

Scientific mapping of interoception research in the context of sport: A bibliometric and network analysis

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Abstract. This study aimed to systematically examine the developmental dynamics, intellectual structure, and thematic orientations of the scientific literature on interoception in the context of sport through bibliometric methods. Specifically, it sought to identify publication trends, country and institutional collaborations, citation structures, journal clustering patterns, and conceptual concentration areas. The study was conducted using the Web of Science Core Collection database with the keywords “interoception” and “sport.” Publications between 2004 and 2026 were screened, and 125 studies were included following a preliminary selection process. Data were analyzed using the Bibliometrix R package and the Biblioshiny interface. VOSviewer software was employed to visualize bibliometric networks and examine co-citation clusters. The analyses included annual scientific production, country distribution, international collaboration rates, citation analysis, keyword co-occurrence networks, journal co-citation analysis, and thematic mapping. A total of 125 publications were analyzed. The field demonstrated a marked increase in productivity after 2015, reaching its peak in 2021. The annual growth rate was 3.2%. The average number of authors per document was 4.82, with an international co-authorship rate of 41.6%. The mean citation count was 22.52, and the average document age was 4.65 years. Scientific production was concentrated in specific countries, with the United Kingdom contributing the highest number of publications. Co-citation analysis revealed that the literature clusters predominantly around psychology, neuroscience, and cognitive science. In the keyword analysis, “interoception,” “accuracy,” and “sensitivity” emerged as the terms with the highest total link strength. Thematic mapping indicated that these concepts were positioned as motor themes, whereas “physical activity” and “fatigue” were identified as emerging themes. The literature on interoception in the context of sport represents a rapidly growing and increasingly interdisciplinary field, particularly diversifying through psychophysiological and cognitive mechanisms. The findings suggest that future research should address the relationships among sport performance, body awareness, and neurophysiological regulation processes within more integrative models. By mapping the knowledge structure and developmental trajectories of the field, this study provides a strategic framework for future investigations.

Introduction

Interoception is a multidimensional construct encompassing the processes by which the organism perceives, represents, and regulates its internal physiological states (Craig, 2002; Craig, 2009). This construct includes the central processing of internal signals such as heartbeat, respiration, visceral sensations, and autonomic nervous system activity

by the central nervous system, with the insular cortex widely recognized as the primary neuroanatomical hub of interoceptive awareness (Craig, 2009; Critchley & Harrison, 2013). In recent years, interoception has been conceptualized as more than mere physiological signal detection; rather, it is considered a multilayered structure comprising subdimensions such as interoceptive accuracy, sensitivity, and subjective awareness (Garfinkel et al.,

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2015; Murphy et al., 2020). This multidimensional model has enabled a more systematic explanation of the relationships between interoceptive processes and cognitive as well as emotional regulation mechanisms.

The neuroscience literature indicates that interoception plays a central role in emotion regulation, decision-making, risk evaluation, and self-awareness processes (Barrett & Simmons, 2015; Seth & Tsakiris, 2019). In particular, predictive coding and embodied cognition frameworks propose that internal bodily signals are not merely passively perceived but are integrated with expectation-based predictive mechanisms (Barrett, 2019; Seth & Tsakiris, 2019). This theoretical perspective provides an important foundation for explaining the relationship between interoception and performance-related processes such as perceived exertion, fatigue regulation, and stress responses.

Within the sports science's literature, interoception has increasingly emerged as a prominent field of inquiry, particularly in relation to performance optimization and self-regulation. Significant associations have been reported between interoceptive accuracy and stress tolerance, anxiety levels, and performance stability in high-performance athletes (Laborde et al., 2022; Norton & Edwards, 2015). Studies based on heartbeat perception paradigms indicate that interoceptive accuracy is linked to autonomic regulatory capacity and psychophysiological flexibility (Critchley et al., 2004). Furthermore, evidence suggests that levels of physical activity may exert regulatory effects on interoceptive sensitivity (Herbert et al., 2012; Jones & Hollandsworth, 1981). However, the majority of research conducted within the sport context relies on experimental designs with relatively small sample sizes, and comprehensive macro-level evaluations that analyze the overall knowledge structure and thematic orientations of the field remain limited.

In interdisciplinary fields characterized by rapidly increasing scientific output, the systematic mapping of the knowledge structure holds strategic importance. Bibliometric analysis is a powerful methodological approach that enables the identification of a research field's intellectual architecture through publication trends, citation networks, collaboration structures, and thematic clustering (Aria & Cuccurullo, 2017; Van Eck & Waltman, 2017). In particular, co-citation and keyword co-occurrence analyses serve as essential

tools for detecting theoretical concentration points and emerging research themes within a given field (Donthu et al., 2021). Although the interoception literature has been extensively examined within psychology and neuroscience, no comprehensive bibliometric study has yet systematically analyzed the global distribution, collaboration networks, citation structures, and thematic development dynamics of research produced specifically in the context of sport. Whereas previous bibliometric work has mapped interoception predominantly within clinical, psychological, or neuroscientific frameworks, the present study is the first to delimit and map the literature situated at the intersection of interoception and sport, thereby isolating a research space that has so far remained dispersed across adjacent disciplines. This gap makes it difficult to evaluate the epistemic development of the field and to strategically position future research directions. Accordingly, the originality of this study lies in providing the first integrated scientific map of this emerging domain. Its theoretical contribution is to clarify the conceptual structure and intellectual foundations linking interoception to sport, whereas its practical contribution is to offer researchers, journals, and research groups an evidence-based framework for identifying productive themes, collaboration opportunities, and underexplored areas. In line with this rationale, the study aims to examine publications on sport and interoception indexed in the Web of Science Core Collection between 2004 and 2026 through bibliometric methods, in order to reveal the scientific production dynamics, international collaboration structure, citation relationships, and thematic development trajectories of the field. By mapping the knowledge structure of this interdisciplinary domain situated at the intersection of sports science and psychophysiology, the study seeks to provide a theoretical and methodological framework to guide future research.

In line with this aim, the study is guided by the following research questions: (RQ1) How has scientific production on interoception in the context of sport evolved between 2004 and 2026? (RQ2) Which countries, institutions, and authors are the most productive and influential, and how are international collaborations structured? (RQ3) How are citations and core sources distributed, and which co-citation and intellectual structures characterize the knowledge base of the field? (RQ4) Which keywords and themes are most central, and how are they

positioned in terms of development degree and centrality? (RQ5) Which emerging or underdeveloped themes indicate future research directions at the intersection of interoception and sport? Given the descriptive and exploratory nature of bibliometric mapping, the study does not test directional hypotheses; rather, these research questions structure the analyses and guide the interpretation of the findings.

Materials and Methods

Research Design

This study employed a bibliometric analysis approach. Bibliometric methodology refers to the

quantitative mapping and analysis of scientific publications (Ellegaard & Wallin, 2015). It enables a comprehensive visualization of the knowledge base of a given research field from a holistic perspective. Through bibliometric techniques, studies across various disciplines can be examined using parameters such as author, publication year, document type, keywords, and page count. Accordingly, this method contributes to revealing the depth, scope, and overall landscape of a research topic. In addition, bibliometric analysis facilitates the presentation of the current state and developmental trajectory of scientific production (Liu, 2022).

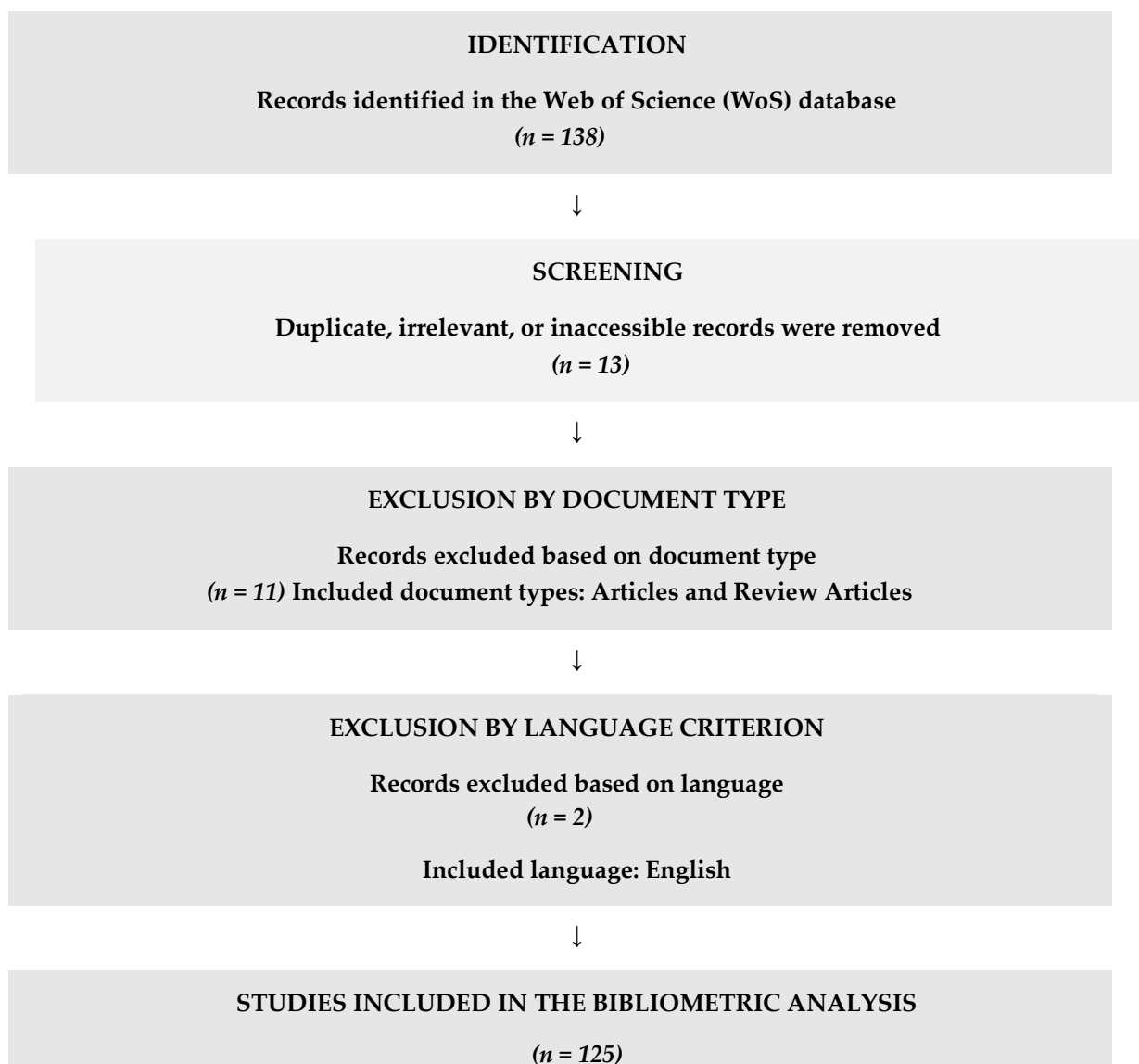


Figure 1. Flow diagram illustrating the selection process of publications included in the study

In this study, the literature search was conducted using the Web of Science Core Collection database. During the search process, the keywords “interoception” and “sport” were used in combination. The initial search yielded a total of 138 records. In the preliminary screening phase, duplicate, irrelevant, or inaccessible studies were removed, and 125 studies were included for further evaluation. At this stage, a total of 13 records were excluded. Based on document type, 110 of the included studies were classified as research articles and 17 as review articles. Eleven records that did not meet the document type criteria were excluded from the analysis. Regarding language criteria, only publications in English were included, resulting in a final sample of 125 studies. Two publications in

languages other than English were excluded. Following this selection process, the identified studies were analyzed to systematically evaluate the literature examining the relationship between interoception and sport (Figure 1).

Dataset

The search query was deliberately restricted to the core concepts “interoception” and “sport” in order to preserve conceptual specificity and to prevent the inclusion of broader and more peripheral themes such as general physical activity or exercise psychology. This decision was made intentionally to ensure that the research focus remained directly concentrated on the relationship between interoception and sport.

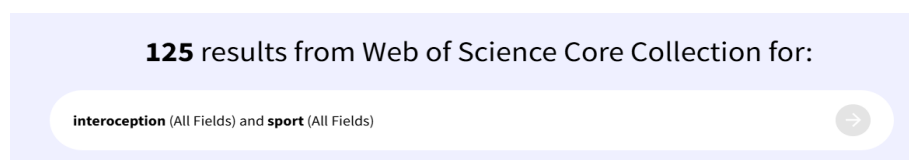


Figure 2. Number of records retrieved from the Web of Science Core Collection database search

Figure 2 illustrates the volume of records retrieved from the Web of Science Core Collection search. Within the Core Collection, no restrictions were applied regarding the citation indexes (SCI-Expanded, SSCI, and ESCI), and all accessible and eligible records were considered for analysis. The eligibility assessment and screening steps that produced the final dataset are detailed above and summarized in the flow diagram (Figure 2).

Data Collection Tools and Data Analysis

For this study, data were obtained from the WoS database, which provides extensive bibliographic

This study utilized bibliometric analysis methods to examine the quantitative and structural characteristics of academic publications. The types of analyses applied and their objectives are presented in Table 1.

Ethical Statement

According to the ULAKBİM TR Index Ethics Committee Principles published in 2020; ethical committee approval is mandatory for qualitative or quantitative research involving data collection from

coverage. The retrieved data were analyzed using the Bibliometrix R package developed by Aria and Cuccurullo (2017). In addition, the Biblioshiny web application was utilized to provide an interactive graphical user interface during the analysis process, and access to this interface was established through the RStudio platform. For the visual presentation of the results and the analysis of bibliometric networks, the open-access VOSviewer software, a scientific mapping tool developed for the analysis and visualization of bibliometric networks, was employed (Van Eck & Waltman, 2017).

participants through methods such as surveys, interviews, focus groups, observations, experiments, and discussions, as well as for studies in which humans and animals participate in experimental or scientific processes, and for research evaluated within the scope of personal data protection. In this regard, we declare that our study falls outside the scope mentioned above; therefore, it does not require ethical committee approval, and that all ethical principles were followed in the conduct and publication process of the research.

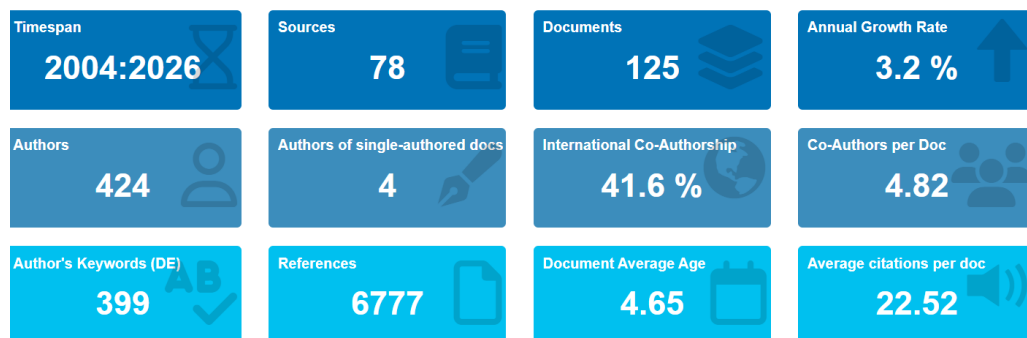
Table 1. Bibliometric analysis types used in the study and their purposes.

Analysis Type	Purpose
Main Information	Main information is used to reveal key descriptive indicators.
Annual Scientific Production	Examining the development of scientific output in the field over the years.
Countries' Annual Scientific Production Frequency	To identify the countries and institutions with the highest broadcasting volumes.
Annual Citation Rate	Annual citation rate is used to assess the impact level of studies in the literature.
Keyword Analysis	To identify the dominant themes and research focuses.
Citation Analysis	To identify the most influential and highly cited studies.
Journal Distribution and Co-Citation Analysis	Examining core journals and inter-journal relationships.
Most Relevant Authors	This identifies the researcher who has made the greatest contributions to research in the fields of interoception and sports, and whose work has been a cornerstone of the literature.
Journals Related to the Topic	It refers to the publication platform where studies focusing on the relationship between interoception and sport are most frequently published, and which defines the scientific framework of the field.
Thematic Map Analysis	Classifying the level of development of research themes.

Results

This section systematically presents the quantitative findings obtained from the statistical

analyses performed on the study's dataset, and comprehensively demonstrates the key indicators that reveal the developmental dynamics of the research area.

**Figure 3.** Main information.

A total of 125 documents published between 2004 and 2026 and indexed in 78 different sources were analyzed within the scope of this study. Although data from 2026 were included in the analysis, it should be noted that the year is not yet complete; therefore, the findings related to 2026 should be interpreted as reflecting the current status rather than the full annual output. Since 2026 represents an ongoing publication year, the corresponding results require cautious interpretation. The dataset, covering

approximately 22 years, indicates that the research field has followed a stable developmental trajectory. An annual growth rate of 3.2% suggests a sustainable, though not rapid, upward trend in scientific production. Across the publications, 424 authors contributed, with only 4 single-authored documents and an average of 4.82 co-authors per document, indicating that collaborative research is the dominant mode of knowledge production in the field. Furthermore, an international co-authorship rate of

41.6% demonstrates that a substantial proportion of studies were produced through cross-national collaboration, reflecting the field's integration into global academic networks.

The presence of 399 author keywords highlights a high level of conceptual diversity, while the total of 6,777 cited references indicates a strong grounding in the existing literature. The average document age of

4.65 years suggests that the literature is relatively recent, and the mean citation count of 22.52 per document reflects a satisfactory level of academic impact. Overall, the findings suggest that the field is characterized by a high level of international collaboration, steady scientific productivity, and strong visibility within the academic literature (Figure 3).

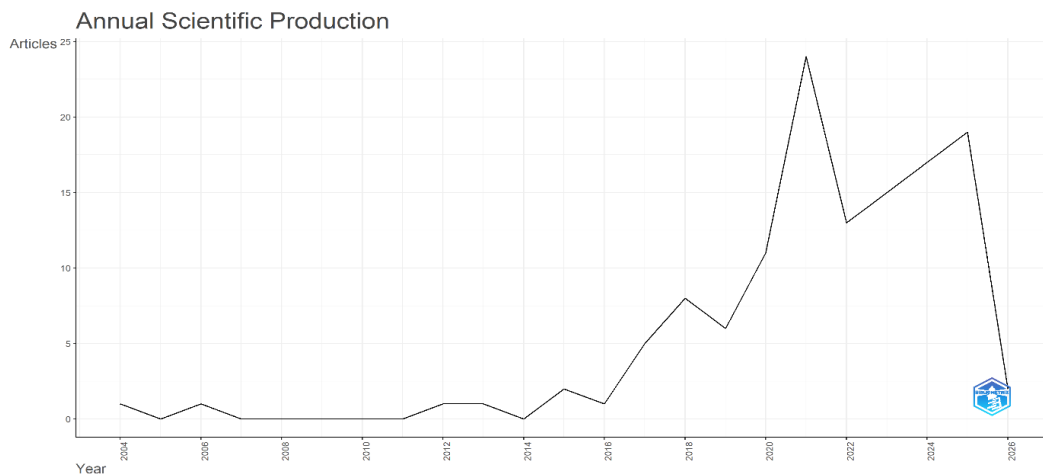


Figure 4. Annual scientific output.

An examination of the annual scientific output graph reveals that the number of publications remained quite low and limited between 2004 and 2014. An upward trend began in 2015, with a significant increase observed particularly after 2017. 2021 stands out as the period with the highest number of publications. While a fluctuating trend is observed after 2022, output continues at a higher level compared to previous years. The decrease in 2026 is most likely due to the year not yet being complete. Overall, the graph shows a significant increase in studies in the fields of interoception and sports, especially in recent years (Figure 4).

Table 2. Scientific output of countries

Country	Frequency
United Kingdom	125
Germany	56
Hungary	54
France	43
United States of America	32
Canada	24
Australia	22
Italy	20
Switzerland	16
China	13

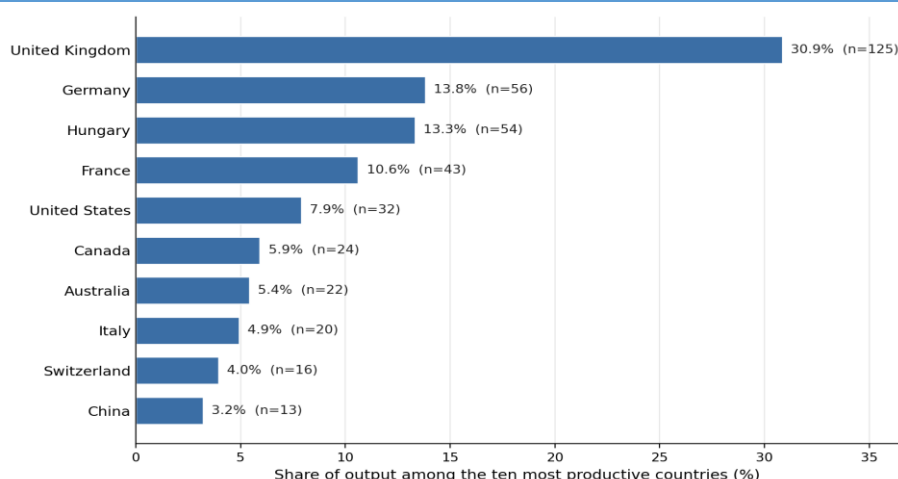


Figure 5. Percentage distribution of scientific output among the ten most productive countries. Percentages represent each country's share of the combined output of these ten countries; because country counts are based on full counting, a single publication may contribute to more than one country.

This table shows the distribution of scientific publications examined within the scope of the bibliometric analysis, by country. Frequency values indicate how many scientific publications represent the respective country in the analyzed dataset. In other words, each country's total contribution to scientific production was measured through the number of publications. Examining the table, the United Kingdom has the highest scientific output with 125 publications. This indicates that the UK has a strong academic output capacity in the analyzed research area and makes a significant contribution to the literature. Germany (56 publications) and Hungary (54 publications) are in second place with very similar values. The publication performance of these two countries indicates that they conduct stable and strong academic activity in the relevant research area. France (43 publications) and the United States (32 publications) exhibit a moderate level of scientific output. Considering that the United States generally has a high scientific output capacity on a global scale, it can be said that its representation in this specific research area is relatively limited. Canada, Australia, and Italy have lower but similar numbers of publications. This situation indicates that the countries in question contribute to the relevant field, but that production is concentrated in certain central

countries. Switzerland (16 publications) and China (13 publications), which are lower on the list, show a more limited representation in the dataset. This may suggest that the research field is relatively new and developing in these countries, or that the dataset is concentrated in certain geographical centers. Overall, it is seen that scientific production does not show a balanced distribution among countries, but is concentrated in certain countries. However, the sum of the country-based frequency values appears to be higher than 125. This is because some publications have authors from more than one country. In bibliometric analyses, multi-authored and internationally collaborative studies are counted separately for each author's country. Country production values were calculated using the full counting method. Publications with authors from more than one country were evaluated as separate contributions for each country. Therefore, the total frequency values for countries may exceed the total number of publications. This should not be considered a methodological error, but rather an indicator of international cooperation. The high frequency of the United Kingdom, in particular, is related to its high representation in international co-authored studies.

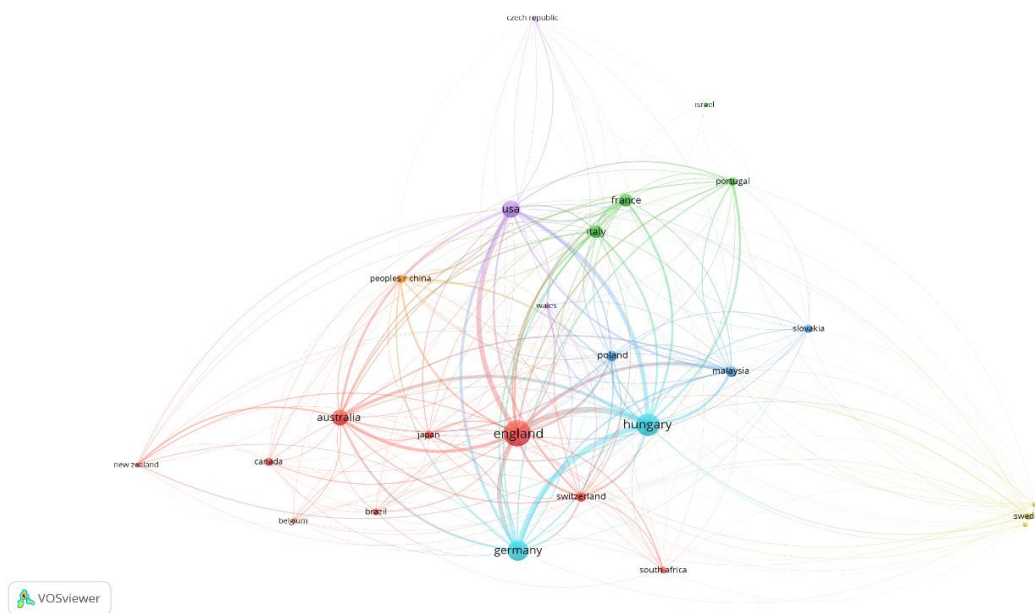


Figure 6. Bibliometric network map between countries.

The network map shows the structure of cooperation between countries, with the United Kingdom (represented at the center), Hungary, Germany, and the United States (USA) standing out with strong connections. The UK is the most central actor, directly connected to many countries, while Hungary and Germany also stand out with strong network relationships. The United States plays a significant bridging role, connecting both European countries and other regions. Portugal, France, and Italy have strong ties within their clusters, while China, Australia, and Canada are more peripheral but integrated into the network with multiple connections. Sweden and New Zealand are located in the more peripheral part of the network and have more limited connections. Overall, the map indicates a dense, European-centric cooperation structure, with the UK playing a decisive central role (Figure 6).

When the findings are evaluated from a national perspective, Türkiye does not appear among the most productive countries (Table 2) or as a central actor

within the international collaboration network (Figure 6), and Turkish authors are not represented among the most prolific researchers in the field (Figure 10). This pattern suggests that interoception research in the context of sport is still at an early and emerging stage in Türkiye, with limited international visibility and a modest contribution to the global knowledge structure. Given the country's active and expanding research capacity in sport sciences and exercise psychology, this finding points to a clear opportunity rather than a structural limitation: the intersection of interoception and sport represents an underexplored yet promising area in which Turkish researchers could increase their scientific output, develop international collaborations, and contribute to the thematic development of the field. Encouraging studies that connect interoceptive accuracy and awareness with sport performance, training adaptation, and athlete well-being would help strengthen national representation within this growing interdisciplinary domain.

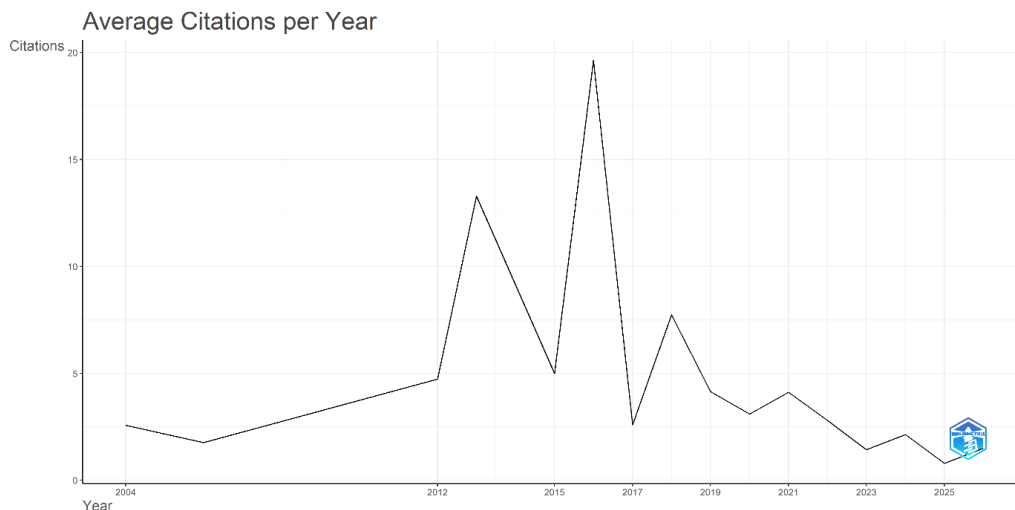


Figure 7. Average annual number of citations.

Examining the graph, it can be seen that the average number of citations fluctuates over the years. Between 2004 and 2012, the average citation showed a low but steady upward trend, while a significant increase was observed in 2013. 2016 is the period with the highest average citation value in the graph, indicating that studies published that year had a strong impact on the literature. However, a decrease was observed in 2017, and in subsequent years, the average citation has followed a lower and more fluctuating trend. A general downward trend in average citation values is seen in the period after 2019; this may be due to the fact that publications in recent years have received fewer citations because sufficient time has not yet passed since their publication. In bibliometric analyses, it is expected that newly published studies naturally have lower average citations. Overall, the graph reveals that while there were publications with high impact in

certain years, citation performance did not show a stable increase between years (Figure 7). It should be emphasized that this decline in average citations in recent years is not inconsistent with the increase in annual scientific production shown in Figure 4. The two indicators capture different dynamics: Figure 4 reflects the number of publications produced each year, whereas Figure 7 reflects the average number of citations those publications have accumulated to date. Because recently published studies have had less time to attract citations (citation lag), the years with the highest output, particularly the post-2020 period, mechanically tend to display lower average citation values even as the field continues to expand. The apparent divergence between rising productivity and declining average citations therefore reflects the maturation lag of the most recent literature rather than a genuine decline in the scientific impact of the field.

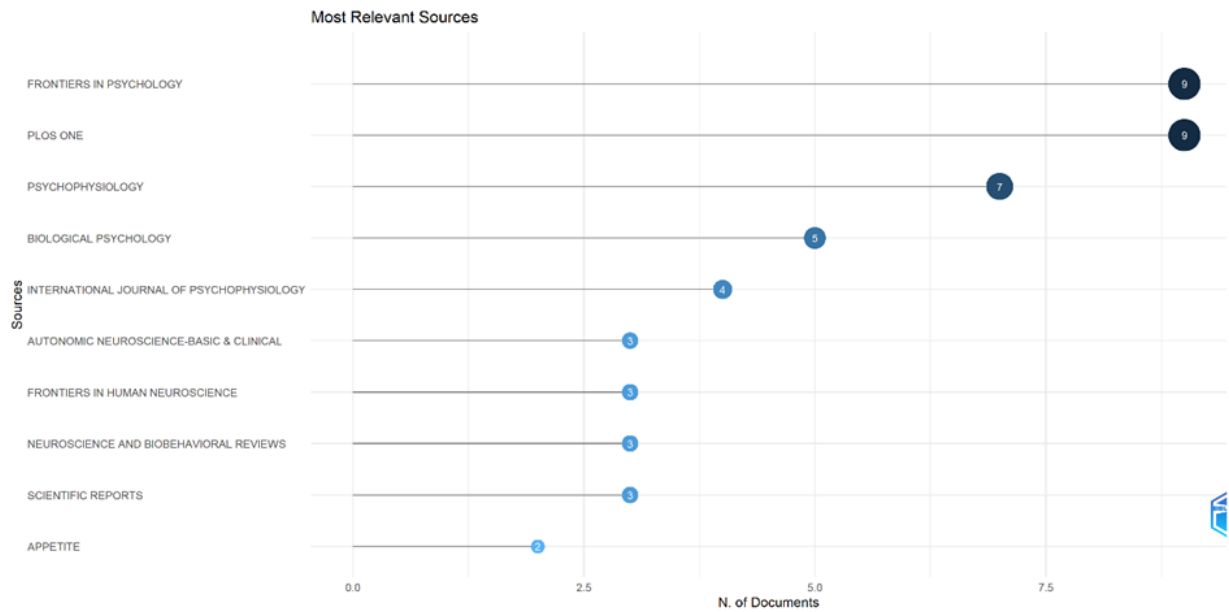


Figure 8. Journals related to the topic.

According to this graph, publication density is concentrated particularly in psychology, psychophysiology, and neuroscience-based journals. The journals with the most publications are Frontiers in Psychology (9 publications) and PLOS ONE (9 publications), indicating that studies on interoception and sports performance are predominantly published in psychology and interdisciplinary journals. These are followed by more physiological and experimental-based journals such as Psychophysiology (7 publications) and Biological Psychology (5 publications). This shows that sports and interoception are examined not only psychologically but also through the lens of the

nervous system, autonomic responses, and biophysiological measurements. Publications in journals such as the International Journal of Psychophysiology, Autonomic Neuroscience, Frontiers in Human Neuroscience, and Neuroscience and Biobehavioral Reviews demonstrate that the field is strongly based on neuroscience and autonomous regulation. This suggests that interoception is addressed in relation to sports performance, stress regulation, and motor control. Overall, a closer look reveals that studies are published more in psychology and neuroscience-focused journals rather than directly in "sports science" journals (Figure 8).

differences. This structure indicates that psychophysiological processes are addressed in relation to behavioral and clinical dimensions within the sport context.

The green cluster is represented by journals including *Journal of Neuroscience*, *Neuropsychologia*, *Brain Research*, and *Applied Physiology*, and covers themes related to neuroscience, brain research, and sport physiology. This suggests that sport and interoception are examined through brain-based mechanisms and physiological regulatory processes.

The blue cluster, centered around journals such as *Trends in Cognitive Sciences*, *Cortex*, and *Psychonomic Bulletin*, reflects themes in cognitive science and cognitive neuroscience. It highlights processes such

as perception, attention, and decision-making, thereby representing the cognitive processing dimension of sport and interoception research.

In the yellow cluster, *Psychophysiology* occupies a central position and demonstrates strong connections with the other clusters, assuming an integrative role between psychology, neuroscience, and cognitive science.

Overall, when both analyses are considered jointly, the findings indicate that research on sport and interoception has developed within an interdisciplinary framework, primarily situated at the intersection of psychology, neuroscience, and cognitive science.

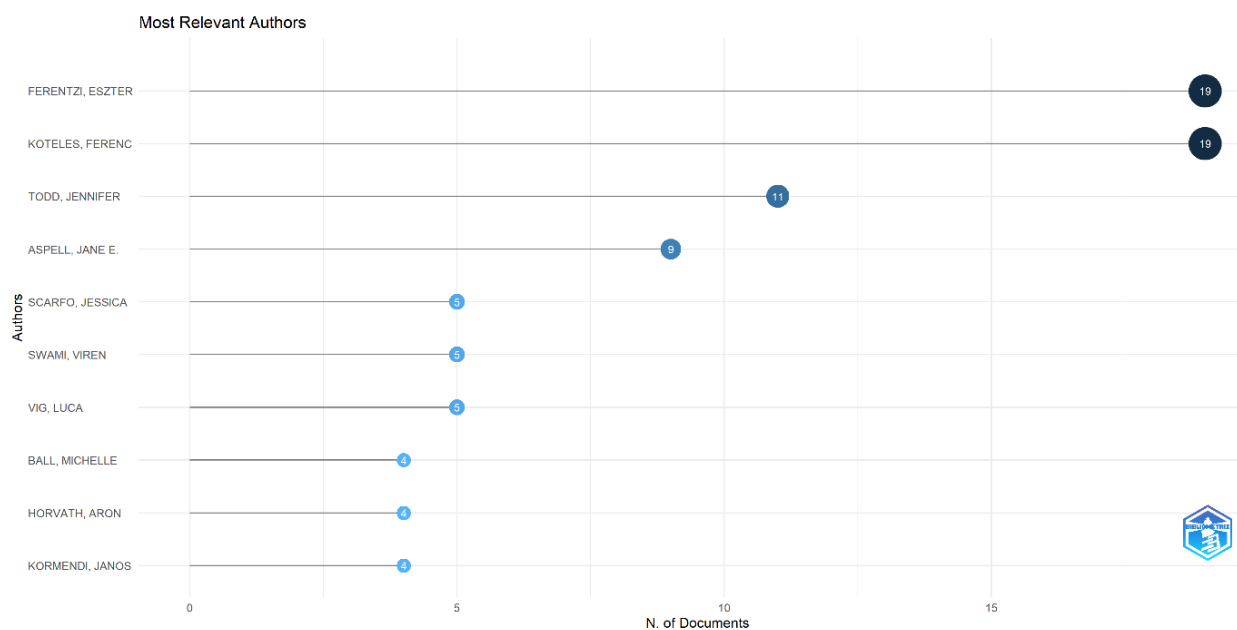


Figure 10. Most relevant authors.

The graph shows the most relevant (productive) authors in the field according to the number of publications. Eszter Ferentzi and Ferenc Köteles stand out as the most productive researchers by far with 19 publications each. They are followed by Jennifer Todd with 11 publications and Jane E. Aspell with 9 publications. Jessica Scarfo, Viren Swami, and

Luca Vig each contribute moderately with 5 publications; while Michelle Ball, Aron Horvath, and Janos Kormendi each have 4 publications. Overall, the distribution shows a clear divergence between the top two authors and a concentration of publication output in the field around specific researchers (Figure 10).

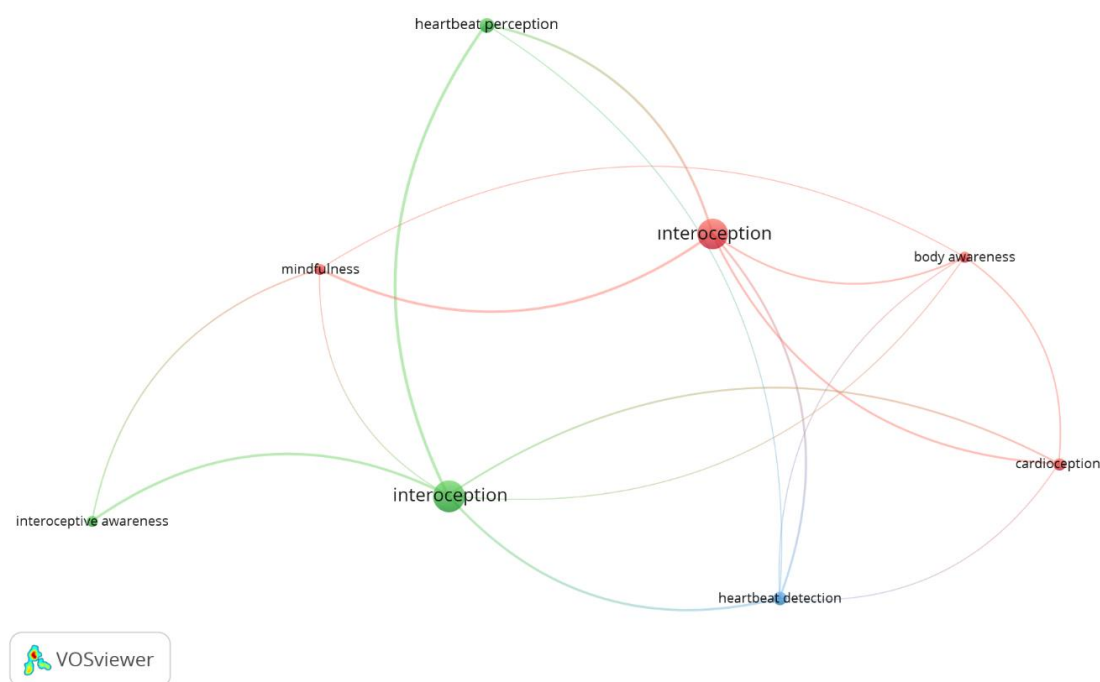


Figure 11. Keyword co-occurrence network.

The keyword co-occurrence network presented in Figure 11 shows the thematic contexts in which concepts are considered together in the interoception literature. In the network, “interoception” is positioned as a central node and is directly linked to the concepts of “interoceptive awareness”, “heartbeat perception”, “heartbeat detection”, “body awareness”, “cardioception”, and “mindfulness”. The green cluster represents measurement approaches based more on body awareness and

heartbeat perception, while the red cluster highlights the relationship between interoception and body awareness and cardioception; and the blue cluster emphasizes experimental tasks such as heartbeat detection. Overall, the network structure reveals that the literature is based on both the subjective awareness dimension and experimental studies based on physiological measurements, and that the concept of interoception plays an integrative role among these sub-themes.



Figure 12. Word cloud.

The word cloud presented in Figure 12 visually illustrates the relative frequency of prominent concepts in the interoception literature. While “interoception” is the largest and most dominant term, representing the core focus of the field, concepts such as “accuracy,” “awareness,” “perception,” and “sensitivity” also appear with high frequency. Furthermore, terms like “interoceptive awareness,”

“heartbeat perception,” “mindfulness,” “emotion,” “anxiety,” and “brain” reflect both the cognitive-emotional dimension and the neurophysiological foundations of the field. Overall, the word cloud shows that the literature focuses on the measurement of interoception (accuracy and sensitivity), the subjective awareness dimension, and its relationship to emotional processes.

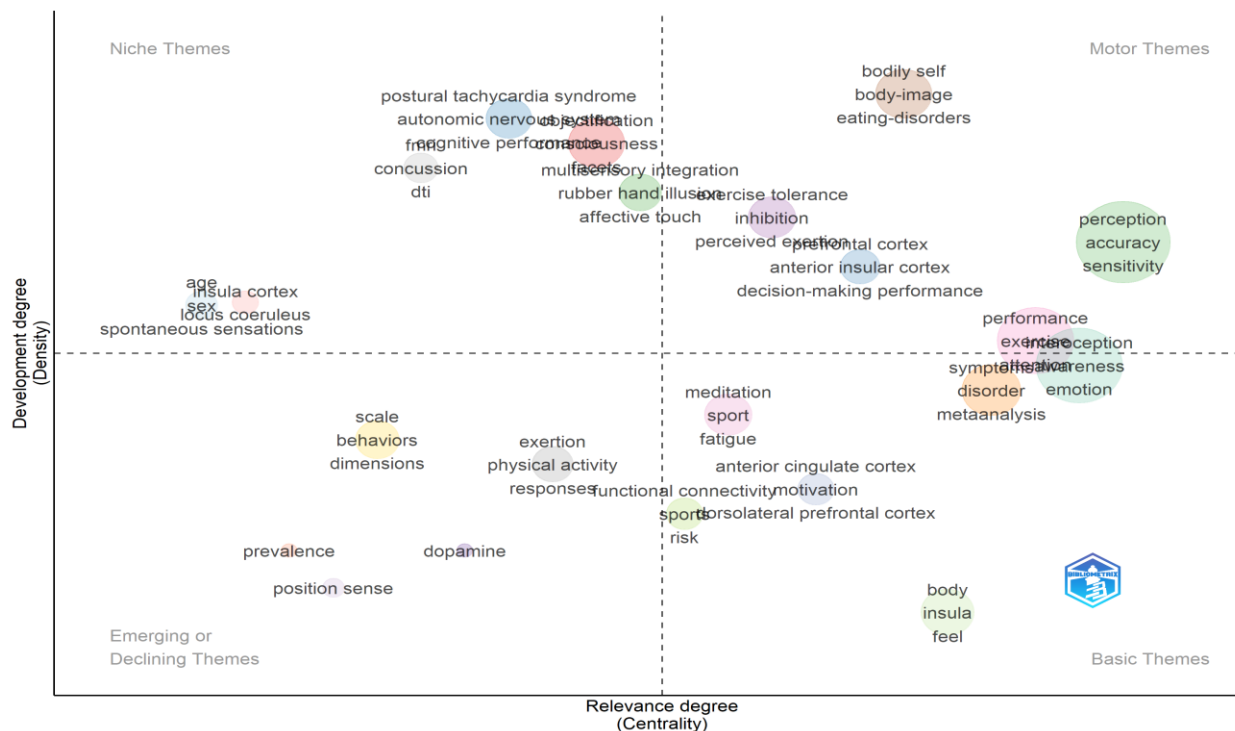


Figure 13. Thematic map.

When the thematic map is examined, it is seen that the concepts in the field of interoception and sport are positioned at different levels of development and centrality. The concepts of perception, accuracy, and sensitivity, located in the motor themes section, show both high centrality and development levels and are among the fundamental and guiding issues of the field. In contrast, themes such as body image, body self, and eating disorders are also among the motor themes, showing that interoception is addressed in relation to body perception and behavioral outcomes (Figure 13).

The inclusion of concepts such as insula (insula cortex), body, and feel in the basic themes section points to the neurobiological foundations of interoception. Among the developing or declining themes are important concepts in the context of sport such as physical activity, fatigue, motivation, and risk. In the niche themes section, more specific clinical

and neurophysiological topics are observed. Overall, the map shows that the literature on interoception and sports is centered on the axis of perceptual accuracy and sensitivity, and diversifies in relation to neurobiological foundations and performance variables.

Discussion

This bibliometric analysis indicates that interoception research in the context of sport has entered a pronounced phase of epistemic expansion over the past decade. In particular, the marked increase in publication output after 2015 suggests that interoception is evolving beyond a predominantly clinical psychology-centered domain and is increasingly integrating with performance science, neuroscience, and cognitive regulation literature. This trend aligns with the reconceptualization of interoception not merely as awareness of internal

sensations, but as a central component of homeostatic regulation, self-regulation, and decision-making processes (Craig, 2009; Critchley et al., 2004).

In recent years, the theoretical framework of interoception has expanded substantially. Damasio (1996), somatic marker hypothesis proposed that bodily signals play a guiding role in decision-making processes. Building on this foundation, Seth (2013) and Tsakiris and De Preester (2018) conceptualized interoception within the predictive processing framework, linking it to brain-based mechanisms of prediction and error correction. According to this model, the organism does not merely passively perceive internal signals; rather, it generates expectations about these signals and continuously attempts to minimize prediction errors. In the context of sport performance, this framework offers a novel perspective on the central regulation of perceived exertion, fatigue evaluation, and stress responses, highlighting interoception as an active and adaptive component of performance control mechanisms.

From a bibliometric perspective, the clustering of the literature around psychology, neuroscience, and cognitive science confirms the multilayered nature of interoception. In particular, studies focusing on the insula, anterior cingulate cortex, and somatosensory networks demonstrate that interoceptive processing is closely integrated with emotional regulation and self-awareness mechanisms (Gu et al., 2013; Menon & Uddin, 2010). However, within the sport context, the direct integration of this neurobiological framework with concrete performance outcomes remains limited. Bibliometric findings reveal that sport science journals occupy a relatively less central position within the network structure, indicating that the field continues to be largely shaped and driven by psychology and neuroscience literature.

The predominance of interoceptive accuracy and sensitivity in the keyword analysis indicates that the field is methodologically grounded largely in heartbeat perception paradigms. However, in recent years, the validity and reliability of these measures have been increasingly questioned (Desmedt et al., 2018; Ring & Brener, 2018). These critiques suggest that assessing interoception solely through cardiac signals may not adequately represent the multidimensional nature of the construct. Murphy et al. (2019) argued that interoception should be evaluated across multiple modalities, including respiration, gastrointestinal sensations, and pain perception. The bibliometric findings indicate that

the literature has not yet fully transitioned toward this multimodal measurement paradigm, reflecting a continued reliance on traditional cardiac-based assessment approaches.

In the thematic map analysis, the positioning of variables such as physical activity, fatigue, and motivation as emerging themes indicates that the integration of interoception into performance models is still at an early stage. Marcora et al. (2009), through the psychobiological model of perceived exertion, and Noakes (2012), with the central regulation theory, argued that performance limits are determined not solely by peripheral physiology but also by central perceptual processes. These theoretical perspectives suggest that interoceptive signals may play a limiting or regulatory role in performance. Furthermore, Brick et al. (2016) demonstrated that self-regulation strategies in endurance performance are closely linked to awareness of internal bodily sensations. Within this framework, interoception holds the potential to become a central variable in performance psychology, contributing to a more integrative understanding of performance regulation mechanisms.

Research examining the effects of physical activity on interoceptive sensitivity further illustrates the expansion trajectory of the field. Higher interoceptive accuracy has been reported in individuals who engage in regular exercise (Herbert & Pollatos, 2012), and athletes have been suggested to exhibit greater autonomic flexibility (Lee et al., 2023; Wittels et al., 2023). However, studies directly linking interoceptive accuracy to concrete performance outcomes in elite athlete populations remain limited. The bibliometric findings corroborate this gap, indicating that although the conceptual bridge between interoception and sport performance is increasingly recognized, empirical integration particularly at the elite performance level has yet to fully mature.

The concentration of citation networks around specific theoretical texts indicates that the interoception literature remains structured largely around foundational conceptual frameworks. In particular, neurocognitive models and body-based awareness approaches constitute the conceptual backbone of the field. At the same time, recent years have witnessed a marked increase in studies examining the relationship between interoception and psychological resilience, stress tolerance, and

anxiety regulation (Farb et al., 2013; Paulus & Stein, 2010; Silvers et al., 2015). These studies suggest that interoceptive signals are not limited to physiological awareness but may also play a central role in emotional regulation and threat evaluation processes. In the context of sport performance, psychological resilience, autonomic regulatory capacity, and decision-making stability under stress are critical determinants of success. Therefore, integrating interoception with these constructs represents a promising research axis. In high-level competitive environments, maintaining performance stability depends on the effective management of the dynamic balance between physiological arousal and cognitive control. Consequently, examining interoceptive accuracy and awareness alongside psychological resilience and performance consistency may contribute to the development of a novel and integrative research line within performance science literature.

Overall, this study demonstrates that the sport and interoception literature represents an interdisciplinary field that has not yet fully integrated with performance science, yet possesses substantial potential for rapid expansion. Moving beyond measurement-based accuracy paradigms, developing multi-modal interoceptive assessment approaches, and increasing experimental designs that establish direct links with performance outcomes will enhance both the theoretical depth and applied relevance of the field. Furthermore, integrating predictive processing and embodied performance frameworks into sport models may provide a more comprehensive explanation of the role of interoception in performance optimization.

Limitations

This study has several limitations that should be considered when interpreting its findings. First, the analysis was based solely on the Web of Science Core Collection; relevant publications indexed in other databases such as Scopus, PubMed, or Google Scholar were not included, which may have constrained the coverage of the dataset. Second, the search was deliberately restricted to the keywords “interoception” and “sport.” As a result, studies that address interoceptive processes using adjacent terms such as “exercise,” “athlete,” or “physical activity” without explicitly using the term “sport” may not have been captured, which should be taken into account when generalizing the results. Third, only publications written in English were included,

introducing a potential language bias and excluding relevant work published in other languages. Fourth, because data for 2026 were not complete at the time of analysis, the figures for the final year reflect only a partial period and should be interpreted with caution. Fifth, country-level production was calculated using the full counting method, so the sum of country frequencies exceeds the total number of publications; while this approach reflects international collaboration, it also inflates the apparent output of countries that participate heavily in co-authored studies. Finally, although the dataset spans 2004 to 2026, the field draws on a number of foundational works that predate this window; these seminal sources were retained intentionally because they define the conceptual and methodological basis of interoception research, but future updates of this map would benefit from incorporating the most recent measurement and theoretical developments. Future studies could address these limitations by drawing on multiple databases, employing broader and more inclusive search strategies, and including publications in additional languages.

Conclusion

This study systematically examined the scientific production dynamics, intellectual structure, and thematic development trajectories of interoception research in the context of sport between 2004 and 2026 using bibliometric methods. The findings indicate that the field has gained significant momentum particularly after 2015, demonstrates a high level of international collaboration, and has evolved within an interdisciplinary framework primarily situated at the intersection of psychology, neuroscience, and cognitive science. However, research directly focusing on sport performance remains positioned among emerging themes.

The results suggest that interoception is becoming increasingly central within the sports sciences literature; nevertheless, its integration with performance outcomes and applied sport contexts has not yet fully matured. The current structure of the field is largely concentrated around experimental paradigms based on interoceptive accuracy and sensitivity measures. In contrast, there is a need to address interoceptive processes more holistically in relation to performance-relevant variables such as load regulation, perceived exertion, stress adaptation, and psychological resilience.

By mapping the knowledge structure of the sport and interoception literature, this study has made visible the theoretical concentration points and the themes with developmental potential within the field. Future research is encouraged to adopt measurement approaches encompassing multiple interoceptive modalities, employ longitudinal designs in elite athlete samples, and integrate interoceptive processes into comprehensive performance models. Furthermore, incorporating predictive processing and central regulation frameworks into sport performance paradigms may provide a more comprehensive understanding of the role of interoception in performance optimization.

In conclusion, interoception research in the context of sport can be characterized as a rapidly developing, strongly interdisciplinary field with substantial growth potential and a need for deeper integration with performance science. This bibliometric evaluation offers a systematic overview of the current landscape and provides a conceptual framework to inform future research strategies.

Future Research Directions

Based on the findings of this study, the following strategic directions are proposed to advance interoception research in the context of sport:

- **Moving Beyond Single-Modality Measurement Paradigms:** The existing literature relies predominantly on cardiac interoception tasks (e.g., heartbeat detection/perception). Future research should develop comprehensive assessment approaches incorporating multiple interoceptive modalities, including respiration, intramuscular tension, visceral sensations, and pain perception.
- **Experimental Designs Directly Linked to Performance Parameters:** There is a need for controlled and longitudinal studies directly examining the relationships between interoceptive accuracy/sensitivity and performance-related variables such as perceived exertion (RPE), central fatigue, load tolerance, stress response, and decision-making performance.
- **Increased Research in Elite Athlete Populations:** Current research is largely based on general population samples. Studies conducted with elite and high-performance athletes would provide clearer insights into the role of interoception in performance stability and psychophysiological flexibility.
- **Integration of Predictive Processing and Central Regulation Models:** Incorporating interoceptive inference, predictive coding, and central regulation frameworks into sport performance theories may enhance understanding of the central mechanisms underlying perceived load and performance limits.
- **Combined Use of Neuroimaging and Autonomic Nervous System Indicators:** Examining insular cortex, anterior cingulate cortex, and salience network activation alongside physiological markers such as heart rate variability (HRV), skin conductance, and respiratory variables would strengthen the neurophysiological basis of the interoception–performance relationship.
- **Integration with Psychological Resilience and Emotion Regulation:** Comprehensive models should be developed to investigate the associations between interoception, stress tolerance, performance anxiety, and psychological resilience.
- **Testing Intervention and Training Programs:** Randomized controlled trials are needed to evaluate the effects of mindfulness, breath awareness, biofeedback, and body awareness–based interventions on interoceptive sensitivity and performance outcomes.
- **Development of Standardized Measurement Protocols:** Considerable measurement heterogeneity exists in the literature. Establishing valid, reliable, and sport-specific interoceptive assessment protocols is essential for methodological consistency.
- **Strengthening Interdisciplinary Collaboration:** Methodological integration between sport sciences, neuroscience, and performance psychology should be enhanced, and multi-center research networks should be expanded.
- **Development of Applied Performance Models:** Conceptual frameworks integrating interoceptive processes into load management, recovery strategies, and performance optimization models should be developed to bridge theoretical knowledge and applied sport practice.

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Conflict of Interest

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Not applicable.

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