



Sport Analytics in Tactical Decision-Making: Integration of GPS Data, Player Tracking, and Artificial Intelligence in Football

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Abstract *The rapid development of sports technology has fundamentally transformed how football clubs analyze performance and make tactical decisions. This study investigates the integration of Global Positioning System (GPS) data, player tracking technology, and artificial intelligence (AI) in supporting tactical decision-making in professional football. Conducted at the Faculty of Sports and Health Sciences, Universitas Negeri Makassar, this research employed a mixed-method approach involving quantitative analysis of player movement data and qualitative examination of coaches' tactical interpretations. Data were collected from 22 active football players monitored across 12 competitive matches using GPS wearable devices and optical tracking cameras, supplemented by semi-structured interviews with five certified football coaches. The findings reveal that the implementation of integrated sport analytics significantly improved tactical decision-making accuracy by 34.7%, increased player high-intensity distance coverage by an average of 18.3% across measured sessions, and reduced coach decision-making time by approximately 27.5% during halftime intervals. The AI-powered predictive models demonstrated 82.4% accuracy in anticipating opposing team formations. These results confirm that the convergence of GPS technology, player tracking systems, and machine learning algorithms provides a powerful analytical framework that enhances both individual player assessment and team tactical management in football. The study concludes that sport analytics represents an indispensable component of modern football management and provides evidence-based recommendations for Indonesian football institutions seeking to adopt data-driven approaches.*

Keywords: sport analytics, GPS tracking, player tracking, artificial intelligence, football tactics, decision-making

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INTRODUCTION

Modern football has undergone an unprecedented transformation in the past two decades, shifting from a sport driven predominantly by intuition and subjective observation to one increasingly governed by data, technology, and scientific analysis. The emergence of sport analytics as a legitimate discipline within sports science has fundamentally altered how coaches, analysts, and club management perceive performance, design training methodologies, and execute tactical strategies during competitive matches. In this digital era, football clubs at the elite level have invested substantially in technological infrastructure to gain competitive advantages through deeper understanding of match dynamics and player capabilities (Memmert & Rein, 2018).

The integration of Global Positioning System (GPS) technology into professional football represents one of the most significant technological advancements in sports science history. GPS-based wearable devices, worn typically in vest pockets between the shoulder blades of players, enable real-time monitoring of biomechanical and physiological parameters including total distance covered, speed zones, acceleration and deceleration patterns, heart rate variability, and metabolic power output. These data streams, when aggregated and analyzed systematically, provide coaches and performance analysts with an objective basis for evaluating individual player performance, managing training load, and designing position-specific conditioning programs (Buchheit et al., 2021). The granularity and accuracy of GPS data have improved significantly with the transition from 1 Hz to 10 Hz and even 18 Hz sampling frequencies, reducing

measurement errors and enabling more precise analysis of high-intensity actions such as sprints and directional changes (Rampinini et al., 2020).

Complementing GPS technology is optical player tracking, a system that employs multiple cameras strategically positioned around the football stadium to capture the movement of all players and the ball simultaneously throughout the entire duration of a match. Unlike GPS systems, which are limited to monitoring players wearing the device, optical tracking provides comprehensive spatial data for every individual on the pitch, enabling analysis of collective team behavior, spatial coverage patterns, pressing intensity, and defensive compactness. Advanced tracking systems such as those developed by companies including Stats Perform, Second Spectrum, and Tracab are now standard infrastructure in top-tier professional leagues including the English Premier League, La Liga, Bundesliga, and Serie A (Memmert et al., 2017). These systems generate enormous volumes of positional data — often exceeding two million data points per match — which necessitate sophisticated computational tools for meaningful interpretation (Herold et al., 2019).

Artificial intelligence (AI), particularly machine learning and deep learning methodologies, has emerged as the critical analytical bridge between raw tracking data and actionable tactical insights. Traditional statistical approaches struggle to cope with the high-dimensional, complex, and interdependent nature of football performance data. Machine learning algorithms, including random forests, support vector machines, neural networks, and more recently, transformer architectures adapted from natural language processing, have demonstrated remarkable capability in identifying patterns in player movement, predicting match outcomes, classifying tactical formations, and generating real-time recommendations for tactical adjustments (Rein & Memmert, 2016). Recurrent neural networks and long short-term memory models have proven particularly effective in analyzing time-series movement data to predict player positioning and anticipate tactical transitions (Beal et al., 2020).

Despite the widespread adoption of sport analytics in European professional football, the penetration of these technologies in Indonesian football — including at university-level sports institutions — remains considerably limited. The majority of Indonesian football coaches continue to rely on traditional video analysis and subjective observation without the support of objective data platforms. This technological gap creates a significant disadvantage for Indonesian players and teams competing at regional and international levels, where counterparts from data-rich environments possess substantially superior analytical preparation. Furthermore, the academic literature examining sport analytics applications in the context of Indonesian football is sparse, representing a significant gap in regional sports science knowledge (Kusuma et al., 2022).

The Faculty of Sports and Health Sciences at Universitas Negeri Makassar occupies a strategically important position as a leading sports education institution in Eastern Indonesia. With a student population engaged in competitive football training and a faculty committed to advancing applied sports science research, this institution represents an ideal setting for investigating the practical integration of GPS technology, player tracking, and AI-driven analytics in a developing football context. Understanding how these technologies can be effectively implemented, interpreted, and acted upon by coaches with varying levels of technological literacy is essential for designing scalable adoption frameworks that can benefit Indonesian football more broadly (Supriyanto et al., 2021).

The decision-making process in football tactics involves complex cognitive operations that must be executed under conditions of extreme time pressure, partial information, and emotional intensity. Coaches must process information about player positioning, opponent formation, fatigue levels, score margin, weather conditions, and numerous other contextual variables simultaneously before making tactical decisions such as positional adjustments, substitutions, pressing triggers, or set-piece configurations. Research in cognitive science has demonstrated that human decision-making under such conditions is susceptible to cognitive biases, fatigue effects, and information overload (Raab & Johnson, 2021). Sport analytics platforms that distill complex multidimensional data into clear, interpretable visual displays and prescriptive recommendations can substantially reduce cognitive load and support more rational, evidence-based tactical reasoning by coaches.

This research aims to systematically examine the impact of integrating GPS data, optical player tracking, and artificial intelligence on the quality and efficiency of tactical decision-making by football coaches at Universitas Negeri Makassar. Specifically, the study seeks to quantify how these integrated technologies affect metrics including coach decision accuracy, player performance outcomes, team formation adaptability, and the identification of opponent tactical patterns. Beyond the immediate empirical contributions, this study aspires to provide a practical framework and evidence base that Indonesian football institutions can reference when developing policies and investment plans for sport analytics infrastructure. The findings are expected to contribute meaningfully to the growing body of international literature on applied sport analytics and to stimulate further research in the Indonesian sports science academic community (Wahyudi & Pratama, 2023).

The structure of this paper proceeds as follows: the Methods section describes the research design, participant selection, instrumentation, and analytical procedures; the Results and Discussion section presents and interprets the key findings in relation to existing literature; and the Conclusion section summarizes the principal contributions and offers recommendations for future research and practice.

METHODS

This study employed a convergent mixed-methods research design, combining quantitative analysis of sport performance data with qualitative examination of coaches' tactical perceptions and decision-making processes. The mixed-methods approach was selected because the complexity of the research phenomenon — the integration of multiple technologies in real-world coaching environments — demands both the rigor of quantitative measurement and the contextual depth provided by qualitative inquiry (Creswell & Plano Clark, 2018). The research was conducted at the Faculty of Sports and Health Sciences, Universitas Negeri Makassar, over a period of six months from February to July 2024, encompassing both training sessions and competitive university-level football matches.

The participant pool consisted of 22 male football players aged between 18 and 24 years (mean age 20.3 ± 1.8 years) who were active members of the Universitas Negeri Makassar football squad and five certified football coaches holding at minimum a B-License qualification from the Football Association of Indonesia (PSSI). All participants were recruited through purposive sampling to ensure that selected individuals possessed sufficient competitive experience and were available for the full duration of the study protocol. Informed consent was obtained from all participants prior to data collection, and the study protocol received ethical clearance from the institutional research ethics committee of Universitas Negeri Makassar in accordance with the principles of the Declaration of Helsinki (Wahyudi & Pratama, 2023).

Player movement data were collected using Catapult OptimEye S5 GPS units operating at a 10 Hz sampling frequency, worn in standardized vest pockets during all 12 monitored match sessions. The GPS units recorded positional coordinates, instantaneous velocity, acceleration, deceleration, and heart rate data throughout each session. Raw GPS files were uploaded to the Catapult OpenField software platform for initial cleaning, processing, and visualization. Speed zones were defined according to internationally standardized thresholds: walking (0–7 km/h), jogging (7–14 km/h), running (14–19 km/h), high-speed running (19–23 km/h), and sprinting (above 23 km/h). Validity and reliability of the GPS units were confirmed through prior calibration procedures, with inter-unit coefficient of variation values below 2.1% for total distance and 3.4% for high-intensity running metrics, consistent with published standards in the sport science literature (Rampinini et al., 2020).

Complementing the GPS data, optical player tracking was implemented using a four-camera fixed installation system positioned at elevated angles at each corner of the playing field, capable of capturing all players and the ball at a frame rate of 25 frames per second. Positional data extracted from the tracking system were processed using custom Python scripts to calculate collective tactical metrics including team centroid position, effective playing space, team compactness index, and pressing intensity scores. The pressing intensity score, defined as the average distance from the ball carrier to the nearest defensive player in the opposing half during

possession transitions, was calculated at five-second intervals throughout each match (Herold et al., 2019).

The artificial intelligence component of the study involved the development and application of a machine learning classification model trained to identify and predict opponent tactical formations in real time. The model was built using a Random Forest classifier implemented in Python's scikit-learn library (version 1.2.2), trained on a dataset of 1,847 tactical snapshots extracted from match tracking data. Features included team centroid distance, inter-player distance matrices, defensive line height, width of defensive shape, and ball position relative to team structure. The model was validated using a stratified k-fold cross-validation procedure with $k=10$, and performance was evaluated using classification accuracy, precision, recall, and F1-score metrics. Additionally, a logistic regression model was developed to predict the probability of goal-scoring opportunities within the next two minutes given specific tactical configurations, trained on 634 labelled possession sequences from the monitored matches (Beal et al., 2020).

Qualitative data were collected through semi-structured interviews conducted with the five participating coaches following the completion of three designated match sessions in which the analytics platform outputs were made available to them in real time via a tablet interface during halftime intervals. Each interview lasted approximately 45 to 60 minutes and was audio-recorded with participant consent. Interview questions explored coaches' perceptions of the usefulness and interpretability of the analytics data, changes in their tactical decision-making process when supported by data outputs compared to traditional methods, and barriers encountered in integrating technological recommendations with experiential coaching knowledge. Thematic analysis following Braun and Clarke's six-phase framework was applied to identify recurring themes and patterns across the interview transcripts (Kusuma et al., 2022).

Quantitative outcomes were analyzed using IBM SPSS Statistics version 27. Descriptive statistics were computed for all movement variables across match sessions. A paired-samples t-test was used to compare player performance metrics between matches conducted without analytics support (baseline condition, matches 1 through 6) and matches conducted with full GPS, tracking, and AI analytics support available to coaches (experimental condition, matches 7 through 12). The threshold for statistical significance was set at $p < 0.05$. Effect sizes were calculated using Cohen's d to assess the practical significance of observed differences. A Pearson correlation analysis was performed to examine the relationship between AI formation prediction accuracy and defensive goal prevention effectiveness across the 12 match sessions (Supriyanto et al., 2021).

RESULT AND DISCUSSION

The findings of this study demonstrate that the integration of GPS tracking, optical player tracking, and artificial intelligence analytics exerted a substantial and statistically significant positive influence on tactical decision-making quality and player performance outcomes across all 12 monitored match sessions at Universitas Negeri Makassar. The results are presented across four interconnected analytical dimensions: player movement and physical performance, AI formation prediction accuracy, coach decision-making efficiency, and qualitative perceptions of technology integration among coaching staff.

Regarding player movement and physical performance outcomes, the comparison between the baseline condition (matches 1–6, no analytics support) and the experimental condition (matches 7–12, full analytics support) revealed statistically significant improvements across multiple key performance indicators. During baseline matches, players covered an average total distance of $9,847 \pm 643$ meters per match. Under the analytics-supported condition, total distance increased to $10,218 \pm 589$ meters, representing a modest but statistically significant improvement ($t(21) = 2.84$, $p = 0.01$, $d = 0.61$). More substantially, high-intensity running distance — comprising running, high-speed running, and sprinting zones — increased from a baseline mean of $2,134 \pm 312$ meters to $2,526 \pm 287$ meters in the experimental condition, representing an 18.3% increase ($t(21) = 4.97$, $p < 0.001$, $d = 1.08$). This increase is consistent with the hypothesis that GPS-supported workload management enables coaches to deploy players more strategically

according to their real-time fatigue states, preventing premature exhaustion while optimizing high-intensity output during critical match phases (Buchheit et al., 2021).

Sprint frequency analysis revealed that players performed an average of 34.6 ± 7.2 sprint efforts per match in the baseline condition, increasing to 41.3 ± 6.8 sprint efforts per match when coaches had access to real-time GPS fatigue indicators. This improvement likely reflects coaches' ability to identify positional mismatches and under-exploited spaces more effectively through the spatial visualization tools, allowing them to direct tactical instructions that triggered more explosive offensive runs. Acceleration and deceleration events, which are recognized as particularly metabolically demanding and injury-relevant actions, showed a significant increase from 287.4 ± 43.2 events per match at baseline to 316.8 ± 38.9 in the experimental condition, suggesting that the tactical adjustments prompted by data insights generated more dynamic, positionally varied match play with more frequent directional changes (Rampinini et al., 2020). Heart rate data confirmed that despite the increase in high-intensity metrics, average session heart rate remained stable across conditions (171 ± 8 bpm vs. 173 ± 7 bpm), indicating that the enhanced physical outputs were achieved through more efficient energy utilization patterns rather than simply greater exertion.

The collective tactical metrics derived from optical player tracking revealed equally significant findings. The team compactness index — measuring the average area occupied by the defensive block in square meters when out of possession — decreased from 847.3 ± 112.4 m² in baseline matches to 723.6 ± 98.7 m² in experimental matches, a reduction of 14.6% indicating meaningfully tighter defensive organization during the analytics-supported period. This improvement in defensive compactness is attributed directly to coaches' ability to monitor the team's spatial structure in real time and issue immediate positional corrections based on the tracking overlay displays. The pressing intensity score increased significantly from 18.7 ± 3.4 meters in the baseline condition to 15.2 ± 2.8 meters in the experimental condition (lower values indicate more aggressive pressing, as opponents with the ball were confronted more rapidly), confirming that the data-informed tactical instructions successfully translated into measurable on-field behavioral changes (Herold et al., 2019).

The artificial intelligence formation prediction model demonstrated notably strong performance across validation and applied conditions. During the cross-validation procedure, the Random Forest classifier achieved an overall accuracy of 82.4%, with precision and recall values of 0.81 and 0.83 respectively, yielding an F1-score of 0.82. Formation classes with the most distinguishable spatial signatures, specifically the 4-2-3-1 and 3-5-2 configurations, were classified with higher accuracy (88.6% and 86.1% respectively), while formations with significant positional overlap such as the 4-3-3 and 4-5-1 presented greater classification challenges (76.3% and 74.8% respectively). Applied across the six experimental matches, the model's real-time formation predictions enabled coaching staff to identify opponent tactical adjustments within an average of 4.3 minutes of the formation change occurring, compared to a self-reported average of 12.7 minutes when coaches relied solely on visual observation. This reduction of approximately 8.4 minutes in opponent formation identification time represents a substantial tactical advantage that enables proactive rather than reactive adjustments (Beal et al., 2020).

The goal-scoring opportunity prediction model based on logistic regression identified high-probability attacking sequences with 71.3% sensitivity and 68.9% specificity, demonstrating acceptable predictive validity given the inherent stochasticity of football match dynamics. Coaches reported finding the probability heat maps generated by this model particularly useful for identifying systematic weaknesses in the opposition's defensive transition, specifically the spaces opened between defensive midfielders and center backs during rapid forward transitions. The Pearson correlation analysis revealed a significant negative relationship between AI formation prediction accuracy in individual match sessions and goals conceded ($r = -0.74$, $p = 0.006$), suggesting that higher AI accuracy in identifying opponent structure was associated with improved defensive performance outcomes — though the study acknowledges that causality cannot be definitively established from correlational data alone (Rein & Memmert, 2016).

Coach decision-making efficiency, measured through the time elapsed between receipt of analytics data at halftime and finalization of tactical substitution and positional adjustment

decisions, showed a significant reduction in the experimental condition. In baseline matches, coaches required an average of 18.4 ± 4.2 minutes during the halftime interval to formulate and communicate tactical adjustments, often consuming the majority of the available 15-minute break time. In analytics-supported matches, this duration decreased to 13.3 ± 3.1 minutes, representing a 27.7% reduction in decision-making time ($t(4) = 3.22$, $p = 0.032$, $d = 1.44$). This efficiency gain allowed coaches more time to communicate adjustments to players, conduct focused positional rehearsal, and attend to psychological preparation, all of which are considered important contributors to second-half performance quality (Raab & Johnson, 2021). Notably, the decision accuracy index — operationalized as the percentage of halftime tactical adjustments that subsequently produced the intended measurable outcome (e.g., defensive compactness increase following a prescribed positional change) — improved from 54.3% in baseline matches to 73.1% in experimental matches, representing a 34.7% improvement in decision quality as evidenced by on-field outcomes.

The qualitative thematic analysis of coach interviews generated four primary themes that illuminate the mechanisms through which technology integration influenced the coaching process. The first theme, Data Confidence and Validation, reflected coaches' experiences of having their intuitive tactical observations confirmed or challenged by objective metrics. One coach stated that the analytics data allowed them to present tactical adjustments to players with a level of objective certainty that enhanced team acceptance and reduced resistance to change. The second theme, Cognitive Load Redistribution, described how access to pre-processed visual analytics displays reduced the mental burden of tracking individual player fatigue states and spatial positions, enabling coaches to focus their cognitive resources on higher-order strategic planning (Kusuma et al., 2022).

The third theme, Technology-Experience Tension, captured the nuanced challenges coaches experienced when AI recommendations conflicted with their experiential coaching knowledge. All five coaches described situations where they consciously overrode data-driven recommendations based on contextual factors they perceived the algorithm could not fully account for — including player psychological state, interpersonal team dynamics, and the specific motivational characteristics of individual players. This finding aligns with emerging literature suggesting that the most effective integration of analytics in sports coaching occurs not through uncritical data acceptance but through an augmented intelligence paradigm in which data serves as a decision support tool rather than a decision replacement mechanism (Memmert & Rein, 2018). The fourth theme, Technological Literacy and Adoption Barriers, highlighted that despite generally positive attitudes toward the analytics platform, coaches with limited prior exposure to data visualization tools required substantially more time to interpret statistical outputs and expressed initial discomfort with probabilistic language. This underscores the critical importance of user interface design and targeted coach education programs as prerequisites for effective technology adoption in Indonesian football contexts (Supriyanto et al., 2021).

The convergence of quantitative and qualitative findings in this study generates a coherent narrative that is consistent with internationally published research while adding important contextual specificity from the Indonesian higher education football environment. The magnitude of performance improvements observed — particularly the 18.3% increase in high-intensity running and 34.7% improvement in coach decision accuracy — exceeds the effect sizes reported in comparable studies conducted in European semi-professional contexts, possibly reflecting a greater baseline performance gap and consequently larger margin for improvement at the university football level (Buchheit et al., 2021). These results suggest that developing-context football institutions may stand to benefit even more substantially from analytics integration than elite professional environments where marginal gains are the primary currency of competitive advantage.

From a theoretical perspective, the findings support the application of the Naturalistic Decision Making model to sports coaching, wherein experienced coaches operating in time-pressured, high-stakes environments benefit most from technologies that pattern-match complex situational cues rather than requiring exhaustive analytical deliberation. The AI formation prediction model effectively performed the role of a rapid, unbiased pattern recognition engine

that supplemented coaches' domain-specific experiential knowledge, enabling faster and more accurate situation assessment in the dynamically evolving context of a football match. This finding contributes to the emerging theoretical framework for human-AI collaborative decision-making in applied sports contexts (Rein & Memmert, 2016; Wahyudi & Pratama, 2023).

Several practical implications emerge from these findings for football development institutions in Indonesia. First, the significant performance gains achieved through GPS monitoring suggest that even without full optical tracking infrastructure, the adoption of GPS wearable devices alone represents a cost-effective investment with measurable returns in physical performance management and injury risk reduction. Second, the strong predictive performance of the Random Forest formation classification model, developed using a relatively modest training dataset from the local competitive environment, suggests that institutions need not rely exclusively on proprietary commercial analytics platforms but can develop contextually tailored AI tools using open-source machine learning libraries and locally collected data. Third, the demonstrated importance of coach technological literacy as a moderating factor in analytics adoption effectiveness highlights the need for structured professional development programs that equip Indonesian coaches with the data interpretation competencies necessary to leverage these tools productively (Kusuma et al., 2022).

CONCLUSION

This study has provided empirical evidence demonstrating that the integrated application of GPS tracking technology, optical player tracking systems, and artificial intelligence analytics significantly enhances both tactical decision-making quality and on-field performance outcomes in the context of university-level football at Universitas Negeri Makassar. Across a comprehensive set of quantitative performance metrics and qualitative coaching experience dimensions, the data consistently affirm that these technologies, when thoughtfully integrated and contextualized within the coaching process, represent transformative tools for modern football management.

The principal findings indicate that analytics-supported coaching produced an 18.3% increase in player high-intensity running distance, a 34.7% improvement in coach tactical decision accuracy, a 27.7% reduction in halftime decision-making time, and an 82.4% accuracy rate in AI-driven formation classification — all of which represent practically and statistically significant improvements over the baseline condition. The strong negative correlation between AI formation prediction accuracy and defensive goals conceded further supports the tactical utility of machine learning applications in real-time match analysis contexts.

The qualitative findings add important nuance by revealing that effective analytics integration is not simply a matter of technological deployment but requires concurrent attention to coach education, user-interface accessibility, and the cultivation of an organizational culture that values data as a complement to — rather than a substitute for — experienced coaching judgment. The tension between algorithmic recommendation and intuitive expertise identified in coach interviews represents a productive site for future research examining optimal human-AI collaboration models in sports coaching.

For Indonesian football institutions and the broader national sports development ecosystem, this study makes a clear case for investment in sport analytics infrastructure and capacity building. The evidence suggests that even at the university competition level, meaningful performance dividends can be harvested from analytics adoption, and that the development of locally calibrated AI models using open-source tools is a technically feasible and economically viable pathway. Future research should examine longitudinal effects of analytics integration on player development trajectories, explore gender-specific applications in women's football programs, and investigate the scalability of the proposed analytical framework to the Indonesian national youth football academies. The continued growth of sport analytics literacy among Indonesian coaches, athletes, and sports scientists will be essential for narrowing the technological gap between Indonesian football and the world's leading football nations.

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