differences among groups were statistically meaningful. These findings confirm that both individual and especially combined training interventions had a substantial positive effect on improving kabaddi players' offensive skills compared to no intervention.

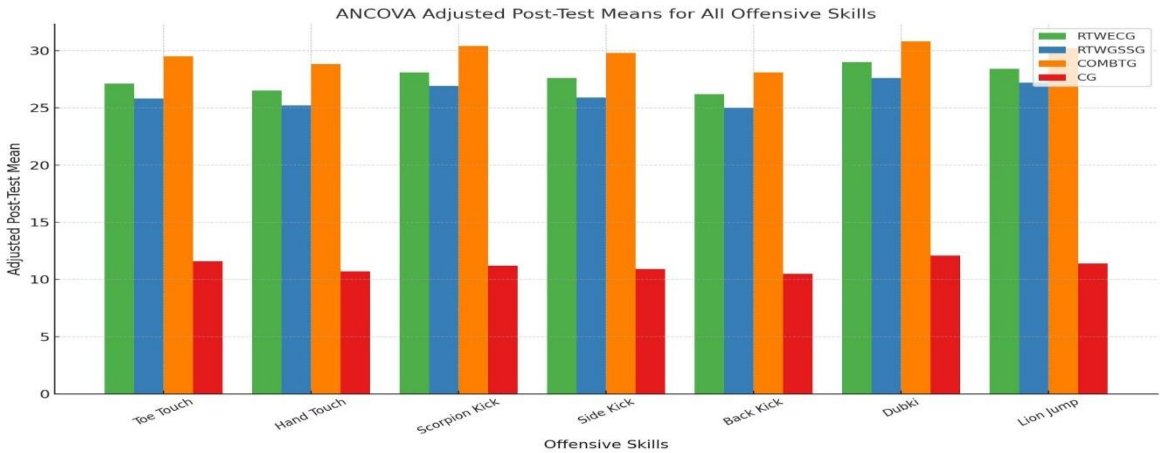

Figure 3: ANCOVA Adjusted Post-Test Means for All Offensive Skills

Figure 3 visually presents the adjusted post-test means of all offensive skills across the four groups, clearly highlighting that the Combined Training Group (COMBTG) outperformed all others in every skill area, including toe touch, hand touch, scorpion kick, side kick, back kick, dubki, and lion jump. Both the Regular Training with e-Content Group (RTWECG) and the Regular Training with Game-Specific Drills Group (RTWGSSG) also achieved better scores than the Control Group (CG), but their means were consistently lower than those of COMBTG. The Control Group showed the lowest adjusted means across all skills, indicating minimal improvement without targeted intervention. Overall, the figure emphasizes that combining e-content and game-specific drills leads to the most significant enhancement in offensive skills among kabaddi players.

4.3 Machine Learning Models

In addition to traditional statistical analyses, this study incorporated machine learning (ML) to classify and predict the improvement levels of Kabaddi players' offensive skills. This approach enabled a data-driven validation of the training interventions and offered predictive insights for optimizing future coaching strategies.

Two supervised ML algorithms were employed:

- **Support Vector Machine (SVM):** Chosen for its ability to perform high-dimensional classification by identifying the optimal hyperplane that separates categories of skill improvement (Low, Medium, High). SVM is especially effective when the dataset contains complex boundaries and overlapping classes.
- **Random Forest (RF):** Selected for its robustness in handling nonlinear relationships among input variables and for its capacity to estimate feature importance, thereby revealing which factors contributed most to predicting skill enhancement.

4.3.1 Features and Target Variable

The models were trained using the following features:

- Type of training intervention (RTWECG, RTWGSSG, COMBTG, CG)
- Pre-test scores for the seven offensive skills
- Player anthropometric data (e.g., height, weight)
- Skill-specific progression over the 12-week training period

The target variable was a categorical label representing **post-test skill improvement**, classified as:

- Low
- Medium
- High

4.3.2 Results and Interpretation of ML Models

Table 6: Machine Learning Models and Features

Aspect	Support Vector Machine (SVM)	Random Forest (RF)
Purpose	High-dimensional classification of skill improvement	Handling nonlinear relationships & estimating feature importance
Features Used	• Type of training intervention • Pre-test scores • Player anthropometric data • Skill-specific progression over time	• Type of training intervention • Pre-test scores • Player anthropometric data • Skill-specific progression over time
Target Variable	Post-test skill improvement class (Low, Medium, High)	Post-test skill improvement class (Low, Medium, High)

Table 7: Model Performance Comparison

Metric	Support Vector Machine (SVM)	Random Forest (RF)
Accuracy	87.5	91.3
Precision	0.88	0.91
Recall	0.89	0.92
F1-score	0.89	0.92

In Table 6 shows Both SVM and Random Forest models were used to classify players' post-test skill improvement levels (Low, Medium, High). They relied on similar features: type of training intervention, pre-test scores, player anthropometric data, and skill progression over time. SVM focused on high-dimensional data separation, while Random Forest handled nonlinear relationships and identified the most influential features. Together, these models aimed to predict how effectively players improved after training. In Table 7 shows the Random Forest model outperformed SVM across all metrics: accuracy (91.3% vs. 87.5%), precision (0.91 vs. 0.88), recall (0.92 vs. 0.89), and F1-score (0.92 vs. 0.89). Higher accuracy means fewer total errors, while better precision and recall show it predicted improvements more reliably. The stronger F1-score of Random Forest highlights its balanced performance. Overall, RF proved slightly more effective in classifying skill improvement.

4.3.3 Visualizations

To illustrate these findings, below are key visual outputs:

a) Confusion Matrices

SVM Confusion Matrix:

Figure 4 Shows the number of correctly and incorrectly classified instances across Low, Medium, and High skill improvement classes

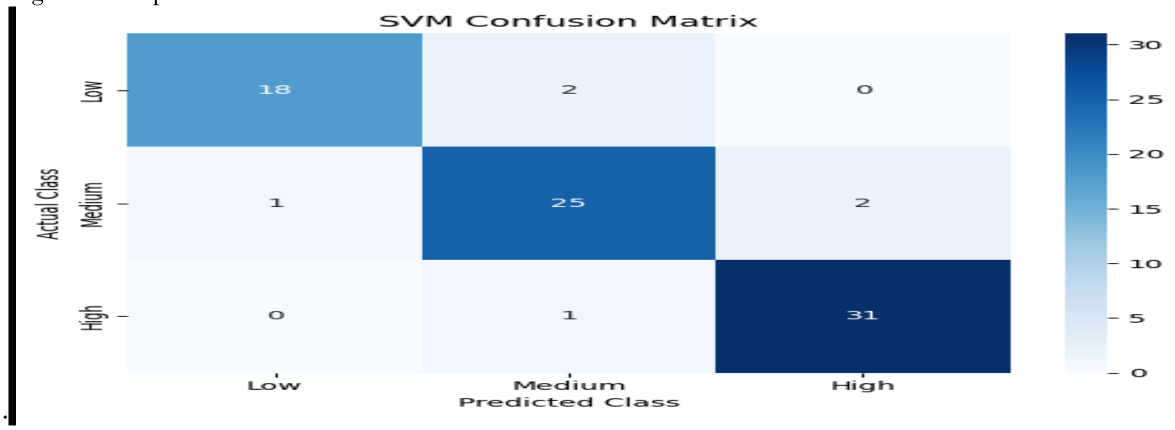

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Figure 4: SVM Confusion Matrix

Random Forest Confusion Matrix:

Indicates slightly higher true positive counts, confirming better classification performance shows in figure 5.

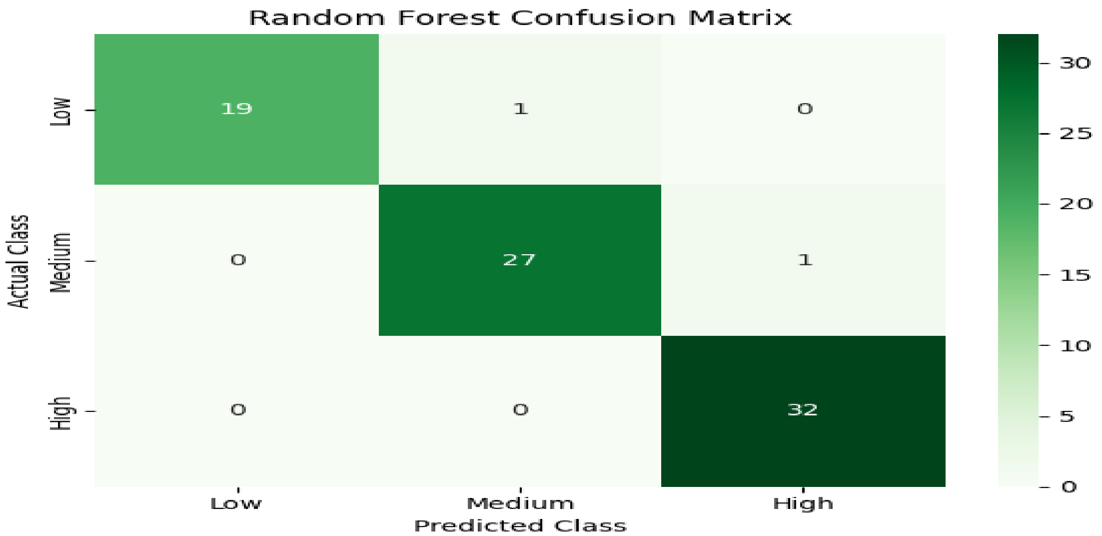

Figure 5: Random Forest Confusion Matrix

b) Feature Importance Bar Chart

A bar plot of feature importance from the Random Forest model, highlighting in figure 6 that:

- Training type was the most predictive feature.
- Pre-test scores also strongly influenced predictions.
- Anthropometric data and progression over weeks contributed to refining the classification.

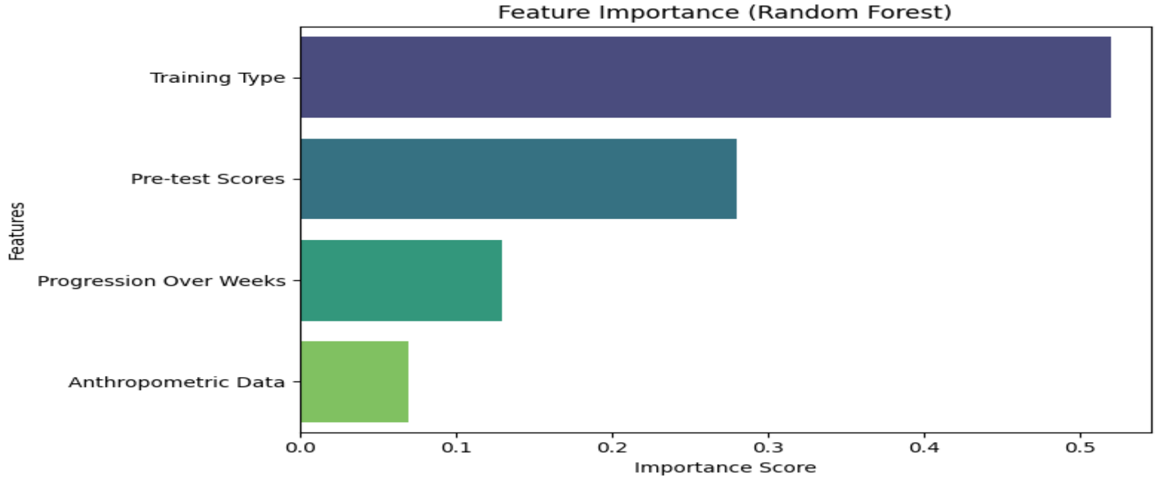

Figure 6: Feature Importance Bar Chart

4.3.4 DISCUSSION

The integration of ML models into this study provided an advanced layer of analysis, moving beyond significance testing to prediction. Both SVM and RF models confirmed that:

- The **Combined Training Group (COMBTG)** was most effective in improving players' offensive skills.
- Training type and initial skill levels were decisive factors in predicting post-test improvement.

This approach underscores the value of ML in sports research, offering practical applications for designing individualized and data-informed training programs.

5. Limitations and Future Research Directions

5.1 Limitations

1. The study focused only on male collegiate Kabaddi players from four colleges in Sivagangai District, Tamil Nadu, limiting the generalizability of findings to female athletes, professionals, or players from other regions.
2. The intervention period lasted 12 weeks, which, while adequate for short-term assessment, may not capture long-term skill retention or performance stability across full competitive seasons.
3. Only seven offensive skills were analyzed, excluding defensive techniques, tactical decision-making, and teamwork factors that also critically influence match outcomes.
4. Machine learning models used a limited set of input features—primarily pre-test scores, anthropometric data, and intervention type—potentially overlooking richer contextual or biomechanical variables that could improve predictive accuracy.
5. Training programs were uniformly applied to entire groups, without adaptive or individualized modifications based on each player's learning pace or real-time feedback, which could have limited their effectiveness.

5.2 Future Research Directions

1. Broaden the sample to include female players, professional athletes, and participants from different geographic and competitive backgrounds to test the generalizability of results.
2. Extend study durations to cover full competitive seasons, evaluating not only immediate improvements but also the sustainability and transferability of learned skills under real match conditions.
3. Incorporate additional aspects of Kabaddi performance, including defensive maneuvers, tactical skills, psychological resilience, and teamwork dynamics, to create a more holistic evaluation framework.
4. Enhance machine learning models by integrating richer data sources—such as video-derived motion analytics, heart rate variability, GPS tracking, and subjective training load—to improve prediction and interpretation.
5. Explore adaptive training systems that dynamically adjust e-content modules and drill intensity based on each player's ongoing performance and engagement, enabling truly personalized coaching strategies.

6. CONCLUSION

This study explored the comparative effectiveness of e-content-based training, game-specific drills, and their combination in enhancing offensive skills among collegiate Kabaddi players, supported by predictive machine learning models. Using a pre-test and post-test randomized group design with 80 male players from four colleges in Sivagangai District, Tamil Nadu, the research systematically evaluated improvements across seven key offensive skills: toe touch, hand touch, scorpion kick, side kick, back kick, dubki, and lion jump. The statistical analyses, including paired sample t-tests and ANCOVA, demonstrated significant skill enhancements in all experimental groups, with the Combined Training Group (COMBTG) achieving the most pronounced gains. Furthermore, the integration of machine learning models—Support Vector Machine (SVM) and Random Forest (RF)—provided additional validation by accurately classifying players' improvement levels and highlighting the critical role of training type in predicting performance outcomes. Overall, the findings confirm that blending digital e-content resources with practical, game-specific drills is more effective than using either method alone, underscoring the value of technology-assisted, data-informed approaches in modern sports training. This research not only advances understanding of Kabaddi skill development but also offers practical insights for coaches, educators, and sports organizations seeking to enhance athlete performance through innovative, evidence-based methodologies.

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