A Comparison Study of Sport Medicine Research Trend Before and After the 4th Industrial Revolution: A Systematic Review

Tenglong Fan[1], Man-Hsu Lin[2], Kijin Kim[1,*]

[1] Department of Physical Education, Keimyung University, Daegu, Republic of Korea
[2] Department of Sport Marketing, Keimyung University, Daegu, Republic of Korea
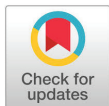
ABSTRACT

OBJECTIVES The purpose of the study is to explore the changing trend of research keywords in the field of sports medicine the contributions of outstanding authors, institutions, and countries participating in the research, and the technologies directly related to the 4th Industrial Revolution (4IR) in the field of 4IR sports medicine before and after 4IR.

METHODS The sample data of this study was retrieved from all the bibliographic information of the top two journals in the sports medicine field (i.e. Sports Medicine and British Journal of Sports Medicine). A bibliometric analysis was carried out by using CiteSpace, and python was used for further text mining on the key nodes in the analysis results.

RESULTS The study has found that cardiovascular disease has always been popular in the research field of sports medicine; improving people's quality of life and avoiding the risk of disease through physical activity, as long as research related to cruciate ligament may appear frequently again in the next few years. After 4IR, the field of sports medicine began to shift from a single study of epidemiology to multidimensional research of epidemiology, preventive medicine and psychology; the population characteristics of the researches began to be more segmented. Also, more collaboration between authors, institutions and institutions involved in sports medicine research has found. Germany and hospitals have become emerging forces after 4IR, and meta-analysis and systematic review are common concerns of Germany and hospitals. The impact of 4IR on sports medicine is mainly manifested in the application of sensors, intelligent monitoring, metabolomics and genomics, which having a great prospect in application.

CONCLUSIONS The study sorted out the changes in research trends in the field of sports medicine before and after 4IR, and at the same time proved that the impact of 4IR on sports medicine has already existed, and more scholars need to pay attention. 4IR has brought new forces and new trends to the field of sports medicine, which deepened the research cooperation in this field. Wearable devices, intelligent monitoring, metabolomics, and genomics have applied and had a positive developing trend in sports medicine field.

Introduction

The first occurrence of sports medicine dates back to the German word 'Sportarzt' in 1908, and Germany has also been recognized as the origin of sports medicine in many studies on the history of sports medicine [1]. Sports medicine began to be valued in American universities, elite athletes, and sports teams after the 1970s [2]. At the end of the 20th century, sports medicine in Britain, India and other countries also started to be well-recognized [1,3]. As an emerging discipline,

Correspondence: Kijin Kim, Department of Physical Education, College of Physical Education, Keimyung University, 1095 Dalgubeuldero, Dalseo-gu, Daegu, KOREA; Tel: +82-053-580-5256; Fax (Optional): +82-053-580-5314; E-mail: kjk744@kmu.ac.kr

sports medicine appeared at the end of the second industrial revolution, and has gone through the complete 3rd industrial revolution since its development.

Those industrial revolutions have continuously accelerated the productivity and the development of technology, and each of them has changed people's living and working patterns. The 4th industrial revolution (4IR) is to accomplish the integration of the real world and the virtual world on the basis of cyber-physical production systems, and the developed technologies involve almost everyone in their life. We live in a digital world of the internet today, and its biggest feature is the extremely strong mobility and the timeliness of information acquisition [4]. According to the information published by the European Commission in 2015, the speeded-up production leads the lead-time faster by 120%, the speed of time to market also raises 70%; moreover, the application of sensor technology monitoring and big data technology identification led to a lower error rate in the production process, which is undoubtedly a great improvement for human social life [5].

The wave of 4IR swept the world rapidly after 2010. For various industries, 4IR is both an opportunity and a challenge [6,7]. Searching on Google Scholar with 'sports medicine' and 'industrial revolution' as keywords found. Firstly, few studies have examined the effects of the 4IR on the field of sports medicine, and a lack of bibliographic data based quantitative analysis and prediction of high-frequency keywords for the coming years. Secondly, current researches believe that artificial intelligence is critical among the impacts of 4IR on the field of sports medicine [8], but the core technology of 4IR is not only artificial intelligence, but also mobile computing, social media, Internet of Things (IOT), big data, predictive analysis and optimization, genetics and biotechnology; those are likely to have a direct impact on the field of sports medicine [9,10].

Since we cannot avoid the wave of 4IR, researchers should realize that understanding the changes and trends of research keywords in the field of sports medicine, the focus of emerging power, and the situation of the application of 4IR technology in the sports medicine field is critical. Therefore, the purpose of this study is two-fold: Firstly, we attempt to find out the impact of 4IR on the field of sports medicine by conducting bibliometric analysis based on two top journals in the field of sports medicine (Sports Medicine and British Journal of Sports Medicine) with 2010 as the cut-off point. Secondly, further explore the impact of 4IR on the field of sports medicine by utilizing crawler code and text analysis code.

Methods

The study implements the analysis and mining of literature data with the help of citespace and python, and the main analysis process is shown in <Figure 1>.

Data collection

Sports Medicine (SM) and British Journal of Sports Medicine (BJSM) were selected as our target journal because both journals are far outperformed other journals ranked in the WOS Sports Science category in all indicators. The full record and cited references of those two journals were download separately by plain text file. Two folders created on the computer and named as 'before 4IR' and 'after 4IR' to keep the downloaded data. Searching by the day of 22 March, 2022, a total of 5069 literature records were retrieved and downloaded in the folder of 'before 4IR', and 5263 records in the folder of 'after 4IR'.

Data analysis

CiteSpace is a software for bibliometric analysis, which can analyze the keyword clustering and bursting of documents in the local database, as well as the cooperation of authors, institutions, and countries [11]. The centrality represents the importance of this node in the network, and the top10 nodes are always valued by researchers [12]

Researchers selected the 'Keywords' option on the main interface of CiteSpace 5.8.R3, and set the value of TopN to 20 in 'Selection Criteria', which means the top twenty most frequent occurrences from each time slice. And then, selected Pathfinder, Pruning sliced networks, Pruning the merged network in 'Pruning', carried out the keyword clustering, and came up with the time zone graphs and burst graphs for keywords. Changed the object of analysis on the main interface, and keep the other things unchanged when analyzing authors, institutions, countries, and generate co-
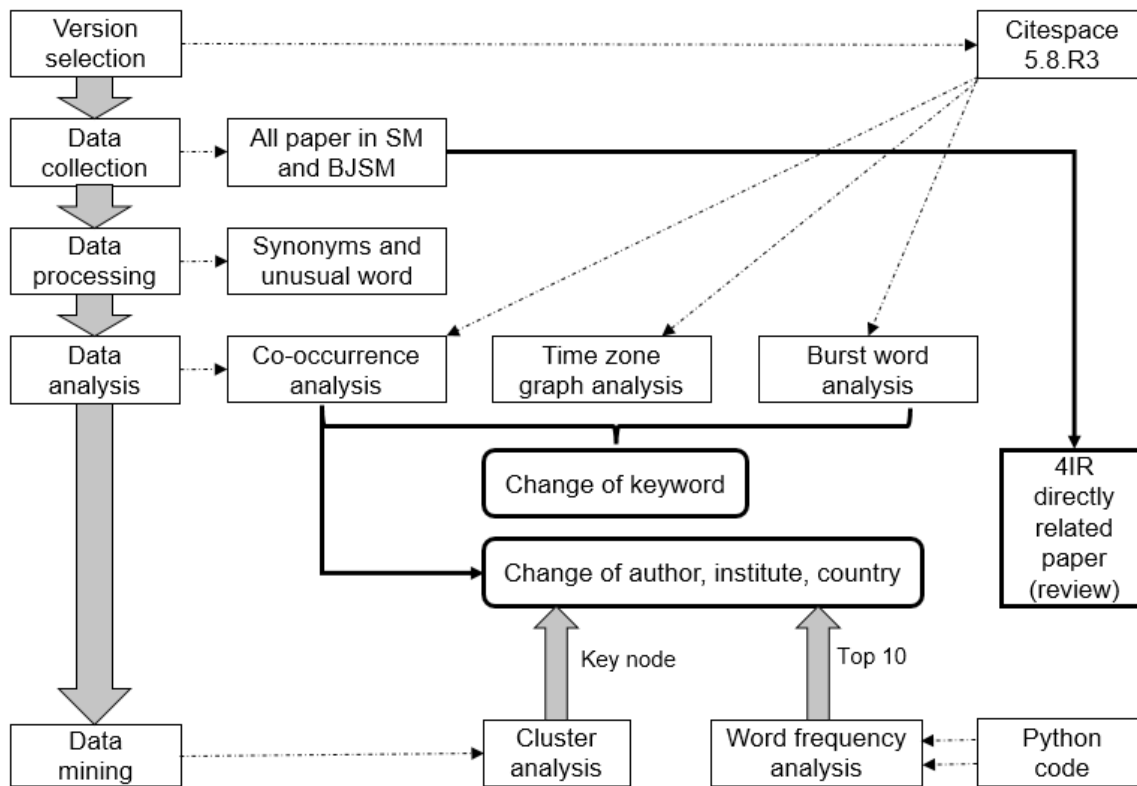
Figure 1. Flow chart of the research

occurrence network for each. Finally, extracted the density of a network from a co-occurrence network and the centrality of each node in the top10 nodes.

Data mining

EXCEL was utilized to separate the DOI from the node information in the co-occurrence network, and python's requests, re, xlrd, xlwt packages to crawl the PubMed website to get the title information corresponding to the DOI number in batch. Used python's split function to perform word frequency statistics for all topic information corresponding to the top 10 nodes of authors, institutions, and countries, and compare the changes in keyword rankings before and after in the top 100 words frequency. Use pandas and gensim packages of python to perform Latent Dirichlet Allocation (LDA) clustering on the topic information corresponding to the 4IR post-4IR institutions and national key nodes. The used code is publicly visible on the personal GitHub page of the researcher. (https://github.com/qq992875076)

Results

Change of keywords before and after 4IR

Clustering the keywords in the keyword co-occurrence network before and after 4IR, the main clusters of keywords before 4IR are: #0performance, #1sport, #2exercise, #3physical activity, #4risk, #5strength, #6skeletal muscle, #7follow up, #8football, #9adult, #10power. The main clusters of keywords after 4IR are #0 epidemiology, # 1 meta-analysis, #2 physical activity, #3 body composition, #4 performance, #5 controlled trial, #6 traumatic brain injury, #7 tendinopathy, #8 reliability, #9 induced bronchospasm.

The clustering labels before and after 4IR, and the main components of the clusters showed that physical activity, physical performance, and tendon-related issues have been the clustering labels in sports medicine before and after 4IR. Elite sports, randomized controlled trials, risk, skeletal muscle, and brain injury have also been significant components of the top 10 clusters, and gender differences have been a constant concern. After 4IR, 'meta-analysis' became the second-ranked

clustering label, thanks to the accumulation of data from a large number of randomized controlled experiments.

Comparing the main contents of the clustering labels before and after 4IR, we found that: (1) the experimental methods became more diverse after 4IR, such as the emergence of new prospective cohorts; (2) the types of diseases concerned in the field of sports medicine also became more diverse after 4IR, especially the emergence of new respiratory-related diseases; (3) ultrasonography also began to appear in the treatment of 'tendinopathy', and (4) sedentary behavior emerges as an important behavior in sports medicine area of concern; (5) the proportion of studies related to strength and power decreased significantly after 4IR. The two clusters, 'strength' and 'power', both disappeared after 4IR, as did the cluster labeled 'football'.

The time zone graphs for keywords were made based on the keyword co-occurrence network before and after 4IR. The year corresponding to the position of the node indicates the year when the node first appeared. The connection between the nodes represents two associated nodes. The size of the nodes represents the number of accumulated literatures. Different colors represent different clustering results. The

result is shown in <Figure 2>.

The research in the field of sports medicine after 1995 has basically formed related research on physical activity, sports injury, crowd prevention, human body function, and disease. New branches related to those are continuously derived before and after 4IR, but no new category found. The 'repeated sprint ability' related to 'human body function' has been concerned and studied after 4IR, and many researches have accomplished.

The node 'consensus statement' appeared 2013 was the largest node showed after 4IR. There are 138 literature records in total, which means that there are 138 researches related to this node in 2013-2022. Relatively stronger related to this node is the appearance of 'data collection procedure' in the same year, 'illness' appeared in 2015, 'cruciate ligament reconstruction' appeared in 2016, and 'surveillance' appeared in 2010. The turning points that appear before and after 4IR are: (1) epidemiology → preventive medicine and psychology; (2) cruciate ligament injury → cruciate ligament reconstruction; (3) hypertrophic heart disease and cardiovascular disease → left ventricular hypertrophic; (4) randomized controlled trial → cohort. Compared with before and after 4IR, the node of 'cruciate ligament injury' in 2010
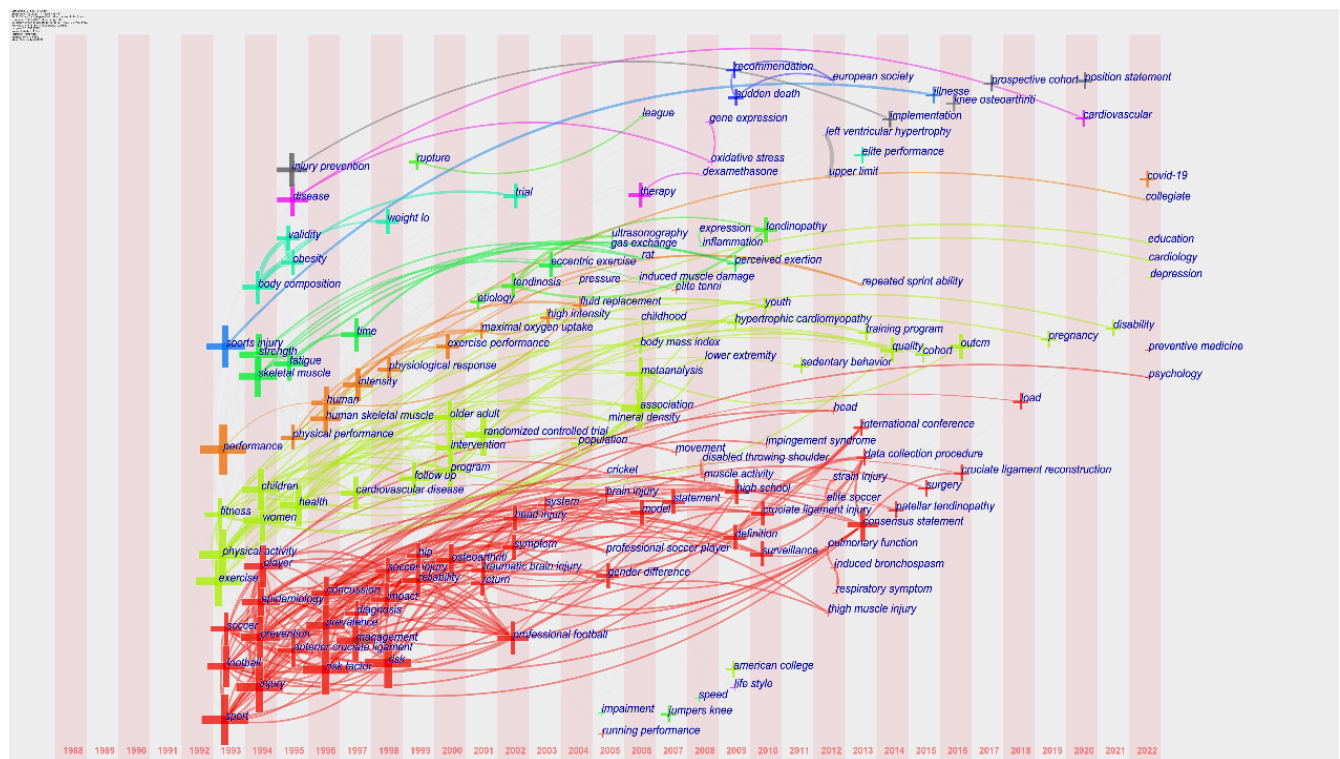

Figure 2. Evolution of hotspots in sports medicine before and after 4IR

and the 'cruciate ligament reconstruction' in 2016 have shown the most obvious contrary, and demonstrated the process from raising the problem to solving the problem during 6 years.

By further checking the annual publication number of the relevant literature in the node information, it can be seen that the researches related to the five nodes 'physical activity', 'sports injury', 'risk', 'reliability', 'professional football', and 'meta-analysis' was skyrocketed comparing before and after 4IR. Some other nodes also similar, such as 'sport', 'epidemiology', 'injury prevention', 'sports injury', 'physical performance'. In order to better explore the new changes in the field of sports medicine after 4IR, the keyword burst function of CiteSpace was used to screen the node information that suddenly appeared since 2011 and lasted over 3 years. The results are shown in <Table 1>.

Table 1. Bursting words after 4IR

Keywords	Begin	2010-2022	Duration
Intervention	2011		12
quality of life	2014		9
consensus statement	2015		8
meta-analysis	2016		7
Health	2018		4
Illness	2019		4
Quality	2019		4
Risk	2019		4
physical activity	2019		4
Anterior cruciate ligament	2019		4
adult	2019		4

The minimum duration for the burst word analysis was 2 years. The parameters of λ was adjusted between 0 and 1 for obtaining as many burst words as possible. And then, import the burst words into EXCEL to screen, and finally screen out the burst words that started to burst after 2011 and lasted for more than 4 years. From the burst words processed by CiteSpace, it can be seen that 'convention' was the word with the longest duration of burst after 4IR, starting from 2011 and lasting for 12 years; 'quality of life', 'consensus statement', and 'meta-analysis' followed after. From these words, we can see

that in the field of sports medicine, improving people's health condition and preventing from disease for better quality of life have been largely studied since 4IR. Meanwhile, research on anterior cruciate ligament (ACL) has also made breakthroughs after 4IR, and research on ACL has been continuously largely focused since 2019.

To sum up, the analysis of keywords indicated that (1) the research in the field of sports medicine after 4IR started to advance from single subject study toward multi-dimensional research in epidemiology, preventive medicine and psychology. (2) Significant breakthroughs have been made in studies related to cardiology and cruciate ligament. (3) since experiment data from randomized controlled trials massively accumulated, meta-analysis and cohort studies began to be concerned by researchers. (4) Sports medicine researchers also began to pay attention to special groups after 4IR, such as pregnant women and the disabled. (5) Improving people's quality of life through physical activity intervention, avoiding the risk of disease, and cruciate ligament-related research would be keywords that may appear frequently in this field in the following few years.

Changes in the authors, institutions, and countries

Through the co-occurrence network analysis on author, institution, and country of CiteSpace, the results see <Table 2> indicates that: (1) After 4IR, the cooperation between authors, institutions and countries involved in sports medicine research has become closer; (2) the top 10 authors in the field of sports medicine largely changed after 4IR, only three authors maintain a stable publication; (3) top10 outstanding research structures before and after 4IR didn't changed much, but hospitals began to show its great potential in the field of sports medicine after 4IR; (4) the centrality of the top 10 countries in the entire national cooperation network is decreasing, indicating that after the 4IR, more countries have begun to pay attention to the development of sports medicine and have achieved certain research results. As the birthplace of the 4IR, Germany has also entered the top 10 queues after the 4IR, which also verifies the necessity of this study.

The focus of top10 authors has changed a lot after 4IR see <Table 3>, which reflected by the decrease of the attention to athletes and training. On the contrary, exercise

Table 2. Main changes of the co-occurrence network before and after the 4IR in authors, institutions and countries

	Author		Institution		Country	
	Before 4IR	After 4IR	Before 4IR	After 4IR	Before 4IR	After 4IR
Density	0.002	0.0063	0.0039	0.0263	0.0252	0.0787
Centrality	0.02	0.65	0.28	0.44	1.77	0.27
Main changes in top10	Only Roald Bahr, Jiri Dvorak, and Karim Miran Khan has remained		Hospital: emerging institutes in Top10		Germany: emerging country in top10	

*Density: Density of co-occurrence network; centrality: sum of the node centralities corresponding to the top 10 authors.

Table 3. Main changes of the co-occurrence network before and after the 4IR in authors, institutions and countries

Top 10 authors			Top 10 institutes			Top 10 countries		
Word	BR	AR	Word	BR	AR	Word	BR	AR
players	12	26	review	6	1	knee	10	42
training	13	89	mete-analysis	-	9	hamstring	-	39
treatment	-	66	international	58	12	ligament	77	38
mete-analysis	-	74				risk	62	10
surveillance	-	71						

* BR: the ranking of keywords before 4IR in the top 100 word frequency; AR: the ranking of keywords after 4IR in the top 100 word frequency. This table only listed the keywords with the largest fluctuations before and after among the top 100 word frequencies.

as an adjunctive therapy yields greater research results, and traditional medical research methods better promoted in sports medicine field after 4IR. It is also worth noting that, discovered from text mining of top authors, the sports injury and illness surveillance system were highly concerned after 4IR.

After 4IR, the number of review-orientated researches began to increase from those outstanding research institutions. Institutions started getting interested in meta-analysis, and also with systematic review were the two research methods that have become more popular. The International Olympic Committee, as an intermediary force, began to influence the research institutions in the field of sports medicine.

Technologies directly related to 4IR

Use 'technology' as a keyword to search in the collected sample data we found that technologies directly related to 4IR were as followed. The first one is the application of wearable devices (sensors) and intelligent monitoring in sports medicine field. Data collection with sensor and data analysis by big data would improve data capture and big data analysis for sports injury and injury monitoring systems, and the popularity of smartphones has contributed to the development of intelligent sports monitoring. The second refers to the application of genomics and metabolomics in sports medicine field. Although the new ion proton sequencer in 2012 could greatly reduce the cost of single gene sequencing, the ethical, moral, social and privacy issues are still needed to face [13]. The rapid development of technologies such as high-throughput DNA sequencing in the field of genomics, big data processing of machine learning algorithms, and gene editing technology may accelerate the accomplishment of precision medicine and gene therapy [14]. Although the new method of using markers to estimate plasma volume provides a new idea for monitoring aerobic exercise, analyzing blood without traditional venipuncture [15], there is no comprehensive metabolomics database, and researchers were not used to saving experimental data in standard metabolomics databases, which could be a difficult problem for the field to be solved [16].

Discussion

As we all know, no research emerges out of thin air; it can be traced back to its roots and evolve and deepen in a certain direction based on what has gone before. Therefore, the first step in academic research is a literature review, the purpose of which is to understand what has been studied before, and to determine what we will study. To deal with the impact of something new on something old, we should first understand what the impact of the former on the latter is. In addition, it is important to understand the impact of the former on the latter, and to sort out the cross-fertilization of the two in the context of the impact, as well as the areas in which the latter may have new collisions in the future under the influence of the former.

4IR has attracted considerable academic attention as a new trend towards automation and as a positive response to the lack of growth of new industries [17]. The field of sports medicine under the influence of 4IR has also seen a part of emerging research in the 21st century, such as sports medicine and artificial intelligence [8], biomimetic materials in sports medicine [18,19], the use of big data in sports medicine [20,21]. The impact of 4IR on the field of sports medicine is also much more than what has been mentioned, according to a search on PubMed it was found that keywords related to 4IR have shown an explosive growth since 2015, and studies have concluded that the current impact of the technologies of 4IR on the field of sports medicine is both an opportunity and a challenge, and that more scholars need to join the research sequence [6].

As for this study, 4IR began to rapidly take the world by storm at the beginning of the 21st century, and Germany officially launched the concept of Industry 4.0 at the Hannover Messe in 2013, with the core purpose of improving the competitiveness of German industry and taking the lead in the new round of industrial revolution, which was first proposed at the World Economic Forum in Davos in January 2016 [22]. In the context of 4IR Germany's National Strategy 2030, Japan's 'Robotics Strategy' and the US Artificial Intelligence Initiative all provide good explanations on how to deal with the impact of the new technologies of 4IR on the country. In the field of sports medicine, there is not much literature that systematically reviews and analyzes the impact of 4IR, and the only one that can be searched is the impact of artificial intelligence on sports medicine mentioned above.

Research in the field of sports medicine has received the impact of 4IR technologies. Artificial intelligence among 4IR technologies has first received the attention of sports medicine researchers, but the impact of other new technologies on sports medicine is not very clear yet, and there is no similar review and analysis type of research on the impact of 4IR on the field of sports medicine. Therefore, this study is a comprehensive review and analysis of the emerging technologies of 4IR and the opportunities and challenges that these emerging technologies bring to the field of sports medicine to point out the direction for the subsequent development of sports medicine, and also to provide macroscopic suggestions for research in the field of sports medicine to deal with the impact brought by 4IR.

The cardiovascular disease has become the leading cause of disease and death in most countries, but coronary heart disease is largely preventable. Exercise can improve symptoms such as angina and congestive heart failure, and lack of exercise may lead to an increased risk of cardiovascular disease [23]. Exercise has been recognized as an intervention to improve cardiovascular disease, which explains why the effect of exercise on cardiovascular disease has always been a research hotspot in the field of sports medicine. Ligament reconstruction provides a solution for ACL injury. However, due to the need for a semitendino-femoral graft for cruciate ligament reconstruction, with the continuous updating of technology, new bionic materials may be added, and early fixation, delayed weight-bearing and protection of grafts are the current concerns of sports rehabilitation patients [24].

As we all know, the arrival of 4IR brings technologies such as 5G network and Internet of Things. 5G networks enable faster communication between different regions, institutions, and countries, and IOT technology enables remote access to sensor data and remote control of the physical world [25]. These two technologies have greatly improved the efficiency of collaboration between authors, institutions and countries involved in sports medicine research. This closer collaboration is also conducive to the development of sports medicine.

In sports medicine, the rise of hospitals among research institutions is an inevitable trend. As one of the countries of origin of the 4IR, Germany is also the origin of sports medicine. Whether this has a causal relationship with the rise of Germany in the field of sports medicine after the 4IR has not yet been proved by research. The common concerns for hospitals and Germany are meta-analyses and systematic reviews. Meta-analysis is to screen previous studies, integrate data, and determine whether there is an impact and the size of the impact by estimating the mean and variance [26], while systematic reviews are mainly to screen relevant literature to understand the development status, existing problems, and possible solutions of a certain research [27].

In this CiteSpace bibliometric analysis study, the top 10 authors, institutions, and countries were regarded as outstanding contributors in this field. Finding outstanding contributors in this field is also a result of CiteSpace bibliometric analysis research, but such research only identifies these contributors, and the topics that those focus on has not been highly concerned [28,29,30].

By using crawler code and conducting word frequency analysis, this study compared and analyzed the word frequency changes of the top 10 authors, institutions, and countries with the number of published papers before and after 4IR. It provided a new research idea for exploring the concerns of outstanding contributors in the field, which is, on the basis of CiteSpace, use the crawler code to obtain the topic information corresponding to the top10 nodes, and analyze the word frequency of these topic information, the purpose is to understand the concerns of authors, institutions, and countries that have made outstanding contributions in the field

The impact of 4IR on the field of sports medicine has gradually come to the attention of researchers as 4IR began to sweep through various industries worldwide from Germany after 2010. Ramkumar et al. [8] suggested that AI is the representative technology of 4IR and the next preamble in medicine, but there is still a long way to go before AI can change the whole field of sports medicine. Claudino, Capanema, and Santiago [31] also pointed out that when searching three databases using 'artificial intelligence' and 'sports medicine', there were almost no results, suggesting that there is still much to be done to improve the knowledge of artificial intelligence in sports medicine. In this study, a search of the Google Scholar database with the terms 'industrial revolution' and 'sports medicine' also revealed only a few relevant results, with most of them referring to the progress, potential trends, and future challenges in the field of artificial intelligence in sports medicine. Research also proves that the impact of 4IR on the field of sports medicine is not limited to artificial intelligence. The application of genomics, metabolomics and wearable devices in sports medicine has also been concerned by researchers with great research achievements. Kim also pointed out that the digital health care system is a high-tech fusion system using advanced technologies such as artificial intelligence, big data, robotics, IOT, 3D printing, virtual augmented reality, stem cells, genomic analysis, and other genetic rehabilitation technologies, and proposed the development strategy of 'human-centered science and convergence with various disciplines' for the field of sports medicine to 4IR [32].

Conclusions

The analysis of keywords revealed that the effect of exercise on patients with cardiovascular disease has been a hot topic of research in the field of sports medicine, and special populations such as pregnant women, people with disabilities, and sedentary behavior began to receive attention after 4IR. There is closer collaboration between authors, institutions and countries involved in sports medicine research, and Germany and hospitals have become an emerging force in the field after 4IR. 4IR has brought new forces and new trends to the field of sports medicine, which deepened the research cooperation in this field. Wearable devices, intelligent monitoring, metabolomics, and genomics have applied and had a positive developing trend in sports medicine field. We should take 'human-centered science and convergence with various disciplines' as our main strategy to react the impact of 4IR on sports medicine.

Acknowledgments

Conflicts of Interest

The authors declare no conflict of interest.

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