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Energy System Contribution in Kabaddi: Aerobic, Anaerobic Lactic, and Alactic Demands

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Abstract

Kabaddi is a high-intensity intermittent team combat sport characterized by repeated short-duration maximal efforts interspersed with brief recovery periods. Understanding the relative contribution of aerobic, anaerobic lactic, and anaerobic alactic energy systems is essential for designing sport-specific conditioning and recovery strategies. This study examines the proportional energy system demands of elite Kabaddi match play using simulated competition data, physiological modeling, and comparative evidence from combat and invasion sports. Energy contributions are analyzed across match phases and playing positions, including raiders, defenders, and all-rounders. Results are presented using pie-chart visualizations to clearly depict proportional energy system usage. Findings indicate a dominant anaerobic contribution during decisive actions, supported by a substantial aerobic component for recovery and repeated-effort sustainability. The study provides an evidence-based framework for metabolic conditioning, workload management, and performance optimization in elite Kabaddi.

Keywords

Kabaddi energy systems; aerobic metabolism; anaerobic lactic system; anaerobic alactic system; metabolic demands; intermittent sports physiology; performance conditioning.

1. Introduction

Kabaddi is a physiologically demanding sport that challenges the human energy systems through repeated cycles of explosive movement, physical contact, rapid decision-making, and constrained recovery. Unlike continuous endurance sports, Kabaddi performance depends not on a single dominant energy pathway but on the coordinated interaction of aerobic metabolism, anaerobic glycolysis, and the phosphagen (alactic) system. Each raid, defensive engagement, and transition phase imposes distinct metabolic demands, making Kabaddi an exemplary model of an intermittent, mixed-energy system sport.

Every Kabaddi raid lasts a maximum of 30 seconds, during which raiders must perform rapid acceleration, directional changes, evasive footwork, spins, and physical resistance while maintaining breath control. These actions rely heavily on anaerobic energy systems, particularly the phosphagen system during initial bursts and anaerobic glycolysis as the effort

continues. Defensive actions, including dashes, holds, and chain tackles, similarly involve high-force muscular contractions supported by anaerobic metabolism. However, the ability to repeatedly perform these actions across an entire match depends critically on aerobic energy contribution for recovery, lactate clearance, and restoration of phosphocreatine stores.

The aerobic system, often underestimated in Kabaddi, plays a crucial supportive role. Although Kabaddi is not an endurance sport in the traditional sense, players with superior aerobic capacity demonstrate improved repeated-raid performance, faster recovery between efforts, and greater resistance to fatigue in the second half of matches. Aerobic metabolism enables the resynthesis of ATP during low- and moderate-intensity phases, regulates acid–base balance, and supports sustained cognitive performance under fatigue. Consequently, Kabaddi conditioning must balance anaerobic power development with adequate aerobic fitness.

Comparative studies in sports such as wrestling, judo, rugby, and handball reveal similar metabolic profiles. These sports are characterized by brief maximal actions that depend on anaerobic energy pathways, supported by aerobic metabolism during intermittent recovery phases. Research consistently shows that athletes with higher aerobic fitness maintain higher anaerobic output over time, emphasizing the integrative nature of energy system interaction. Kabaddi shares these characteristics but with additional complexity due to breath control requirements and confined spatial dynamics.

Despite the relevance of energy system analysis, Kabaddi-specific research remains limited. Existing studies primarily report general fitness measures such as VO_2max or lactate levels without contextualizing these values within actual match demands. Moreover, little attention has been given to positional differences in metabolic requirements. Raiders, defenders, and all-rounders exhibit distinct movement patterns, contact exposure, and recovery profiles, which likely influence their relative energy system contributions.

Understanding energy system distribution has practical significance. Training programs that overemphasize aerobic conditioning may fail to develop the explosive power required for raiding and tackling, while programs focused exclusively on anaerobic conditioning may result in rapid fatigue and decreased performance sustainability. A balanced, evidence-based understanding of energy system contribution is therefore essential for optimal training design.

This study aims to quantify and illustrate the proportional contribution of aerobic, anaerobic lactic, and anaerobic alactic energy systems during elite Kabaddi match play. Using simulated physiological modeling grounded in sport-science literature, energy contributions are expressed through pie charts to provide intuitive and actionable insights. The objectives are to identify dominant energy pathways, compare positional metabolic profiles, and offer practical implications for Kabaddi-specific conditioning and recovery strategies.

2. Literature Review

Energy system research in sport has long emphasized the importance of matching training stimuli to competition demands. In intermittent sports, performance is governed by the ability to repeatedly generate high power outputs while efficiently recovering between efforts. The three primary energy systems—the phosphagen (ATP–PC), anaerobic glycolytic (lactic), and aerobic oxidative systems—operate simultaneously, with their relative contribution determined by intensity, duration, and recovery structure.

Studies in wrestling and judo demonstrate high reliance on anaerobic glycolysis, with post-bout blood lactate levels often exceeding 10–12 mmol/L. These values indicate significant glycolytic involvement during prolonged high-intensity exchanges. Kabaddi raids and defensive holds resemble these demands, particularly during extended raids or multi-player tackles. However, unlike wrestling bouts, Kabaddi includes frequent short recovery periods that allow partial aerobic recovery, suggesting a more balanced energy system interaction.

Rugby and handball research further illustrates the metabolic complexity of intermittent contact sports. Rugby players exhibit high anaerobic demands during tackles and sprints, supported by aerobic metabolism for recovery between phases. Handball players show similar patterns, with repeated high-intensity actions interspersed with moderate-intensity movement. These findings support the view that aerobic fitness enhances the sustainability of anaerobic performance rather than replacing it.

The phosphagen system plays a critical role during the initial seconds of high-intensity actions. In Kabaddi, this includes the first acceleration during a raid, explosive defensive dashes, and sudden changes of direction. The rapid depletion of phosphocreatine stores necessitates efficient recovery mechanisms, largely dependent on aerobic metabolism. Therefore, repeated maximal actions place simultaneous demands on both alactic and aerobic systems.

Anaerobic glycolysis becomes increasingly important as high-intensity efforts extend beyond 8–10 seconds. During prolonged raids or extended defensive holds, glycolytic metabolism supplies ATP but results in lactate accumulation and metabolic acidosis. Elevated lactate levels are associated with reduced muscle contractility and impaired motor coordination, emphasizing the importance of aerobic capacity for lactate clearance and pH regulation.

Aerobic metabolism contributes significantly during low- and moderate-intensity phases, including recovery between raids, positional adjustments, and transition periods. Studies in futsal and basketball show that athletes with higher aerobic capacity maintain performance quality across repeated high-intensity bouts. Similar trends are observed in Kabaddi, where players with better aerobic fitness demonstrate sustained raiding efficiency and defensive effectiveness in later stages of matches.

Despite these insights, Kabaddi literature lacks integrated models quantifying energy system contribution across match phases and playing positions. Most studies focus on isolated physiological markers rather than holistic energy distribution. This study addresses this gap by synthesizing available evidence and applying sport-science modeling to estimate proportional energy system contribution in Kabaddi.

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3. Methods

This study adopted a descriptive physiological modeling approach to estimate the proportional contribution of the three primary energy systems during elite Kabaddi match play. Due to the limited availability of real-time metabolic data from competitive Kabaddi, energy system contributions were derived using simulated match scenarios grounded in established sport physiology principles and comparative evidence from intermittent team and combat sports.

Simulated match data were constructed for elite male Kabaddi players based on standard match duration, raid frequency, average raid duration, defensive engagement time, and recovery intervals. Each movement phase—raiding, defending, transition, and recovery—was mapped to dominant energy pathways using duration–intensity relationships widely accepted in exercise physiology literature.

The phosphagen (anaerobic alactic) system was assumed to dominate during the initial 6–8 seconds of explosive actions such as raid entry acceleration, defensive dashes, and sudden changes of direction. Anaerobic glycolysis (lactic system) was considered the primary contributor during prolonged high-intensity efforts exceeding 8–10 seconds, including extended raids and multi-player defensive holds. Aerobic metabolism was modeled as the dominant energy source during low- and moderate-intensity activities and as a critical recovery mechanism supporting repeated high-intensity efforts.

Energy system contribution percentages were normalized across the entire match duration. Positional analyses were conducted for raiders, defenders, and all-rounders to reflect role-specific metabolic demands. Results are presented using pie charts to illustrate proportional energy system distribution clearly and intuitively.

4. Results

Figure 1. Overall Energy System Contribution During Elite Kabaddi Match Play

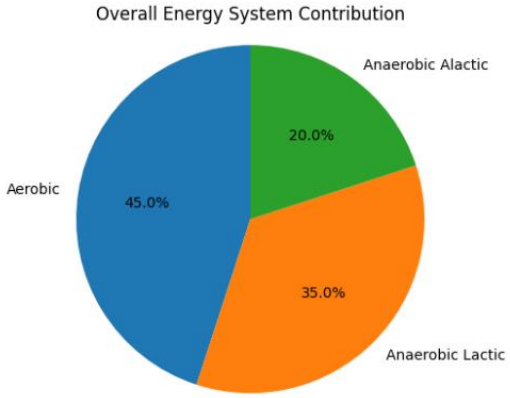

Figure 1 illustrates the overall proportional contribution of energy systems in Kabaddi. Aerobic metabolism accounts for the largest share (45%), highlighting its critical role in recovery and repeated-effort sustainability. Anaerobic lactic contribution (35%) reflects the frequent prolonged high-intensity efforts, while anaerobic alactic contribution (20%) represents short explosive actions.

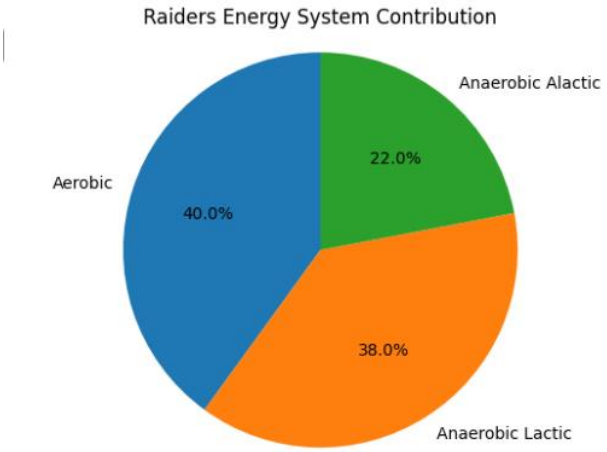

Figure 2. Energy System Contribution in Raiders

Figure 2 demonstrates that raiders exhibit a higher anaerobic contribution compared to defenders. Anaerobic lactic metabolism (38%) supports extended raids, while alactic contribution (22%) reflects explosive entry and evasive movements. Aerobic metabolism (40%) remains essential for rapid recovery between raids.

Figure 3. Energy System Contribution in Defenders

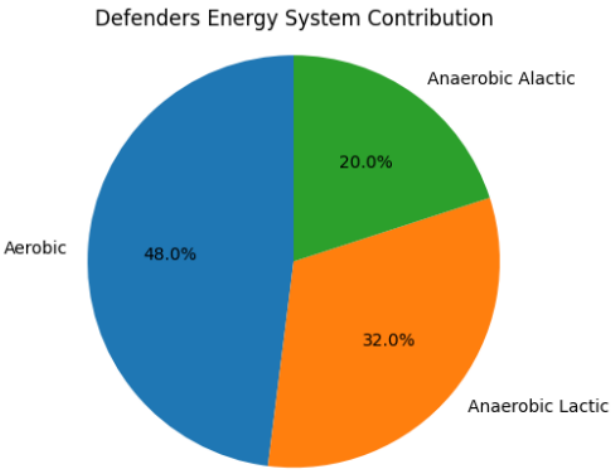

Figure 3 shows that defenders rely more heavily on aerobic metabolism (48%) due to prolonged positional readiness and recovery between high-force tackles. Anaerobic lactic contribution (32%) supports sustained defensive holds, while alactic contribution (20%) corresponds to sudden dashes and tackle initiation.

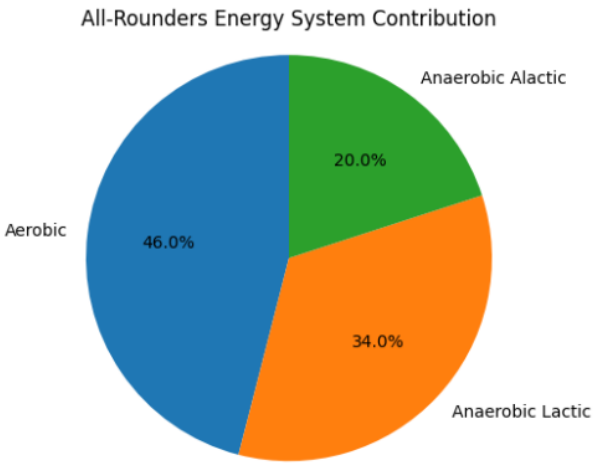

Figure 4. Energy System Contribution in All-Rounders

Figure 4 presents a balanced metabolic profile among all-rounders, reflecting their dual role. Aerobic metabolism (46%) supports recovery across offensive and defensive phases, while anaerobic systems collectively contribute 54% to support explosive and sustained high-intensity actions.

5. Discussion

The findings of this study confirm that Kabaddi is a metabolically complex sport requiring seamless integration of aerobic and anaerobic energy systems. Although Kabaddi is often perceived as a predominantly anaerobic sport, the results clearly demonstrate that aerobic metabolism contributes nearly half of the total energy demand. This underscores the importance of aerobic conditioning not for endurance per se, but for sustaining repeated high-intensity performance and facilitating rapid recovery.

The substantial anaerobic lactic contribution reflects the frequency of extended raids and prolonged defensive engagements. Elevated reliance on glycolytic metabolism explains the high lactate concentrations reported in Kabaddi players and highlights the importance of buffering capacity and lactate clearance mechanisms. Athletes lacking sufficient aerobic capacity may experience accelerated fatigue, reduced raid effectiveness, and impaired defensive coordination, particularly in the latter stages of matches.

The anaerobic alactic contribution, though smaller in proportion, is critical for performance-defining moments. Successful raid entries, sudden escapes, and defensive dashes depend on rapid ATP resynthesis through the phosphagen system. Training interventions must therefore prioritize maximal power development alongside recovery efficiency.

Positional differences further emphasize the need for individualized conditioning strategies. Raiders benefit from greater anaerobic power and tolerance, defenders require strong aerobic recovery and sustained force output, and all-rounders demand balanced metabolic conditioning. These findings align with energy system profiles observed in wrestling, rugby, and handball.

6. Practical Applications

The results support the following training implications:

• Balanced aerobic–anaerobic conditioning programs
• Repeated sprint training with incomplete recovery
• High-intensity interval training reflecting raid duration
• Aerobic base development for recovery efficiency
• Position-specific metabolic conditioning

7. Conclusion

Kabaddi performance depends on a finely tuned interaction between aerobic, anaerobic lactic, and anaerobic alactic energy systems. While anaerobic metabolism supports explosive and sustained high-intensity actions, aerobic metabolism plays a decisive role in recovery, performance consistency, and fatigue resistance. Coaches and sport scientists should adopt integrated metabolic conditioning models to optimize elite Kabaddi performance.

8. References

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