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A Review of Triathlon Research: A Scientometrics Perspective

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Abstract

The popularity of triathlon is increasing in China. There is no scientometrical study of the development trend and evolution of triathlon research, despite the significant contribution of triathlon studies to the growth of sports science research. We performed a comprehensive scientometric analysis of 892 research publications between 1996 and 2021, with 12,285 references from 252 journals within the Social Science Citation Index related to sports science. Numerous countries, researchers, universities, and institutes with abundant triathlon studies publications were identified. In addition, we found a mixed multitude of connected research trends that have shaped the nature and development of triathlon research worldwide. Specifically, a document co-citation analysis identified several major research clusters, key topics, connections, and bursts (sudden citation surges)a. For example, the foci of clusters #0 through #5 were found to be perceptual learning, regressive eye movement (s), attributive adjective (s), stereotypical gender, discourse processing, and bilingual adult (s). As an in-depth study, the content of all the key clusters was extensively analyzed and synthesized. Finally, we examined how the observed patterns led to new trends by grounding the results in a data-driven theory of scientific revolution. The current study presents implications for future research as the first scientometric assessment of triathlon studies in sport sciences.

1. Introduction

Triathlon is a unique sport that comprises a consecutive swim, cycle, and run disciplines completed over various distances. There has been a rise in interest in triathlon research across many sports fields in recent years. Some of these areas include the investigation of the training and competition readiness in Triathlon (Etxebarria et al., 2019), psychological profiling (Olmedilla et al., 2018), triathlon performance (Lepers, 2019), triathlon injuries (Kienstra et al., 2017) and physiological and neuromuscular response (García-Pinillos et al., 2016). In addition, various evaluations of triathlon research in sport sciences and other domains have been published, including physiology (G. P. Millet & V. E. Vleck, 2000), multi-modality (Hayashi et al., 2015), illness epidemiology (Guevara et al., 2020), biomechanics (Millet & Vleck, 2000), medical help (Alexander, 2011), sports development and delivery (Phillips & Newland, 2014). While such literature reviews help give a unified narrative of published research, they have significant drawbacks.

The first flaw in past assessments is their depth and breadth (Chen et al., 2009). The writers of these reviews often synthesize and segment a small corpus of papers to examine the status of research. Reading enormous articles, identifying significant ideas and relationships, and concluding takes time and effort; therefore, such emphasis is primarily due to cognitive limits. “Essential activities for interpretation such as classification, summarization, synthesis, and integration are not only cognitively demanding but also insufficiently supported,” according to Chen et al. (2010). Aside from their limited generalizability to the complete area of study (specialty) (Chen, 2004), conventional review methodologies often neglect the dynamics and relationships between articles, authors, and the journals in which the studies were published. The above data is crucial for understanding (i) intellectual turning moments within a specialty, (ii) the connections across specializations, and (iii) the evolution of knowledge through time (Chen, 2004, 2013; Chen & Leydesdorff, 2014). Further, there is no scientometric study on the development trend and evolution of triathlon research in sports sciences.

To fill these gaps, the current study used Scientometrics to compile all accessible triathlon studies from 1984 to 2021. Scientometrics is a branch of science that studies measuring and analyzing academic publications. Measuring the influence of research articles and scholarly journals, the comprehension of scientific citations, and the use of such metrics in policy and management settings are all major study topics (Leydesdorff & Milojević, 2012). Additionally, scientometrics relies on a broad collection of quantitative methods, from descriptive statistics and data visualization to advanced econometric techniques, network science approaches, machine-learning algorithms, mathematical analysis, and computer simulation, including agent-based modeling (Fortunato et al., 2018). Identifying disciplinary boundaries is a strength of scientometrics (Fortunato et al., 2018). Bibliometrics is a quantitative study of publications to identify specific types of phenomena (Hérubel, 1999). A variety of studies in Sport Marketing (Ghasemi et al., 2021), handball (Prieto et al., 2015), aikido (Gutiérrez García et al., 2018), Sports Tourism (Jiménez-García et al., 2020), and exercise psychology (Khoo et al., 2021) have used bibliometrics. There has been no scientific inquiry in detailed research on the development trend and evolution of triathlon research in sports sciences.

According to Chen et al. (2010), in a range of scientific domains, the scientometric method is becoming increasingly extensively applied as a result of (1) the large bibliographic databases, such as Scopus and Web of Science, are readily available (Bar-Ilan, 2008). (2) the availability of software packages for visualizing and mining texts, such as VosView (Leiden University, Leiden, Netherlands) and CiteSpace (Chen, Drexel University, USA), and (3) the difficulty of evaluating vast volumes of data from many sources, specifically the failure to find co-citations using standard review techniques.

Instead of reviewing a few articles in specialization and drawing conclusions from them, this study used WoS to find relevant publications and then segmented and synthesized them using CiteSpace software (Chen, 2016; Chen et al., 2010). A review analysis was supplied only when the primary trends within a specialism had been identified.

2 Methods

2.1 Data source

According to our experience, the Web of Science could return irrelevant results. For this reason, a rigorous set of inclusion criteria was used to create the dataset in the current study. In the beginning, the search engine of WoS was set to search for "triathlon" in the titles, keywords, and abstracts. The WoS search was then refined by choosing Sport Sciences as the topic area.

The publication type was then refined to articles in the second round of searches. After reading the titles and abstracts of the suggested publications, only those closely related to triathlon research were considered. From 1996 to 2021, 892 publications were produced because of this approach. The data was then downloaded into RIS prepared files from the WoS repository.

Following that, the "Import/Export" option in CiteSpace Version 5.8 (Chen, 2016; Chen et al., 2010) was used to convert the RIS formatted files to a CiteSpace-friendly format with a 100% success rate. Although file conversion success rates varied, a rate of more than 95% was regarded as trustworthy (Chen, 2013). CiteSpace generated the networks from 892 articles by identifying 847 publications and 12,285 references (n=847+12285=13,132). Due to the lack of co-citations from other publications in the network, the remaining 45 articles were removed from the study.

2.2 Data analysis

2.2.1 Descriptive statistics

An analysis of frequency data was performed to determine the number of triathlon papers that were published annually, the names of the journals where the articles were published, and the names of the most productive authors, universities, and institutions, as well as the countries and regions where the authors resided when the papers were published. The research into triathlon across sports sciences has exhibited exponential growth since 1996 (Figure 1A). A relative increase of two-to-four times was observed after 2008 compared with the early 1990s and early 2000s.

Figure 1B highlights the most prolific authors, with Knechtle B at the top of the publication list (48 papers), followed by Hausswirth C (29 papers), and Brisswalter J, and Hue O (28 papers each), Knechtle P (26 papers). Additionally, there was one author with twenty-three papers, two authors with twenty-two papers each, one author with twenty-one papers, three authors with twenty papers, nineteen papers, eighteen papers respectively, two authors with seventeen papers each, three authors with twelve papers each, one author with eleven articles, five authors with ten papers each, two authors with nine papers each. Regarding the universities and institutes involved in triathlon research, the UNIVERSITY OF ZURICH topped the list with 43 articles. At the same time, the UNIVERSITY OF CAPE TOWN was placed in the second position with 36 papers, UNIVERSITE DE MONTPELLIER has ranked the third position with 32 papers (Figure 1C). Figure 1D shows that the authors published most papers (148 papers) from the USA, followed by France (125 papers) and Australia (123). Other countries were further down the list, including England (84 papers), SWITZERLAND (66 papers), SPAIN (64 papers), SOUTHAFRICA (53 papers), CANADA (48 papers), BRAZIL (44 papers), and NEW ZEALAND (38 papers).

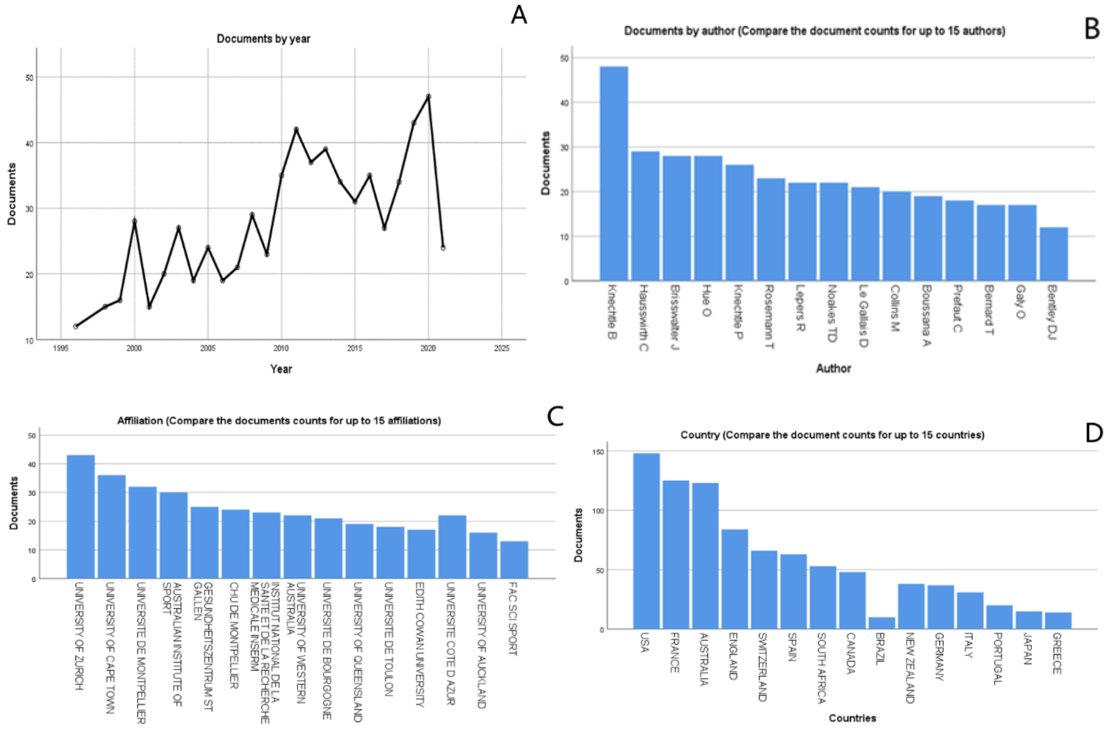

Figure 1. Frequency analysis of the 892 publications on triathlon in sport sciences studies.

2.2.2 Dual-map overlay

The CiteSpace program (Chen, 2016; Chen et al., 2010) was used to create a dual-map overlay to compare the present level of triathlon research in sport sciences to other specializations. The literature was divided into two categories by the dual-map overlay: (1) cited journals and (2) citing journals (i.e., the latter cited its references from the former). The strength of these groups' links was graphically portrayed and quantified. The current study's map overlays triathlon publications and journal clusters often mentioned in sport science onto a base map drawn from the WoS, including over 10,000 journals (Chen & Leydesdorff, 2014).

2.2.3 Network visualization

A network was initially built to simulate the corpus' intellectual structure, which contained published articles from 1996 to 2021. This approach involved investigating and visualizing relevant journals, publications, and subjects. A time-slicing approach was used to do a document co-citation analysis (DCA) and a journal co-citation analysis (JCA) that mapped a specialty domain in terms of a time series of networks (Chen, 2016). The JCA was used to identify significant journals, whereas the DCA was utilized to find impactful documents and publishing clusters.

2.2.4 Quality control and impact

The modularity Q index and the average silhouette metric were used to assess the quality of the DCA and JCA networks and the homogeneity of the discovered clusters (Chen et al., 2010). The modularity Q index runs from 0 to 1, with higher indices suggesting more trustworthiness. The average silhouette measure goes from -1 to 1, with higher values indicating more uniformity.

Additionally, the burstness and betweenness of prominent articles and journals were calculated (Kleinberg, 2003). A red ring around the node indicates a citation burst, a quick rise of citations for a given article. According to (Chen & Song, 2017), a burst is an increase in the frequency of citations during a short period. Betweenness is a metric of the impact that reflects how close publications or journals are. Because they link more publications or journals and, as a result, more information and pathways move through them, publications with a higher betweenness would significantly affect the network (Chen, 2016).

3. Results

3.1 Generating the dual-map overlay

Figure 2 illustrates how the multiple labels on the dual-map overlay were obtained from journal titles representing the disciplines used in the mapping. The citing journals are shown on the left, while the cited journals are displayed on the right. The arcs in the map show citation linkages that begin on the left with the citing journals and end on the right with the cited journals, illustrating how the citing journals are related to the cited journals. The ovals reflect the number of writers who have published in the field and the number of articles that have been published in the field. The wide oval on the left, for example, suggests that there are several authors and works on triathlon in the domains of "Neurology, Sports, and Ophthalmology" in sport sciences. The width of the oval represents the author-to-paper ratio, while the height of the oval represents the number of articles published.

The current view depicts the z-score function, with the thickness of the connecting lines indicating the importance of the relationships. The thick line connecting "Neurology, Sports and Ophthalmology" on the left and "Rehabilitation, Sport" on the right, for example, represents the most significant connections between triathlon papers published in "Neurology, Sports and Ophthalmology" journals and papers published in "Rehabilitation, Sport" journals. The relationship between

"Neurology, Sports and Ophthalmology" and "Molecular, Biology, Genetic" shows that the first set of authors/papers referenced the second group of publications. A correlation was discovered between "Neurology, Sports and Ophthalmology" and "Health, Nursing, Medicine," establishing a credible link between triathlon research and these branches of study.

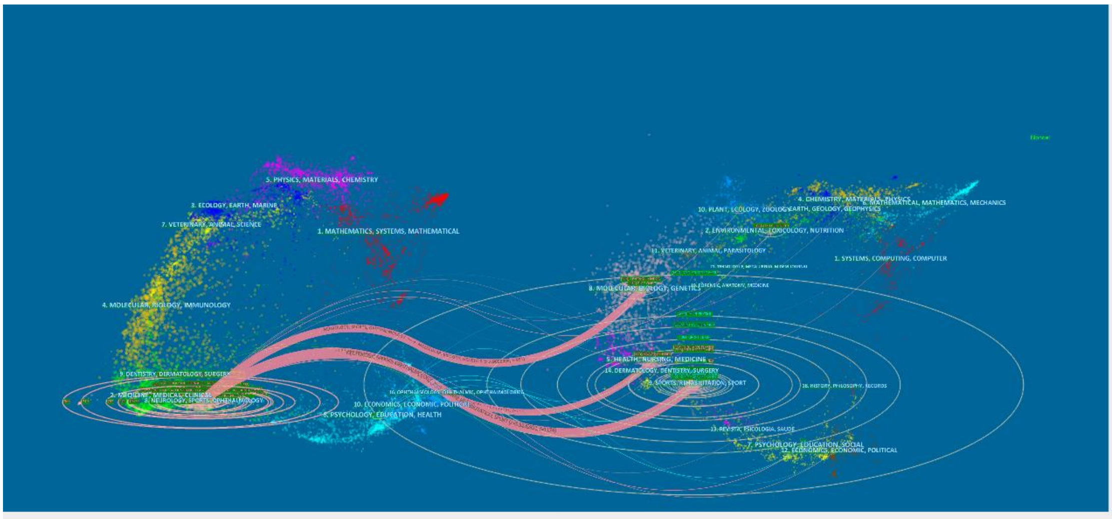

Figure 2. The dual-map overlay for triathlon research.

3.2 Document co-citation analysis

In this investigation, the modularity Q index and the average silhouette metric for the DCA network were 0.5731 and 0.8693, respectively, indicating that the network has an adequate degree of dependability and homogeneity. CiteSpace Version 5.8 software automatically retrieved 14 significant clusters with labels based on the Latent Semantic Indexing (LSI) analysis, as illustrated in Figure 3 (Deerwester et al., 1990). Smaller clusters were not shown since they lacked strength and connectivity

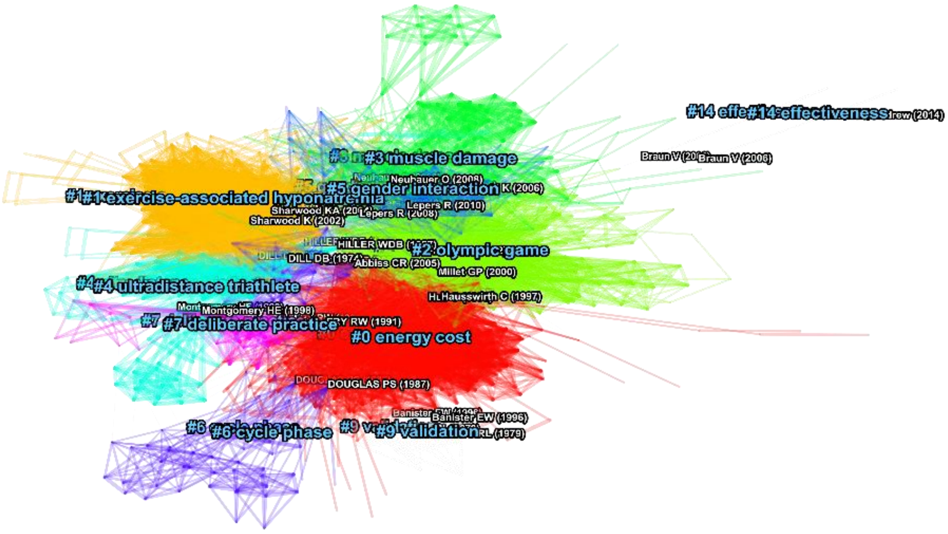

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Figure 3. Hierarchical structure of the document co-citation analysis (DCA) network consisting of multiple clusters. (Modularity Q index=0.5731; Average Silhouette =0.8693).

Figure 4 depicts the critical data clusters on a horizontal line, with cluster labels on the right side. The nodes with the outer purple rings have a high betweenness centrality, a metric for determining strategic placements and the capacity to link nodes in a network (Chen, 2016).

The cluster's lifespan is shown by the length of each line (Chen, 2016). Clusters are numbered from zero to one, with Cluster #1 being the most significant and Cluster #0 being the smallest. The longevity of specialization varies, as indicated in the timeline overview. Some clusters last for over 50 years, while others are only there for a few years. Cluster 0 had a long lifespan (1953–2007), but Cluster 14 had a significantly shorter lifespan (1989–2013). Some clusters will continue to exist until 2020, the most recent publication for one of the mentioned references in this research. The text-mining and keyword analysis algorithm in CiteSpace software created cluster labels such as energy cost (0), exercise-associated hyponatremia (1), Olympic game (2), and muscle injury (3).

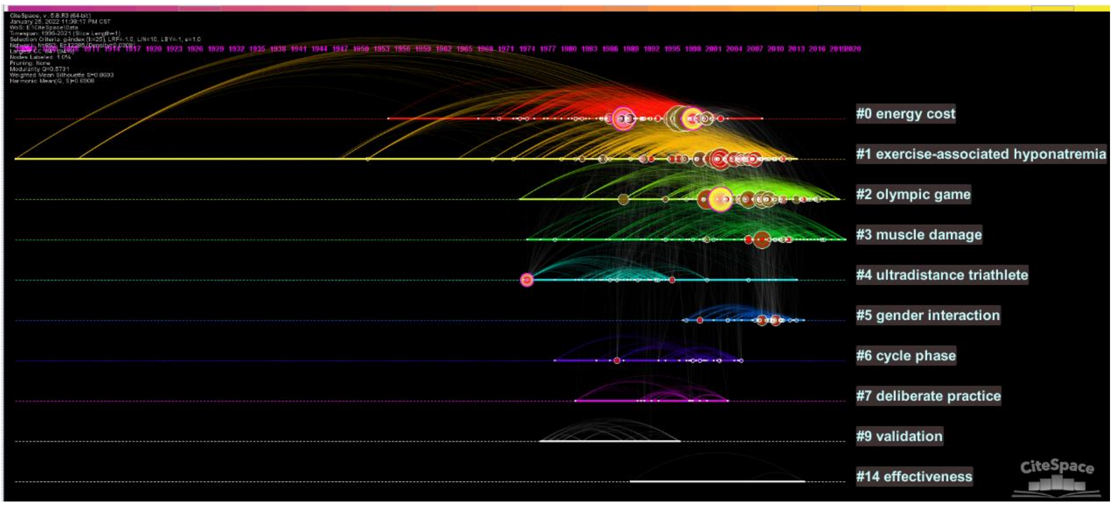

Figure 4. Visualization of published research clusters emerging from 1902 to 2020, using the Document Co-Citation Analysis (DCA). (Modularity Q index = 0.5731; Average Silhouette = 0.8693).

3.3 Document co-citation analysis: burst detection

The most impactful or landmark papers in the area that caught scholars' attention were identified using a burst detection method (Kleinberg, 2003). The 15 significant bursts in citations are shown in Table 1, with the length of each explosion shown in the correct columns. The data showed a clear drifting trend, showing that new research subjects had developed over time and that formerly highly cited papers had progressively been supplanted by more recent publications. For example, Brisswalter (2000)'s citation burst, which has a strength or citation burst weight of 6.11, lasted five years (2001–2005), while Speedy et al. (2001)'s citation burst lasted another five years (2006–2010). These findings showed these publications were significant for the specialty understudy, particularly in their bursts' early and late years. Co-burst patterns, when two or more publications gain the same magnitude of strength during the same period, are another exciting discovery from Table 1. The burst periods of Ball et al. (2004) and Laursen et al. (2006), for example, overlap (2007–2011), while the burst periods of Cohen and Zimmerman (1978) and Le Meur et al. (2009) overlap (2013–2021), despite the former having greater strength in both bursts. The papers took anywhere from 5 (Hausswirth et al., 2000) to 9 years (Le Meur et al., 2009) to become a focal point and reach citation bursts. Finally, the most recent citation bursts are Cohen and Zimmerman (1978), Le Meur et al. (2009), and Lepers, Rüst, et al. (2013).

Table 1. Top 15 references with the most robust citation bursts.

References	Year	Strength	Begin	End
Brisswalter (2000)	2000	6.11	2001	2005
Hausswirth (1999)	1999	6.01	2002	2009
Sharwood (2004)	2004	9.95	2006	2012
Speedy (2001)	2001	9.29	2006	2010
Ball (2004)	2004	6.83	2007	2011
Almond (2005)	2005	6.19	2007	2012
Laursen (2006)	2006	6.09	2007	2011
Sawka (2007)	2007	8.78	2010	2016
Lepers (2008)	2008	7.33	2010	2013
Noakes (2005)	2005	6.12	2010	2015
Hew-Butler (2007)	2007	5.95	2010	2012
Cohen (1988)	1988	6.92	2013	2021
Le Meur (2009)	2009	6.12	2013	2021
Suzuki (2006)	2006	6.23	2015	2018
Lepers (2013)	2013	6.97	2016	2021

Table 2. Coverage and content of the clusters.

Coverage	Total reference	Representative authors[1]	Suggested title of the cluster
Cluster 0			
0.11	40	Hue (1998)	Energy cost
0.11	37	Kreider (1988)	
0.08	27	Otoole (1995)	
0.07	35	Sleivert (1996)	
0.06	39	Hausswirth (1997)	
Cluster 1			
0.09	36	Sharwood (2002)	Exercise-associated hyponatremia
0.08	29	Speedy (2001)	
0.08	28	Kimber (2002)	
0.06	27	Speedy (1999)	
0.05	21	Laursen (2006)	
Cluster 2			
0.12	48	Bentley (2002)	Olympic game
0.06	25	Hopkins (2009)	
0.05	39	Millet (2000)	
0.04	26	Cohen (1988)	
0.04	17	Jeukendrup (2005)	
Cluster 3			
0.08	25	Neubauer (2008)	Muscle damage
0.04	12	Del Coso (2012)	
0.03	4	Ackland (2012)	
0.01	16	Suzuki (2006)	
0.01	8	Pfeiffer (2012)	
Cluster 4			
0.1	25	Dill (1974)	Ultradistance triathlete
0.06	22	Hiller(1987)	
0.01	12	Otoole (1995)	
0.01	6	Hiller (1989)	
0.01	2	Applegate (1989)	
Cluster 5			

0.02	20	Lepers (2008)	Gender interaction
0.01	15	Lepers (2010)	
0.01	15	Bernard (2010)	
0.01	8	Gulbin (1999)	
Cluster 6			
0.08	11	Douglas (1987)	Cycle phase
0.01	4	Laursen (2002)	
0.01	4	Foster (1993)	
Cluster 7			
0.01	4	Montgomery (1998)	Deliberate practice
0.01	2	Myerson (1999)	
Cluster 9			
0.00	2	Banister (1996)	Validation
0.00	2	Shepley (1992)	
0.00	1	Armstrong (1990)	
Cluster 14			
0.01	7	Braun V (2006)	Effectiveness
0.00	2	Sparkes(2014)	
0.00	1	Atchley (1989)	

[1] The publications reported in this table constitute the most prominent bursts per cluster.

Table 3. Top 25 cited journals with the most robust citation bursts.

Cited Journals	Strength	Begin	End
Annals of Sports Medicine and Research	18.07	1996	2004
Medicine and Science in Sports and Exercise	15.68	1996	2006
European Journal of Applied Physiology	14.66	1996	2005
Medicine & Science in Sports & Exercise	13.61	1996	2001
American review of respiratory disease	10.01	1998	2005
Respiratory Physiology & Neurobiology	8.31	1999	2005
Scandinavian Journal of Medicine & Science in Sports	5.93	1999	2001
Exercise and Sport Sciences Reviews	5.65	2001	2007
Canadian Journal of Applied Physiology	8.21	2002	2006
Current Sports Medicine Reports	5.75	2006	2013
European Journal of Clinical Nutrition	6.77	2007	2012
Journal of Experimental Biology	7.18	2008	2010
Journal of Electromyography and Kinesiology	6.72	2008	2013
Journal of Athletic Training	6.09	2010	2018
International Journal of Sports Physiology and Performance	17.82	2013	2021
Scandinavian Journal of Medicine & Science in Sports	12.69	2014	2021
The Journal of Strength & Conditioning Research	10.9	2014	2021
Open Access Journal of Sports Medicine	9.38	2014	2021
Journal of Human Sport and Exercise	8.84	2014	2021
European Journal of Sport Science	10.86	2015	2021
Applied Physiology, Nutrition, and Metabolism	10.19	2015	2018
Extreme Physiology & Medicine	6.08	2015	2021
Frontiers in Physiology	12.66	2018	2021

3.4 Document co-citation analysis: cluster characteristics

The key clusters with the most citing published work per cluster are shown in Table 2 (clusters #8, #10, #11, #12, #13 were removed since they did not have highly citing publications). The number of references per cluster referenced by the articles in their bibliography is shown in the coverage column. For example, Hue et al. (1999) had a coverage index of 0.11, indicating that this work mentioned 11% of the total references in this cluster. Some articles were crucial to over one cluster. O'Toole and Douglas (1995), which occurred in clusters #0 and #4, suggested a relationship between the various groupings of publications (Chen & Song, 2017). The "Discussion" section delves further into the content and breadth of each cluster.

3.5 Journal co-citation analysis

The average silhouette metric and the modularity Q index for the JCA network in this research were 0.5731 and 0.6213, respectively, indicating that the journal network exhibited low degrees of homogeneity and connectivity. The top 25 journals in the field with the most significant citation bursts are shown in Table 3. Medicine and Science in Sports and Exercise (1996–2001) and Annals of Sports Medicine and Research (1996–2004) had the earliest citation bursts in triathlon research, while Extreme Physiology & Medicine (2015–2021) and Frontiers in Physiology (2018–2021) had the most recent citation bursts. Annals of Sports Medicine and Research (strength=18.07) is the most influential journal in the triathlon specialty in sports sciences, followed by International Journal of Sports Physiology and Performance (strength=17.82), Medicine and Science in Sports and Exercise (strength=15.68), and European Journal of Applied Physiology (strength=14.66).

4 Discussion

This study uses DCA and JCA, two co-citation analyses from Scientometrics, to investigate 847 publications on triathlon research in sports sciences from WoS. Throughout the study, 25 influential journals and 14 clusters of research were identified. Below are the main characteristics of each cluster from the DCA and their contributions to triathlon research in sports sciences, followed by findings from the JCA and implications of these findings.

4.1 Document co-citation analysis (DCA)

4.1.1 Cluster 0: Energy cost

This cluster investigated (1) the cardiovascular and thermal differences between training and triathlon performance (Kreider et al., 1988). (2) Physiology underlies triathlon performance (O'Toole & Douglas, 1995). (3) Physical and physiological elements linked to triathlon performance. Le Gallais et al. (1998) discovered that a 10-kilometer run after 40 kilometers of cycling had a greater oxygen cost than a 10-kilometer run alone, despite no changes in biomechanical characteristics such as stride length (SL) or stride frequency (SF). The findings backed up previous research (Guezennec et al., 1996; Kreider et al., 1988; O'toole et al., 1989).

An experimental classic-distance triathlon run vs. a control run resulted in substantial increases in VO_2, V_E, HR, arteriovenous oxygen difference, and rectal temperature, according to Kreider et al. (1988). Compared to the whole triathlon run or a control run, Le Gallais et al. (1998) found that the cycle-run transition is specific for metabolic and cardiorespiratory variables but generic for biomechanical metrics SL and SF. This emphasizes the need for multi-block training for triathletes to imitate the physiological reactions encountered during swim-cycle and cycle-run transitions.

A similar study by O'Toole and Douglas (1995) showed that triathlon performance produced cardiovascular and thermal responses not experienced when performing the events independently, which resulted from thermoregulatory and cardiovascular adaptations in conjunction with the degradation of mechanical efficiency during prolonged triathlon performance.

Hausswirth et al. (1997) reported a significant alteration in running kinematics at the end of a marathon run (MR), and a triathlon run (TR) carried out at the same speed. These results agree with Hausswirth et al. (1997) in this cluster, which suggested that different parts of the biceps femoris were active due to hip tension and knee flexion while cycling. Suzuki et al. (1982) asserted that the biceps femoris showed a double burst activation pattern under cycling intensity near competition velocity.

Sleivert and Rowlands. (1996) stated, similarly to Hausswirth et al. (1997), that the physiological demands of endurance swimming, cycling, and running have been well researched, but that the findings cannot be directly applied to successful triathlon performance due to the physiological demands of competing in prolonged sequential exercise. As a result, Sleivert and Rowlands. (1996) investigates the physical and physiological aspects linked to triathlon performance. They discovered that: (1) Body composition might affect swimming, cycling, and running in diverse ways in several tests. Extra body fat may assist in minimizing hydrodynamic drag and increase buoyancy while swimming. Unlike swimming, where hydrodynamic drag is the most difficult force to overcome, gravity is the most difficult force to overcome while running. If the additional weight is muscle mass, the increase in frontal surface area with increasing body weight is counterbalanced by an increase in absolute power production in cyclists. (2) Successful endurance athletes in swimming, cycling, and running, as well as triathletes, often have high levels of aerobic power (VO_{2max}). Swimming's lower VO_{2max} values may be ascribed in part to the increased muscle mass needed. (3) The capacity of a triathlete to exercise at a lower percentage of VO_{2max} for a given submaximal exertion has been linked to performance in the triathlon. A mix of elements, including aerobic power, the economy of movement, and the anaerobic threshold, impact this. (4) Because metabolic acidosis and increased glycogen depletion limit endurance time when exercise intensity exceeds the anaerobic threshold, the influential endurance athlete is frequently defined by the capacity to execute significant levels of work at or just below the anaerobic threshold. (5) At a constant speed, a more economical triathlete consumes less oxygen than their less economical counterpart, allowing them to travel quicker or save energy for the latter parts of a race. The massive variance in 10km race performance times of highly experienced runners with equal VO_{2max} values has been proven to be due to the economy.

Finally, Boussana et al. (2001) expected that the reduction in respiratory muscle strength and endurance after a run-cycle trial would be higher than after a cycle-run trial because changes gained during cycling may be partly reversed during the next run. To verify this theory, we measured respiratory muscle strength and endurance before and after a cycle-run trial that mimicked the triathlon sequence and compared the findings to a balanced run-cycle test that mimicked the duathlon sequence. The results demonstrate that following the cycle-run series, respiratory muscle strength and endurance were reduced more diminutive and that cycling caused a higher drop in respiratory muscle endurance than running. Boussana et al. (2001) discovered that cycling causes more inspiratory muscle exhaustion than jogging. This might be related to the crouching posture of cycling, which increases ribcage muscular activation, or to the inspiratory load technique, which assesses rib cage muscle exhaustion more accurately. Other relevant publications in this cluster include Schabort et al. (2000), who looked at how physiological variables can accurately predict triathlon race time; Laursen et al. (2000), who looked at how 3000m of swimming affects performance and physiological variables during a subsequent 3-h cycle time trial in highly trained ultra-endurance triathletes; and Miura et al. (1997), who looked at the relationship between Olympic distance triathlon and economy as measured by percent

VO_{2max}.

4.1.2 Cluster 1: Exercise-associated hyponatremia

In this cluster, Sharwood et al. (2002), Speedy et al. (2001), Kimber et al. (2002), Laursen et al. (2006), and Hew-Butler et al. (2007) were identified as the most influential publications. Sharwood et al. (2002) found that (1) Percentage change in body weight was linearly related to postrace serum sodium concentrations but unrelated to postrace rectal temperature or performance in the marathon. (2) A very low incidence of (asymptomatic) hyponatremia and medical casualties in the inaugural South African Ironman triathlon despite or perhaps because of the conservative drinking policy advocated for the race. Speedy et al. (2010) demonstrated that the triathletes who developed hyponatremia had evidence of fluid overload despite modest fluid intakes. They lose approximately 2.5 kg of weight during an ultradistance triathlon, most likely from sources other than fluid loss (loss of fat, glycogen, and water stored with glycogen). Relatedly, Laursen et al. (2006) found that, despite losing 2.4 (1.2) kg (3%) of body mass over the course of a 10-hour Ironman triathlon, individuals maintained a one °C core temperature and urine specific gravity and plasma [Na+] levels within normal limits. So, in line with prior results, modest hypohydration (in terms of body mass loss) in some of the best performing triathletes in an Ironman triathlon was described, with no connection to core temperature or field hyperthermia. As a result, the research disproves the widely held idea that body mass reduction influences core body temperature. Many scholars have put up various views to prevent hyperthermia during the triathlon. For instance, Noakes (2003) found that excessive drinking among these participants can lead to hyponatremia severe enough to cause fatalities. A more reasonable approach is to urge these participants not to drink as much as possible but to drink ad libitum (according to the dictates of thirst) no more than 400–800 mL/hour. Lawrence (1996) concluded that, during ambient heat stress, increased perspiration increases the need for fluid replenishment. During prolonged activity, add carbohydrates to the fluid replacement solution to maintain blood glucose levels and postpone exhaustion, and electrolytes (mainly NaCl) to improve palatability and lower the risk of hyponatremia. During activity, 600-1200mlhT of 4-8 percent carbohydrate solutions may be consumed to meet both fluid and carbohydrate needs. During prolonged activity, 0.5-0.7g sodium per liter of water should be consumed to replenish sweat loss. Chorley et al. (2007) found that, weight change provides objective data to help runners make smart fluid consumption decisions to avoid dehydration and overhydration. If marathon runners do not drop 0.75 kg and develop early signs of exercise-associated hyponatremia (EAH), they should seek medical help right once (mild confusion, nausea, vomiting, shortness of breath). Non-elite marathon runners should keep an eye on their sweat rate throughout training and anticipate losing one kilogram of body weight during the race. In the event that they are unable to lose weight, runners should be aware of early EAH symptoms and seek medical assistance if they occur during or after the race.

Other research addressing a possible link between fluid and electrolyte intake and the production of peripheral oedemas contributed to the overwhelming evidence for hyponatremia as triathlon advanced. According to the findings, fluid consumption was linked to changes in limb volumes, with athletes who consumed more fluid seeing an increase in limb volume (Bracher et al., 2012; Kipps et al., 2011; Siegel et al., 2007).

Other research addressing a link between fluid and electrolyte intake and the production of peripheral oedemas contributed to the overwhelming evidence for hyponatremia as triathlon advanced. According to the findings, fluid consumption was linked to changes in limb volumes, with athletes who consumed more fluid seeing an increase in limb volume (Beis et al., 2012; Garth & Burke, 2013; Hue et al., 2014; Tam, 2010). It appears that elite marathoners do not maintain their body mass (BM) within the recommended range of 2% to 3% when competing in successful marathons and that a tolerable degree of dehydration may not be detrimental to performance but may even be helpful since it prevents a significant increase in BM due to excessive consumption.

Other significant publications in this cluster include Glace et al. (2002), Cox et al. (2002), Montain et al. (2006), Bergeron (2007), and Eastwood et al. (2008).

4.1.3 Cluster 2: Olympic Game

Studies in this cluster adopted certain sports events, notably the Olympic Games (i.e., the modern most fantastic international sports competition that held once every four years.), to investigate the physical and physiological characteristics of triathletes and address the specific technical aspects of triathlon and the effect that these characteristics have on exercise metabolism during a triathlon event (Bentley et al., 2002). In other words, the development of a triathlon is primarily affected by the Olympic games. For instance, Lepers, Knechtle, et al. (2013) found that triathlon performance depends on locomotion modes, with lower differences seen in swimming than in cycling and running for both elite and non-elite triathletes. Sex-related differences increase with advancing age, most likely due to physiological, sociological, and psychological changes.

Another related research area explores how triathletes manage their work and energy over a triathlon event or exercise task using diverse pacing strategies (Abbiss & Laursen, 2008). Several studies supported this, including Mattern et al. (2001), who employed a cycling time trial (TT) with thirteen United States Cycling Federation male cyclists (aged 19 ± 29 years) in which they were required to complete a 20 km TT. Based upon differences in Volume of expired air (V_E), VO_2, Respiratory exchange ratio (RER), Rating of perceived exertion (RPE), and Heart rate (HR) during the first 4 minutes, Mattern et al. interpreted these data to indicate that manipulation of starting strategy did impact these variables. The (self-selected) SS (time trial) TT yielded higher blood lactic acid (LA) concentrations after the start phase. These more increased initial blood LA values may have resulted in early fatigue, affecting the subjects' ability to maintain their VO_2 or VO_2 concerning LAT and PO later in the event. The findings of this research match other sports' pacing data. In both running and swimming, a high beginning workload during an endurance sport leads to higher LA concentrations in the blood. This seems to impede athletes' capacity to maintain a high intensity, resulting in poor performance (McCabe & Sanders, 2012; Robinson et al., 1958; Staab et al., 1992). Robinson et al. (1958) observed that a rapid start resulted in greater post-exercise LA levels. The authors determined that for a 0.75-mile run; it was best to run the first half at a little slower than average pace. In a 30-minute simulated running race, Staab et al. (1992) observed that a high starting workload yielded greater LA values than an equal pace. McCabe and Sanders (2012) have advised 1500 m freestyle swimmers to use a negative split strategy (swim the second half faster than the first) to reduce the amount of LA accumulated early in the race. Our research shows that 10 out of 13 riders accomplished their quickest time during the 15% TT.

Based on these findings, we found an increasing focus on strategic aspects that may affect performance in the Olympic distance triathlon. Several studies have examined the benefits of drafting in triathlon events.

Chatard et al. (1998) found that drafting allows the swimmer to reduce the energy cost of swimming propulsion and gain time for swimming at maximal speed. Bassett Jr et al. (1991) found that drafting altered metabolic responses to swimming in submaximal settings, i.e., 95 percent of peak speed across a 549-m swim. The rate of perceived effort was lowered by 21–12%, and oxygen intake by 8–12%. Swimming in a drafting stance reduces hydrodynamic drag. The lead swimmer's sinking in the water seems to be the critical component in reducing body drag (Chatard & Wilson, 2003). In triathlon, another parameter taken into consideration is wearing a wetsuit. Delextrat et al. (2003) demonstrated a significant decrease in heart rate (7%) in drafting during a 750-m race where the 'draftees' wear a wetsuit. In addition, Mollendorf et al. (2004) evidenced the possibility that bodysuits that cover the torso and legs (i.e., as in triathlon) could reduce drag and improve the performance of swimmers. Other relevant publications in this cluster include Heiden and Burnett (2003), Millet and Bentley (2004), Chapman et al. (2009), Chapman et al. (2008), and Cox et al. (2010).

4.1.4 Cluster 3: Muscle Damage

This cluster is based on Neubauer et al. (2008) and Gomez-Merino et al. (2006), who found muscle damage a prominent feature in triathlon research. Using damage as the primary variable, studies in this cluster are primarily grounded by a multimodality framework that views damage during triathlon as taking various forms, including electrolyte imbalance, inflammation, muscular stress, etc. (Baur et al., 2016; Coso et al., 2012; Neubauer et al., 2008). To fully understand muscle injury during the triathlon, it is essential to comprehend a combination of these stressors. There is an array of studies supporting the multimodality of muscle damage. For instance, Bassit et al. (2010) investigated the protective effect of short-term creatine supplementation (CrS) upon plasma markers of injury in skeletal muscle (CK) and liver glutamic oxaloacetic acid transaminase (GOT), glutamic pyruvic acid transaminase (GPT). A more significant increase of plasma C-reactive protein (CRP) levels in triathletes was observed, which may be associated with damage in non-skeletal muscle tissue. Therefore, the results presented herein suggest that short-term CrS before an Ironman competition attenuates exercise-induced muscle injury. Specifically, Gillum et al. (2006) that the completion of a half Ironman triathlon is dependent on a high rate of whole-body CHO oxidation and muscle glycogenolysis, and rates of muscle glycogen resynthesis may be dampened during the recovery from such an event by the eccentric damage resulting from the run portion of the race. Lastly, both male and female triathletes showed a statistically significant increase in 8-OHdG (blood biomarkers, 8-hydroxy-2′-deoxyguanosine), with Zainudin et al. (2019) arguing that indicates that there could be increased evidence of DNA damage among triathletes.

Furthermore, triathlon assessments of body composition and muscle damage are influenced by different technical methods. These techniques include reference methods (Liang & Lauterbur, 2000; Martin et al., 1992; Martin et al., 1985; Martin et al., 1990; Runge et al., 2009), laboratory methods(Bellisari & Roche, 2005; Brozek, 1963; Bullen et al., 1965; Wang et al., 2010; Wells et al., 2007) and field methods (Ackland et al., 2012; Matthie, 2008; Müller, 2009). In terms of the reference methods, Wang et al. (2010) evaluated DXA value by elemental composition and DXA % fat by the five-component (5C) model, giving the first comprehensive examination of the fundamental and related physical basis for the DXA value upon which DXA body composition calculations are based. A complete understanding is achievable when considering DXA foundation models in the context of whole-body composition research. In terms of the laboratory methods, with the BOD POD Body Composition System and hydrostatic weighing, Vescovi et al. (2002) evaluated the accuracy of plethysmography in estimating body fat from hydrostatic weight by air displacement plethysmography (ADP). According to the study, ADP overstated percent body fat in female athletes by 8% and a slimmer group by 16%. Vescovi et al. (2002) stated that coaches and trainers should consider SF before ADP when evaluating body composition in female college athletes.

Additionally, they recommend that sports scientists continue to examine any possible bias in ADP caused by gender and body composition. With field methods, Nevill et al. (2010) identify when body mass index (BMI) is not a valid measure of adiposity in athletes, and they propose an adjustment to allow the BMI of athletes to reflect the adiposity commonly associated with non-athletes. According to the contrasting associations, they calculated the BMI of athletes using the same adiposity related to age-matched controls. Additionally, they argued that this simple adjustment allows the BMI of athletes and non-athletes to be used with increased confidence in epidemiological research examining the effect of BMI.

4.1.5 Cluster 4: Ultradistance triathlon

Ultra-endurance refers to activities that last over six hours, such as ultramarathon and ultra-triathlon events, long-distance swimming, ultra-cycling, and cross-country skiing. (Scheer, 2019). The ultra-endurance triathlon (UET) is a three-sport event that comprises a 3.8-kilometer swim, a 180-kilometer cycle ride, and a 42.2-kilometer marathon run (Laursen & Rhodes, 2001). Many researchers have looked at how elements like extended exercise's fluid and substrate need lead to a lower exercise intensity during UET performance. (Anderson et al., 1994; Applegate, 1991; Coyle, 1994; Coyle & Montain, 1992; Speedy et al., 1999) According to Applegate (1991), these athletes' high caloric expenditures need an ample supply of fuel from all sources, including carbohydrate (CHO), fat, and protein. Ultra-distance triathlon, for example, requires a significant amount of energy expenditure, and the ability to sustain a consistent performance depends on an appropriate supply of metabolic fuels (R. B. Kreider, 1991; Laursen & Rhodes, 1999). Intense activity (over 60% VO2max) may be sustained for extended periods if enough CHO is available for energy (Coyle, 1994). If enough CHO is available for energy, intense activity (over 60% VO2max) may be sustained for lengthy periods (Fallowfield et al., 1995; Rauch et al., 1999). The preservation of fluid and electrolyte balance is the second fundamental problem arising from the prolonged duration of the triathlon. Dehydration is caused by bodily water loss via sweating, which hinders the heat dissipation process, resulting in raised deep body (core) temperatures and decreased endurance performance (Coyle & Montain, 1992). Most recently, Speedy et al. (1999) that 73% of athletes with severe hyponatremia gained or kept their weight, indicating that fluid overload contributes to hyponatremia. Considering the decreased renal function, it has been postulated that the retained fluid is kept in the extracellular space.

The anaerobic threshold (AT) has been widely researched regarding ultra-triathlons and its component sports of swimming, cycling, and running (Borg, 1982; Dengel et al., 1989; Farber et al., 1991; G. G. Sleivert & Wenger, 1993).

The swim component is not a crucial stage in overall triathlon performance since it accounts for less than 10% of total triathlon time and has no statistically meaningful association with overall triathlon performance (Dengel et al., 1989). However, triathlon swimmers must exert physical effort. A lower percentage of VO_{2max} has been reported to be required to reach a rating of perceived exertion during swimming than in cycling (Borg, 1982), and triathlon swimmers' lactate levels are highest during the swim leg of the event (Farber et al., 1991; Faria, 1992).

The capacity of a cyclist to sustain an exceptionally high rate of energy expenditure over an extended period while maintaining a high economy of effort is incredibly reliant on their AT. (Coyle, 1995; Fallowfield et al., 1995). Both Neumayr et al. (2003) and O'toole (1987) independently reported that the cycling phase of the Hawaiian Ironman is completed at a heart rate of roughly 75% of the maximum heart rate. The O'Toole research also discovered that during maximal cycle ergometry testing, 75% of HRmax correlated to HR at T_{vent}, implying that athletes do the cycling phase of the Ironman at a level that approximates HRT_{vent}. The association between VO_{2max} and triathlon run performance has been studied in the running segment. Butts et al. (1991) reported a strong relationship between VO_{2max} and triathlon run time (r = 0.84) during an Olympic distance triathlon in a heterogeneous sample of triathletes. G. G. Sleivert and Wenger (1993) noted substantial relationships between the speed at T_{vent} and triathlon run time during a short-course triathlon in both males (r = 0.73) and females (r = 0.88). A half-Ironman competition results in a lesser relationship between treadmill run VO2max and run time (r = 0.55; p > 0.05). (Dengel et al., 1989). As a result, having a high aerobic capacity is associated with better performance among people with varying fitness degrees. The ability to maintain high fractional utilization of VO2max over a sustained period determines endurance running version in more highly trained athletes (Farrell et al., 1979; Sjodin & Svedenhag, 1985). Triathletes have been found to have running thresholds ranging from 70 to 85 percent of their maximum oxygen uptake (VO_{2max}) (De Vito et al., 1995; Schneider et al., 1990; G. G. Sleivert & Wenger, 1993). De Vito et al. (1995) and Zhou et al. (1997) independently reported a strong correlation between T_{vent} run speed and run time (r =–0.85) during Olympic distance triathlons. In contrast, the relationships between T_{vent} run speed and UET marathon run performance are demonstrated to be reduced (r=–0.76) according to Langill (1993).

4.2 Journal co-citation analysis

The JCA identified *Medicine and Science in Sports and Exercise* as the journal with the most extended burst duration (10 years), followed by *European Journal of Applied Physiology* (9 years), and *Annals of Sports Medicine and Research*, *Journal of Athletic Training, International Journal of Sports Physiology and Performance* (8 years). Four journals, including *The Journal of Strength & Conditioning Research* (strength =10.9), had a burst span of seven years. The journal with the enormous burst was *Annals of Sports Medicine and Research* (strength =18.07, 1996–2004). *Medicine and Science in Sports and Exercise* (strength =15.68, 1996–20006) had the second-largest burst, followed by *European Journal of Applied Physiology* (strength=14.66, 1996–2005). The journals with the most recent high burstness are *International Journal of Sports Physiology and Performance*, *Scandinavian Journal of Medicine & Science in Sports*, and *Frontiers in Physiology*, which, among other subjects, aim to advance the knowledge of the sport and exercise physiologists, sport performance researchers, and other sport scientists in the field of sports physiology and performance.

5 Implications of the study

The study makes three critical advances compared with previous bibliometric research on triathlon (Holt & Holden, 2018; G. P. Millet & V. E. Vleck, 2000; Wu et al., 2014). First, in Scientometrics' text-mining and clustering algorithms, we were able to identify interrelationships between the triathlon specialization and other sports science domains. The dual-map overlay revealed that triathlon research in sport sciences had the most ties to sports and natural sciences research and some relationship to neurology, rehabilitation, medicine, genetics, and biology. While significant linkages across disciplines imply a well-established and sometimes routine interaction, weak ties might signal the beginnings of interdisciplinary study or a change in researchers' focus from inside the area to outside. This pattern may signal the beginning of a progressive paradigm change (Shapere, 1964) and the onset of a new conceptualization stage (Chen et al., 2009). While the simple citation of publications from other disciplines cannot be considered proof of paradigm changes, it may be seen as evidence that a group of sports researchers has drawn inspiration from different domains, which is a required (but inadequate) component of a paradigm shift.

Second, several distinct yet interconnected clusters of triathlon research have been identified since 1902, each marked by a series of bursts. For the first time, hidden chronological patterns in this area have been identified, allowing researchers to investigate how the field has changed through time. The progression of the clusters over time indicates the stages of evolution of the specialty. In many publications in each cluster, theoretical frameworks from other clusters are adopted or drawn upon, which suggests that the specialty of triathlon in sport sciences has reached what defined as the "instrument building stage," characterized by the application of new tools and methods in research to generate new insights and detect anomalies. Furthermore, the clusters' end date may be considered knowledge codification, which is defined by "poor productivity of knowledge" and routinization of research (Chen & Song, 2017), where cluster-specific knowledge and discovery products dwindle and finally terminate (Chen & Song, 2017). Due to this, cluster #2 (Olympic Games) and cluster #3 (muscle damage) are considered the current frontiers of triathlon research in sport sciences, as both continue to flourish. In Cluster 3, the third stage of a revolution involves applying instruments and frameworks beyond science. According to Chen (2017), when interdisciplinary approaches emerge in a cluster of knowledge domains outside of information science, such as regenerative medical medicine and strategic management research, it will be considered a Stage III specialization. The specialty's instruments are being applied to other subjects. Despite this, the pattern of theoretical frameworks transfer from cluster #7 to other clusters is interdisciplinary, and further investigation is warranted to understand its impact on other relevant fields.

Third, we identified several publications that crossed multiple clusters. It's critical to recognize an article's potential for making outstanding or unexpected connections across different clusters. Theoretically, science's most remarkable contributions result from boundary-spanning ideas (Chen, 2017). There may be a correlation between these publications' intellectual base (the cited publications of the cluster) and the topics addressed in other clusters (Chen, 2017), or vice versa. It is essential to carefully examine the methodology and frameworks of publications of this kind, as they have considerable potential for transformation. The three main implications of this study provide a framework for future research in scientometrics and bibliometrics within triathlon and sports sciences.

6 Conclusion

In conclusion, the scientometric technique utilized in this study demonstrated the dynamic nature of triathlon research in sports sciences. We could map the specialty borders, linkages between articles in the corpus, and notable research trends by using visualization and co-citation methods. The development of triathlon across all relevant specialties would be a fascinating study focus for the future. This would be a large-scale investigation on the advancement and decline of significant research trends across disciplines.

References

Abbiss, C. R., & Laursen, P. B. (2008). Describing and understanding pacing strategies during athletic competition. *Sports Medicine, 38*(3), 239-252.

Ackland, T. R., et al. (2012). Current status of body composition assessment in sport. *Sports Medicine, 42*(3), 227-249.

Alexander, S. J. (2011). *A review of athletes presenting for medical assistance at the 2011 Ironman South Africa triathlon event.* UNIVERSITY OF WITWATERSRAND JOHANNESBURG SOUTH-AFRICA,

Anderson, M., et al. (1994). Preexercise meal affects ride time to fatigue in trained cyclists. *Journal of the American Dietetic Association, 94*(10), 1152-1154.

Applegate, E. A. (1991). Nutritional considerations for ultraendurance performance. *International Journal of Sport Nutrition and Exercise Metabolism, 1*(2), 118-126.

Ball, S. D., et al. (2004). Comparison of anthropometry to DXA: a new prediction equation for men. *European journal of clinical nutrition, 58*(11), 1525-1531.

Bar-Ilan, J. (2008). Which h-index?—A comparison of WoS, Scopus and Google Scholar. *Scientometrics, 74*(2), 257-271.

Bassett Jr, D. R., et al. (1991). Metabolic responses to drafting during front crawl swimming. *Medicine and Science in Sports and Exercise, 23*(6), 744-747.

Bassit, R. A., et al. (2010). Effect of short-term creatine supplementation on markers of skeletal muscle damage after strenuous contractile activity. *European Journal of Applied Physiology, 108*(5), 945-955.

Baur, D. A., et al. (2016). Fluid retention, muscle damage, and altered body composition at the Ultraman triathlon. *European Journal of Applied Physiology, 116*(3), 447-458.

Beis, L. Y., et al. (2012). Drinking behaviors of elite male runners during marathon competition. *Clinical Journal of Sport Medicine, 22*(3), 254-261.

Bellisari, A., & Roche, A. (2005). Anthropometry and ultrasound. *Human body composition, 2*, 109-128.

Bentley, D. J., et al. (2002). Specific aspects of contemporary triathlon. *Sports Medicine, 32*(6), 345-359.

Bergeron, M. F. (2007). Exertional heat cramps: recovery and return to play. *Journal of sport rehabilitation, 16*(3).

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & science in sports & exercise*.

Boussana, A., et al. (2001). The effect of exercise modality on respiratory muscle performance in triathletes. *Medicine and Science in Sports and Exercise, 33*(12), 2036-2043.

Bracher, A., et al. (2012). Fluid intake and changes in limb volumes in male ultra-marathoners: does fluid overload lead to peripheral oedema? *European Journal of Applied Physiology, 112*(3), 991-1003.

Brozek, J. (1963). Densitometric analysis of body composition: revision of some quantitative assumptions. *Ann NY Acad Sci, 110*, 113-140.

Bullen, B. A., et al. (1965). Ultrasonic reflections used for measuring subcutaneous fat in humans. *Human Biology*, 375-384.

Butts, N., et al. (1991). Correlations between VO2max and performance times of recreational triathletes. *The Journal of sports medicine and physical fitness, 31*(3), 339-344.

Chapman, A. R., et al. (2008). Patterns of leg muscle recruitment vary between novice and highly trained cyclists. *Journal of Electromyography and Kinesiology, 18*(3), 359-371.

Chapman, A. R., et al. (2009). A protocol for measuring the direct effect of cycling on neuromuscular control of running in triathletes. *Journal of Sports Sciences, 27*(7), 767-782.

Chatard, J.-C., et al. (1998). Performance and drag during drafting swimming in highly trained triathletes. *Medicine and Science in Sports and Exercise, 30*(8), 1276-1280.

Chatard, J.-C., & Wilson, B. (2003). Drafting distance in swimming. *Medicine and Science in Sports and Exercise, 35*(7), 1176-1181.

Chen, C. (2004). Searching for intellectual turning points: Progressive knowledge domain visualization. *Proceedings of the National Academy of Sciences, 101*(suppl 1), 5303-5310.

Chen, C. (2013). *Mapping scientific frontiers: The quest for knowledge visualization*: Springer Science & Business Media.

Chen, C. (2016). *CiteSpace: a practical guide for mapping scientific literature*: Nova Science Publishers New York.

Chen, C. (2017). Science mapping: a systematic review of the literature. *Journal of data and information science, 2*(2).

Chen, C., et al. (2009). Towards an explanatory and computational theory of scientific discovery. *Journal of Informetrics, 3*(3), 191-209.

Chen, C., et al. (2010). The structure and dynamics of cocitation clusters: A multiple-perspective cocitation analysis. *Journal of the American Society for information Science and Technology, 61*(7), 1386-1409.

Chen, C., & Leydesdorff, L. (2014). Patterns of connections and movements in dual-map overlays: A new method of publication portfolio analysis. *Journal of the association for information science and technology, 65*(2), 334-351.

Chen, C., & Song, M. (2017). *Representing scientific knowledge*: Springer.

Chorley, J., et al. (2007). Risk factors for exercise-associated hyponatremia in non-elite marathon runners. *Clinical Journal of Sport Medicine, 17*(6), 471-477.

Cohen, L., & Zimmerman, A. (1978). Changes in serum electrolyte levels during marathon running. *South African Medical Journal, 53*(12), 449-453.

Coso, J. D., et al. (2012). Muscle damage and its relationship with muscle fatigue during a half-iron triathlon.

Cox, G. R., et al. (2002). Effect of different protocols of caffeine intake on metabolism and endurance performance. *Journal of Applied Physiology*.

Cox, G. R., et al. (2010). Race-day carbohydrate intakes of elite triathletes contesting olympic-distance triathlon events. *International Journal of Sport Nutrition and Exercise Metabolism, 20*(4), 299-306.

Coyle, E. F. (1994). Fluid and carbohydrate replacement during exercise: How much and why? *Sports Sci Exch, 7*, 1-7.

Coyle, E. F. (1995). Integration of the physiological factors determining endurance performance ability. *Exercise and sport sciences reviews, 23*, 25-63.

Coyle, E. F., & Montain, S. J. (1992). Carbohydrate and fluid ingestion during exercise: are there trade-offs? *Medicine and Science in Sports and Exercise, 24*(6), 671-678.

De Vito, G., et al. (1995). Decrease of endurance performance during Olympic triathlon. *International Journal of Sports Medicine, 16*(01), 24-28.

Deerwester, S., et al. (1990). Indexing by latent semantic analysis. *Journal of the American society for information science, 41*(6), 391-407.

Delextrat, A., et al. (2003). Drafting during swimming improves efficiency during subsequent cycling. *Medicine and Science in Sports and Exercise, 35*(9), 1612-1619.

Dengel, D. R., et al. (1989). Determinants of success during triathalon competition. *Research Quarterly for Exercise and Sport, 60*(3), 234-238.

Eastwood, A., et al. (2008). Stability of hemoglobin mass over 100 days in active men. *Journal of Applied Physiology, 104*(4), 982-985.

Etxebarria, N., et al. (2019). Training and competition readiness in triathlon. *Sports, 7*(5), 101.

Fallowfield, J. L., et al. (1995). The influence of ingesting a carbohydrate-electrolyte beverage during 4 hours of recovery on subsequent endurance capacity. *International Journal of Sport Nutrition and Exercise Metabolism, 5*(4), 285-299.

Farber, H. W., et al. (1991). The endurance triathlon: metabolic changes after each event and during recovery. *Medicine and Science in Sports and Exercise, 23*(8), 959-965.

Faria, I. E. (1992). Energy expenditure, aerodynamics and medical problems in cycling. *Sports Medicine, 14*(1), 43-63.

Farrell, P. A., et al. (1979). Plasma lactate accumulation and distance running performance. *Med Sci Sports, 11*(4), 338-344.

Fortunato, S., et al. (2018). Science of science. *Science, 359*(6379), eaao0185.

García-Pinillos, F., et al. (2016). Physiological and neuromuscular response to a simulated sprint-distance triathlon: effect of age differences and ability level. *The Journal of Strength & Conditioning Research, 30*(4), 1077-1084.

Garth, A. K., & Burke, L. M. (2013). What do athletes drink during competitive sporting activities? *Sports Medicine, 43*(7), 539-564.

Ghasemi, H., et al. (2021). Analysis of Sport Marketing Researchers in Google Scholar. *Research in Sport Management and Marketing, 2*(1), 24-32.

Gillum, T. L., et al. (2006). Muscle glycogenolysis and resynthesis in response to a half Ironman triathlon: a case study. *International Journal of Sports Physiology and Performance, 1*(4), 408-413.

Glace, B., et al. (2002). Food and fluid intake and disturbances in gastrointestinal and mental function during an ultramarathon. *International Journal of Sport Nutrition and Exercise Metabolism, 12*(4), 414-427.

Gomez-Merino, D., et al. (2006). Comparison of systemic cytokine responses after a long distance triathlon and a 100-km run: relationship to metabolic and inflammatory processes. *European Cytokine Network, 17*(2), 117-124.

Guevara, S. A., et al. (2020). 077 Injury and illness epidemiology and risk factors in short course triathlon: a systematic review. *British Journal of Sports Medicine, 54*(Suppl 1), A34-A34.

Guezennec, C. Y., et al. (1996). Increase in energy cost of running at the end of a triathlon. *European Journal of Applied Physiology and Occupational Physiology, 73*(5), 440-445. doi:10.1007/bf00334421

Gutiérrez García, C., et al. (2018). A bibliometric review of scientific production on aikido from the 1970s to today.

Hausswirth, C., et al. (1997). Relationships between running mechanics and energy cost of running at the end of a triathlon and a marathon. *International Journal of Sports Medicine, 18*(05), 330-339.

Hausswirth, C., et al. (2000). Evolution of electromyographic signal, perceived exertion and running economy during different types of prolonged exercises. *Int J Sports Med, 21*, 1-8.

Hayashi, D., et al. (2015). *Multimodality imaging of upper and lower extremity injuries in triathlon-a pictorial review*.

Heiden, T., & Burnett, A. (2003). Triathlon: The effect of cycling on muscle activation in the running leg of an Olympic distance triathlon. *Sports Biomechanics, 2*(1), 35-49.

Hérubel, J.-P. V. (1999). Historical bibliometrics: Its purpose and significance to the history of disciplines. In: JSTOR.

Hew-Butler, T., et al. (2007). Maintenance of plasma volume and serum sodium concentration despite body weight loss in ironman triathletes. *Clinical Journal of Sport Medicine, 17*(2), 116-122.

Holt, E., & Holden, A. (2018). A risk-benefit analysis of maintaining an aerobic-endurance triathlon training program during pregnancy: a review. *Science & Sports, 33*(5), e181-e189.

Hue, O., et al. (2014). A pilot study on how do elite surfski padllers manage their effort and hydration pattern in the heat. *Biology of Sport, 31*(4), 283.

Jiménez-García, M., et al. (2020). A bibliometric analysis of sports tourism and sustainability (2002–2019). *Sustainability, 12*(7), 2840.

Khoo, S., et al. (2021). Sport and exercise psychology research from the Asian and South Pacific region: A bibliometric analysis. *Asian Journal of Sport and Exercise Psychology, 1*(1), 21-29.

Kienstra, C. M., et al. (2017). Triathlon injuries: Transitioning from prevalence to prediction and prevention. *Current Sports Medicine Reports, 16*(6), 397-403.

Kimber, N. E., et al. (2002). Energy balance during an ironman triathlon in male and female triathletes. *International Journal of Sport Nutrition and Exercise Metabolism, 12*(1), 47-62.

Kipps, C., et al. (2011). The incidence of exercise-associated hyponatraemia in the London marathon. *British Journal of Sports Medicine, 45*(1), 14-19.

Kleinberg, J. (2003). Bursty and hierarchical structure in streams. *Data mining and knowledge discovery, 7*(4), 373-397.

Kreider, et al. (1988). CARDIOVASCULAR AND THERMAL RESPONSES OF TRIATHLON PERFORMANCE. *Medicine and Science in Sports and Exercise, 20*(4), 385-390. doi:10.1249/00005768-198808000-00010

Kreider, R. B. (1991). Physiological considerations of ultraendurance performance. *International Journal of Sport Nutrition and Exercise Metabolism, 1*(1), 3-27.

Langill, R. H. (1993). *Prediction of triathon performance from ventilatory threshold measurements.* University of British Columbia,

Laursen, P. B., & Rhodes, E. C. (1999). Physiological analysis of a high intensity ultraendurance event. *Strength & Conditioning Journal, 21*(1), 26.

Laursen, P. B., & Rhodes, E. C. (2001). Factors affecting performance in an ultraendurance triathlon. *Sports Medicine, 31*(3), 195-209.

Laursen, P. B., et al. (2000). The effects of 3000-m swimming on subsequent 3-h cycling performance: implications for ultraendurance triathletes. *European Journal of Applied Physiology, 83*(1), 28-33.

Laursen, P. B., et al. (2006). Core temperature and hydration status during an Ironman triathlon. *British Journal of Sports Medicine, 40*(4), 320-325.

Lawrence, E. (1996). Exercise and fluid replacement. *Med. Sci. Sports Exerc, 28*.

Le Gallais, D., et al. (1998). Effect of a classic triathlon on blood lactate concentrations during a graded exercise test. *Science & Sports, 13*(6), 275-277. doi:10.1016/s0765-1597(99)80005-7

Le Meur, Y., et al. (2009). Influence of gender on pacing adopted by elite triathletes during a competition. *European Journal of Applied Physiology, 106*(4), 535-545.

Lepers, R. (2019). Sex difference in triathlon performance. *Frontiers in Physiology*, 973.

Lepers, R., et al. (2013). Trends in triathlon performance: effects of sex and age. *Sports Medicine, 43*(9), 851-863.

Lepers, R., et al. (2013). Relative improvements in endurance performance with age: evidence from 25 years of Hawaii Ironman racing. *Age, 35*(3), 953-962.

Leydesdorff, L., & Milojević, S. (2012). Scientometrics. *arXiv preprint arXiv:1208.4566*.

Liang, Z.-P., & Lauterbur, P. C. (2000). *Principles of magnetic resonance imaging: a signal processing perspective*: "The" Institute of Electrical and Electronics Engineers Press.

Martin, A., et al. (1992). Effects of skin thickness and skinfold compressibility on skinfold thickness measurement. *American journal of human biology, 4*(4), 453-460.

Martin, A., et al. (1985). Prediction of body fat by skinfold caliper: assumptions and cadaver evidence. *International journal of obesity, 9*, 31-39.

Martin, A., et al. (1990). Anthropometric estimation of muscle mass in men. *Medicine and Science in Sports and Exercise, 22*(5), 729-733.

Mattern, C., et al. (2001). Impact of starting strategy on cycling performance. *International Journal of Sports Medicine, 22*(05), 350-355.

Matthie, J. R. (2008). Bioimpedance measurements of human body composition: critical analysis and outlook. *Expert review of medical devices, 5*(2), 239-261.

McCabe, C. B., & Sanders, R. H. (2012). Kinematic differences between front crawl sprint and distance swimmers at a distance pace. *Journal of Sports Sciences, 30*(6), 601-608.

Millet, & Vleck. (2000). biomechanical adaptations to the cycle to run transition in Olympic triathlon: review and practical recommendations for training. *The British Journal of Sports Medicine*.

Millet, G. P., & Bentley, D. J. (2004). The physiological responses to running after cycling in elite junior and senior triathletes. *International Journal of Sports Medicine, 25*(03), 191-197.

Millet, G. P., & Vleck, V. E. (2000). Physiological and biomechanical adaptations to the cycle to run transition in Olympic triathlon: review and practical recommendations for training. *British Journal of Sports Medicine, 34*(5), 384-390.

Miura, H., et al. (1997). Economy during a simulated laboratory test triathlon is highly related to Olympic distance triathlon. *International Journal of Sports Medicine, 18*(4), 276-280. doi:10.1055/s-2007-972633

Mollendorf, J. C., et al. (2004). Effect of swim suit design on passive drag. *Medicine and Science in Sports and Exercise, 36*(6), 1029-1035.

Montain, S., et al. (2006). Exercise associated hyponatraemia: quantitative analysis to understand the aetiology. *British Journal of Sports Medicine, 40*(2), 98-105.

Müller, W. (2009). Towards research-based approaches for solving body composition problems in sports: ski jumping as a heuristic example. *British*

Journal of Sports Medicine, 43(13), 1013-1019.

Neubauer, O., et al. (2008). Recovery after an Ironman triathlon: sustained inflammatory responses and muscular stress. *European Journal of Applied Physiology, 104*(3), 417-426.

Neumayr, G., et al. (2003). Heart rate response to ultraendurance cycling. *British Journal of Sports Medicine, 37*(1), 89-90.

Nevill, A. M., et al. (2010). Adjusting athletes' body mass index to better reflect adiposity in epidemiological research. *Journal of Sports Sciences, 28*(9), 1009-1016.

Noakes, T. (2003). Fluid replacement during marathon running. *Clinical Journal of Sport Medicine, 13*(5), 309-318.

O'toole, M. (1987). Cardiovascular responses to prolonged cycling and running. *Annals of Sports Medicine., 3*, 124-130.

O'toole, M., et al. (1989). Lactate, oxygen uptake, and cycling performance in triathletes. *International Journal of Sports Medicine, 10*(06), 413-418.

O’Toole, M. L., & Douglas, P. S. (1995). Applied physiology of triathlon. *Sports Medicine, 19*(4), 251-267.

Olmedilla, A., et al. (2018). Psychological profiling of triathlon and road cycling athletes. *Frontiers in Psychology, 9*, 825.

Phillips, P., & Newland, B. (2014). Emergent models of sports development and delivery: The case of triathlon in Australia and the US. Sport Management Review, 17, 107–120. In.

Prieto, J., et al. (2015). A bibliometric review of the scientific production in handball. *Cuadernos de psicología del deporte, 15*(3), 145-154.

Rauch, H., et al. (1999). Effects of ingesting a sports bar versus glucose polymer on substrate utilisation and ultra-endurance performance. *International Journal of Sports Medicine, 20*(04), 252-257.

Robinson, S., et al. (1958). Influence of fatigue on the efficiency of men during exhausting runs. *Journal of Applied Physiology, 12*(2), 197-201.

Runge, V. M., et al. (2009). *The physics of clinical MR taught through images*: Springer.

Schabort, E. J., et al. (2000). Prediction of triathlon race time from laboratory testing in national triathletes. *Medicine and Science in Sports and Exercise, 32*(4), 844-849. doi:10.1097/00005768-200004000-00018

Scheer, V. (2019). Participation trends of ultra endurance events. *Sports Medicine and Arthroscopy Review, 27*(1), 3-7.

Schneider, D., et al. (1990). Ventilatory threshold and maximal oxygen uptake during cycling and running in triathletes. *Medicine and Science in Sports and Exercise, 22*(2), 257-264.

Shapere, D. (1964). The structure of scientific revolutions. *The Philosophical Review, 73*(3), 383-394.

Sharwood, K., et al. (2002). Weight changes, sodium levels, and performance in the south African Ironman Triathlon. *Clinical Journal of Sport Medicine, 12*(6), 391-399. doi:10.1097/00042752-200211000-00012

Siegel, A. J., et al. (2007). Hyponatremia in marathon runners due to inappropriate arginine vasopressin secretion. *The American journal of medicine, 120*(5), 461. e411-461. e417.

Sjodin, B., & Svedenhag, J. (1985). Applied physiology of marathon running. *Sports Medicine, 2*(2), 83-99.

Sleivert, & Rowlands. (1996). Physical and physiological factors associated with success in the triathlon. *Sports Medicine, 22*(1), 8-18. doi:10.2165/00007256-199622010-00002

Sleivert, G. G., & Wenger, H. A. (1993). Physiological predictors of short-course triathlon performance. *Medicine and Science in Sports and Exercise, 25*(7), 871-876.

Speedy, D. B., et al. (2001). Fluid balance during and after an ironman triathlon. *Clinical Journal of Sport Medicine, 11*(1), 44-50.

Speedy, D. B., et al. (1999). Hyponatremia in ultradistance triathletes. *Medicine and Science in Sports and Exercise, 31*(6), 809-815.

Staab, J. S., et al. (1992). Metabolic and performance responses to uphill and downhill running in distance runners. *Medicine and Science in Sports and Exercise, 24*(1), 124-127.

Suzuki, S., et al. (1982). EMG activity and kinematics of human cycling movements at different constant velocities. *Brain Research, 240*(2), 245-258.

Tam, N. (2010). *The maintenance of Body Fluid Homestasis during exercise when drinking ad Libitum.* University of Cape Town,

Vescovi, J. D., et al. (2002). Evaluation of the BOD POD for estimating percent fat in female college athletes. *The Journal of Strength & Conditioning Research, 16*(4), 599-605.

Wang, Z., et al. (2010). Estimation of percentage body fat by dual-energy x-ray absorptiometry: evaluation by in vivo human elemental composition. *Physics in Medicine & Biology, 55*(9), 2619.

Wells, J. C., et al. (2007). BMI compared with 3-dimensional body shape: the UK National Sizing Survey. *The American journal of clinical nutrition, 85*(2), 419-425.

Wu, S. S., et al. (2014). Factors influencing pacing in triathlon. *Open Access Journal of Sports Medicine, 5*, 223.

Zainudin, H., et al. (2019). Training induced oxidative stress-derived DNA and muscle damage in triathletes. *The Eurasian journal of medicine, 51*(2), 116.

Zhou, S., et al. (1997). Correlations between short-course triathlon performance and physiological variables determined in laboratory cycle and treadmill tests. *The Journal of sports medicine and physical fitness, 37*(2), 122-130.