

ISSN Print: 2394-1685
ISSN Online: 2394-1693
IJPESH 2026; 13(10): 71-74
www.kheljournal.com
Received: 18-08-2026
Accepted: 27-09-2026
Published: 09-10-2026

Yuvaraj S
Assistant Physical Director, Takshashila University, Jaipur, Rajasthan, India

B Vidhya
Physical Education Teacher, Tamil Nadu, India

M Keerthana
Assistant Physical Director, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India

Yogeswarane P
Vice President, Villupuram Rocketball Association, Tamil Nadu, India

Corresponding Author:
Yuvaraj S
Assistant Physical Director, Takshashila University, Jaipur, Rajasthan, India

Cardiovascular load, neuromuscular fitness profiles, time-motion bioenergetics, and change of direction kinematics in Rocket Ball: An integrated sports science field study

Yuvaraj S[1], B Vidhya[2], M Keerthana[3], Yogeswarane P[4]

DOI: https://www.doi.org/10.22271/kheljournal.2026.v13.i10a.4854

Abstract
This field study documents selected cardiovascular, neuromuscular fitness characteristics, time-motion bioenergetics, and change of direction (COD) kinematics of 50 Rocket Ball players (N = 50) during match-related activity. Paired-samples t-tests reveal a statistically significant elevation in cardiovascular strain from resting conditions (87.82 ± 9.41 bpm) to high-intensity match play (131.06 ± 12.85 bpm; $t(49) = 21.43$, $p < 0.001$). Pearson product-moment correlation coefficients (r) demonstrate a strong inverse relationship between lower-body explosive power (standing broad jump) and 30 m sprint duration (r = -0.88, $p < 0.001$), as well as a moderate inverse correlation between high-intensity heart rate and sprint times (r = -0.42, p = 0.002). Time-motion analysis indicates an intermittent high-intensity work-to-rest ratio (1:3.0 to 1:4.0) heavily dependent on the ATP-PC energy system supported by aerobic recovery. Furthermore, biomechanical COD evaluations show mean plant contact times of 0.28 ± 0.08 s and 2–4 directional changes per active play episode, emphasizing the critical role of eccentric knee extensor strength. These statistical, bioenergetic, and kinematic analyses establish comprehensive normative benchmarks for Rocket Ball performance.

Keywords: Rocket Ball, Cardiovascular load, Heart rate, Neuromuscular fitness, Time-motion analysis, Bioenergetics, Change of direction (COD), Kinematics, Plant contact time

1. Introduction

Rocket Ball is a fast-paced, intermittent team sport where players continuously shift between short, explosive efforts—such as sprinting, passing, receiving, jumping, and rapid directional changes. Because match play demands both physical power and metabolic endurance, understanding how an athlete's body responds during a game is essential for effective coaching. Monitoring heart rate gives us direct insight into internal physiological strain across different phases of play, while physical fitness tests help quantify external athletic qualities like linear speed, lower-body power, and flexibility. By pairing stage-wise heart rate tracking, time-motion bioenergetics, and change of direction (COD) biomechanical profiling with field performance tests, this study evaluates the internal and external physical demands of Rocket Ball and explores how explosive fitness capacity connects with match intensity.

2. Objectives

- Measure cardiovascular responses across resting, warm-up, and high-intensity match play conditions.
- Evaluate key neuromuscular fitness traits, including lower-body power (standing broad jump), flexibility (sit-and-reach), upper-body mobility (arm flexibility), and acceleration (30 m sprint).
- Quantify time-motion variables, positional movement demands, and primary bioenergetic energy system contributions during match play.
- Evaluate Change of Direction (COD) kinematic parameters, including plant contact times (T_{plant}), cycle durations (T_{total}), cutting angle profiles, and 3-phase COD mechanics.
- Apply paired t-tests to assess significant heart rate changes across match stages.
- Analyze relationships between physical fitness tests and cardiovascular responses using Pearson correlation coefficients (r).

2394-1693, 2026, 13(10). Downloaded from https://www.doi.org/10.22271/kheljournal.2026.v13.i10a.4854 by International Journal of Physical Education, Sports and Health on [09/10/2026]. See the Terms and Conditions (https://www.kheljournal.com) for rules of use; OA articles are governed by the applicable Creative Commons License

3. Methods

3.1 Participants

The study cohort included 50 active male Rocket Ball players (N = 50) affiliated with regional sports associations and competitive clubs across Tamil Nadu. All participants routinely engaged in structured training and local competition.

3.2 Field measurements, time-motion & biomechanical COD profiling

- **Cardiovascular & Time-Motion Monitoring:** Resting heart rate was recorded prior to activity. Heart rate was evaluated immediately following standardized warm-ups and during peak high-intensity match play, alongside recorded peak maximum heart rate values. Single-value field blood pressure readings were recorded during initial assessments. To examine physiological and movement characteristics, match play across competition video datasets was analyzed using time-motion analysis principles, capturing work-to-rest intervals, movement vectors, and active vs. passive durations.
- **Change of Direction (COD) Kinematic Analysis:** To quantify COD performance during Rocket Ball match play, time-motion video analysis and sports biomechanics principles (cutting angles, plant-phase contact times, and deceleration mechanics) were applied. COD maneuvers were categorized by cutting angles (shallow < 45°, sharp 45°–90°, sharp pivot/180° turn, and lateral shuffling) to break down plant contact duration (T_{plant}) and total cycle duration (T_{total}).
- **Neuromuscular & Fitness Testing:**

• **Lower-Body Power:** Evaluated via Standing Broad Jump (SBJ), recording the best distance out of three trials in meters.
• **Flexibility:** Hamstring and lower-back mobility were measured using the Sit-and-Reach test (cm across three trials). Bilateral shoulder/arm flexibility was logged in both right-to-left and left-to-right directions.
• **Linear Speed:** Measured using a timed 30 m sprint in seconds.

3.3 Statistical analysis

Data were analyzed using descriptive statistics (Mean ± Standard Deviation). Paired-samples t-tests (t-ratio) evaluated physiological load shifts across activity phases. Pearson product-moment correlation coefficients (r) assessed relationships between physical performance measures and cardiovascular variables. Statistical significance was established at $\alpha = 0.05$.

4. Results

Table 1. Stage-Wise Cardiovascular Load Comparison (t-Test Analysis)

Comparison Pair	Mean Diff. (bpm)	Std. Dev.	t-Ratio (t)	df	*p*-Value
Resting HR vs. Warm-up HR	33.96	8.12	29.58	49	< 0.001*
Warm-up HR vs. High-Intensity HR	9.28	11.45	5.73	49	< 0.001*
Resting HR vs. High-Intensity HR	43.24	14.26	21.43	49	< 0.001*
High-Intensity HR vs. Max HR	73.56	12.10	42.98	49	< 0.001*

**Statistically significant at $p < 0.05$.*

Table 2. Performance & Physiological Correlations (Pearson *r* Analysis)

Variable Pair	Pearson *r*	Interpretation	*p*-Value
SBJ (Best) vs. 30 m Sprint	-0.88	Very strong negative correlation	< 0.001*
Sit & Reach vs. 30 m Sprint	-0.64	Moderate-to-strong negative correlation	< 0.001*
High-Intensity HR vs. 30 m Sprint	-0.42	Moderate negative correlation	0.002*
SBJ (Best) vs. Sit & Reach	+0.71	Strong positive correlation	< 0.001*
Resting HR vs. High-Intensity HR	+0.18	Weak positive correlation (non-significant)	0.212

**Statistically significant at $p < 0.05$.*

Table 3. Summary of Physical and Physiological Metrics (N = 50)

Parameter	Mean ± SD	Minimum	Maximum
Resting HR (bpm)	87.82 ± 9.41	71.00	110.00
Warm-up HR (bpm)	121.78 ± 7.18	110.00	145.00
High-Intensity HR (bpm)	131.06 ± 12.85	79.00	148.00
Recorded Peak Max HR (bpm)	204.62 ± 2.38	201.00	209.00
Standing Broad Jump Best (m)	2.12 ± 0.22	1.40	2.50
Sit & Reach Best (cm)	38.24 ± 6.85	20.00	50.00
30 m Sprint (s)	5.21 ± 0.36	4.75	6.03

4.1 Physical & bioenergetic demands of Rocket Ball match play

To examine the physiological and movement characteristics of Rocket Ball, match play across competition video datasets was analyzed using time-motion analysis principles. The game exhibits a high-intensity, intermittent work-to-rest profile dominated by the ATP-PC (phosphagen) energy system, supported by aerobic recovery mechanisms during dead-ball intervals.

23941693, 2026, 1(10), Downloaded from https://www.doi.org/10.22271/kheljournal2026.v13.i10a.4854 by International Journal of Physical Education, Sports and Health on [09/10/2026]. See the Terms and Conditions (https://www.kheljournal.com) for rules of use; OA articles are governed by the applicable Creative Commons License

Table 4. Work-Rest Profile and Time-Motion Analysis Summary

Performance Parameter	Quantitative Value / Range	Operational Definition / Field Context
Active Play Duration (Work)	3.5 s - 7.5 s ($\mu \approx 5.2$ s)	Continuous play episode from whistle/throw-in to ball dead or post-hit.
Rest / Passive Phase	12.0 s - 24.0 s ($\mu \approx 17.5$ s)	Time interval between play stoppage, ball retrieval, and set-piece positioning.
Work-to-Rest Ratio	1 : 3.0 to 1 : 4.0	Intermittent high-intensity exercise profile requiring rapid in-tra-game recovery.
Active Court Time Ratio	20% - 25% Active / 75% - 80% Rest	Ratio of active movement time relative to total match time elapsed.
Sprint Burst Duration	1.2 s $^{-3}$.0 s	High-acceleration linear/diagonal efforts during offensive drives and coverage.
Sprint Distance	4.0 m - 12.0 m	Short-distance acceleration bounded by court dimensions and 12-ft zone limit.
Sprint Frequency	4 - 7 efforts / minute	Micro-acceleration frequency per minute of active match time.
Primary Movement Vectors	Acceleration, Deceleration, Lateral Shuffling (2-4 m), Jump-Throws	Multi-directional movement pattern featuring plant-and-cut mechanics and rebounds.

4.2 Positional time-motion & physical demand profile

Table 5. Positional Demands and Tactical Movement Characteristics

Position / Role	Predominant Movement Patterns	Relative Work Load	Primary Energy System
Primary Attacker / Thrower	Maximal 3-step dynamic drives, jump-throws, high de-celeration forces	Very High	ATP-PC (Anaerobic Alactic)
Wingers / Rebound Catchers	Diagonal cutting, high-acceleration sprints (8-12 m), aerial rebound jumps	High	ATP-PC + Fast Glycolysis
Defenders / Out Players	Lateral shuffling (2-4 m), low-velocity zone coverage, rapid backpedaling	Moderate	Aerobic + Short Anaerobic Bursts

4.3 Change of direction (COD) kinematic & biomechanical analysis

During match play, players undergo rapid changes of direction when evading defenders, cutting to receive passes, or transitioning from an offensive throw to a defensive backpedal. COD is evaluated in terms of Plant Contact Time (T_{plant}, the time spent changing direction at the pivot point) and Total COD Task Time (T_{total}, encompassing deceleration, plant, and acceleration).

Table 6. Change of Direction (COD) Kinematic Parameters across Movement Types

COD Movement Type	Contact / Plant Time (T_plant)	Total COD Cycle Time (T_total)	Operational / Tactical Context
Shallow Cutting Angle (< 45°)	0.18 s - 0.28 s	0.60 s - 0.90 s	High-velocity curved runs and diagonal cuts to re-ceive a pass on the wing.
Sharp Cutting Angle (45° - 90°)	0.28 s - 0.42 s	0.90 s $^{-1}$.30 s	Rapid side-stepping to bypass a defender outside the 12-ft arc boundary.
Sharp Pivot / 180° Turnaround	0.40 s - 0.62 s	1.30 s $^{-1}$.80 s	Immediate transition from an offensive post-throw to defensive backpedaling/sprinting.
Lateral Defensive Shuffling (COD)	0.22 s - 0.35 s	0.50 s - 0.80 s	Quick directional shifts (left-to-right) along the 12-ft semi-circle arc to block throw lanes.

Note: Ground contact time (T_plant) during explosive COD reflects impulse generation and eccentric muscle control.

Breakdown of the 3-phase COD cycle

A complete Change of Direction maneuver consists of three distinct biomechanical phases:

- **Deceleration Phase (0.30 s - 0.50 s):** Eccentric loading of the quadriceps and gastrocnemius/soleus complex to reduce forward velocity.
- **Plant / Pivot Phase (0.18 s - 0.62 s):** Foot contact with the ground where re-orientation of trunk and mass center occurs (peak lateral/braking ground reaction force).
- **Re-Acceleration Phase (0.35 s - 0.60 s):** Concentric triple extension (hip, knee, ankle) to accelerate in the new vector (0 - 5 m).

23941693, 2026, 13(10), Downloaded from https://www.doi.org/10.22271/kheljournal2026.v13.i10a.4854 by International Journal of Physical Education, Sports and Health on [09/10/2026]. See the Terms and Conditions (https://www.kheljournal.com) for rules of use; OA articles are governed by the applicable Creative Commons License

Table 7. Change of Direction (COD) Temporal and Kinematic Profile Summary

Parameter	Quantitative Range / Average	Biomechanical Significance
Mean Plant Contact Time (T_{plant})	0.28 s ± 0.08 s	Measures explosive reactive strength and impulse generation during foot strike.
Total COD Duration (T_{total})	0.85 s $^{-1}$.45 s	Measures total time lost during directional transition (Deceleration + Plant + Acceleration).
COD Frequency per Active Episode	2 - 4 changes / episode	High agility demand driven by defender avoidance and court boundaries.
Dominant Cutting Angle	45° - 90°	Reflects sharp cutting mechanics around the 12-ft semi-circle arc.
Key Neuromuscular Demand	Eccentric Knee Extensor Strength	Essential for absorption of braking forces during rapid deceleration before re-acceleration.

5. Discussion

The statistical patterns, bioenergetic profiles, and COD kinematic parameters observed across players shed light on the multi-dimensional physical demands of Rocket Ball:

- **Cardiovascular Shifts & Bioenergetics:** The jump from resting baseline (87.82 bpm) to high-intensity match play (131.06 bpm) was substantial ($t = 21.43$, $p < 0.001$). The significant elevation from warm-up to live match conditions ($t = 5.73$, $p < 0.001$) underscores how rapidly internal workload spikes during explosive work episodes. The observed 1:3.0 to 1:4.0 work-to-rest ratio further highlights the primary reliance on the ATP-PC system for maximal energy delivery during attack bursts, supported by aerobic mechanisms to resynthesize phosphocreatine during passive rest intervals.
- **Neuromuscular Power & COD Biomechanics:** The strong negative correlation between standing broad jump distance and 30 m sprint times ($r = -0.88$) demonstrates that lower-body explosive power is a primary driver of acceleration. Time-motion and COD analysis corroborate this, showing that 2–4 directional changes occur per active episode, with plant contact times averaging 0.28 ± 0.08 s. The high eccentric loading demanded during the deceleration phase (0.30–0.50 s) highlights that reactive strength and eccentric knee extensor capacity are crucial for minimizing total COD cycle time (T_{total} = 0.85–1.45 s).

6. Practical applications & research synthesis

- **Movement Profile Focus:** Rocket Ball is an explosive, intermittent sport defined by ultra-short maximal accelerations (< 3 s) over short distances (4–12 m). Top-end speed is less critical than acceleration (0–5 m explosive power) and sudden deceleration mechanics.
- **Bioenergetic Target Conditioning:** The observed 1:3 to 1:4 work-to-rest ratio highlights the need for a well-developed ATP-PC system for maximal power output during scoring attempts, paired with a robust aerobic base to accelerate phosphocreatine resynthesis during 15–20 s dead-ball intervals.
- **Agility & COD Training Integration:** Conditioning protocols must target 45°–90° cutting mechanics and rapid plant phase execution (T_{plant} < 0.30 s). Incorporating eccentric strength drills (e.g., flywheel squatting, drop jumps, braking deceleration drills) will enhance knee extensor force absorption and reduce total COD duration.
- **Conditioning Applications & RSA:** Physical preparation should emphasize Repeated Sprint Ability (RSA) using short intervals (5 s work / 15–20 s rest), multi-directional change-of-direction (COD) drills, and single-leg plyometrics for rebound jumping and 3-step plant-and-throw executions.
- **Flexibility & Mobility Protocols:** The correlation between flexibility and sprint metrics ($r = -0.64$) suggests that dynamic stretching and joint mobility work should remain a staple in daily warm-up routines to support optimal stride mechanics.

7. Conclusion

Quantifying internal heart rate load, neuromuscular test measures, time-motion bioenergetics, and Change of Direction (COD) kinematics reveals that Rocket Ball relies heavily on a combination of lower-body explosive acceleration, intermittent ATP-PC power output, dynamic eccentric deceleration capabilities, reactive impulse generation during foot plant, and aerobic recovery resilience. These integrated statistical, biomechanical, and bioenergetic benchmarks offer physical education teachers, strength and conditioning coaches, and sports science practitioners empirical guidelines to fine-tune agility training, manage player fatigue, reduce injury risk during sharp cutting maneuvers, and optimize match performance.

References

1. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. Journal of Sports Sciences. 2006;24(7):665–674.
2. Bishop D, Girard O, Mendez-Villanueva A. Repeated-sprint ability—Part II: Recommendations for training. Sports Medicine. 2011;41(9):741–756.
3. Sheppard JM, Young WB. Agility literature review: Classifications, training and testing. Journal of Sports Sciences. 2006;24(9):919–932.
4. Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. Journal of Strength and Conditioning Research. 2005;19(1):76–78.
5. Haff GG, Nimphius S. Training principles for power. Strength and Conditioning Journal. 2012;34(6):2–12.

How to cite this article: S Y, Vidhya B, Keerthana M, P Y. Cardiovascular load, neuromuscular fitness profiles, time-motion bioenergetics, and change of direction kinematics in Rocket Ball: An integrated sports science field study. *International Journal of Physical Education, Sports and Health*. 2026;13(10):71-74. doi: https://www.doi.org/10.22271/kheljournal.2026.v13.i10a.4854

2394169, 2026, 13(10), Downloaded from https://www.doi.org/10.22271/kheljournal.2026.v13.i10a.4854 by International Journal of Physical Education, Sports and Health on [09/10/2026]. See the Terms and Conditions (https://www.kheljournal.com) for rules of use; OA articles are governed by the applicable Creative Commons License