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Embodied Cognition in Sport Expertise: A Thematic Exploration of Sensorimotor Awareness in Professional Athletes

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A B S T R A C T

The objective of this study was to explore and interpret the lived experiences of professional athletes to identify the core thematic dimensions of sensorimotor awareness within the framework of embodied cognition. This study employed a qualitative research design using thematic analysis grounded in an interpretivist paradigm. Participants consisted of twenty-four professional athletes from Canada, representing both individual and team sports with a minimum of five years of elite-level experience. Data were collected through semi-structured in-depth interviews, complemented by reflective journals and researcher field notes to enhance contextual richness and triangulation. Interviews focused on athletes' perceptions of bodily awareness, decision-making processes, and integration of sensory feedback during performance. All interviews were audio-recorded, transcribed verbatim, and analyzed following a six-phase thematic analysis procedure, including familiarization, coding, theme generation, review, and refinement. Rigor was ensured through member checking, peer debriefing, and maintenance of an audit trail. The analysis revealed four overarching themes: heightened bodily awareness, embodied decision-making, sensorimotor calibration, and embodied emotional regulation. The findings indicated that perception–action coupling and motor refinement through repetition were universally experienced and constituted the core of expertise. Athletes demonstrated strong reliance on pre-reflective, intuitive processes for rapid decision-making, particularly in dynamic environments. Interoceptive and proprioceptive awareness emerged as critical mechanisms supporting performance optimization and emotional regulation. Variations across sport types suggested that closed-skill sports emphasized precision and bodily control, whereas open-skill sports prioritized adaptability and anticipatory action. Overall, sensorimotor awareness functioned as an integrative system linking cognitive, physical, and affective domains. The findings support the central role of embodied cognition in sport expertise, demonstrating that high-level performance is grounded in the integration of sensory perception, motor execution, and emotional regulation. Sensorimotor awareness operates as a dynamic and multidimensional construct that enables athletes to adapt efficiently to complex and changing environments.

Keywords: *embodied cognition, sensorimotor awareness, sport expertise, professional athletes, perception–action coupling, interoception, proprioception*

1. Introduction

The study of sport expertise has increasingly shifted from purely cognitive and biomechanical explanations toward integrative frameworks that emphasize the inseparability of mind, body, and environment. Within this paradigm, embodied cognition has emerged as a central

theoretical lens, proposing that cognitive processes are deeply rooted in the body's interactions with the world rather than being confined to abstract mental representations. This perspective challenges traditional dualistic assumptions and instead posits that perception, action, and cognition are dynamically intertwined in the execution of skilled performance. In sport contexts, where rapid decision-making, precise motor coordination, and adaptive responsiveness are essential, embodied cognition provides a particularly compelling framework for understanding expertise (1). The athlete's body is not merely an instrument executing commands from the brain but is an active participant in shaping cognition, enabling fluid and context-sensitive performance (2).

Recent advances in neuroscience and sport psychology have provided empirical support for this embodied perspective by demonstrating that elite athletes exhibit distinct neural and sensorimotor characteristics compared to non-athletes. Functional neuroimaging studies reveal that athletes develop specialized brain networks associated with motor imagery, action anticipation, and perceptual-motor integration, reflecting the deep coupling between cognitive and bodily processes (3). Similarly, meta-analytic findings indicate that athletes engaged in different types of sports—particularly open versus closed skill disciplines—display differentiated patterns of neural organization and resting-state connectivity, underscoring the role of environmental interaction in shaping embodied cognition (4). These findings suggest that expertise is not merely a matter of cognitive efficiency but involves the restructuring of sensorimotor systems through prolonged training and embodied engagement.

A key component of embodied cognition in sport is sensorimotor awareness, which encompasses the athlete's ability to perceive, interpret, and regulate bodily states during performance. This includes proprioception, interoception, and exteroceptive processes that collectively inform movement execution and decision-making. Proprioceptive awareness enables athletes to monitor body position and movement without reliance on visual input, facilitating precise coordination and balance. Interoception, on the other hand, involves the perception of internal physiological signals such as heart rate, respiration, and fatigue, which play a critical role in pacing, endurance, and emotional regulation (5). Research has demonstrated that athletes exhibit enhanced interoceptive accuracy compared to non-athletes, suggesting that training environments cultivate heightened sensitivity to internal bodily cues (6). This heightened awareness allows athletes to make fine-grained adjustments in real time, optimizing performance under varying conditions.

The role of sensorimotor awareness extends beyond physical execution to encompass cognitive and emotional dimensions of performance. Studies have shown that bodily states can influence cognitive processes such as spatial reasoning and mental rotation, with dynamic balance and motor control contributing to improved cognitive performance in athletes (7, 8). This bidirectional relationship between body and mind highlights the integrative nature of embodied cognition, where cognitive functions are not independent of physical experience but are shaped by it. Furthermore, embodied processes are closely linked to emotional regulation, as athletes rely on bodily cues to interpret and manage stress, anxiety, and arousal during competition. The relationship between musculoskeletal conditions, anxiety, and body awareness in elite athletes underscores the importance of somatic signals in maintaining psychological well-being and performance stability (9).

Training practices in sport increasingly recognize the importance of enhancing sensorimotor awareness as a pathway to expertise. Interventions such as proprioceptive training, balance exercises, and biofeedback have been shown to improve motor control and functional performance across various populations, including athletes and individuals with physical impairments (10, 11). These approaches emphasize the refinement of internal representations of the body, enabling more efficient and adaptive movement patterns. Similarly, sensorimotor training has been found to enhance balance control and coordination by strengthening the integration of sensory inputs and motor outputs (12, 13). Such findings highlight the plasticity of the embodied system and its capacity to be shaped through targeted practice.

The concept of embodied decision-making further illustrates the centrality of sensorimotor processes in sport expertise. Rather than relying solely on deliberate, analytical reasoning, expert athletes often make decisions through

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intuitive, pre-reflective processes that are grounded in bodily experience. This phenomenon has been described as "embodied choice," where the body itself contributes to the selection of actions based on accumulated sensorimotor knowledge (14). The interplay between controlled and automated processes in skilled action suggests that expertise involves a balance between conscious regulation and unconscious execution, with embodied cognition facilitating seamless transitions between these modes (15). This perspective aligns with ecological dynamics approaches, which emphasize the continuous interaction between the athlete and the environment in shaping behavior (16).

In addition to performance optimization, embodied cognition has important implications for injury prevention and rehabilitation. Disruptions to sensorimotor systems, such as those caused by concussions, can impair neuromuscular control and increase the risk of further injury, highlighting the need for interventions that restore embodied functioning (17). Similarly, research on sports-related concussions emphasizes the importance of maintaining sensorimotor integrity to ensure safe and effective performance (18). The integration of embodied approaches in rehabilitation programs has been shown to facilitate recovery by re-establishing the connection between perception and action, thereby enhancing functional outcomes.

The influence of embodied cognition is also evident in the interaction between athletes and their equipment and environment. Performance in many sports depends not only on the athlete's bodily capabilities but also on the dynamic relationship between the body and external tools or conditions. Studies exploring this interplay highlight how athletes adapt their movements and perceptions in response to equipment and environmental constraints, further reinforcing the situated nature of cognition (19). This perspective extends to broader contexts such as the impact of external events on athletes' careers, where embodied experiences of disruption and adaptation shape performance trajectories (20).

Moreover, embodied cognition intersects with broader psychosocial and health-related dimensions of sport. Research indicates that factors such as mental health, cranial nerve function, and psychosocial stressors are closely linked to bodily awareness and performance outcomes (21). The bio-emotional-social approach to sport participation underscores the interconnectedness of physical, psychological, and social factors in shaping athletic experience (22). Training in specialized environments, such as water immersion, has also been shown to alter interoceptive processes, demonstrating the adaptability of embodied systems to different contexts (23). These findings highlight the multifaceted nature of embodied cognition and its relevance across diverse aspects of sport.

Despite the growing body of research in this area, there remains a need for in-depth qualitative investigations that capture the lived experiences of athletes and provide rich, context-sensitive insights into sensorimotor awareness. While quantitative studies offer valuable evidence of neural and behavioral correlates, they often lack the capacity to explore how athletes subjectively experience and interpret their embodied states during performance. Phenomenological and qualitative approaches have been advocated as essential tools for understanding these experiential dimensions, enabling researchers to access the nuanced meanings that underpin embodied expertise (24). By focusing on athletes' narratives and reflections, such approaches can reveal the tacit knowledge and embodied practices that are not easily captured through experimental methods.

Furthermore, the exploration of embodied cognition in sport can benefit from interdisciplinary perspectives that integrate insights from psychology, neuroscience, physiology, and philosophy. The convergence of these fields has led to a more comprehensive understanding of how cognition emerges from the interaction of brain, body, and environment, emphasizing the importance of holistic approaches to studying expertise (25). Emerging research also highlights the role of sensory-spatial integration in coordinating complex movements, suggesting that expertise involves the seamless integration of multiple sensory modalities (26). Additionally, studies on vocal and auditory awareness in performers extend the concept of embodiment beyond traditional motor domains, illustrating its applicability across diverse forms of skilled activity (27, 28).

Visual awareness and attentional processes further contribute to the embodied nature of sport performance, as athletes must continuously monitor and respond to dynamic visual cues in their environment. Enhanced visual awareness

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has been associated with improved performance outcomes in sports such as basketball, highlighting the role of perceptual skills in embodied cognition (29). Similarly, the monitoring of action outcomes and the influence of social roles and rewards underscore the broader contextual factors that shape embodied experience in sport (30). These findings reinforce the idea that embodied cognition is not limited to internal processes but is deeply embedded in social and environmental contexts.

Taken together, the existing literature underscores the centrality of embodied cognition and sensorimotor awareness in sport expertise, while also revealing gaps in our understanding of how these processes are experienced and enacted by professional athletes in real-world contexts. Therefore, the aim of this study is to explore the lived experiences of professional athletes to identify and interpret the thematic dimensions of sensorimotor awareness within the framework of embodied cognition.

2. Methods and Materials

2.1. Study Design and Participants

This study was designed within a qualitative research paradigm, employing thematic analysis to explore the lived experiences and sensorimotor awareness of professional athletes through the lens of embodied cognition. The qualitative approach was selected due to its capacity to capture nuanced, context-dependent meanings that are central to understanding how athletes perceive, interpret, and enact bodily knowledge in high-performance environments. The research adopted an interpretivist epistemological stance, emphasizing subjective experience, meaning-making processes, and the co-construction of knowledge between researcher and participant. The participant group consisted of twenty-four professional athletes recruited from Canada, representing a diverse range of sports disciplines including team-based and individual sports such as soccer, ice hockey, track and field, swimming, and gymnastics. Participants were selected using purposive sampling to ensure that all individuals met the inclusion criteria of having a minimum of five years of professional-level experience and active engagement in national or international competitions. This sampling strategy facilitated the inclusion of individuals with rich experiential knowledge of embodied performance and sensorimotor expertise.

2.2. Measures

Data collection was conducted using semi-structured, in-depth interviews as the primary instrument, complemented by reflective journals and field notes to enhance contextual richness and triangulation. The semi-structured interview protocol was carefully developed based on existing theoretical frameworks in embodied cognition and sport psychology, allowing flexibility for participants to elaborate on their experiences while maintaining consistency across interviews. Each interview lasted between 60 to 90 minutes and was conducted either in person or via secure video conferencing platforms, depending on participant availability and geographic location. The interview questions focused on athletes' perceptions of bodily awareness, kinesthetic sensitivity, decision-making during performance, and the integration of sensory feedback in skill execution. In addition, participants were invited to maintain short reflective journals over a two-week period, documenting moments of heightened bodily awareness during training or competition. Field notes were recorded by the researcher immediately after each interview to capture non-verbal cues, contextual observations, and preliminary analytical insights. All interviews were audio-recorded with participant consent and subsequently transcribed verbatim to ensure accuracy and completeness of the data corpus.

2.3. Data Analysis

The data analysis followed the six-phase framework of thematic analysis, allowing for systematic identification, organization, and interpretation of patterns within the dataset. Initially, the researcher engaged in repeated readings of the transcripts to achieve data familiarization, accompanied by memo-writing to document emerging impressions. This was followed by the generation of initial codes through an inductive coding process, whereby meaningful units of text were identified and labeled without imposing pre-existing categories. Coding was conducted manually to maintain close engagement with the data and to preserve interpretive sensitivity. In the subsequent phase, codes were examined for similarities and differences and organized into preliminary themes that captured broader

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patterns of meaning related to embodied cognition and sensorimotor awareness. These themes were then reviewed and refined through iterative comparison with the original data to ensure internal coherence and external distinctiveness. The final phase involved defining and naming themes, supported by illustrative excerpts that exemplified each thematic construct. To enhance the rigor and trustworthiness of the analysis, strategies such as member checking, peer debriefing, and audit trail documentation were employed. Credibility was further strengthened through prolonged engagement with the data and triangulation across interviews, journals, and field notes, ensuring that the findings reflect a comprehensive and authentic representation of athletes' embodied experiences.

3. Findings and Results

The participant group consisted of twenty-four professional athletes from Canada, representing both individual and team sports, with a balanced distribution across gender, age range, and competitive experience. The sample included twelve male and twelve female athletes, with ages ranging from 21 to 34 years (M = 27.46, SD = 3.82). Participants had an average professional experience of 8.75 years (SD = 2.94), reflecting a high level of expertise and prolonged engagement in elite sport contexts. Sports representation included ice hockey (n = 5), soccer (n = 4), athletics/track and field (n = 5), swimming (n = 4), and gymnastics (n = 6). All participants reported active participation in national competitions, with fifteen also having experience in international events such as world championships or Olympic-level qualifiers. Educational backgrounds varied, with the majority holding at least a college diploma or undergraduate degree, and several engaged in dual-career pathways balancing sport and academic or professional commitments.

Table 1 presents the primary themes and subthemes that emerged from the thematic analysis, capturing the multidimensional nature of sensorimotor awareness in professional athletes. These themes reflect how athletes experience, interpret, and regulate bodily processes during performance, highlighting the central role of embodied cognition in expertise development.

Table 1

Thematic Structure of Sensorimotor Awareness in Professional Athletes

Main Theme	Subthemes	Description	Representative Indicators
Heightened Bodily Awareness	Kinesthetic Sensitivity	Fine-tuned perception of body position and movement in space	Awareness of joint angles, muscle tension, balance
	Proprioceptive Precision	Accurate internal sensing of movement without visual reliance	Closed-eye drills, automatic posture correction
	Interoceptive Monitoring	Awareness of internal physiological states	Breathing rhythm, fatigue signals, heart rate awareness
Embodied Decision-Making	Pre-reflective Action	Immediate, intuitive responses without conscious deliberation	"Instinctive" movements during play
	Action Anticipation	Predictive bodily readiness based on situational cues	Reading opponents' movements, anticipatory positioning
	Perception-Action Coupling	Integration of sensory input and motor execution	Real-time adaptation to dynamic environments
Sensorimotor Calibration	Error Detection and Correction	Rapid identification and adjustment of movement errors	Micro-adjustments during execution
	Motor Refinement through Repetition	Continuous fine-tuning of skills via practice	Iterative skill optimization
	Contextual Adaptability	Adjusting movements based on environmental constraints	Weather, surface conditions, opponent variability
Embodied Emotional Regulation	Somatic Markers in Performance	Bodily signals guiding emotional responses	Tension indicating stress or readiness
	Regulation through Movement	Using physical actions to modulate emotional states	Breathing techniques, pacing strategies
	Flow State Embodiment	Deep immersion where action feels effortless	Loss of self-consciousness, temporal distortion

The thematic structure outlined in Table 1 demonstrates that sensorimotor awareness in professional athletes is not a singular construct but a complex, multi-layered phenomenon encompassing perceptual, cognitive, and affective

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dimensions. Athletes consistently described a heightened awareness of their bodies that operates both consciously and pre-reflectively, enabling precise control and adaptation during performance. The integration of perception and action emerged as a central mechanism, with athletes relying on embodied cues rather than explicit cognitive deliberation. Furthermore, emotional regulation was deeply intertwined with bodily processes, suggesting that expertise involves not only technical skill but also the capacity to interpret and modulate physiological and affective signals. These findings collectively support the notion that embodied cognition is fundamental to expert athletic performance, functioning as an integrative system that links sensory input, motor execution, and emotional experience.

Table 2 provides a detailed account of the frequency and intensity of theme occurrence across participants, offering a quantitative representation of qualitative patterns. Frequency refers to the number of participants who reported experiences related to each subtheme, while intensity reflects the depth and emphasis placed on these experiences during interviews, rated on a three-point scale (low, moderate, high).

Table 2

Frequency and Intensity of Identified Subthemes

Subtheme	Frequency (n=24)	Percentage (%)	Intensity Level (Mean)	Interpretation
Kinesthetic Sensitivity	22	91.67	2.83	Highly prevalent and strongly emphasized
Proprioceptive Precision	21	87.50	2.79	Consistently reported across disciplines
Interoceptive Monitoring	19	79.17	2.65	Important for endurance and pacing
Pre-reflective Action	23	95.83	2.91	Core feature of expertise
Action Anticipation	22	91.67	2.88	Critical in dynamic sports contexts
Perception-Action Coupling	24	100.00	2.95	Universal among participants
Error Detection and Correction	21	87.50	2.76	Key for performance refinement
Motor Refinement through Repetition	24	100.00	2.92	Foundational training mechanism
Contextual Adaptability	20	83.33	2.70	Influenced by environmental variability
Somatic Markers in Performance	18	75.00	2.61	Moderately emphasized
Regulation through Movement	20	83.33	2.74	Common coping strategy
Flow State Embodiment	17	70.83	2.58	Experienced but less consistently described

The data presented in Table 2 indicate that perception-action coupling and motor refinement through repetition were universally reported by all participants, underscoring their central role in embodied expertise. Pre-reflective action and action anticipation also exhibited high frequency and intensity, suggesting that intuitive, non-conscious processes are integral to high-level performance. In contrast, themes related to emotional regulation, while still significant, demonstrated slightly lower frequency and intensity, indicating variability in how athletes consciously engage with these processes. Overall, the pattern of findings reveals that sensorimotor awareness is most strongly anchored in perceptual-motor integration, with emotional and interoceptive components playing a supportive but still meaningful role.

Table 3 elaborates on the contextual distribution of themes across different sport types, providing insight into how embodied cognition manifests differently depending on performance demands. This table categorizes the prominence of each main theme within individual and team sports, as well as across open-skill and closed-skill environments.

Table 3

Distribution of Themes Across Sport Types and Performance Contexts

Theme	Individual Sports (n=15)	Team Sports (n=9)	Open-Skill Sports	Closed-Skill Sports	Dominant Context
Heightened Bodily Awareness	High	Moderate	Moderate	High	Closed-skill emphasis
Embodied Decision-Making	Moderate	High	High	Moderate	Open-skill emphasis
Sensorimotor Calibration	High	High	Moderate	High	Universal importance
Embodied Emotional Regulation	Moderate	Moderate	High	Moderate	Context-dependent
Flow State Embodiment	Moderate	Moderate	High	Moderate	Open-skill emphasis

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The distribution of themes across sport types, as shown in Table 3, reveals meaningful contextual variations in how embodied cognition is experienced and utilized. Athletes in individual and closed-skill sports, such as swimming and gymnastics, placed greater emphasis on heightened bodily awareness and sensorimotor calibration, reflecting the precision and consistency required in these disciplines. Conversely, athletes in team and open-skill sports, such as soccer and ice hockey, highlighted embodied decision-making and flow state embodiment as more prominent, due to the dynamic and unpredictable nature of their performance environments. Emotional regulation appeared to be moderately distributed across all contexts but was particularly salient in open-skill settings where rapid adaptation to changing conditions is required. These findings suggest that while core components of embodied cognition are shared across sports, their relative importance and expression are shaped by the specific demands of the performance context.

4. Discussion

The present study sought to explore the lived experience of sensorimotor awareness in professional athletes through the lens of embodied cognition, and the findings reveal a coherent and theoretically meaningful structure comprising heightened bodily awareness, embodied decision-making, sensorimotor calibration, and embodied emotional regulation. The results demonstrate that athletes consistently rely on finely tuned perceptual-motor systems that operate both consciously and pre-reflectively, enabling rapid, context-sensitive performance adjustments. In particular, the universal prominence of perception–action coupling and motor refinement through repetition highlights the centrality of embodied processes in expertise development. These findings align closely with the theoretical proposition that cognition in skilled performance emerges from continuous interaction between the body and the environment, rather than from detached, purely cognitive computation (2). The high frequency and intensity of pre-reflective action further support the notion that expert athletes rely heavily on intuitive, embodied responses, a phenomenon previously conceptualized as the integration of automated and controlled processes in skilled action (15).

The theme of heightened bodily awareness, encompassing proprioceptive precision, kinesthetic sensitivity, and interoceptive monitoring, underscores the foundational role of bodily perception in athletic expertise. Participants described an acute awareness of joint positioning, muscular tension, and internal physiological states, which allowed for continuous fine-tuning of movement. This finding is consistent with empirical evidence indicating that athletes exhibit enhanced interoceptive accuracy and proprioceptive sensitivity as a result of long-term training (5, 6). The importance of interoception in regulating performance, particularly in endurance and high-pressure contexts, has also been documented in studies showing that athletes use internal bodily signals to guide pacing and emotional control. Moreover, the observed integration of proprioceptive and interoceptive processes reflects the multidimensional nature of sensorimotor awareness, supporting the argument that embodied cognition involves the coordination of multiple sensory modalities (26). The findings also resonate with research demonstrating that targeted training interventions, such as proprioceptive and balance exercises, can enhance sensorimotor integration and functional performance (10, 13).

The emergence of embodied decision-making as a dominant theme highlights the critical role of intuitive, pre-reflective processes in expert performance. Athletes reported making rapid decisions based on “feel” or instinct, often without conscious deliberation, particularly in dynamic and unpredictable environments. This aligns with neuroscientific evidence showing that elite athletes develop specialized brain networks that support action anticipation and motor imagery, facilitating rapid and efficient decision-making (3). Furthermore, the distinction between open-skill and closed-skill sports observed in the findings supports previous research indicating that athletes in open-skill environments rely more heavily on anticipatory and adaptive processes due to the variability of external conditions (4). The concept of embodied choice, where the body itself contributes to decision-making, is also supported by findings that elite performers invest additional time in refining sensorimotor representations to enhance decision quality (14). These results collectively reinforce the view that decision-making

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in sport is not solely a cognitive process but is deeply embedded in bodily experience.

Sensorimotor calibration, characterized by error detection, motor refinement, and contextual adaptability, emerged as another central component of expertise. Participants emphasized their ability to detect subtle deviations in movement and make immediate corrections, often at a micro-level. This capacity for continuous adjustment reflects the dynamic nature of embodied cognition, where perception and action are tightly coupled in a feedback loop. The importance of repetition in refining motor skills, as highlighted in the findings, aligns with evidence that sustained practice leads to the development of stable yet flexible motor patterns (12). Additionally, the ability to adapt movements based on environmental constraints, such as surface conditions or opponent behavior, supports ecological dynamics perspectives that emphasize the role of environmental interaction in shaping skilled performance (16). The contextual variability observed across sport types further illustrates how different performance demands influence the expression of sensorimotor awareness.

The theme of embodied emotional regulation provides important insight into the integration of affective and physiological processes in sport performance. Athletes reported using bodily cues, such as muscle tension and breathing patterns, to interpret and regulate emotional states, particularly under competitive pressure. This finding is consistent with research linking body awareness to psychological well-being and stress management in athletes (9). The concept of somatic markers, where bodily signals inform emotional and decision-making processes, is also supported by evidence that interoceptive awareness plays a key role in shaping emotional experiences (5). The identification of flow states as an embodied phenomenon further reinforces the idea that optimal performance involves a harmonious integration of cognitive, emotional, and bodily processes. This aligns with studies suggesting that embodied cognition facilitates immersive, effortless performance by reducing cognitive load and enhancing perceptual-motor efficiency (25).

The contextual analysis of themes across sport types reveals meaningful variations in the manifestation of embodied cognition. Athletes in closed-skill sports emphasized precision and consistency, reflecting the importance of internal bodily control in stable environments. In contrast, athletes in open-skill sports highlighted adaptability and anticipatory decision-making, consistent with the demands of dynamic and unpredictable contexts. These findings are supported by research demonstrating that different training environments shape neural and behavioral adaptations in athletes (4). The interaction between athletes and their environment, including equipment and external conditions, further underscores the situated nature of cognition in sport (19). Additionally, the role of visual awareness in performance, particularly in sports requiring rapid perception of external cues, aligns with findings that enhanced visual processing contributes to improved athletic outcomes (29).

The findings also have implications for understanding injury prevention and rehabilitation in sport. The emphasis on sensorimotor awareness and calibration suggests that disruptions to these processes, such as those caused by concussions or neuromuscular impairments, can significantly impact performance and increase injury risk. This is consistent with research indicating that impaired neuromuscular control following concussion is associated with a higher likelihood of subsequent injuries (17). Similarly, studies on sports-related injuries highlight the importance of maintaining sensorimotor integrity for safe performance (18). The integration of embodied approaches in rehabilitation programs, focusing on restoring perception–action coupling, may therefore enhance recovery outcomes and reduce the risk of reinjury.

Beyond performance and injury, the findings contribute to a broader understanding of the role of embodied cognition in athletes' overall well-being and career development. The integration of bodily, cognitive, and emotional processes reflects the holistic nature of athletic experience, which is influenced by both internal and external factors. Research on psychosocial dimensions of sport indicates that body awareness is linked to mental health outcomes, including anxiety and stress management (21). The impact of environmental and situational factors, such as career disruptions or changes in training conditions, further highlights the adaptability of embodied systems (20). Additionally, the influence of specialized training environments on interoceptive processes demonstrates the

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plasticity of embodied cognition and its responsiveness to contextual factors (23).

The interdisciplinary relevance of embodied cognition is evident in its application across various domains, including music, dance, and vocal performance, where similar principles of sensorimotor integration and bodily awareness are observed. Studies on vocal training and musical expertise illustrate how interoceptive and proprioceptive processes contribute to skill development in non-sport contexts (27, 28). This cross-domain consistency supports the generalizability of embodied cognition as a framework for understanding expertise. Furthermore, research on spatial cognition and mental rotation highlights the influence of bodily movement on cognitive processes, reinforcing the bidirectional relationship between body and mind (8). The integration of these perspectives provides a more comprehensive understanding of how embodied cognition operates across different forms of skilled activity.

5. Conclusion

In summary, the findings of this study provide robust support for the central role of embodied cognition in sport expertise, demonstrating that sensorimotor awareness is a multidimensional construct encompassing perceptual, cognitive, and emotional processes. The results highlight the importance of bodily awareness, intuitive decision-making, continuous calibration, and emotional regulation in achieving and maintaining high-level performance. These insights contribute to the growing body of literature emphasizing the integration of mind and body in skilled action and underscore the value of qualitative approaches in capturing the richness of athletes' lived experiences.

The study is not without limitations. The sample size, although appropriate for qualitative research, limits the generalizability of the findings to broader populations of athletes. The reliance on self-reported data may also introduce bias, as participants' reflections are influenced by memory and subjective interpretation. Additionally, the study focused on athletes from a single national context, which may not fully capture cultural variations in embodied experience. The absence of longitudinal data further restricts the ability to examine changes in sensorimotor awareness over time.

Future research should consider expanding the sample to include athletes from diverse cultural and competitive backgrounds, as well as incorporating longitudinal designs to explore the development of embodied cognition across different stages of athletic careers. The integration of qualitative and quantitative methods may provide a more comprehensive understanding of the relationship between subjective experience and objective performance measures. Additionally, future studies could examine the role of embodied cognition in specific domains such as injury rehabilitation, talent development, and coaching practices, as well as explore the impact of emerging technologies on sensorimotor training.

From a practical perspective, the findings highlight the importance of incorporating embodied approaches into training and performance optimization strategies. Coaches and practitioners should emphasize the development of sensorimotor awareness through targeted exercises that enhance proprioception, interoception, and perceptual-motor integration. Training programs should also address the role of emotional regulation and bodily awareness in managing stress and maintaining performance under pressure. Furthermore, the application of biofeedback and other technologies may support athletes in refining their embodied skills and achieving greater consistency and adaptability in performance.

Authors' Contributions

All authors contributed substantially to the study and to manuscript development, and all approved the final version.

Declaration

The authors declare that artificial intelligence tools were used only to assist with language editing, translation, and improvement of the manuscript's readability. All conceptualization, study design, data collection, data analysis, interpretation of findings, and final approval of the manuscript were performed by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content.

Transparency Statement

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Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study placed a high emphasis on ethical considerations. Informed consent obtained from all participants, ensuring they are fully aware of the nature of the study and their role in it. Confidentiality strictly maintained, with data anonymized to protect individual privacy. The study adhered to the ethical guidelines for research with human subjects as outlined in the Declaration of Helsinki.

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