RESEARCH PAPER

Seeing The Unseen Essence Of Players' Footprints Beyond The Game Of Kabaddi: Decoding The Infrared Images

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ABSTRACT
The application of Infrared thermal imaging technique is increasingly common in sports performance and fitness assessment and has got global recognition in past few years. **Background:** The usage of thermal imaging technology for ensuring fair play and accuracy during fast-paced games has been demonstrated in several sports performance analysis studies. **Objective:** This paper aimed to detect the effectiveness of infrared thermal image to navigate the raider's pathways in Kabaddi. **Methodology:** FLIR-E50 thermal camera was used in this investigation to capture the video of State Level Intercollegiate Kabaddi Tournament for Men - 2023-2024 held at The Gandhigram Rural Institute, Gandhigram and the training sessions of men Kabaddi team of Gandhigram Rural Institute (Deemed to be University), Gandhigram. From the recorded videos, Raiders' running bonus technique was separated for analysis. Raiders' running bonus technique was analysed by using thermal image. **Conclusion:** Infrared thermal imaging had a good distinguish method to navigate raiders' footpath and real-time visualization of the raiders' footprint while on the playing surface/crossing the bulk line/bonus line/ side line/back line/centre line /and lobby in Kabaddi.

Key words: Kabaddi, Running Bonus, Thermal Image and Raiders

How to cite this article: P. Sivakumar, C. Sugumar., Seeing The Unseen Essence Of Players' Footprints Beyond The Game Of Kabaddi: Decoding The Infrared Images ..Int J Drug Deliv Technol. 2026;16(12s): 130-139. DOI: 10.25258/ijddt.16.12s.14
Source of support: Nil.
Conflict of interest: None

INTRODUCTION

Technology has become integral to modern sports in the last few decades. Technology's significant impacts on sports are the enhancement of athletic equipment, athletic performance, analysis of performance, revolution in the broadcasting of sports events in media platforms and transformation of the fan experience in the world of sports. Technology has completely upended how fans assimilate and interact with sports. In addition to this, it transforms the entire sports media landscape, modernizing sports facilities and operations. Meanwhile, technology aids in diagnosing the injury, preventing injury and rehabilitating athletes. Technology has also played a vital role in improving officiating and refereeing in sports (How Technology is Transforming Sports: 9 Ways Its Changing Sports).

The use of technology in sports is increasing rapidly, in the way of analyzing the contribution of players, tactics and strategy applied by the teams to enhance the winning opportunities to become a world champions. Apart from these, the technology elaborately assists the referees to take real time clear-cut decision without affecting the match outcome. It prevents the referees to avoid vague decisions on the basis of guessing. Similarly, in Football, to predict goal and fouls & off-side goal line technology (GLT), Video Assistant Referee (VAR) is used in FIFA organized tournaments. **In** 2022 FIFA World Cup held in Qatar, **semi-automated offside technology** (SAOT) was introduced to assists the referees to take real time decisions.

In the game of Cricket and Tennis Hawk-Eye system has become familiar and to predict the trajectory of the ball movement. The other innovative technologies used in Cricket for performances analysis and assists the referees are Edge detection, Ball Tracking, Smart Bails, Bird's Eye View, Drones, Graphics & Animations, Power Analysis, Speed Gun, Pitch Vision, Decision Review System (DRS), Smart Ball and Snick-o-meter technology. In Field Hockey and Kabaddi **Video** referrals (an Umpire referral and a Team referral) are used to adjudicate the players as well as

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the officials. Lot of technological applications in sports has been evolved by means of persistent research.

The thermal image technique is widely used in many domains, irrespective of its application. It is a fantastic technology usually used in sports medicine to understand the effect of physical activity on the human body and analyse the body temperature variations during warm-up sessions, match situations and post-match recovery. On the other hand, it provides safety in motor sports such as cycling, open-wheeled racing and superbike racing. For instance, thermal cameras monitor the tire and brake temperatures, detecting and preventing mechanical doping in motor sports events. So, Thermal imaging is now gaining traction in the sports world and the quest for superior performance (Thermal imaging: the innovations pushing back the boundaries in the sports world).

The heat-map colour depict data values and make it convenient to read pattern, trend and anomalies (What is Heatmap Data Visualization and How to Use It? - GeeksforGeeks). "A picture is worth a thousand words". **Martin Drahansky, et al., (2023)**, explained how the thermal image can be easily deployed in a person-detection and localization system to alert the security staff, analyzed the flow of people in a commercial plaza and controlled the environment in workplaces. **Goes, et al., 2021 and Rein & Memmert, 2016** analyzed the tactics of the professional Soccer teams with the support of Big Data. Heat-map data visualization is an effective tool to drive valuable insights on decision-making.

Kabaddi is one of the most popular combat sports in Southern Asia. The game got its attraction among international sports with the playing combination of many offensive and defensive skills. The intention of the raider and defensive player(s) in Kabaddi is indirectly proportionate to each other to get point(s). In that prospective, the investigators intended to describe the bonus point and running bonus technique in Kabaddi. The raiding side finds opportunities to score a bonus point when defensive side has six or more players on the mat. A raider crosses the bonus line or the raiders' foot lands over the bonus line without touching it, the raiders wins a bonus (+1) point even though the raider gets out during the raid. An attempt of a raider to initiate his running movement from right side and approach towards the left side to cross the bonus line and vice versa is called as Running Bonus Technique. To comprehend the game of Kabaddi, the readers may witness final match played between India vs Iran in Asian Championship 2022 https://youtu.be/06DPZr4Dkt8?si=SwEdNWJKOp9WVwBk.

The advantages of technology are profoundly used in many sports discipline with broader prospectus whereas in Kabaddi the utilization of contribution of technology is still at negligible state. Without the technological inputs and implementations, sports performance analysis, prediction of factors enhancing performance, on filed real time decision making by the players and officials are likely to be loitering for exploring resources in layers of desert and spheres of sky. The above said technological input has become an essential component of modern refereeing, ensuring fair play and accuracy during fast-paced games. The influence of technology in the recent era of sports is well understood by the investigators and they are stimulated by the usages and advantages of the above facts therefore, a revolutionary attempt has been initiated through this investigation to reveal facts of thermal image and how it could explore the hidden facts in crossing / touching the lines, the contact of offensive and defensive players and executions bonus in Kabaddi.

Objectives of the study

To ensure fair play in the game of Kabaddi, researcher's mind instigated to adopt the Infrared thermal image technique to understand the raider's pathway while they exhibit running bonus technique. Based on that, the following objectives have been sketch-out in this study.

1. Navigation of running bonus techniques.
2. Analyzing the sequence of raiders' footprint in running bonus techniques
3. Find out the appropriate paths for running bonus technique in scoring point(s).
4. Weather the raider abides the rules to secure a bonus point.
5. To identify weather the players have touched or crossed the court markings during the play.

Methodology

Location of the study area:

The study has been conducted in multipurpose indoor stadium (MIS) of The Gandhigram Rural Institute (Deemed to be University) (GRI), Gandhigram, Dindigul District, Tamilnadu, India and its Latitude is 10°16'49.95"N and Longitude is 77°55'59.83"E.

Climatic Condition of the Study Area

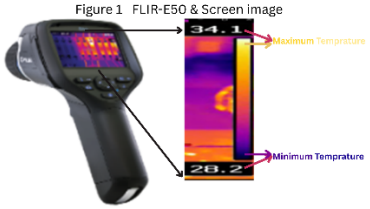
The whole test was administered inside the MIS of GRI, Gandhigram for three days. The first and second test were conducted during the training session of GRI men Kabaddi team on 30.01.2024, 31.01.2024 & 09.09.2025 and fourth test administered during semi-final and final match of State Level Intercollegiate Kabaddi Tournament organized by

GRI on 19.03.2024. Weather condition of the testing days minimum and maximum temperature recorded were (first test day) 23°C and 35°C, (second test day), 23°C and 34°C, 26°C and 37°C (Third day) and (fourth test day) 23°C and 38°C.

Tool and its specifications

FLIR-E50 18mm coupled with ThermaCAM Researcher and ALTAIR 5.50 was used for analysis. It captures the high infrared resolution images with 43,200 pixels. It works with the thermal sensitivity of <0.05°C. It performs with optimized temperature ranges from -4 to 1202°F (-20 to 650°C), spectral range from 7.5 to 13µm, records the video with the **frame rate** of 60Hz and the captured images are displayed clearly in 3.5" touch screen (landscape) and 3.1-megapixel resolution. Figure 1 illustrates the research instrument, FLIR-E50, and its thermal image. The screen image of the FLIR-E50 displays distinct colours in relation to temperature variation from minimum to maximum.

Figure 1 FLIR-E50 & Screen image

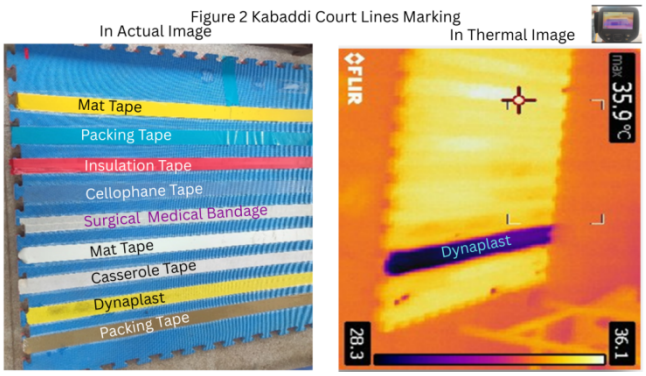


Method of Qualitative Data Extraction

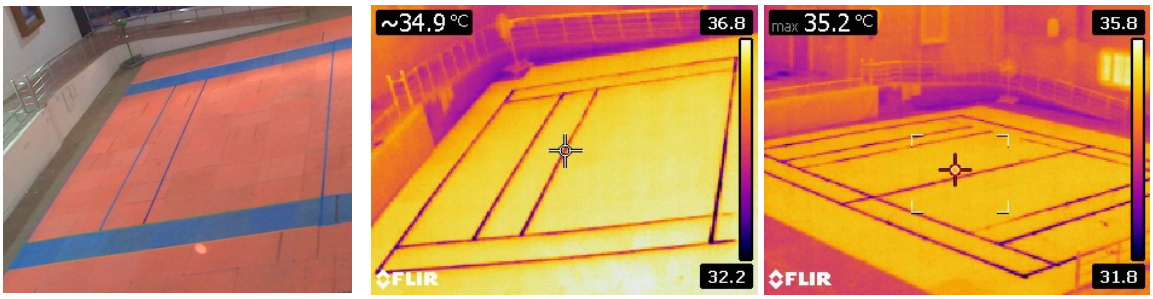
The research focused on précised execution of running bonus technique of the raider. To achieve the objectives of this Study, FLIR-E50 18mm thermal camera was used which is available in the Centre for Rural Energy, GRI, Gandhigram. The camera was fixed at the height of 10meters and 3meters away from playing area to capture relevant images from training and match sessions. For court marking, different kinds of adhesive tapes were used on par with existing court marking tape. The markings done with those tapes were not visible in thermal image. Hence the researchers attempted with dynaplast which distinctively visible and clearly differentiate the court marking from playing surface as in figure 2. FLIR-E50 18mm helped the researcher to visualize the actual and thermal image of Kabaddi court and its markings as portrayed in Figure 3 & 4.

Visualization of Kabaddi court marking in Mat Surface

Figure 2 Kabaddi Court Lines Marking



Visualization of actual and thermal view of Kabaddi playing surface and its markings



Thermal image camera recorded the, GRI Men Kabaddi team training session 1, training session 2, semi-final and final match of State Level Intercollegiate Kabaddi Tournament for Men - 2023-2024 held at GRI which were considered enough for the analysis. In the captured videos, the videos of the players' infringement in relation to court marking and executed running bonus technique and its appropriate execution to secure a bonus point were separated by repeated and radical observation. The thermal videos were converted into thermal images to interpret the ideology behind the running bonus technique involved in securing a bonus point and players violation with court markings.

The investigators had an insightful approach to differentiate the foot prints of the raiders from defenders while executing running bonus technique. In that approach, the thermal images clearly exhibited variations in the colours of playing surface, court marking, players' jersey and fair body parts and foot prints. For the purpose of analysis, the researchers keenly observed the foot prints of the raider and relevant court markings.

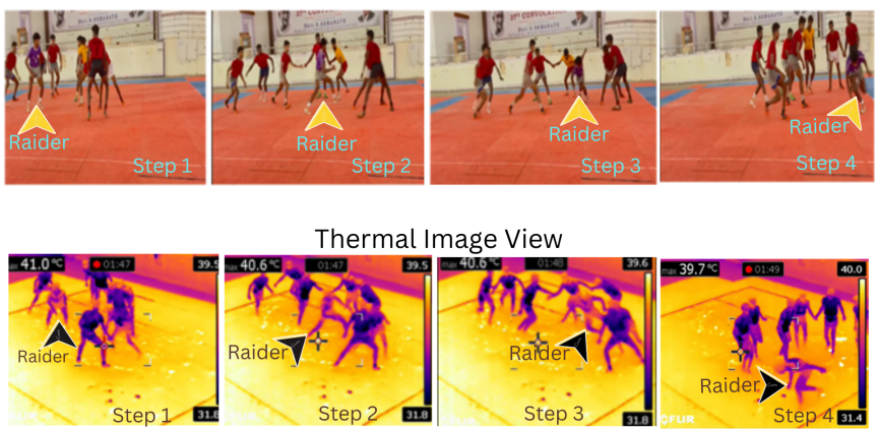
1. The foot prints of the raiders in the thermal image were encircled and chained to create a path which navigate the running bonus technique
2. Foot prints of the raider while crossing the bonus line was marked in letter 'B' for better examination.
3. Further, infringements of the player with the line were marked in letter 'I'.

To fulfill the objectives of the study, the following captured thermal images are displayed below for analysis.

Analysis

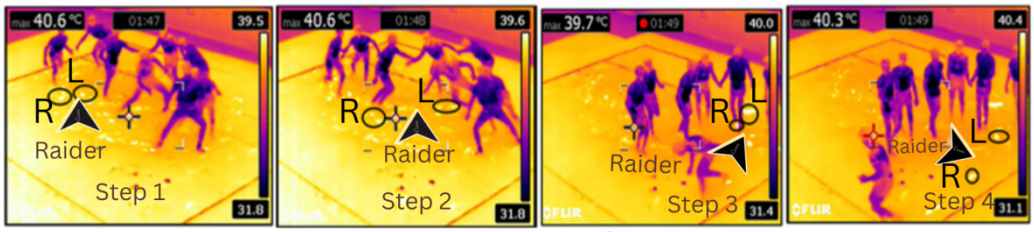
The investigators prioritize the infra-red images to have an unbiased analysis of right and left raiders' running bonus technique, navigation of movement pattern, bonus execution and players' infringement of the lines. Interestingly, the thermal images were studied carefully and step by step to re-examine the actual facts associated with the study objectives.

Figure - 4 Left Raiders' Movement pattern of Running bonus technique



It is understood from figure 4, that raiders are indicated with arrow mark and the actual and thermal images explicate the left raiders' movements while executing running bonus technique. The images explain the sequence of running bonus procedure i.e. step 1 preparatory stride for running bonus, step 2 anticipate for penultimate stride, step 3 execution of bonus and step 4 follow through after bonus execution.

Figure - 5 Foot print of Left Raiders' Movement pattern in Thermal image



R & L indicates right and left Foot prints

In figure 5, the left raiders' foot prints were encircled for the better understanding of movement pattern involved in execution of running bonus technique.

Figure - 6 Illustration of Left Raiders' (right and left) Foot prints

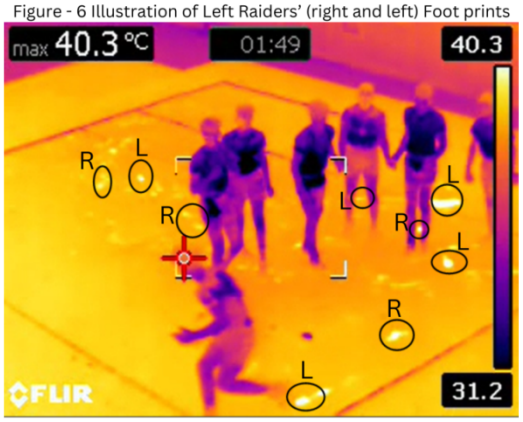
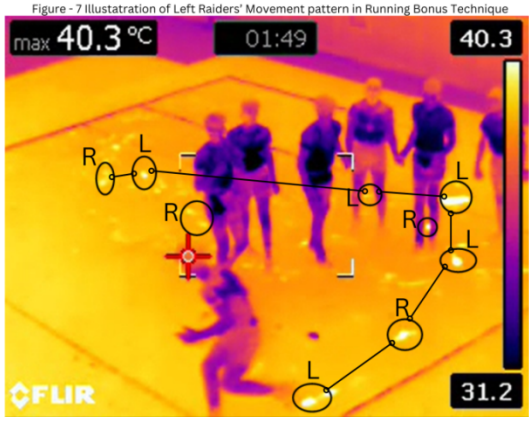


Figure - 7 Illustatration of Left Raiders' Movement pattern in Running Bonus Technique



The sequences of movement pattern involved in running bonus technique were analyzed through figure 6 &7. The encircled footprints were chained to reveal actual movement of the left raider.

Figure - 8 Illustatration of Right Raiders' Movement pattern in Running Bonus Technique

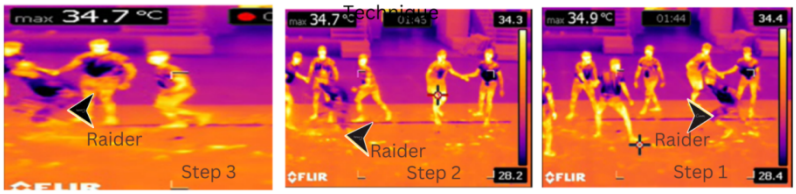
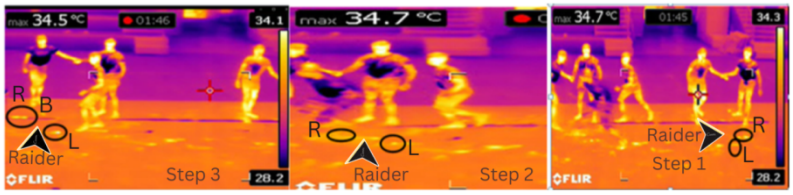


Figure - 9 Foot print of Right Raiders' Movement pattern



For the best understanding of the right raiders' movements while executing running bonus technique, the sequence of raiding were indicated with arrow in figure 8. The right and left foot prints of right raider were encircled to indicate the raider's paths and the procedures of running bonus technique in figure 9.

Figure - 10 Illustatration of Right Raiders' Movement pattern in Running Bonus Technique

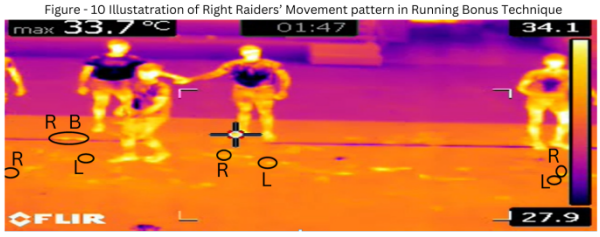
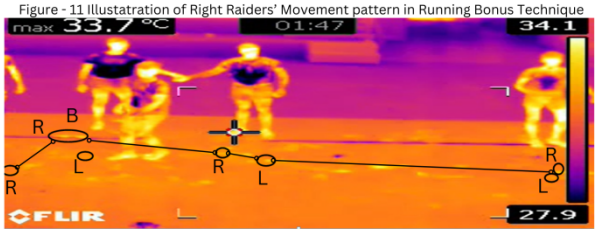


Figure - 11 Illustatration of Right Raiders' Movement pattern in Running Bonus Technique



The sequences of movement patterns involved in the running bonus technique were observed in Figures 10 and 11. The encircled right raider's footprints were chained to highlight the actual path of the right raider. Raiders' lead leg footprints were considered to foresee the paths which are clearly visible in figures 7 and 11. The investigators' insightful vision on figures 7 and 11 persistently notifies the unique path of left and right raiders in the movement pattern of the running bonus technique. The path resembles the shape of an 'L'.

Figure - 12 Illustrations of right Raiders' Foot Prints in Bonus Execution

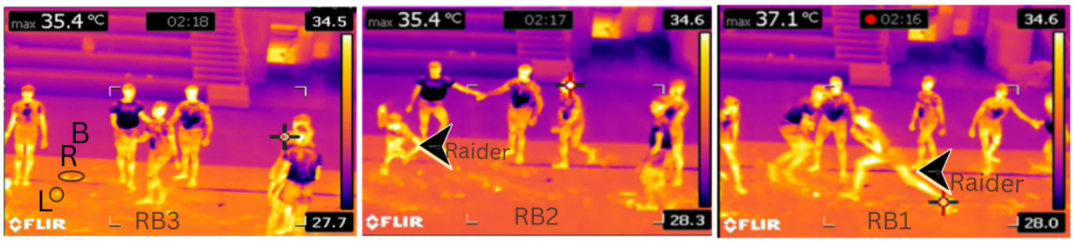
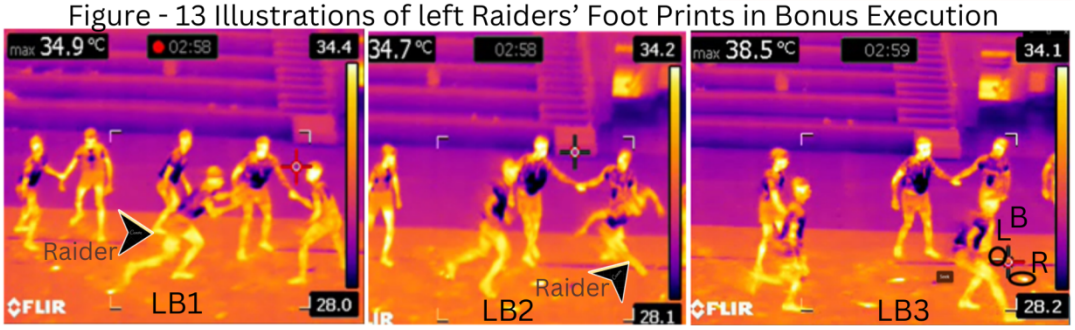
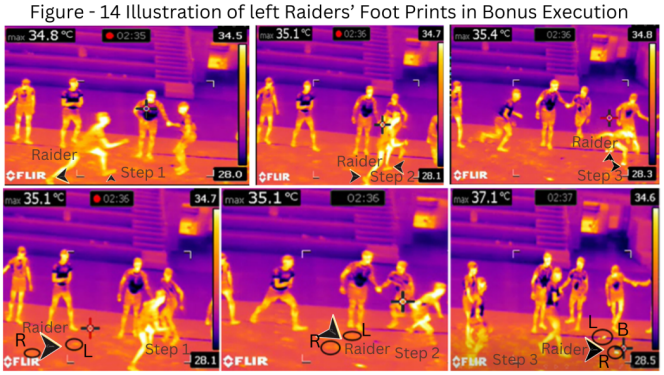


Figure - 13 Illustrations of left Raiders' Foot Prints in Bonus Execution



Figures 12 and 13 show the left and right raiders' footprints at the moment of scoring a bonus point. The analysis of the RB2 and LB2 images portrayed that the left and right raiders had executed the bonus in a similar method. Encircled images of RB3 and LB3 displayed the clinical precision of the footprints of the left and right raiders while in bonus execution. The images show that the raiders ' footprints completely cross the bonus line in accordance with the bonus rule.

Figure - 14 Illustration of left Raiders' Foot Prints in Bonus Execution

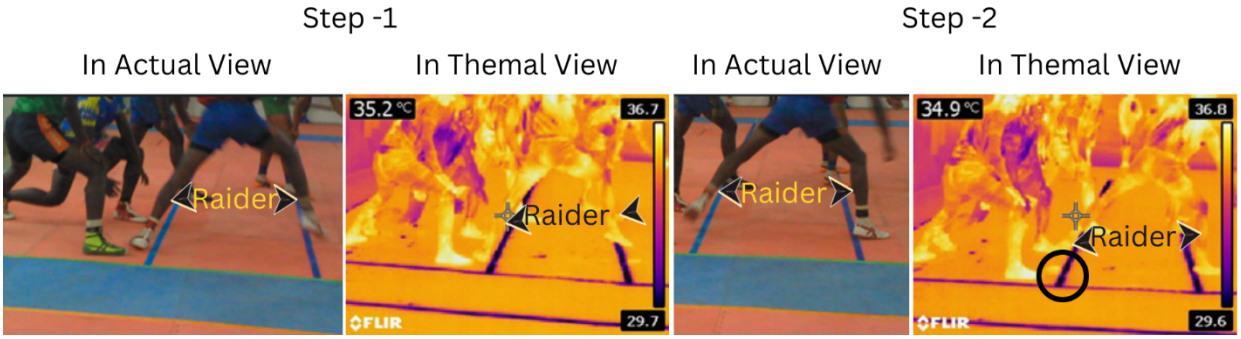


Raiders' foot placements were indicated with an arrow mark and foot prints were encircled in figure 14. From Figure 14 / Step 3, it is identified that the raider's foot placement and prints were in contact with the bonus line. The

figures enabled the researcher to justify whether the raider had crossed or touched the bonus line while executing and securing a bonus point by considering the foot placement and foot print images.

Bonus line crossing close view of Raiders legs

Figure - 15 Illustration of Raiders' (lead leg) Foot prints



To declare the bonus point, the raiders' lead and trail legs should be on and off the playing surface, respectively. In Figure 15, it is visualized that the lead leg of the raiders' foot placement is on the playing surface, whereas the trail leg is off the surface. In Figure 15, the footprint of the raiders' lead leg is visualized, and no such observation is evident for the trial leg.

Line cross / touch by leg & hand

Figure - 16 Illustration of Line Infringments by Foot

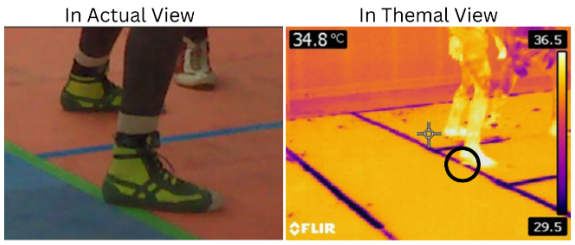
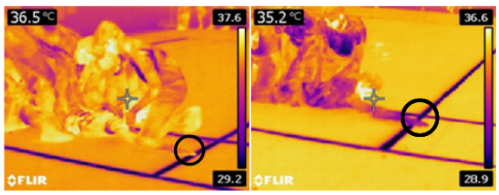


Figure - 17 Illustration of Line Infringements by Hand



Figures 16&17 show the fact to adjudicate whether the players are in infringement with the line. The body contact image revealed by figure 16 shows that the defender's foot has crossed the lobby, which is confirmed with the thermal image footprint. The researchers understand from Figure 17: thermal view -1 that the raider's hand is in contact with the line but not crossed exactly. The thermal image footprint and hand touch revealed by Figure 16 &17 assists in confirming the infringement. It is a known fact that an ordinary image can only reveal a tactile image, whereas the technical advantage of thermal image, as fuel for visualization, shows the prints of the tactile image, which assist the TV umpire to reshape their officiating versatility to rewrite the future of Kabaddi

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Discussion

Kabaddi is one of the fast phased game, fans were experienced heart-pounding raids, thrilling action, on the mat with pulsating energy. As an umpire, to avoid guess whistling, it could greatly be admired and respected by the players, coaches, and spectators. In that view, thermal image could assist the officials to adjudicate; weather the raider applies the applicable technique to score a bonus. In the recent past, many explorations have occurred by using thermal cameras to explore the skin temperature variations in various sports disciplines. Similarly, **Wagner Romao et al., 2021** have attempted a study to examine the temperature variations in the muscles of the trunk and limbs in three different occasions, like pre, after and 10 minutes after the endurance session with the support of an infrared camera. However, in his systematic review, it was stated that 70% of the sports-related thermal studies were reviewed by FLIR cameras. The quality of thermal image mainly depends on the software, equipment quality and data

collection procedures, i.e. stability, distance, camera angle, acclimatization, ambient temperature, and relative humidity. By keeping the above key elements in mind, for collecting the data, the investigators prioritised the FLIR camera to obtain the thermal images of Kabaddi players. **David Garrido et. al., (2022)**, used the optical tracking method as a standardized tool to explain the players' positions and understand the players' occupied area during a Soccer match with a heat map. The consequence of heat mapping of a particular match enables the coaches to have a clear road map for the subsequent matches/tournaments. In that way **Fabiola Haas et. al., (2023)**, applied the heat map method to analyze the valuable insights on linkage of handedness and position of players, racket holding types, offensive and defensive playing strategy in Table Tennis. Thermal image studies were conducted by **Tumilty et al., 2019** on cross-country season**, Balci et al., 2016** on skin temperature during submaximal and maximal exercises**, Tanda, 2016** during running exercise**, Smith & Havenith, 2011** on sweating patterns and **Merla, et al., 2010** in temperature variations. The above researchers had utilized the thermal camera and its procedure to obtain data conveniently. The perceptive vision from recorded videos, observation from earlier study conducted by **Sivakumar et al., 2025,** the present study sample images and figure 7 & 11 repeatedly provoked the investigators to imagine a unique path and explored that the movement of left and right raiders resembled like a shape of an 'L'.

According to the nature of the game, in every occasion the scoring a point (s) depends on the common phenomena such as raider touching or crossing the bulk line / bonus line / side line / back line / center line / lobby and defender touching or crossing the side line / back line / center line / lobby in Kabaddi. The findings of the present study specify that thermal image is a distinguishing method to monitor the infringements of the defenders with the sideline, back line, center line and lobby; raiders with crossing the bulk line/bonus line/sideline/back line/center line /and lobby in Kabaddi. In addition, the thermal image is an innovative technique to navigate raiders' footpath and real-time visualization of the raiders' footprint while on the playing surface.

Application of thermal imaging could help the TV umpire in taking objective decision in the following ways:

1. To minimize the human error and ensure the fair play with utmost satisfaction.
2. To avoid human error in producing true champion or to declare loser champion.
3. Thermal image can give detailed information about whether the players' foot lands astray or not.
4. While video referral, TV umpire can only see the visual changes but at the same time thermal image aids to pinpoint the tactile image and visualize it.
5. High infrared resolution images instantly relay information to the referees, leaving no room for doubt about whether a bonus point should be awarded.
6. Integrated approach of Thermal image and video referrals methods to enrich spectator experiences in the way of what was actually happened during the game and crucial moment as well.

Conclusion

Thermal image technology is a powerful tool in sports analytics, which includes analyzing team strategies, player movements, and performance metrics. In the present study, the researcher intended to track the movement of raiders and visualize their footprints in Kabaddi using FLIR-E50 18mm equipment. Regarding the equipment used in this study, the captured infrared images were clear and precise. From the high infrared resolution images Fig. 4 to17 the following conclusions was drawn:

1. High infrared resolution images precisely navigate the raiders' running bonus technique.
2. Infrared thermal images instantly pinpoint and provide real-time visualization of the raiders' footprint while crossing the bonus line.
3. Thermal images serves as an unbiased eye that monitors raiders' footprint whether the raiders' foot touched or crossed the bonus line.
4. Infrared thermal imaging is a good distinguishing method to identify the raiders' movement pattern while scoring a bonus point.
5. The infrared thermal image could easily predict infringements of the players with the lines.

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