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Forecasting the Future of Futsal Performance: Integrating Artificial Intelligence, Cognitive Factors, and Environmental Constraints

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ABSTRACT

This review aimed to forecast the future of futsal performance by integrating evidence from artificial intelligence (AI), cognitive science, and ecological dynamics. Futsal is a high-intensity, time-constrained sport characterized by rapid transitions, frequent ball contacts, and continuous perception–action coupling. A narrative review approach was adopted to synthesize peer-reviewed studies relevant to performance analysis, decision-making, tactical behavior, and technology-enhanced training. The literature indicates that AI-driven tools, including machine learning models, tracking systems, and wearable technologies, are increasingly used to monitor player behavior, optimize workloads, and support tactical analysis. At the same time, cognitive factors such as executive functions, anticipation, attention, and perceptual-cognitive expertise play a central role in successful performance in team sports, particularly in fast and information-rich environments such as futsal. Environmental constraints, including space, rules, number of players, and task design, further shape behavior through adaptive interactions between the athlete and the game context. Taken together, these domains suggest that futsal performance should be conceptualized as a dynamic, multidimensional system rather than as an outcome of isolated physical or technical qualities. The review proposes that the future of futsal performance will depend on the integration of intelligent technologies, high-level cognitive functioning, and ecologically valid training environments.

Keywords: futsal, artificial intelligence, executive functions, ecological dynamics, performance analysis

Introduction

Futsal has developed into a highly demanding team sport that requires players to operate under intense spatial and temporal pressure. Compared with outdoor football, futsal is played in a smaller area, involves more frequent changes of possession, and exposes players to a greater density of technical and tactical interactions within shorter time windows (Moore et al., 2014; Spyrou et al., 2023). These characteristics make futsal a particularly relevant context for studying complex performance systems in sport. Traditional performance analysis in futsal and related invasion games has often emphasized physiological output, technical actions, and match statistics. Although these indicators remain important, they are insufficient to explain how high-level performance emerges in dynamic game situations (Garganta, 2009; Hughes & Bartlett, 2002).

Contemporary sport science increasingly recognizes that performance is shaped by the interaction of multiple subsystems, including cognition, environmental constraints, and technological feedback (Davids et al., 2013; Memmert et al., 2017; Rein & Memmert, 2016). One of the most significant recent developments in this area has been the rise of artificial intelligence. AI-based tools are now widely used in sport for performance tracking, injury-risk monitoring, opponent analysis, and predictive modeling (Bunker & Thabtah, 2019; Rein & Memmert, 2016). Advances in global positioning systems, inertial sensors, and other microtechnologies have allowed coaches and analysts to obtain more precise data about player movement, workload, and tactical organization (Cummins et al., 2013). Although many of these systems were first developed in outdoor team sports, their principles are increasingly relevant to futsal, especially as tracking and video-analysis tools become more refined and context-sensitive (Spyrou et al., 2023). Alongside these technological developments, cognitive science has provided strong evidence that successful performance in team sports depends heavily on higher-order mental processes. Team-sport athletes must rapidly perceive relevant information, inhibit inappropriate responses, anticipate opponents' actions, and select adaptive solutions under pressure (Mann et al., 2007; Williams & Ford, 2008). Research on executive functions has shown that skilled football players tend to outperform less skilled players on measures of cognitive flexibility, working memory, and inhibitory control (Verburgh et al., 2014; Vestberg et al., 2012; Vestberg et al., 2017). In fast-paced sports such as futsal, where decisions often need to be made within fractions of a second, such cognitive qualities may be especially important. A third major line of research comes from ecological dynamics and the constraints-led approach. From this perspective, performance is not produced solely by internal capacities but emerges from the interaction between the athlete, the task, and the environment (Araújo et al., 2006; Davids et al., 2013). In futsal, constraints such as pitch dimensions, player density, ball speed, numerical superiority or inferiority, and rule modifications can all shape tactical behavior, creativity, and decision-making (Travassos et al., 2012; Vilar et al., 2012). This framework has important implications for training design because it suggests that representative and adaptable practice environments are essential for developing expertise. Despite substantial progress in each of these areas, research often continues to treat technology, cognition, and environmental constraints as separate topics. This fragmentation limits the ability of researchers and practitioners to understand how modern futsal performance is actually produced. AI tools may generate increasingly rich data, but their value depends on how players perceive and use information. Likewise, cognitive abilities may support decision-making, but they are always expressed within a specific task and environmental context. Environmental constraints can promote adaptation, but their effectiveness depends on the cognitive and technological systems surrounding performance. Therefore, the purpose of the present review is to provide an integrated and future-oriented perspective on futsal performance. Specifically, this review examines how artificial intelligence, cognitive factors, and environmental constraints interact to shape performance outcomes, training processes, and tactical development in futsal. By synthesizing these domains, the article proposes a more comprehensive model of performance and identifies directions for future research and applied practice in elite and developmental futsal settings.

Methodology

This study used a narrative review design to synthesize literature relevant to the future of futsal performance. A narrative approach was selected because the objective was not to estimate a pooled effect size but to integrate evidence from several complementary domains, including AI-based performance analysis, perceptual-cognitive expertise, ecological dynamics, and applied training research in futsal and related team sports. A structured search was conducted using Google Scholar, PubMed,

Web of Science, and Scopus. Search combinations included terms such as “futsal performance,” “futsal analysis,” “artificial intelligence in sport,” “machine learning sport prediction,” “executive functions in soccer,” “perceptual-cognitive expertise,” “ecological dynamics sport,” “constraints-led approach,” and “small-sided games football.” Additional backward citation tracking was used to identify foundational sources relevant to decision-making, tactical analysis, and training design. Studies were considered eligible if they met the following criteria: (1) they were published in peer-reviewed academic outlets; (2) they were written in English; (3) they addressed one or more of the core domains of this review—technology/AI, cognition, or environmental constraints; and (4) they were directly related to futsal or to invasion team sports with clear conceptual relevance to futsal. Studies were excluded if they were purely descriptive without analytical relevance, unavailable in full text, or not clearly connected to performance mechanisms. Priority was given to systematic reviews, meta-analyses, conceptual papers with strong theoretical influence, and empirical studies widely cited in the areas of team-sport performance, executive functions, perceptual-cognitive expertise, and ecological dynamics. Because futsal-specific research remains smaller than the literature on outdoor football, selected football studies were included when their findings were theoretically transferable to futsal. The selected studies were then organized into three analytical domains: (1) AI and technological systems, (2) cognitive and perceptual factors, and (3) environmental constraints and ecological adaptation. The final synthesis focused on identifying recurring themes, conceptual links, and future implications for performance modeling in futsal.

Research Findings

The reviewed literature indicates that futsal performance is best understood through the interaction of three major domains: technological systems, cognitive processes, and environmental constraints. The first domain concerns AI and performance technologies. Studies consistently show that data-driven systems have become central to modern performance analysis. Machine learning techniques are increasingly used for outcome prediction, pattern recognition, and tactical analysis in team sports (Bunker & Thabtah, 2019). In parallel, tracking technologies and wearable sensors provide continuous data on movement, workload, and positional behavior, allowing more precise monitoring of performance and training demands (Cummins et al., 2013). In high-performance settings, these tools also support risk management and return-to-play planning by helping practitioners monitor load accumulation and possible injury exposure (Gabbett, 2016). The broader literature on sports analytics suggests that technology is moving from descriptive reporting toward predictive and decision-support applications (Memmert et al., 2017; Rein & Memmert, 2016). The second domain concerns cognition. Across the reviewed studies, a clear pattern emerged: successful team-sport performance depends heavily on executive functioning, perceptual skill, and fast decision-making. Meta-analytic evidence indicates that expert athletes outperform less skilled athletes on perceptual-cognitive measures (Mann et al., 2007). Research in football has further shown that executive functions are associated with present and future performance level (Verburgh et al., 2014; Vestberg et al., 2012; Vestberg et al., 2017). In practical terms, these abilities support scanning, anticipation, selective attention, and rapid response adaptation. Given the smaller playing area and compressed timing in futsal, these cognitive demands are likely even more pronounced than in many outdoor contexts (Moore et al., 2014; Williams & Ford, 2008). The third domain concerns environmental constraints. Ecological and constraints-led studies show that player behavior is strongly shaped by task and environmental conditions rather than by individual ability alone (Araújo et al., 2006; Davids et al., 2013). In futsal and related team sports, modifications to space, player numbers, and rules influence tactical creativity, interaction patterns, and movement solutions (Travassos et al., 2012; Vilar et al., 2012). Small-sided and conditioned games are especially important because they allow coaches to target both tactical and physical outcomes while preserving ecological validity (Hill-Haas et al., 2011). Taken together, the literature indicates that none of these domains operates independently. Technology generates information, cognition supports

interpretation and action, and environmental constraints shape what actions become possible or functional. This interdependence suggests that the future of futsal performance lies not in a single innovation but in the coordinated integration of all three domains.

Discussion and Conclusion

The present review supports the view that futsal performance should be conceptualized as a dynamic system emerging from the interaction of technological, cognitive, and environmental factors. This conclusion has important implications for both theory and practice. First, AI and performance technologies are likely to become even more influential in futsal over the coming years. The transition from descriptive analytics to predictive systems means that coaches and analysts will increasingly rely on models capable of identifying patterns before they become visible through conventional observation alone (Bunker & Thabtah, 2019; Rein & Memmert, 2016). However, the review also makes clear that more data do not automatically produce better decisions. The effectiveness of technological systems depends on the quality of interpretation, the relevance of collected variables, and the extent to which the information can be integrated into coaching and player behavior. Second, the literature strongly suggests that cognitive capacities remain central to elite performance. Executive functions, attentional control, and perceptual-cognitive expertise are not peripheral additions to technical skill; they are fundamental mechanisms through which players adapt to the demands of high-speed team sports (Mann et al., 2007; Verburgh et al., 2014; Vestberg et al., 2017). In futsal, where players operate in tighter spaces and under greater time pressure, cognitive efficiency may be especially important for anticipating play, selecting among options, and reorganizing behavior after rapid transitions.

Third, ecological dynamics provides a critical corrective to overly reductionist models of performance. A player does not "use" cognitive ability or technology in isolation. Rather, performance emerges through the continuous interaction between the athlete and the environment (Araújo et al., 2006; Davids et al., 2013). For this reason, training design must preserve representative features of competition. Constraint manipulation—through adjustments in pitch area, player number, rule structure, or tactical emphasis—can be used to channel attention, stimulate creativity, and increase adaptive learning (Travassos et al., 2012; Vilar et al., 2012). The most important implication of the review is therefore integrative. AI provides measurement and feedback, cognitive factors shape interpretation and decision-making, and environmental constraints determine what forms of behavior are invited or suppressed. When these components are aligned, training and performance systems become more powerful. For example, tracking technologies may identify recurring tactical inefficiencies, cognitive assessment may reveal whether players struggle with scanning or inhibition under pressure, and representative practice constraints may then be adjusted to target those specific weaknesses. At the same time, several limitations in the current literature should be acknowledged. Futsal-specific evidence remains more limited than the corresponding football literature, and many applied insights still come from neighboring team sports. In addition, some technological systems are more established in outdoor football than in futsal, partly because of differences in space, equipment, and tracking infrastructure. There is also a risk that enthusiasm for analytics may outpace the interpretive frameworks needed to use those data meaningfully.

Future research should therefore move in three directions. First, more futsal-specific studies are needed on AI-supported performance analysis and tactical modeling. Second, greater integration is required between executive-function research and game-based performance measures. Third, ecological training studies should increasingly examine how technological feedback can be embedded within representative learning environments rather than being treated as a separate layer of analysis. Overall, the future of futsal performance will likely belong to systems that combine smart technology, cognitively demanding decision environments, and ecologically valid training design.

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Authors' Contributions

Authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

AI use statement

Artificial intelligence–assisted tools were used only for language refinement and editorial support. The conceptualization, synthesis of the literature, interpretation of the evidence, and final approval of the manuscript were performed by the authors.

Ethical Considerations

This study is a review article and did not involve direct data collection from human participants. The article was prepared in accordance with accepted academic and ethical standards for scholarly writing, source use, and citation.

Transparency of Data

Not applicable.

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