

Retraction

Retracted: Research on the Academic Impact of Sports in the Multidimensional Matrix Evaluation Framework

Discrete Dynamics in Nature and Society

Received 22 August 2023; Accepted 22 August 2023; Published 23 August 2023

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] R. Zhang and Y. Liu, "Research on the Academic Impact of Sports in the Multidimensional Matrix Evaluation Framework," *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 7248148, 11 pages, 2021.

Research Article

Research on the Academic Impact of Sports in the Multidimensional Matrix Evaluation Framework

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Received 1 November 2021; Revised 15 November 2021; Accepted 20 November 2021; Published 10 December 2021

Academic Editor: Gengxin Sun

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Sport trade frictions have continued to evolve and escalate, which has a great impact on sport academic cooperation. In order to objectively assess the impact of sports scholarship on China and provide evidence to support future changes in sports academic cooperation, this study takes 269,647 academic papers produced by sports alone from 2010–2018 as the research object and integrates explicit, implicit, and performance information contained in the paper output to construct a multidimensional matrix assessment framework. The horizontal dimension splits the collaborative research output into three mutually exclusive subsets: China-led collaborative research, sport-led collaborative research, and bisectational collaborative research; the vertical dimension systematically analyzes the characteristics of collaborative sport academic research in terms of participants, research content, and research level. The purpose of this study is to characterize the role and status of academic cooperation between the two countries through a long period, large sample, and multidimensional perspective, to make an objective assessment of the impact of academic cooperation between the two countries, and to provide evidence to support a reasonable response to the impact of changes in the relationship between the two countries on academic cooperation.

1. Introduction

Academic cooperation in sport is an important part of scientific and technological cooperation in sport [1]. It has become one of the most dynamic areas in the relations between the two countries, and the academic cooperation between the two countries has made important contributions to improving mutual understanding and promoting the development of relations between the two countries [2]. A systematic assessment of the status and role of China in sport academic cooperation can help correctly judge the impact of academic cooperation between the two countries on China and provide reasonable countermeasures for possible changes in sport academic cooperation in the future [3].

Academic cooperation in sport has been one of the hot topics of interest to scholars in science and technology policy research, and many scholars have conducted relevant research in this area. In the 1980s, studies on academic

cooperation in sport were mainly the scientific and technological activities carried out in sport countries. For example, [4] introduced the cooperation between sport in digital seismic networks. In the same year, Ambassador Li Mingde of the Chinese Embassy in Sports published an article in the Chinese Science Foundation about the office, semi-official, and civil cooperation in sport science and technology [5]. After 2000, bibliographic methods, status qua description, and analysis have become the main methods to study sports science and technology cooperation. Based on the SCI sport co-authored papers from 2004–2008, the authors of [6] analyzed the five universities with the highest participation in sport cooperation institutions and carried out the analysis of cooperation networks of key institutions [7]. The authors of [8] used the SCI papers from 1978–2005 as a sample and analyzed the cooperation trends, key cooperation institutions, and the main participating third countries. The authors of [9] sorted out the key institutions and outputs of sport science and technology

cooperation. The authors of [10] analyzed the current situation and future trends of sport science and technology cooperation in terms of developmental stages, fields, and cooperation targets. The existing studies have used quantitative and qualitative methods to analyze academic cooperation in sport from multiple perspectives.

The new historical conditions of today have put forward new demands on the content of research on academic cooperation in sports: an objective analysis of the status and role of China in academic cooperation in sports and a correct understanding of the impact of academic cooperation in sports are the basis for reasonable responses in the future [11]. To this end, this paper constructs a matrix assessment framework based on the output of academic papers included in the Scopus database from 2010 to 2018, which is solely composed of cooperation between two countries in the sport. Based on a long time span, large sample data, and multidimensional information, we make an objective evaluation of the current situation of academic cooperation in sport. The new historical conditions of today have put forward new demands on the content of research on academic cooperation in sports: an objective analysis of the status and role of China in academic cooperation in sports and a correct understanding of the impact of academic cooperation in sports are the basis for reasonable responses in the future. To this end, this paper constructs a matrix assessment framework based on the output of academic papers included in the Scopus database from 2010 to 2018, which is solely composed of cooperation between two countries in sport. Based on a long time span, large sample data, and multidimensional information, we make an objective evaluation of the current situation of academic cooperation in sport and provide evidence to support future measures.

1.1. Research Framework and Data Sources. A matrix evaluation framework was constructed in this study, as shown in Figure 1. Horizontal dimension: based on the affiliation of the first author and the corresponding author, academic papers on sport collaboration were divided into three mutually exclusive subsets: China-led, sports-led, and co-led [12]. Collaborative outputs with both first and corresponding authors from sport institutions were considered as sports-led collaborative studies, and the outputs of both first and corresponding authors from sport institutions were considered as co-led collaborative studies.

Longitudinal dimension: we analyze the characteristics of academic cooperation research in both countries in terms of target, level, and content in terms of participants, research level, and research content. Among them, research on the participant dimension is conducted in terms of the degree of participation and the type of participating institutions [13]. The degree of participation refers to the extent of participation of scholars in collaborative research in both countries, which are measured by the proportion of collaborative research output to the total international collaborative research output in both countries in the same period. The type of institutions involved in collaborative research refers to the proportion of different types of

institutions in collaborative research, measured as the proportion of the output of different types of institutions to the total output of collaborative research. Research content dimension analyzes the characteristics of each subset of collaborative research in terms of the novelty of keywords and the development trend of research topic clusters [14]. The novelty of keywords reflects the characteristics of the research content in the “past tense” and “present tense,” while the development trend of the research topic cluster predicts the characteristics of the research content in the “future tense.” The organic combination of the two dimensions enables the evaluation and prediction of research content characteristics over time. The research level dimension introduces the Field Weighted Citation Impact (FWCI) index developed by Elsevier in the SciVal database to measure the academic research level of each collaborative research subset [15, 16]. The FWCI measures the level of scholarship in each subset of collaborative research by comparing the total number of citations that actually generated the average expected number of citations for the subject matter in the field. The FWCI is an effective tool for cross-sectional comparisons across multiple disciplines by comparing the actual total number of citations that generated the average expected number of citations for the subject matter in the field to evaluate the level of the target group.

As for the data source, this paper is based on the multidimensional information of authors, participating institutions, keywords, abstracts, etc. contained in the academic papers solely generated by the collaboration between two countries in sports, which are collected in Scopus database and its associated database SciVal from 2010 to 2018, to conduct the impact assessment of academic collaboration in sports. The datum was retrieved and downloaded on December 26, 2020. As of the date of download, the total number of collaborative papers with sport participation in the database was 350,378, of which 269,647 papers were only from two sport countries. In order to exclude the influence of other participating countries, this paper analyzes the output of collaborative papers with the participation of only two sports countries [17, 18].

2. Multidimensional Matrix

2.1. Multidimensional Matrix Representation. An Nth-order multidimensional matrix represents multilingual mapping in N subspaces. In the text, we use capital letters in flower font to denote a multidimensional matrix, which means that $\mathcal{X} \in \mathbb{C}^{1 \times 2 \times 3 \times \dots \times N}$ represents an Nth-order multidimensional matrix, equivalent to a transformation of a matrix, and $\mathcal{X}_{i_1 i_2 \dots i_N}$ is used to denote a component of an Nth-order multidimensional matrix [19]. Similarly, a multidimensional diagonal matrix can be defined as $\mathcal{A} \in \mathbb{C}^{1 \times 1 \times 1 \times \dots \times 1}$. The order of a multidimensional matrix is the total number of its “dimensions” or “modes.” The size of a multidimensional matrix implies the range of values of its dimensions. For example, a multidimensional matrix $\mathcal{X} \in \mathbb{C}^{2 \times 3 \times 4 \times 5}$ is of order 4. Dimension 1 has size 2, dimension 2 has size 3, dimension 3 has size 4, and dimension 4 has size 5. A multidimensional matrix can be thought of as a generalization of a matrix. For

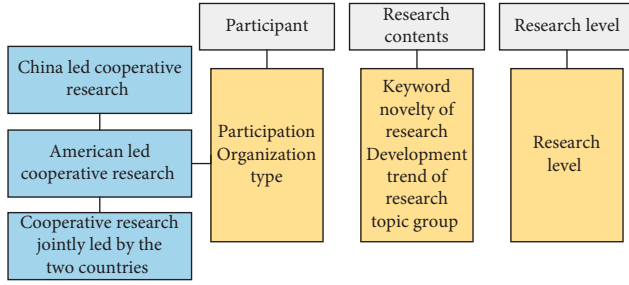


FIGURE 1: Matrix assessment framework.

example, a three-dimensional matrix is seen as equivalent to a rectangle (see Figure 2).

As in Figure 3, the four-dimensional matrix is an extension of the three-dimensional matrix along the one-dimensional as shown in Figure 4.

2.2. TUCKER Decomposition Model. Scholar Tucker first proposed the Tucker decomposition, so it is named as the TUCKER decomposition. Similar to the PARAFAC decomposition [20], Tucker decomposition also divides the multidimensional matrix into a core multidimensional matrix and a factor matrix, but it should be noted that the core multidimensional matrix here is not necessarily a diagonal matrix. To more clearly represent the relationship between the PARAFAC decomposition and the TUCKER decomposition, Figure 5 compares the difference between the two, with Tucker decomposition in the upper half of the figure and the Tucker decomposition in the lower half. From these two figures, it can be seen that PARAFAC decomposition is a special form of Tucker decomposition. Once the ordinary core multidimensional matrix degenerates into a diagonal core multidimensional diagonal matrix, Tucker decomposition becomes a PARAFAC decomposition. Define the Tucker decomposition as follows:

$$\begin{aligned} \mathcal{X} &\approx \sum_{r_1=1}^{R_1} \cdots \sum_{r_N=1}^{R_N} a_{r_1 r_2 \cdots r_N} \mathbf{b}_{r_1} \circ \mathbf{b}_{r_2} \circ \cdots \circ \mathbf{b}_{r_N} \\ &= \mathcal{D} \times_{\mathbf{B}_1} \times_{\mathbf{B}_2} \cdots \times_{\mathbf{B}_N} \end{aligned} \quad (1)$$

Its mode-1 expansion vectorization is

$$\text{vec}(\mathbf{X}_{(1)}) = (\mathbf{B}_N \otimes \mathbf{B}_{N-1} \otimes \cdots \otimes \mathbf{B}_1) \text{vec}(\mathcal{D}_{(1)}), \quad (2)$$

where $a_{r_1 r_2 \cdots r_N}$ is the element in the core multidimensional matrix $\mathcal{D} \in \mathbf{R}^{R_1 \times R_2 \times \cdots \times R_N}$, $\mathbf{B}_n = [b_1, b_2, \dots, b_{R_n}] \in \mathbf{R}^{I_n \times R_n}$ is the factor matrix, $\text{vec}(\mathbf{X}_{(1)})$ is the mod-1 vectorization of the multidimensional matrix \mathcal{X} , and $\text{vec}(\mathcal{D}_{(1)})$ is the mod-1 vectorization of the core multidimensional matrix \mathcal{D} .

As for the PARAFAC decomposition, other formula properties can be used to represent the Tucker decomposition. A commonly used formula is given here [21, 22]. Multiple linear rank (Tucker rank): unlike the PARAFAC decomposition, the new rank of the Tucker decomposition is redefined here and is called multiple linear rank. The

matrilinear rank of a multidimensional matrix is (R_1, R_2, \dots, R_N) . In addition, if the exact value of the Tucker decomposition can be obtained, matrilinear rank of the multidimensional matrix $\mathcal{X} \in C^{I_1 \times I_2 \times I_3 \times \cdots \times I_N}$ is defined as

$$r_l(\mathbf{X}) = (r(\mathbf{X}_{(1)}), r(\mathbf{X}_{(2)}), \dots, r(\mathbf{X}_{(N)})), \quad (3)$$

where $\mathbf{X}_{(n)}$ is the mod n matrix of the multidimensional matrix \mathcal{X} and $r(\mathbf{X}_{(n)})$ denotes the rank of the mod n matrix of the multidimensional matrix.

And, it will have the following important properties:

- (1) The rank of any multidimensional matrix PARAFAC is equal to its core multidimensional matrix \mathcal{D} .

$$r(\mathcal{X}) = r(\mathcal{D}). \quad (4)$$

- (2) If the multidimensional matrix \mathcal{X} has a column full rank factor matrix, then its multiple linear rank (R_1, R_2, \dots, R_N) satisfies

$$R_n \leq \prod_{k \neq n}^N R_k, \quad \forall n. \quad (5)$$

- (3) If the multidimensional matrix \mathcal{X} has column-full rank factor matrices [23].
- (4) If the multidimensional matrix \mathcal{X} has column-full rank factor matrices, then the Frobenius parametrization (F-parametrization for short) of the multidimensional matrix \mathcal{X} and its core multidimensional matrix \mathcal{D} are equal.

$$\|\mathcal{X}\|_F = \|\mathcal{D}\|_F. \quad (6)$$

They are called orthogonal Tucker decomposition. As shown in Figure 6, if there are N unit matrices in the factor matrix, they are usually called Tucker- N decomposition. For example, $\mathcal{X} = \mathcal{D} \times_{\mathbf{B}_1} \times_{\mathbf{B}_2} \times_{\mathbf{B}_3} \times_{\mathbf{I}_{4n}}$, which calls a Tucker-2 decomposition.

Some of the operational properties of the Tucker decomposition are described below. Consider two N th-order multidimensional matrices $\mathcal{X} = \mathcal{D}_X \times_{\mathbf{B}_1} \times_{\mathbf{B}_2} \times_{\mathbf{B}_3} \cdots \times_{\mathbf{B}_N}$ and $\mathcal{Y} = \mathcal{D}_Y \times_{\mathbf{C}_1} \times_{\mathbf{C}_2} \times_{\mathbf{C}_3} \cdots \times_{\mathbf{C}_N}$ whose multilingual ranks are (R_1, R_2, \dots, R_N) and (Q_1, Q_2, \dots, Q_N) , respectively, and which will have the following computational properties:

- (1) Kronecker product of two multidimensional matrices:

$$\mathcal{X} \otimes \mathcal{Y} = (\mathcal{D}_X \otimes \mathcal{D}_Y) \times_{\mathbf{B}_1 \otimes \mathbf{C}_1} \times_{\mathbf{B}_2 \otimes \mathbf{C}_2} \cdots \times_{\mathbf{B}_N \otimes \mathbf{C}_N}. \quad (7)$$

- (2) Two multidimensional matrices of the same size and order Hadamard product:

$$\mathcal{X} \circ \mathcal{Y} = (\mathcal{D}_X \otimes \mathcal{D}_Y) \times_{\mathbf{B}_1 \otimes \mathbf{C}_1} \times_{\mathbf{B}_2 \otimes \mathbf{C}_2} \cdots \times_{\mathbf{B}_N \otimes \mathbf{C}_N}. \quad (8)$$

- (3) Inner product of two multidimensional matrices:

$$\begin{aligned}\mathcal{X} &= \mathcal{X} \bullet \mathcal{Y} = (\text{vec}(\mathcal{X})_1)^T \text{vec}(\mathcal{Y})_1 \\ &= (\text{vec}(\mathcal{D}_X)_1)^T \otimes ((\mathbf{B}_1)^T \mathbf{C}_1) \otimes ((\mathbf{B}_2)^T \mathbf{C}_2) \otimes \cdots \otimes ((\mathbf{B}_N)^T \mathbf{C}_N) \text{vec}(\mathcal{D}_Y)_1,\end{aligned}\quad (9)$$

where $\text{vec}(\mathcal{Y})_1 = (\mathbf{B}_N \otimes \mathbf{B}_{N-1} \otimes \cdots \otimes \mathbf{B}_1) \text{vec}(\mathcal{D})_1$.

3. Analysis Results

3.1. Participant Dimension. In terms of participation in collaborative research, Chinese scholars are significantly more involved in sport academic collaboration than sport scholars. From 2010 to 2018, about 4% of the total number of articles published in international collaboration in China were produced solely by functional collaboration in sport. During the same period, less than 0.5% of the total number of articles published in international collaboration in sport were produced solely by functional collaboration in sport [24]. In terms of the roles of scholars from both countries in the collaborative output, the number of papers produced by China-led collaborative research from 2010 to 2018 was 164,788, accounting for 61.11% of the total collaborative output; the number of papers produced by sports-led collaborative research was 10,571, accounting for 3.92% of the total collaborative output; the number of papers produced by both countries in the collaborative research was 94,288, accounting for 94.6% of the total collaborative output [25]. The number of research papers jointly led by both countries is 94,288, accounting for 34.97% of the total number of collaborations. In terms of the annual trend of dominance, the proportion of output led by Chinese institutions has been on the rise in the past decade, increasing from 53% to 65.32%, while the proportion of output led by sports institutions has decreased from 5.36% to 3.09%, and the proportion of output jointly led by both countries has decreased from 41.65% to 31.59%.

In terms of the characteristics of the participating institutions, there is a clear difference between the two countries in terms of the types of institutions involved in collaborative research. In terms of the types of institutions involved in collaborative research in China, universities and state research institutions are the main participants in collaborative research. Universities are the most important participants in China-led collaborative research, accounting for 75% of the output [26]. Chinese universities were the most involved in the sports-led collaborative research, with 50.48% of the output. State research institutions have the next highest participation, with 42.76% of output. The participation of companies and medical institutions differs significantly between the two countries, with the participation of Chinese companies and medical institutions being significantly higher in the sports-led study than in the China-led study [27].

In terms of the types of institutions involved in sport-led collaborative research, whether Chinese, sport-led, or co-led, universities are the main participants, accounting for more than 80% of output, and national research institutions are similar, accounting for no more than 10% of output. The difference is more pronounced in the

participation of companies, with sport companies accounting for about three times as much output as China-led collaborative research.

Universities are the most involved type of institution in both countries. In both China and sport, there are a large number of universities with varying levels of participation. In order to provide a more accurate analysis of the types of universities involved in collaborative research, we further assessed the differences in the types of sport universities involved in collaborative research. In particular, the types of universities in China were classified according to the commonly used 985 universities, 211 universities (excluding 985), and other universities in China. There are various ways to classify universities in sport, and this paper adopts the Academic Ranking of World Universities (ARWU) in view of various factors such as the accessibility of classification data and the recognition of rankings. Ranking of World Universities (ARWU) is used to classify sports universities, and the number of universities is similar to 985 and 211 universities [28].

This paper analyzes the participation of different types of universities by taking into account the output of universities involved in collaborative research in both sport countries. Among Chinese universities involved in collaborative research, 985 universities have the highest percentage of China-led outputs, accounting for 53.87%, while 211 universities (excluding 985) and other universities have similar percentages, 22.04% and 24.10%, respectively. The level of participation of universities in sports-led collaborative research in China is generally negatively correlated with the level of participation: other types of universities have the highest percentage of output at 60.08%, followed by 985 universities at 22.85%, and 211 universities (excluding 985) have the lowest percentage at 17.07%. In terms of the types of universities involved in sport collaboration, the overall trend is similar for both China-led and sports-led collaborative research. Top 300 universities in ARWU have the highest percentage of output, more than half, and the top 300 universities in AR-WU have the highest percentage of co-led collaborative research, 69.25%, followed by other universities, all more than 25% [29]; the universities in ARWU 300–500 have the lowest percentage of output, about 10%, and the lowest percentage of co-led collaborative research, only 1.2%.

In summary, in terms of university participants, the China-led collaborative research mainly attracted universities from both countries, especially Chinese 985 universities and high-level research universities with top 300 sport ARWU rankings. Sports-led collaborative research has attracted a large number of Chinese national research institutions and non-985 and non-211 universities. Sports-led collaborative research also outperforms China-led collaborative research in terms of attracting medical institutions and companies.

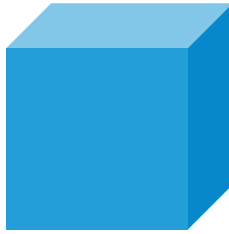


FIGURE 2: Three-dimensional matrix diagram.

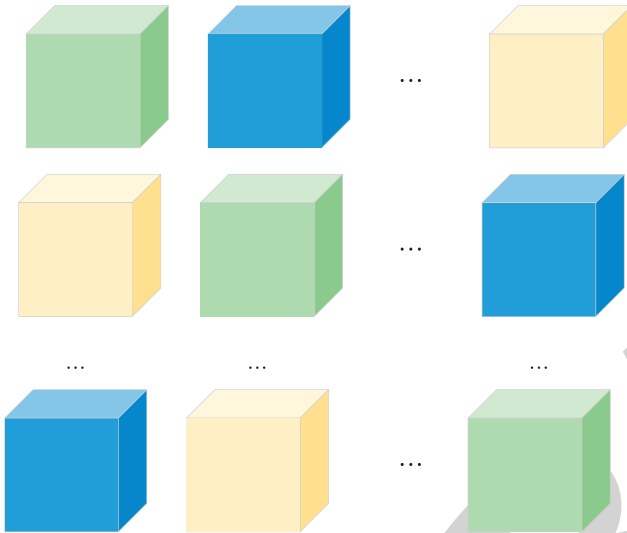


FIGURE 3: Five-dimensional matrix diagram.

3.2. Research Content Dimension. The content of research is the core feature of research activities and reflects the essence of academic cooperation between the two countries. In this paper, we analyze the target of full-time academic cooperation in sports and its impact in terms of the novelty of research content and the development of research topic clusters.

- (1) Novelty of the research contents. The keywords of an article are a high degree of condensation of the research topic and content, and the characteristics of the keywords can reflect the characteristics of the research content and object from an important aspect. In this paper, the novelty of the collaborative research object is evaluated by two indicators: the percentage of new keywords in the papers produced by Sino-US collaboration, NKW.R, and the percentage of papers containing new keywords, NKWA.R. The NKW.R [30, 31] was calculated as follows: first, keywords were extracted from the subset of national and co-lead papers, and the keyword database was established by year. The keywords in year $N+1$ were compared with those in the previous N years, and the keywords that had not appeared in the previous N years were defined as new keywords, and the percentage of new keywords in each year was calculated; finally, the average of the

percentage of new keywords in each year was used as the percentage of new keywords in each collaborative research subset.

Figure 7 shows that both the percentage of new keywords and the percentage of papers containing new keywords are significantly higher in the sports-led collaborative papers than in the China-led collaborative studies. The percentage of new keywords in sports-led collaborative research papers was 19.95%, compared to 5.38% in China, and 4.49% in the sport co-led collaborative papers. The percentage of sports-led collaborative research papers with new keywords was 14.25%, compared to 1.46% in China, and 1.29% for sport co-led papers. It can be seen that, from the perspective of the novelty of research objects, sports-led collaborative research is much more novel than China-led and sports co-led collaborative research in terms of research content and objective novelty [32].

In this study, we found that co-led collaborative researches did not “complement” each other in terms of innovative research content but performed the worst on the measures. To investigate the reasons for this, we examine the impact of domain. To investigate the reasons for this, we investigated the effect of field differences on the innovativeness of research content. In terms of the relationship between the innovation of research content and the percentage of output of the domains (see Figure 8), the more innovative domains co-lead the collaborative research with a relatively low percentage of output. In terms of the relationship between innovation and the percentage of output of a field (see Figure 8), the percentage of output from co-led collaborative research in the more innovative fields is relatively low, while the percentage of output from co-led collaborative research in the less innovative fields is relatively high. For example, the three areas with the best innovation indicators have an NKW.R of over 40%, but there is little co-led collaborative research output. However, there is little co-led collaborative research. The two less innovative fields have NKW.Rs of 9.36%, 10.3%, and 10.3%, respectively, and the proportion of collaborative research output is significantly higher than that of other fields. In terms of the distribution of each type of collaborative research (see Figures 9 and 10), the average percentage of sport-led collaborative research in the more innovative areas ($25% < \text{NKW.R} < 35%$ and $20% < \text{NKWA.R} < 35%$) is significantly higher than that of China-led and co-led, and the average percentage of China-led collaborative research in the less innovative areas ($15% < \text{NKW.R}$) is significantly higher than that of China-led collaborative research. $R < 25%$ and $5\% \text{ NKWA.R} < 20%$ than the other two types, while co-led collaborative research is mostly distributed in less innovative and intermediate areas. It can be seen that the distribution of output across domains can

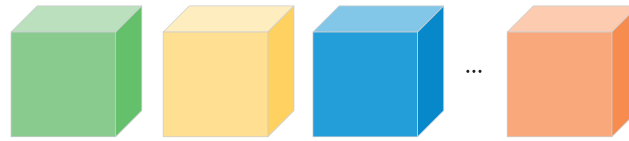


FIGURE 4: Four-dimensional matrix diagram.

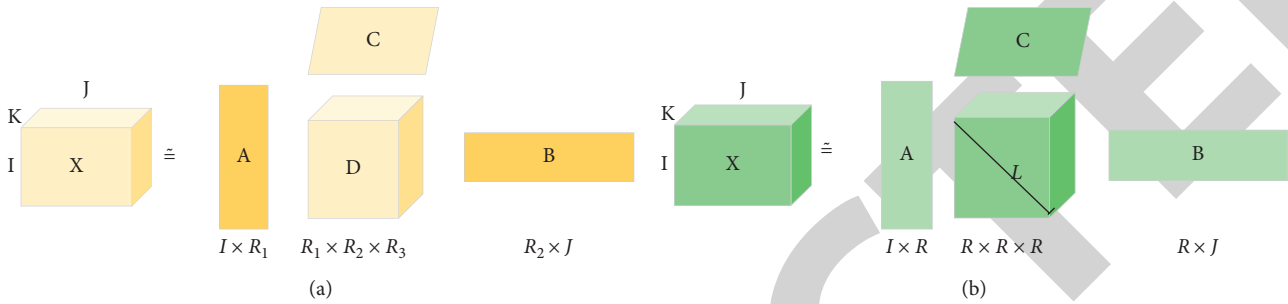


FIGURE 5: Comparison of PARAFAC decomposition and Tucker decomposition of third-order multidimensional matrix.

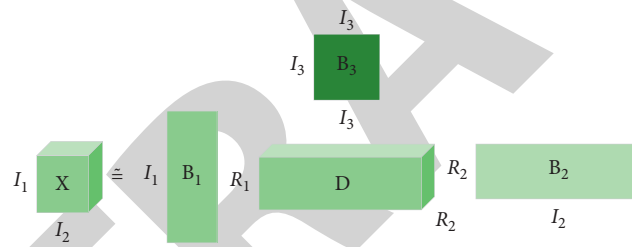


FIGURE 6: Schematic diagram of Tucker-N decomposition.

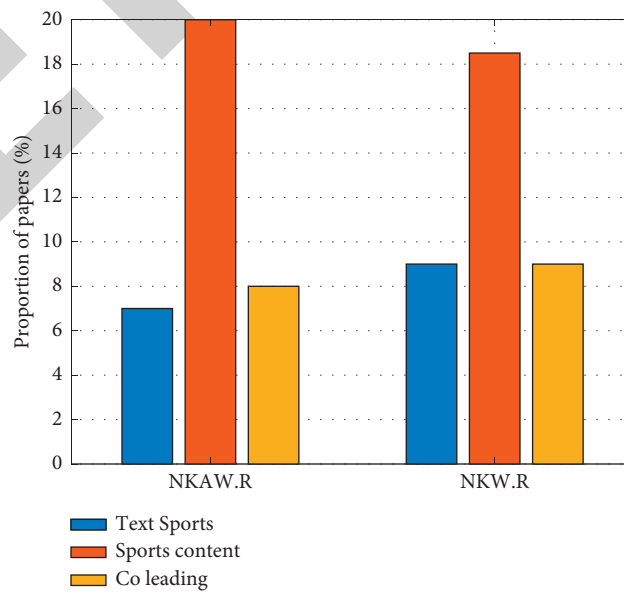


FIGURE 7: Percentage of papers covered by new keywords and new keywords in collaborative research output.

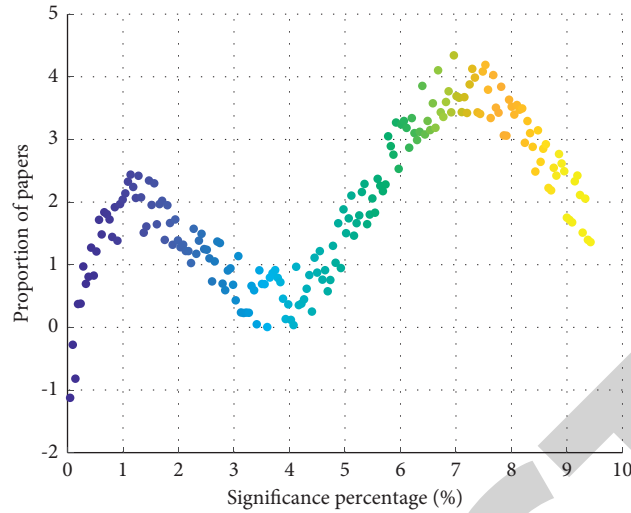


FIGURE 8: Scatter plots of the distribution of co-lead collaborative research output in relation to the percentage of new keywords.

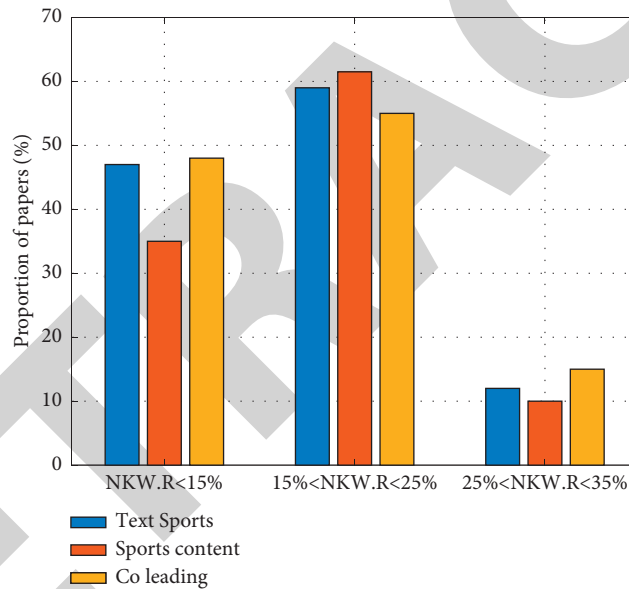


FIGURE 9: Percentage of each dominant type in different stages of NKW.R.

explain the differences in innovativeness between types.

- (2) The development trends of the research content. For the analysis of the development trend of research content, the significant percentage of research topic clusters is used as an indicator to evaluate the development trend of research content. A cluster is a grouping of topics with similar research content, forming a broader, higher-level research topic. Research topic clusters are formed using a direct citation algorithm, and a topic cluster is formed when the strength of citation links among research topics reaches a threshold value [33]. The same researcher or institution can contribute to multiple topic clusters, but an article or a topic can only belong to one

topic cluster. Prominence Percentage (PP) is a metric developed by Elsevier in the Scival database to measure the future trend of research topic clusters. The PP is calculated by integrating the number of citations, views, and average citation score [11] and reflects scholars' opinions on this research cluster. It reflects the attention of scholars to this research topic cluster. For example, a PP value of 98% for a research theme group means that the research theme group enjoys more attention than other 98% research theme groups. Research theme groups with high PP values will attract more scholarly attention in the future, while those with low PP values are considered to gradually "cool down" and fade out of the attention of scholars [34, 35].

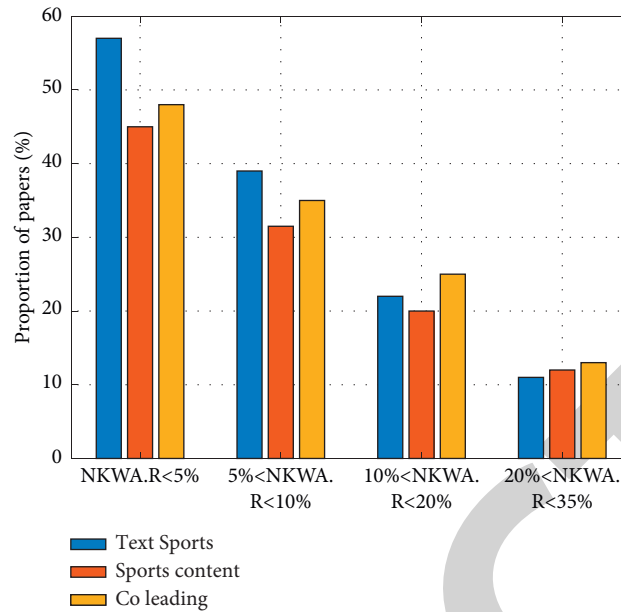


FIGURE 10: Percentage of each dominant type in different stages of NKWA.R.

From 2010–2018, the collaborative research output of sport scholars was concentrated in 11,467 research theme clusters. Among them, 10,517 research topic clusters were focused on by China-led collaborative research, 4,244 research topic clusters were focused on by sport-led collaborative research, and 9,681 research topic clusters were jointly led by the two countries. In terms of the trend of the research content led by each country, the average PP of the sport-led research theme groups is 78.09%, the average PP of the China-led research theme groups is 80.29%, and the PP of the sport co-led research theme groups is 79.93% (see Figure 11). It can be seen that there is not much difference in the trend of research theme clusters among the three types of research theme clusters, but in comparison, China-led collaborative research focuses more on popular research themes, and sports-led collaborative research focuses more on relatively cold research themes.

We further analyzed the future trends of research theme groups in both countries by using the percentage of popular research theme groups as a measure. The top-ranked research topic groups in terms of significance were considered as the top research topic groups. First, the top 1%, 3%, 5%, 10%, and 15% of PP rankings were selected as the top research theme groups by field; second, the percentage of top research theme groups in the collaborative research led by both countries in each field was calculated separately; finally, the percentage of each dominant type in the top research theme groups was calculated. The results show that, in general, the percentage of popular research topic groups in China-led collaborative research is higher than that in sports-led and co-led collaborative research under different thresholds (see Figure 12), which further confirms the conclusion that China-led collaborative research focuses more on popular research subjects.

3.3. Research Level Dimension. The citation impact factor (CIF) of an article is one of the internationally accepted criteria for evaluating and judging the level of output, but it is strongly influenced by disciplinary factors. To solve this problem, Elsevier has developed a normalized citation impact factor (FWCI) in the SciVal database, which evaluates the level of the target group by comparing the actual total number of citations generated with the average expected number of citations for the subject matter in the field and solves the problem that the citation impact factor is affected by disciplinary differences. $FWCI = 1$ means that the output is at the world average of the field; $FWCI > 1$ means that the output receives citations above the world average of the field, assuming $FWCI = 1.48$, which means that output receives citations above 48% of the field. The collaborative sport research outputs in this study cover the full range of disciplines, so the FWCI provides a useful analytical tool for cross-sectional comparisons across multiple disciplines.

This paper uses FWCI as an indicator to evaluate the level of collaborative research and analyzes the characteristics of the level of collaborative research from three aspects: the overall level of collaborative sports research output, the relationship with the level of output of the two countries themselves, and the level of output of each type of subset of collaborative research.

In terms of the overall level of collaborative research, the level of sports collaborative papers has shown a steady but increasing trend over the past decade, with the average FWCI across the field increasing from 1.55 in 2010 to 1.63 in 2018, a ten-year increase of about 5.1%. In terms of the relationship with the overall level of the two countries (see Figure 13), China's all-domain average FWCI has shown a more obvious upward trend in the last decade, from 0.68 in 2010 to 1.06 in 2018, from 34% behind the international average to slightly above the international average. The

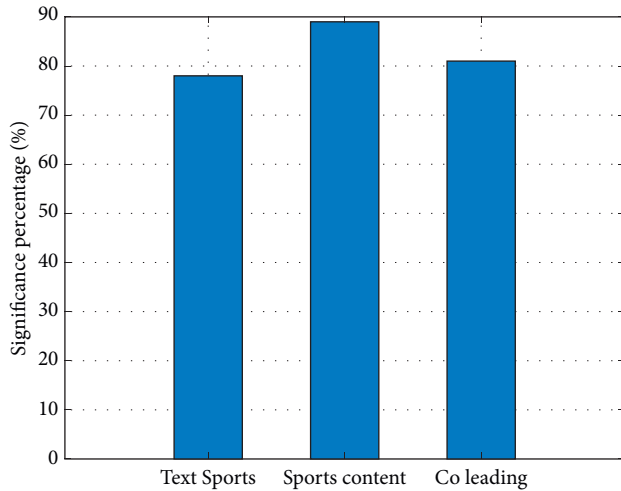


FIGURE 11: Percentage significance of each dominant type of research topic cluster in the whole domain.

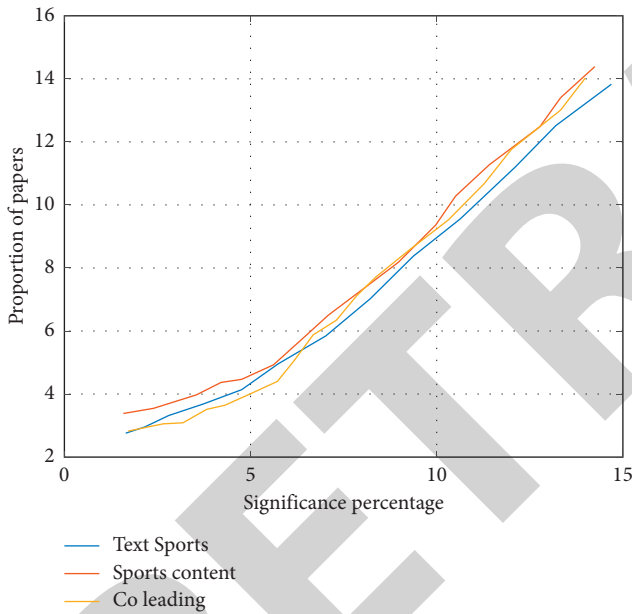


FIGURE 12: Trend of the percentage of popular research theme groups by dominant type with threshold value.

sport-wide FWCI has decreased slightly over the decade, from 1.50 in 2010 to 1.39 in 2018.

In terms of changes in the level of each dominant type of research (see Figure 14), the level of output of China-led collaborative research has generally shown an upward trend, with the FWCI increasing from 1.35 in 2010 to 1.63 in 2018, an increase of about 20.74%. The level of sport-led collaborative research output has fluctuated over the decade, with a fluctuating upward trend from 2010 to 2013, peaking at 1.74 in 2013 and then trending downward to only 1.48 in 2018. The overall level of functional co-led collaborative research output has trended downward, with the FWCI decreasing from 1.79 in 2010 to 1.48 in 2018. FWCI will decline from 1.79 in 2010 to 1.65 in 2018.

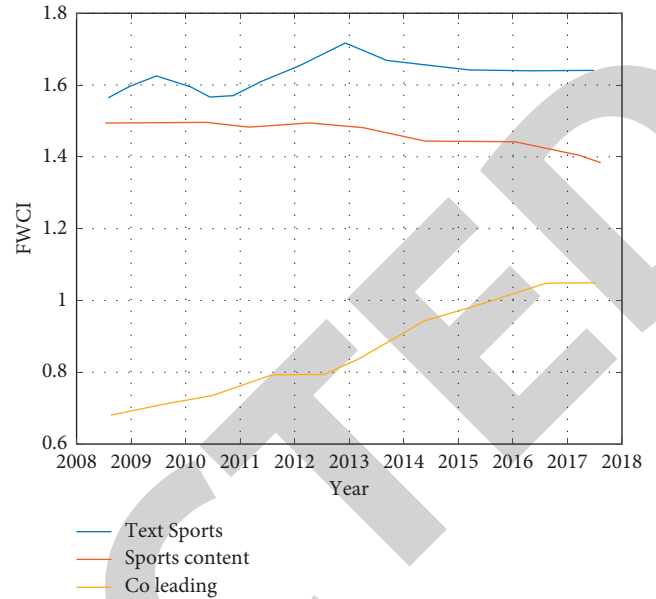


FIGURE 13: Trend of the average FWCI for the whole field of sport and collaborative papers in both countries.

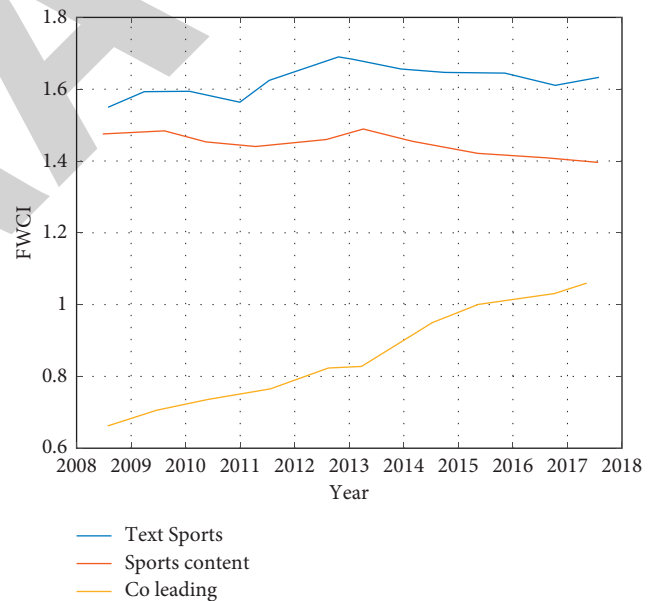


FIGURE 14: Trend of FWCI by type of output, 2008–2018.

4. Conclusions

This paper constructs a matrix assessment framework to evaluate the impact of academic collaboration in sport in three dimensions: participants, research subjects, and levels of collaborative research from 2009–2018:

First, academic cooperation in sport is developing rapidly, and the quantity is increasing, and the quality is stable. In the past decade, the number of academic papers produced by the two countries has increased rapidly, and the level of cooperation has increased steadily. More and more Chinese institutions and

scholars are involved in sport academic cooperation and have reached a certain level of academic research. Academic cooperation in sport has played an important role in cultivating a group of scientific research teams and talents with international level in China.

Second, the relationship between the research levels of the two countries in academic cooperation in sport has become more reciprocal. The average level of sports-led collaborative research in the whole field is similar, and even the level of China-led collaborative research tends to be slightly higher than that of sports-led collaborative research.

Third, China's participation in collaborative sport research is dominated by high-level research teams. In terms of academic output, the level of collaborative sport research output is much higher than the overall academic output in China. In terms of the characteristics of the types of institutions involved, Chinese institutions involved in collaborative research are mainly high level universities and national research institutions. Universities are the main institutions involved in collaborative research in sport, and national research institutions have a very limited share of output. It can be seen that China has a high level of participation in collaborative research with a high level team of mainly elite personnel, and there is more room to improve the level of collaborative research.

Fourth, sports-led collaborative research has shown certain advantages in the selection of research content. In terms of research content, sports-led collaborative research has a significant advantage in terms of novelty of research content, and the development trend of future research topics also shows that it does not follow the research hotspots completely and pays more attention to the cold research topics than China-led collaborative research.

Based on the systematic analysis of the main participants, research contents, and research levels in sport cooperation in the past decade, we have a clearer understanding of the role and status of China in sport academic cooperation. While seeing the achievements, we should also be aware that there are still major gaps in the selection of important research themes and research innovations, and there is room for improvement in the positioning of the mission of national research institutions and the orientation of scientific and technological evaluation.

As for the possible changes of academic cooperation between the two countries in the future, firstly, we should have a clear understanding of our role and status in the cooperation; secondly, we should seek common ground while reserving differences and continue to seek cooperation between scholars of the two countries and further upgrade the level of cooperation with the best sports academic institutions and teams to develop high-level cooperation; lastly, through academic cooperation exchanges, we should identify the problems in China's science and technology evaluation and management. Finally, through academic

cooperation and exchange, we will identify the problems in the evaluation and management of science and technology in China, and through reforming the management and evaluation mechanisms of science and technology, we will guide researchers to strengthen their research in novelty, innovation, and leadership and reduce the research of quick success and tracking, so as to achieve a leap from quantitative to qualitative change.

Data Availability

The datasets used in this paper are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

Acknowledgments

This work was supported by China Education Ministry's Humanities and social science projects named "Chinese sports in the view of Western historiography" under grant No. 20YJC890044.

References

- [1] M. Jarocka, "Transparency of university rankings in the effective management of university," *Business, Management and Education*, vol. 13, no. 1, pp. 64–75, 2015.
- [2] M. A. Lugo, "Comparing multidimensional indices of inequality: methods and application," *Working Papers*, vol. 14, no. 14, pp. 213–236, 2005.
- [3] A. J. Nelson, C. L. Collins, and E. E. Yard, "Ankle injuries among United States high school sports athletes, 2005–2006," *Journal of Athletic Training*, vol. 42, no. 3, pp. 381–387, 2007.
- [4] K. Ibe, Y. Sato, and S. Yamamoto, "Experimental evaluation of i framework development method based on actor relationship matrix," *Ieice Technical Report*, vol. 107, pp. 1–6, 2007.
- [5] D. Svetina, "Assessing dimensionality of noncompensatory multidimensional item response theory with complex structures," *Educational and Psychological Measurement*, vol. 73, no. 2, pp. 312–338, 2013.
- [6] J. I. Newman, "Army of whiteness? Colonel reb and the sporting south's cultural and corporate symbolic," *Journal of Sport & Social Issues*, vol. 31, no. 4, pp. 315–339, 2007.
- [7] I. Gitelman, "Linking multidimensional functional diversity to quantitative methods: a graphical hypothesis-evaluation framework," *Ecology: A Publication of the Ecological Society of America*, vol. 97, no. 3, pp. 583–593, 2016.
- [8] P. Jr, B. Hardin, and N. Frye, "A multi-level examination of personality, exercise, and daily life events for individuals with physical disabilities," *Adapted Physical Activity Quarterly*, vol. 23, no. 2, pp. 129–147, 2006.
- [9] M. Massot, F. Laurent, D. Kah, and S. de Chaisemartin, "A robust moment method for evaluation of the disappearance rate of evaporating sprays," *SIAM Journal on Applied Mathematics*, vol. 70, no. 8, pp. 3203–3234, 2010.
- [10] T. Idemoto, H. Ohyama, and K. Takakura, "Carrier lifetime evaluation of electron irradiated SiGe/Si diode," in *Proceedings of the 2nd Semiconductor Materials and Devices Forum-SMDF-2*, pp. 154–155, Kumamoto, Japan, December 2010.

- [11] T. Xie, C. Zhang, and Z. Zhang, "Utilizing active sensor nodes in smart environments for optimal communication coverage," *IEEE Access*, vol. 7, pp. 11338–11348, 2018.
- [12] M. Y. Khan, A. Jamil, and U. A. Khan, "Association between participation in sports and academic achievement of college students," *International Journal of Academic Research in Business and Social Sciences*, vol. 2, no. 8, p. 419, 2012.
- [13] X. Chen, Y. Yuan, and L. Lu, "A multidimensional trust evaluation framework for online social networks based on machine learning," *IEEE Access*, vol. 7, p. 1, 2019.
- [14] T. H. Vu, M. T. Vu, and V. N. Hoang, "The impact of transformational leadership on promoting academic research in higher educational system in Vietnam," *Management Science Letters*, pp. 585–592, 2020.
- [15] H. Y. Wang, Z. W. Yue, and X. M. Wang, "Evaluation methods of multidimensional comfort for high-speed train based on FANP," *TELKOMNIKA Indonesian Journal of Electrical Engineering*, vol. 12, no. 5, pp. 4101–4106, 2014.
- [16] Z. Zhang, C. Zhang, M. Li, and T. Xie, "Target positioning based on particle centroid drift in large-scale WSNs," *IEEE Access*, vol. 8, pp. 127709–127719, 2020.
- [17] C. Zhang, T. Xie, K. Yang et al., "Positioning optimisation based on particle quality prediction in wireless sensor networks," *IET Networks*, vol. 8, no. 2, pp. 107–113, 2019.
- [18] D. Sibbing, I. Bernlochner, S. Schulz et al., "Prognostic value of a high on-clopidogrel treatment platelet reactivity in bivalirudin versus abciximab treated non-ST-segment elevation myocardial infarction patients," *Journal of the American College of Cardiology*, vol. 60, no. 5, pp. 369–377, 2012.
- [19] X. Zhao, H. Peng, X. Li et al., "Defending application layer DDoS attacks via multidimensional parallelotope," *Security and Communication Networks*, vol. 2020, no. 8, 11 pages, Article ID 6679304, 2020.
- [20] N. F. Kanarek, M. S. Kanarek, D. Olatoye, and M. A. Carducci, "Removing barriers to participation in clinical trials, a conceptual framework and retrospective chart review study," *Trials*, vol. 13, no. 1, p. 237, 2012.
- [21] C. Bothorel, J. D. Cruz, M. Magnani, and B. Mícenková, "Clustering attributed graphs: models, measures and methods," *Network Science*, vol. 3, no. 3, pp. 408–444, 2015.
- [22] R. Rasheed, R. Raouf, and A. Iftikhar, "The impact of stakeholder's pressure on the implementation of CSR practices in Pakistan," *Journal of Education & Social Sciences*, vol. 1, no. 3, pp. 23–33, 2021.
- [23] T. Horváth, de Carvalho, and C. P. L. F. André, "Evolutionary computing in recommender systems: a review of recent research," *Natural Computing*, vol. 16, pp. 1–22, 2016.
- [24] M. Khatari, A. A. Zaidan, and B. B. Zaidan, "Multidimensional benchmarking framework for AQMs of network congestion control based on AHP and group-TOPSIS," *International Journal of Information Technology and Decision Making*, vol. 20, pp. 1–38, 2021.
- [25] C. H. Cao, Y. N. Tang, and D. Y. Huang, "IIBE: an improved identity-based encryption algorithm for WSN security," *Security and Communication Networks*, vol. 2021, Article ID 8527068, 8 pages, 2021.
- [26] D. Wu, C. Zhang, L. Ji, R. Ran, H. Wu, and Y. Xu, "Forest fire recognition based on feature extraction from multi-view images," *Traitement du Signal*, vol. 38, no. 3, pp. 775–783, 2021.
- [27] F. Muñoz-Bullón, M. J. Sanchez-Bueno, and A. Vos-Saz, "The influence of sports participation on academic performance among students in higher education," *Sport Management Review*, vol. 20, no. 4, pp. 365–378, 2017.
- [28] P. W. Routon and J. K. Walker, "Student-athletes? The impact of intercollegiate sports participation on academic outcomes," *Eastern Economic Journal*, vol. 41, no. 4, pp. 592–611, 2015.
- [29] S. Singleton, *The Impact of Sports Participation on the Academic Achievement of African American girls*, Liberty University, Lynchburg, VI, USA, 2016.
- [30] L. Wang, C. Zhang, and Q. Chen, "A communication strategy of proactive nodes based on loop theorem in wireless sensor networks," in *Proceedings of the 2018 Ninth International Conference on Intelligent Control and Information Processing (ICICIP)*, pp. 160–167, IEEE, Chongqing, China, November 2018.
- [31] F. Trudeau and R. J. Shephard, "Physical education, school physical activity, school sports and academic performance," *International Journal of Behavioral Nutrition and Physical Activity*, vol. 5, no. 1, pp. 1–12, 2008.
- [32] H. Li, D. Zeng, L. Chen, Q. Chen, M. Wang, and C. Zhang, "Immune multipath reliable transmission with fault tolerance in wireless sensor networks," in *Proceedings of the International Conference on Bio-Inspired Computing: Theories and Applications*, pp. 513–517, Springer, Singapore, November 2016.
- [33] S. J. Danbert, J. M. Pivarnik, and R. N. McNeil, "Academic success and retention: the role of recreational sports fitness facilities," *Recreational Sports Journal*, vol. 38, no. 1, pp. 14–22, 2014.
- [34] M. H. Saad, B. M. Darras, and M. A. Nazzal, "Evaluation of welding processes based on multi-dimensional sustainability assessment model," *International Journal of Precision Engineering and Manufacturing-Green Technology*, vol. 8, no. 1, pp. 57–75, 2021.
- [35] J. Deng, W. Zeng, S. Luo et al., "Integrating multiple genomic imaging data for the study of lung metastasis in sarcomas using multi-dimensional constrained joint non-negative matrix factorization," *Information Sciences*, vol. 576, pp. 24–36, 2021.