

Structure and trends of international sport nutrition research between 2000-2018: bibliometric mapping of sport nutrition science

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Abstract

Background : The tool kits of bibliometrics and science mapping provide a standard methodology to map the knowledge base of specific fields of science. The aim of the present research is the analysis of the recent international trends of sport nutrition science, as well as the primary identification of the research topics and results of sport nutrition science via enhanced bibliometric methods for the 2000-2018 time period.

Methods: Altogether, 3889 publications were included in this study. We identified the most relevant sport nutrition topics by running a community detection algorithm on the proximity network constructed via bibliographic coupling. The key issues and key concepts of sport nutrition topics as well as their relations were evaluated via network analysis. We also carried a chronological analysis of topics out, and a scientometric evaluative analysis was also created.

Results: We identified the four main basic groups from which the 18 most characteristics topics were analyzed. The 18 topics are the following: Football and physiology; Carbohydrate metabolism; Muscle physiology: Alkalosis and Acidosis; Muscle power enhancement and dietary supplementation; Fluid balance and hydration; Dietary intake and nutrition knowledge; Assessment of Energy Intake of athletes; Bone health, Female Athlete Triad; Fluid intake strategy; Weight management; Nutritional Strategies and human skeletal muscle; Dietary nitrate supplementation; Oxidative stress and dietary supplement use; Dietary supplement use and doping; Oxidative stress, inflammation and dietary antioxidants; Training adaptation and nutritional strategies; Gut Microbiota; Celiac disease. Based on the size of the topic, research on sport nutrition science has put the biggest emphasis on the following three groups: Muscle power enhancement and dietary supplementation; Carbohydrate metabolism; and Oxidative stress and dietary supplement use. The greatest scientific impact can be ascribed to the following topics: Nutritional strategies and human skeletal muscle; Dietary nitrate supplementation; Weight management; and Gut microbiota.

Conclusions: Scientific output on sport nutrition has continuously been rising between 2000-2018. The ratio of topics related to sport nutrition but first of all connected to basic research has decreased significantly within all publications. The results of this study confirm the role of science mapping in the identification of specific research topics and primary research directions in the field of sport nutrition science.

Background

Sport nutrition science lies at the intersection of numerous vast fields of life sciences, such as nutrition science, clinical-, medical-, and health science, biomedical sciences, sport sciences, and food sciences. Sport nutrition science involves the transfer of knowledge related to physical activity and health, metabolism, body composition, diseases, training, injuries, rehabilitation and performance. Sport nutrition as a research topic has attracted great attention in the scientific literature in the field of sport and exercise

science. Various systematic reviews or meta-analyses have been conducted on numerous aspects of sport nutrition because its complex nature and growing interest worldwide [1, 2, 3, 4, 5, 6]. Apart from the classical, systematic literature review and meta-analyses of the field, there are no large-scale, bibliometric analysis of sport nutrition science. For the experts who work with athletes and for sport nutrition practitioners the application of scientific knowledge is essential; nevertheless, because of the vast range, dynamism, and multidisciplinary nature of this knowledge output, its processing and application are inconceivable without the help of modern information science methods built on international literature databases. These serve as indispensable complementary tools to the standard, literature-synthesizing method, such as the systematic review and meta-analyses. In the hierarchy of the reliability/quality of scientific results in sport medicine and also in sport nutrition science (along the so-called “evidence pyramid”), systematic reviews and meta-analyses – the processing method of randomized, controlled trials (RCTs) – lies at the top of the pyramid [7]. To map the knowledge base of the field of sport nutrition science, science mapping can play an outstanding role alongside meta-analysis. Science mapping is a type of analysis that usually investigates a long time period and the structure of literature databases with several thousand-, ten-, or hundred thousands of items [8]. Through the statistical-network theoretical modeling of the referencing, text-similarity, and authorial relations of the literature, science mapping methods facilitate the exploration of the conceptual- thematical structure, trends and dynamism of the field of science, thus the results of science mapping contribute to the increase of the reliability of scientific results [9, 10].

In sport science, bibliometric analysis has been conducted for the analysis of research trends and for the identification of publications with high impact on the fields of sport psychology [11, 12], sport management [13, 14], sport economy [15] and aging and physical activity [16]; however, the analysis of the trends in sport nutrition science has not been performed to date.

Methodology

Research aims

This present research on the field of sport nutrition science includes (1) the identification of relevant and state-of-the-art literature, (2) the analysis of trends, key topics and key issues in sport nutrition science, and (3) the identification of the recent trends of the key topics in the time period of 2000–2018. Our research is the first to present the key topics of the publications in sport nutrition science of the past ten years and their scientometric characteristics with the help of bibliometric tools (through the analysis of reference networks and text mining).

Data Collection

The core sample (basic documents of the data collection) were obtained from the PubMed medical database with a search from MeSH on the basis of key concepts in “sport nutrition and sport physiology”

for the 2000–2018 time period. The search resulted in a core sample of 372 publications. To extend the information content of the core sample, we used the Web of Science (WoS) database. As a first step, we identified the articles citing the core sample on the basis of WoS records, then we incorporated them into the database (n = 1909). Alongside those citing the core, we also identified the publications cited by the core sample (n = 1992). Publications were included in the corpus if they received a minimum of two references from the core sample, thus ensuring the inclusion of only relevant topics. After eliminating duplications, the full corpus included 3889 publications (Fig. 1).

After identifying the publications in the full corpus (data collection) we continued with their scientometric evaluation based on citation impact and journal rank. To analyze citation impact, we obtained the impact indicators belonging to the publications of the full corpus from the InCites database, then we expanded the database with the normalized citation impact and the percentile measures. The rank indicators of the journals belonging to the publications in the full corpus were obtained from the InCites and Journal Citation Report (JCR) databases, after which we expanded the database with the citation quartile based on impact factor.

Mathematical-statistical Analysis

The resulting literature corpus was explored through a multi-step methodology combining text mining and bibliometric processes (Fig. 2), which aimed at mapping the structure, trends, key issues and their trends of sport nutrition science.

The applied methodology comprised three parts:

1.

Identification of topics

The thematic similarity of publications was explored through the text similarity of title words and abstracts. With the Natural Language Processing (NLP) method, the compounded text of the titles and abstracts was reduced to key terms characteristic of the articles, and was represented as the sequence or vector of the frequency of these terms in the articles [17]. A similarity matrix of articles (vectors) were then obtained. To demarcate the topic clusters based on article similarity, we derived a graph from the similarity matrix, which we thus considered as a weighed network describing the similarity relations of the publications based on Cosine similarity:

$$\frac{\sum_{i=1}^n x_i y_i}{\sqrt{\sum_{i=1}^n x_i^2 \sum_{i=1}^n y_i^2}}$$

That is the similarity between article x and y , where x and y , where x_i (y_i) is the weight of term i for article x .

The actual clustering was achieved by running a community detection algorithm on this proximity network constructed via bibliographic coupling, in order to delineate coherent groups of papers. The algorithm used was the "Louvain method", implemented in the igraph R package [18].

2.

The exploration of the key issues, key concepts and relations of topics

The inner structure of theme clusters and their thematic relations were explored via network analysis. When modeling the relations of key concepts, we defined the network of the joint occurrence of the so-called authorial key words assigned to the articles in the cluster, where the strength of the relation between concepts is characterized by the relative frequency of their co-occurrence (among the key words of the same article). In this case, it is represented by the Cosine similarity as the measure of proximity (this time between concepts, not between articles). This semantic network obtained for the cluster was then subjected to the community detection procedure referred to in the previous section, i.e. the Louvain method [19]. As a result, the network of key concepts was partitioned into cohesive subtopics defined by strongly and densely related concepts.

To gain a more clear representation of conceptual relations, we analyzed the semantic network along different lines as well. We subjected the proximity network (as a proximity matrix) to a hierarchical cluster analysis method (after converting similarities into distances for that end, and using the "average" method). The main aim of this additional exercise was to obtain an overview of the domain, where the interrelations of the most relevant concepts are analytically (not only visually) demonstrated by the concept tree resulted from the hierarchical clustering. We call this the "tree view" of the cluster.

3.

The identification of the most important publications (core documents)

For the comprehension and expert characterization of topic clusters, we applied a modern bibliometric method, which algorithmically identifies the most characteristic publications of the topic. The method is the so-called "core documents" methodology [20], the essence of which is the identification of documents which show the biggest possible thematic similarity to the biggest possible segment of the theme (defined by a similarity threshold). We created the list of the identified characteristic publications for each cluster along with the description of the cluster.

Results

In the course of clustering, we identified four basic groups, from which we highlighted the most relevant 18 topics.

We present the 18 topic according to the following four aspect: the number of publications in the cluster (the size of the topic), the distribution of the publications based on publication date, the citation measure of the publications and the analysis of rank of publications within each topic.

The 18 topics are the following:

- 1) Football and physiology
- 2) Carbohydrate metabolism
- 3) Muscle physiology: alkalosis and acidosis
- 4) Muscle power enhancement and dietary supplementation
- 5) Fluid balance and hydration
- 6) Dietary intake and nutrition knowledge
- 7) Assessment of energy intake of athletes
- 8) Bone health, female athlete triad
- 9) Fluid intake strategy
- 10) Weight management
- 11) Nutritional Strategies and human skeletal muscle
- 12) Dietary nitrate supplementation
- 13) Oxidative stress and dietary supplement use
- 14) Dietary supplement use and doping
- 15) Oxidative stress, inflammation and dietary antioxidants
- 16) Training adaptation and nutritional strategies
- 17) Gut microbiota
- 18) Celiac disease

Scientometric Characteristics Of Topics

Size distribution of topics

Based on the absolute and relative size of the topics, that is based on the number of publications belonging to a cluster, we can get an insight into the significance of the explored topics and research trends in sport nutrition science. These data are displayed in Fig. 3., which, besides the number of publications in each cluster, also shows their composition in terms of the core publications identified through the targeted search as well as of the publications citing, and those cited by the core sample. In terms of weight (size), the most dominant topic, with ca. 300 publications, is muscle power enhancement and dietary supplementation, followed by topics with about 200–250 publications: Carbohydrate metabolism; Oxidative stress and dietary supplement use; Nutritional modulation of training adaptation; Dietary nitrate supplementation; Nutritional strategies and human skeletal muscle. This group is closely followed by the topic of Bone health, female athlete triad; Dietary intake and nutrition knowledge; and Assessment of energy intake of athletes, with about 200 publications. The group with 100–150 publications is led by the topics Fluid balance and hydration; and Weight management; moreover, here belong the themes of Football and physiology, the also hydration-related fluid intake strategy, as well as Dietary supplement use and doping. In the 50–100 range, the dominant topics with almost 100 publications are Muscle physiology: alkalosis and acidosis; Oxidative stress, inflammation and dietary antioxidants; also here belong the smaller but well-defined topics of Gut microbiota and Celiac disease. The full size of the topics greatly correlates with their role and importance in the core sample; that is, size ranking also reflects the extent to which the cluster is of “sport physiological” nature.

Chronological Distribution Of Topics

The distribution by publication date of the publications belonging to the identified topics, to put it another way, the chronological distribution of each cluster facilitates the assessment of the trends and relevance of each topic, of their “popular” or “winding down” nature. The distribution of the size of the topics is summarized in Fig. 4., which shows the number of documents belonging to each topic starting from 2010. Based on this, the trend graphs in the table provide an overview of the chronological dynamics of the topics. The trend graphs attest that each topic shows a growing tendency (that is, more and more articles appeared on the given topic in the past decade); each cluster is at its maximum size in the last examined year (2018). The differences between the topics appear in the characteristics and pattern of the increase. According to the latter, with a little simplification, we observe two types of increase: (1) the topic increases gradually from the beginning or middle of the decade, (2) after a relative “stagnation”, the topic shows a rising slope in the last few years. Type (1), gradual increase is most characteristic of the topics Muscle physiology: alkalosis and acidosis; Nutritional strategies and human skeletal muscle, Nutritional modulation and training adaptation. Type (2), sudden increase with a more moderate rising slope, spread over the last four-five years, appears in relation with the topics Football and physiology; Energy intake and nutrition knowledge, Nutritional Strategies and human skeletal muscle, fluid balance and hydration, Fluid intake strategy, Oxidative stress and dietary supplement use; Dietary supplement use and doping, Oxidative stress, inflammation and dietary antioxidants. In case of topics with a Type (2) the slope is rising and normally peaking in the last two years, these are the followings: muscle power enhancement and dietary supplementation, Assessment of energy intake of athletes, Weight management, Gut

microbiota and Celiac disease. A “unique” cluster, with a somewhat different pattern from the two basic types is Carbohydrate metabolism, which, along with some fluctuation, shows a steady output in the topic (also with a slight increase); another is Bone health and Female Athlete Triad, which also shows a steady output with a rising slope in the last examined year.

Citation Measures Of Topics And Journal Ranks

Apart from chronological trends, the relevance and scientific significance of topics can be investigated through the use of these two scientometric indicators (1) the citation measures (of the publications) of individual topics, and (2) the prestige or rank of publications. Citation measures provides information about the scientific impact of the publications of a topic, which is a fundamental approach to the sport nutrition science- relevance of topics.

Instead of the raw citation number, publications are characterized by their position in the citation measures rank order for the research field, called percentile-measure. The clusters with the biggest impact are those whose average, that is, the characteristic value of the relevant articles, is situated closest to 0. Those with a mean below the value of 25 can be considered to have a high general citation index (they belong to the most cited, 25%, citation quartile). Based on this, practically all the identified clusters fall into the high citation measure range, both in terms of their mean, and of the majority (minimum 50%) of their publications. The topics with the biggest impact are: Nutritional Strategies and human skeletal muscle; Dietary nitrate supplementation. A similarly high composite impact is shown by the topics Football and physiology; Carbohydrate metabolism; Bone health and Female Athlete Triad; Weight management; Gut Microbiota.

The rank of publications in this case refers to the rank and recognition of the publishing journals, with the latter representing, in terms of the topics, the “quality” of knowledge transferred in them. To describe the rank and the “quality” of the knowledge content of topics, we applied the citation quartile system. The basis of the approach is the classification of publications into four quality classes according to the rank of the publishing journal. The so-called Q1 journals belong to the upper 25% of the journal rank of the field, Q2 journals belong to the upper 25–50% quartile, Q3 journals are in the lower 25–50%, and Q4, in the bottom 25%. Figure 5. shows the distribution of the articles of the identified clusters among the four classes for each theme. In this case also, we can state that almost all clusters include publications of high quality, inasmuch as in average, 50% of their publications are ranked Q1, and the majority of the rest of the publications belong to Q2, which can also be considered a satisfactory quality rank. Carbohydrate metabolism; Nutritional Strategies and human skeletal muscle; Dietary nitrate supplementation stand out (Fig. 5).

In what follows, utilizing the scientometric assessment of topics, we select the three most significant topic, and showcase their internal structure in terms of key thematic relations based on our text mining and core document methodologies. We illustrated the conceptual network of topics with a dendrogram, and we analyzed the three topic based on their interconnections from the aspects of sport nutrition, sport

physiology, type of sport, dietary supplements and performance diagnostics. The collection of the 18 topics and their core papers are in an additional file. Using an advanced bibliometric method, we obtained the so-called core papers for each research topic, the most representative publications in the cluster [see Additional file 1].

Description of the nutritional strategies and human skeletal muscle cluster

This topic focuses on the relationship between sport performance and the metabolic pathways of skeletal muscle cells. Its most frequent issue is the role of PGC-1 alpha transcriptional regulation especially in relation to mitochondrial biogenesis, citrate synthesis, endurance performance, phosphocreatine as the creatine substrate of performance enhancement, the relation of insulin, free fatty acids and fatigue, protein and carbohydrates (first of all fructose), and also in relation to energy expenditure and regeneration. Depending on the type of the examined sport, endurance training stands out, but high-intensity interval training is also present with almost the same frequency. Of the biological components, the role of P38 MAPK protein kinase is worth emphasizing (Fig. 6).

Description of the dietary nitrate supplementation topic

The complex (sport-) physiological focus of the topic is on the relation network of blood circulation, oxidative metabolism and nitrogen metabolism - and supplementation (in relation to sport activities). Its primary topics are oxygen consumption (related to the concept of efficiency), fatigue, inorganic nitrate substrate related to vascular function, the stimulus-muscle contraction connection, vegetarianism, the enzyme that produces nitrogen oxide substrate, the relation network of hypertension and vasodilatation, inflammation and beta-alanine, and bloodstream. Depending on the type of physical activity, the theme is characterized by endurance training (especially related to oxidative stress and its biomarkers), but also the concept of diving response emerges, first of all related to oxygen uptake – and consumption, but also more loosely to respiratory control. Within further substrata, sodium nitrite, and, with lower frequency, creatine-nitrate emerges. Regarding indices, the use of the VO₂ performance indicator becomes apparent (Fig. 7).

Description of the carbohydrate metabolism topic

From a sport physiological angle, this theme also revolves around the improvement of skeletal muscle function, mostly, however, in relation to carbohydrate metabolism. Its pivotal concepts and issues are lipid oxidation during exercise metabolism processes, nitrogen balance (especially after eating), lean body mass (-increase), aerobic capacity related mostly to fatigue and endurance training, glycemic index, muscle glycogen, and endurance training (and carbohydrate absorption). The last one of these is characteristic for the type of the examined sport; in terms of branch of sport, cycling (time check training) and running emerge. For the examined substrates and dietary supplements, as well as biologically active components, the role of lipid oxidation (time check cycling), and, less frequently of catecholamine (running), sport drinks (cycling) and fructose (endurance training) as well as creatine kinase emerges (Fig. 8).

Discussion

The results of the present study confirm the role of science mapping in (1) the identification of specific research topics, primary research directions (2) the exploration of the relative significance of research directions, their spatial and temporal dynamism. These factors facilitate the more precise identification of major research directions, the optimization of available research resources, and the implementation of developmental research more focused on actual needs. To illustrate the outlined connections, we present the results of our research with the help of the Boston Consulting Group (BCG) matrix, which is widely applied in management practice [21]. This visualization technique uses a coordinate system with one axis showing market share (in our case: the ratio within all sport nutrition publications), and the other axis showing the rate of change over the examined period (2010–2018), (Fig. 9).

The Fig. 9. attests to the great diversity of topics related to sport nutrition: no topic has a ratio of more than ten percent among all publications related to sport nutrition. The number and ratio of publications on muscle power enhancement and dietary supplementation are relatively stable. Further permanent focus is on the topic of dietary supplement use related to oxidative stress and the issue of dietary nitrate supplementation. Over the past decade, the number of publications on the relationship between dietary supplement use and doping and those on athletes' nutrition knowledge has shown the most considerable increase.

An observable tendency is a rising slope in the significance of research on the nutrition of athletes with celiac disease, and the importance of discipline-specific (e.g., football) analysis is also increasing. It is notable that the ratio of topics related to sport nutrition but first of all connected to basic research (e.g., Muscle physiology: alkalosis and acidosis, Carbohydrate metabolism) has decreased significantly within all publications. This may be attributable to the fact that existing knowledge in sport nutrition science has become suitable of offering practical applications (e.g., development of dietary supplements) over the past decade. Based on the figure, four facts can be stated in relation to main directions of development in the future:

1. Basic research continues to have a significant role, as it constitutes the scientific foundation of specific product development;
2. Sport nutrition analyses related to the nutritional awareness of athletes and the restriction of doping substances will have increasing importance;
3. Special nutritional needs (e.g., food intolerance, vegetarianism, observation of religious regulations such as halal products) will also become more and more foregrounded in sports;
4. The importance of nutrition research on the unique needs of specific branches of sport will also be increasing

Our study - like all of literature reviews and bibliometric mapping study - is a necessary compromise between the limits of resources, time-frame of research and length of publication. That's why some limitations of the current study should be highlighted. (1) The pool of publications, used for our research:

We have applied the two most prestigious databases of nutrition and medical and health sciences: the Pubmed and the WoS. The involvement of another databases (e.g. Scopus) and another language (e.g. Chinese) could further increase the set of information, suitable for analysis. (2) We have to take into consideration, that the relation between nutrition and physical performance has a very important, direct practical relevance. That's why the published results of scientific research not necessarily reflect the frontiers of the actual knowledge, because the interests of a) business (e.g. pharmaceutical and/or nutraceutical companies), b) sport (e.g. Olympic teams), as well as c) military and law enforcement organizations (e.g. the analysis of acknowledgement section of articles shows, that one of the main sponsors of – rather cost-intensive research activities – are the armies) often limit the content of published information. A further limiting factor is related to the search strategy. (3) We applied a major MeSH term as a search query instead of creating a detailed search algorithm. (4) We tacitly supposed, that the abstract reflects exactly the key points of the research goals and results. It is possible, that this supposition has been too strong, that's why there some difference between the content of the abstract and that of the text of article.

Conclusions

Our research is the first large-scale bibliometric mapping study that present the key topics of the publications in sport nutrition science of the past ten years. In the course of the bibliometric analysis of sport nutrition science research, we analyzed 3889 scientific publications, which allowed an insight into the most relevant research trends, the scientific impact of publications, the diachronic distribution of specific research directions, and the rank of publications. Altogether, we were able to identify four main groups. From the four main groups, we analyzed the 18 most dominant topics, from which three are portrayed in detail in the present article.

Based on the size of the topics, research in sport nutrition science has put the biggest emphasis on the three topics of muscle power enhancement and dietary supplementation, carbohydrate metabolism, oxidative stress and dietary supplement use. Training adaptation makes up nearly 8% of the full corpus, another 8% is made up by the relationship of performance and nutrition, and the assessment of energy intake of athletes, finally, 8% is made up by dietary intake of athletes and nutrition knowledge. Regarding the prevalence of the specific topics, muscle power enhancement and dietary supplementation, assessment of energy intake of athletes, weight management, gut microbiota, and celiac disease have rapidly become outstanding research topics in the last two years. Topics with the biggest scientific impact are Nutritional strategies and human skeletal muscle, Dietary nitrate supplementation, Weight management, and Gut microbiota. In terms of the quality of the transferred information, the topics Carbohydrate metabolism; Nutritional strategies and human skeletal muscle; and Dietary nitrate supplementation stand out.

Our research provided a justification for applying bibliometric analysis in four dimensions of the research topic:

- a. Based on the number of publications in the cluster (the size of the topic), we get an insight into the impact of identified topics and research directions in the field of sport nutrition science.
- b. The distribution of the publications based on publication date shows the trends and relevance of the specific topics.
- c. The citation measure of the publications of a topic shows the scientific impact of publications of specific topics, which is a fundamental approach to the sport nutrition science relevance of themes.
- d. The exploration of the prestige or rank of publications within each cluster: in this case, rank of publication means the rank or recognition of the publishing journal, with the latter representing, in terms of the themes, the “quality” of transferred knowledge related to the theme.

It can be stated that the sport nutrition is a rapidly developing, organically evolving, interdisciplinary field of science. New frontiers of knowledge and challenges of demand force a constantly increasing scope of this science, parallel with continuous deepening of understanding the interplay of different biological and chemical systems with inherent demand of modern sport. Results of the current research highlight the importance of bibliometric mapping studies in this field, because this approach offers an exact way to determine the future, prospective ways of further development and promote the optimal allocation of scarce intellectual and material resources of research.

Abbreviations

MeSH

Medical Subject Headings

NPL

Natural Language Processing

WoS

Web of Science

JCR

Journal Citation Report

Declarations

Ethics approval

Not applicable

Consent for publication

Not applicable

Availability of data and materials

A part of data generated or analyzed during this study are included in this published article [and its supplementary information files]. The complete datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AK and SS conceptualized and designed the research project, SS conducted the statistical analysis, AK interpreted the results. ÁT was a major contributor in writing the manuscript. OT and GYB have substantively revised the work, ZL prepared the figures and tables and wrote the manuscript with revisions. All authors read and approved the final manuscript.

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Figures

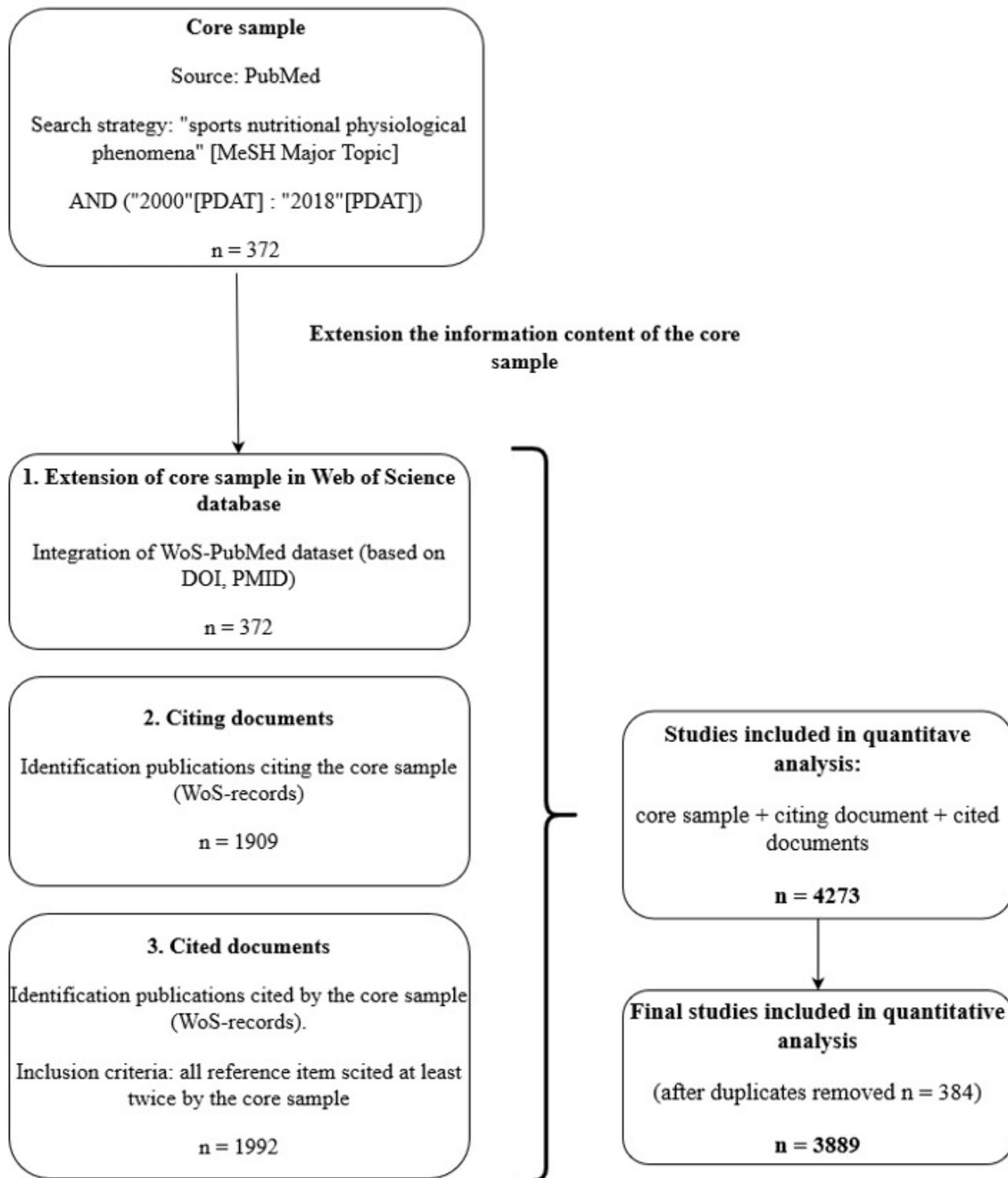


Figure 1

Flowchart of database construction

Topics	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Trend
Football and physiology	5	3	2	5	5	12	14	15	22	5	
Carbohydrate metabolism	11	15	14	12	8	13	21	21	26	4	
Muscle physiology: alkalosis and acidosis	3	4	7	7	9	7	9	9	12	2	
Muscle power enhancement and dietary supplementation	19	9	6	9	16	24	23	42	66	6	
Fluid balance and hydration	6	7	7	8	7	14	10	17	21	8	
Dietary intake and nutrition knowledge	4	8	4	5	8	14	23	36	44	2	
Assessment of energy intake of athletes	5	7	5	5	4	13	18	28	51	6	
Bone health, Female Athlete Triad	10	8	12	13	16	11	17	19	29	4	
Fluid intake strategy	4	6	8	3	8	5	12	17	22	4	
Weight management	6	7	9	5	11	11	9	25	28	4	
Human skeletal muscle and nutrition	16	10	3	14	10	12	19	27	33	1	
Dietary nitrate supplementation	7	9	10	15	15	32	27	38	34	5	
Oxidative stress and dietary supplement use	12	9	9	9	16	24	29	25	35	5	
Dietary supplement use and doping	2	4	2	3	3	13	12	21	32	7	
Oxidative stress, inflammation and dietary antioxidants	2	2	3	4	6	13	9	20	17	4	
Training adaptation and nutritional strategies	6	9	4	12	16	28	32	37	37	11	
Gut microbiota	1	2	1	2	3	5	5	20	26	8	
Celiac disease	1	2	1	1	2	5	6	12	18	0	

Figure 4

Chronological distribution of topics

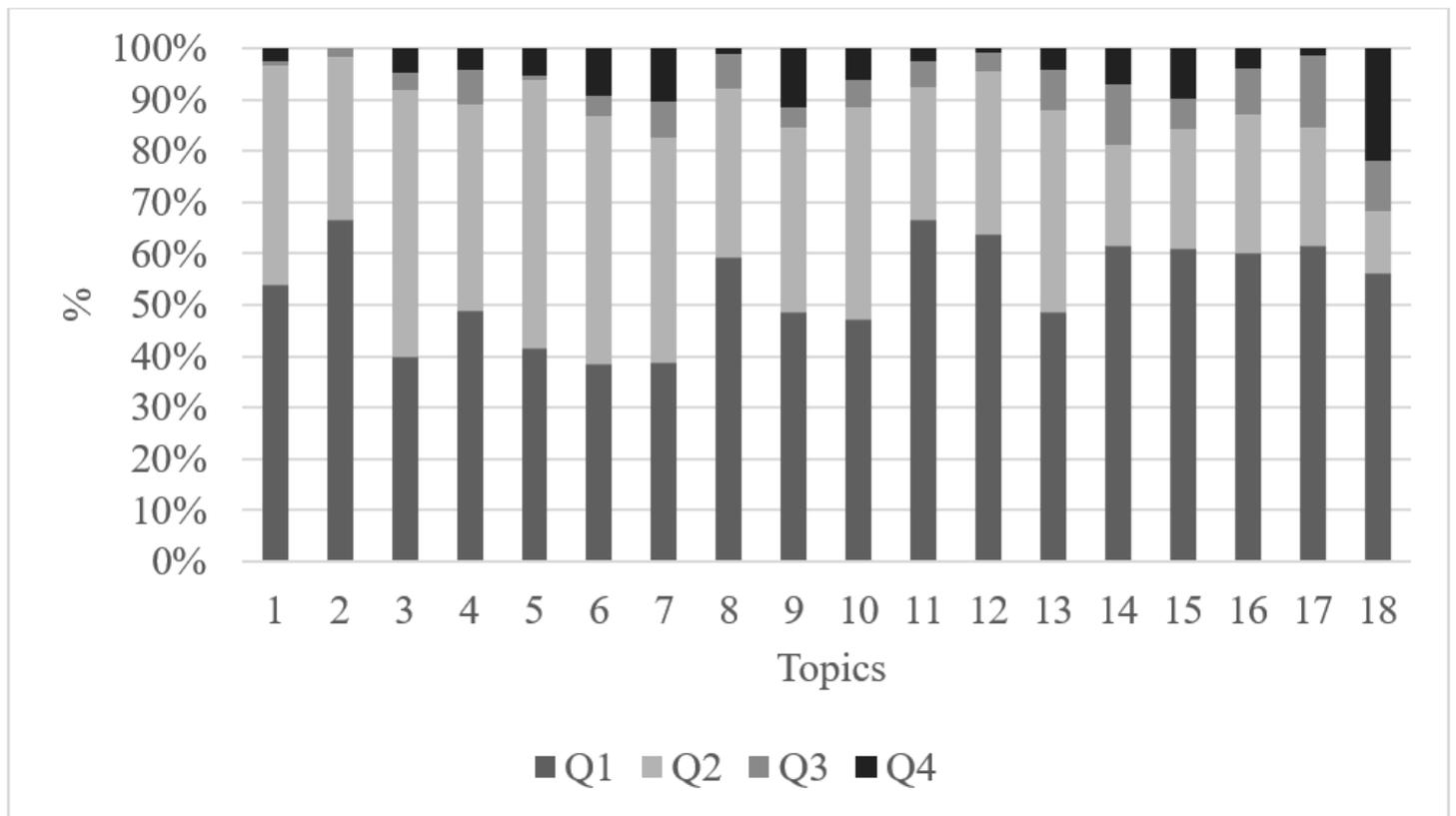


Figure 5

The rank of publications in the citation quartile system

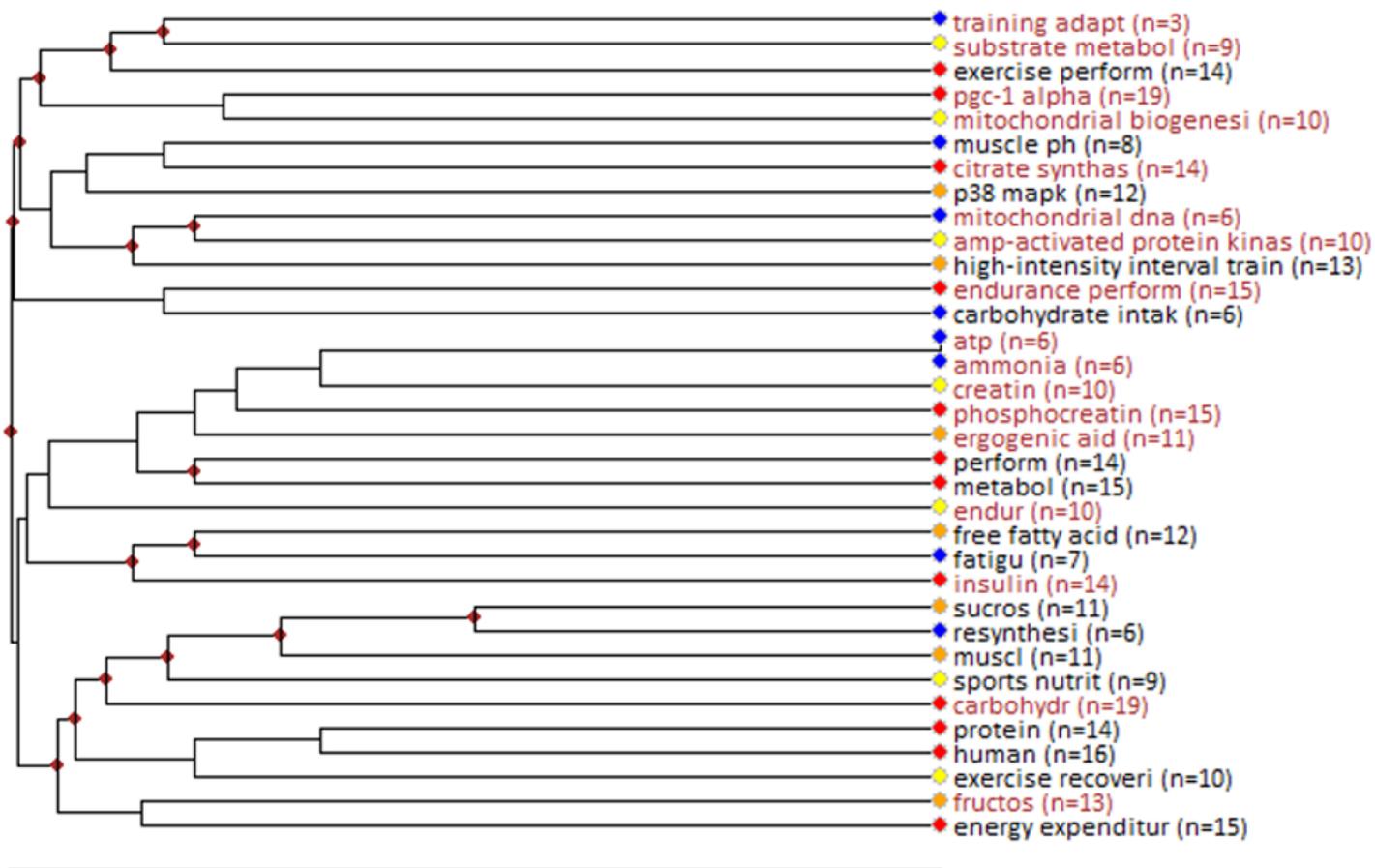


Figure 6

Nutritional strategies and human skeletal muscle topic. Notes: The key words and concept groups belonging together are displayed in the same letter color. Next to each key word, color code designates the occurrence frequency and importance of the given concept within the theme (color legend: red: high frequency, belonging to the top citation quartile of the distribution; orange: frequent, belonging to the third citation quartile of the distribution; yellow: medium frequency, belonging to the second citation quartile of the distribution; blue: low frequency, belonging to the bottom citation quartile of the distribution).

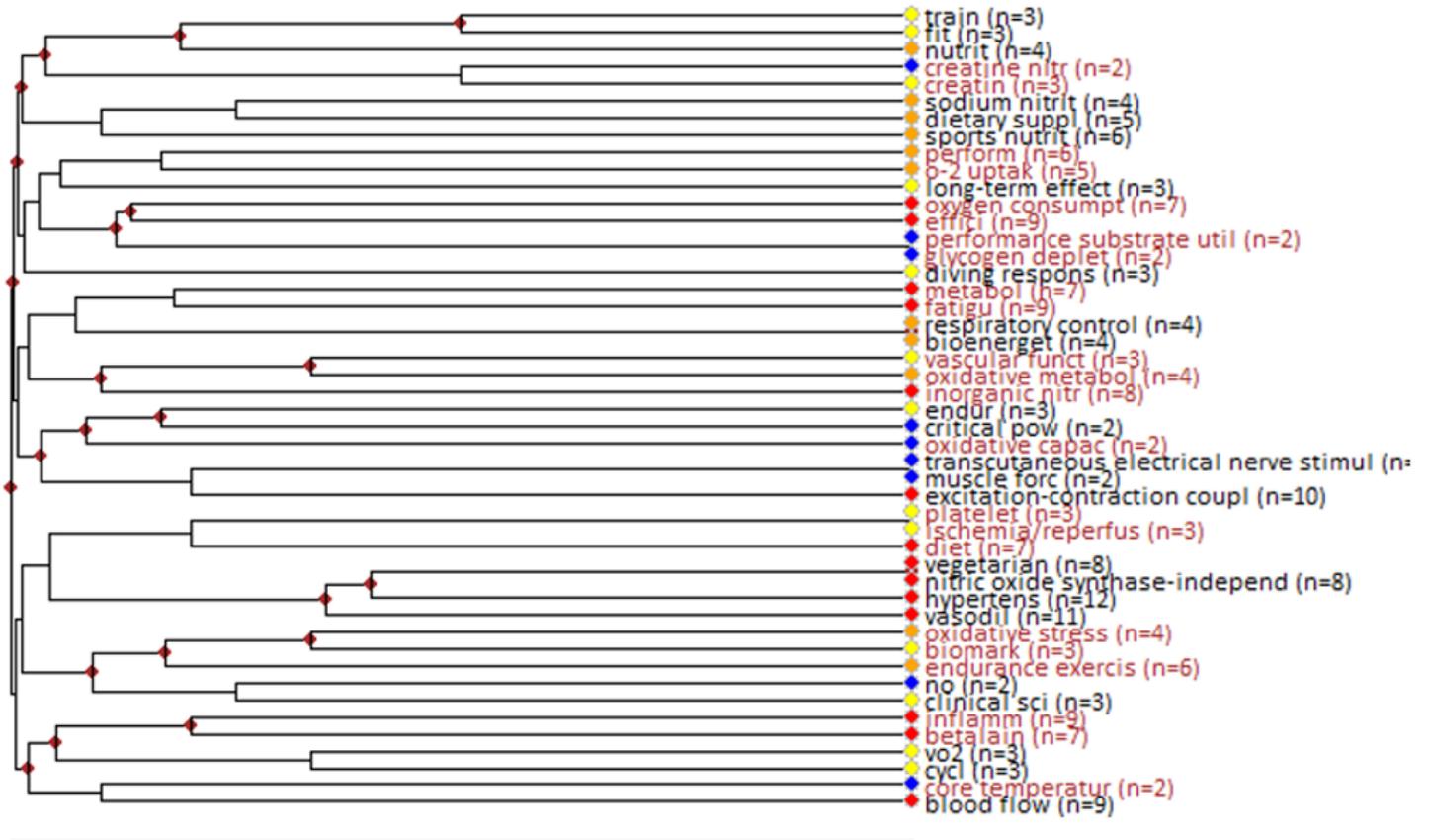


Figure 7

Dietary nitrate supplementation topic

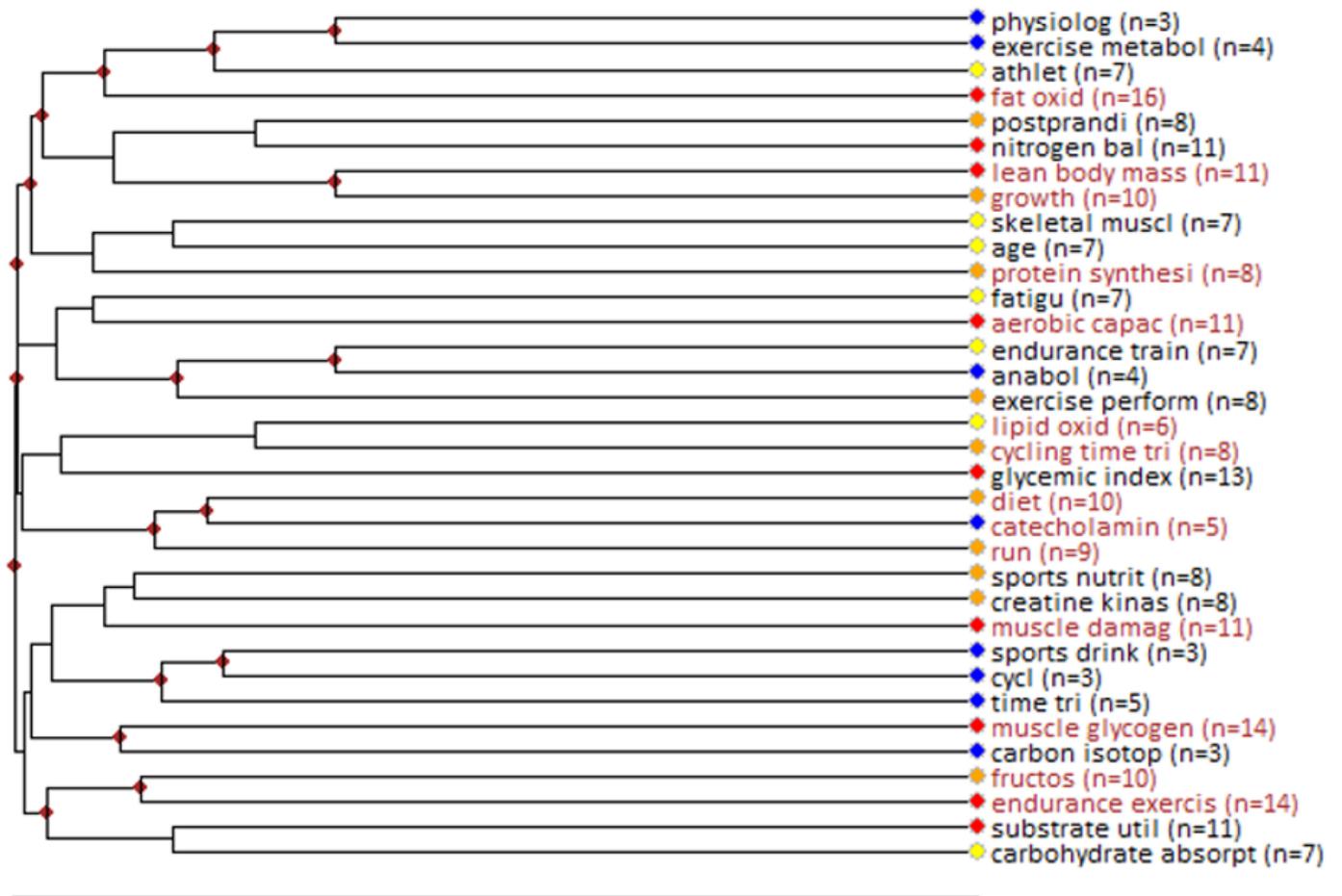


Figure 8

Carbohydrate metabolism topic

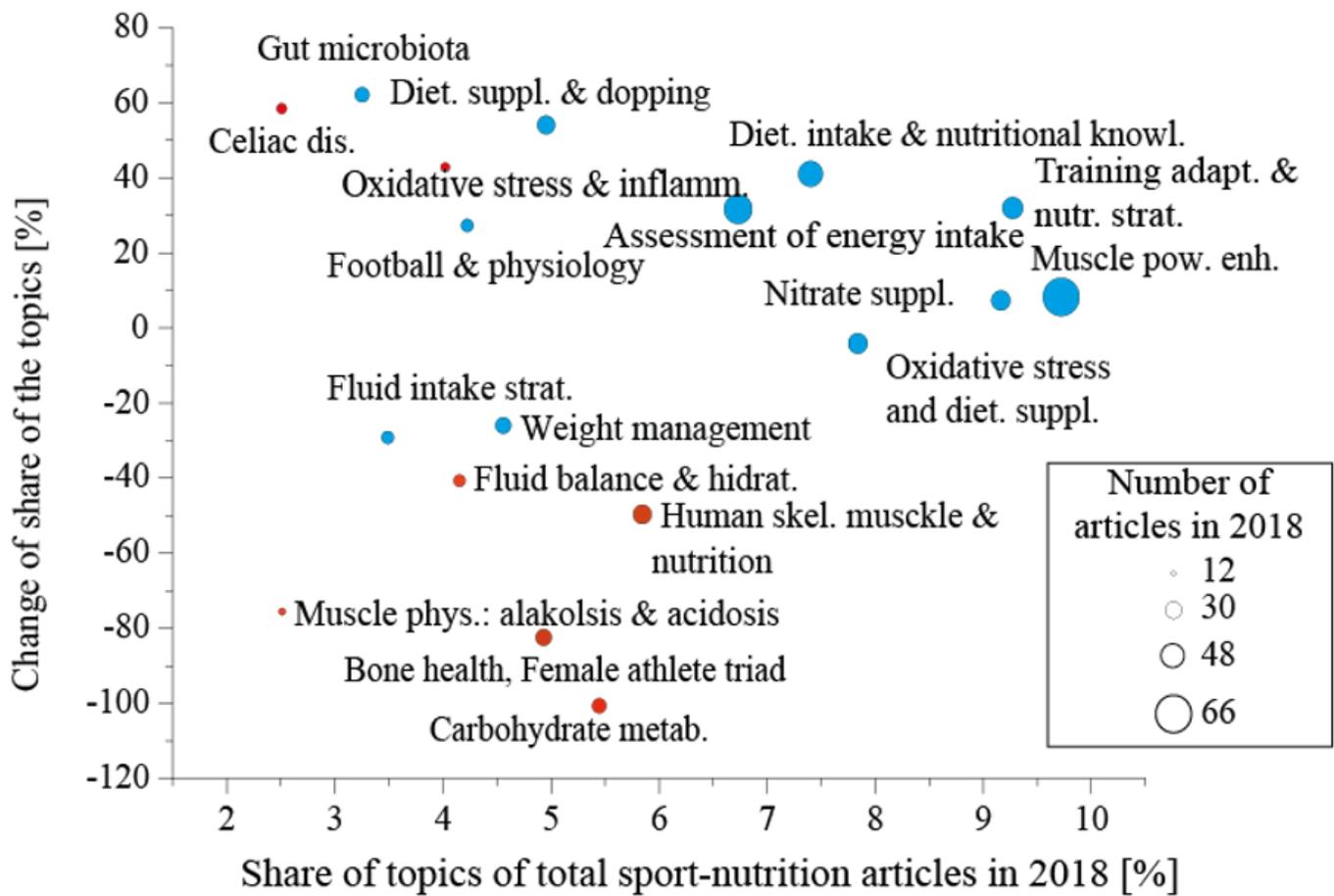


Figure 9

BCG matrix of sport nutrition research trends (color legend: red: topics related to basic research, blue: main directions of applied researches)

Supplementary Files

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