

# Top 50 most-cited articles in medicine and science in football

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## ABSTRACT

**Objectives** To conduct a comprehensive mapping analysis to the scientific literature published in football aiming to identify the areas of bigger interest and potential for further exploration.

**Methods** The data were obtained by a search conducted on the Web of Science. Articles were listed based on citation frequency. We used an open-source bibliometric R-package for the comprehensive bibliometric analyses.

**Results** The number of citations per article ranged from 251 to 869 (median 323; IQR 125). The yearly number of citations ranged from 8 to 54 (median 26; IQR 11). Most of the articles (76%) were of level III of evidence, 10% were level II and 14% were level IV. Within the top 50 most-cited articles, 40 articles were original research (37 observational and 3 experimental studies), 9 were review articles and 1 was a thesis. From the 40 original research articles, 50% involved elite players, 73% were exclusive to male players and 80% involved adult players only. The topic area with the highest number of articles was sports medicine (44%), followed by training and testing (32%), performance analysis (14%) and physiology (10%). No study within the top 50 was devoted to biomechanics, nutrition, sport psychology, coaching or social sciences.

**Conclusions** The lack of experimental studies within the top 50 most-cited articles in football clearly underpins how far we still are from establishing the theoretical and methodological guidelines for the applied science and medicine in football.

areas that have attracted most of the interest until now. As an extension to this bibliometric analysis, we will be able to identify the topics that have received less scientific attention so far. The lack of attention, indicated by the low number of citations, might indicate relatively lower studies' quality and/or less interest by the community.

In the current manuscript, we used automated software workflows to perform comprehensive mapping analysis to the scientific literature published in football. The bibliometric analyses were used to establish the top 50 most-cited articles in medicine and science in football, aiming to explore the impact of the most prominent publications, journals, authors and networks.

## METHODS

The data in this study were obtained by a search conducted on the Web of Science (Clarivate Analytics, USA). There were no restrictions applied based on availability of abstract, study type, language and human versus non-human research objects or any kind of time limitation. Keywords 'soccer' and 'football' were searched in terms of topic (including four sections: paper title, abstract, author keywords and KeyWords Plus) based on the full collection (10 April 2018). Our search produced 41 191 published articles between 1888 and 2018. Thereafter, they were listed based on citation frequency from the highest to the lowest. All articles focused on football or with a population of football players were considered eligible for analysis, but if no independent data were presented for football players, the article was excluded.

The 50 most-cited articles were reviewed by two investigators (JB and PF) and the following information was extracted according to their specific characteristics: (1) year of publication, (2) journal title, (3) number of citations, (4) number of annual citations, (5) authorship and (6) level of evidence (I–V) from Oxford Centre for Evidence-Based Medicine 2011.<sup>5</sup>

## INTRODUCTION

Given the increasing number of academic publications in football, even the most fervent reader will appreciate it is impossible to keep up to date with all publications. Moreover, the football community is flooded with empirical contributions from different sources and networks that tend to mislead and fragment knowledge and evidence. One simple tool to evaluate the quality of research conducted is the number of citations. Bibliometric analyses are used by organisations, institutes and universities to evaluate the quality of the research output. This type of analysis is widely used in other disciplines like medicine and its sub-specialties.<sup>1–4</sup>

In sports, and especially in football science, bibliometric analysis might first assist in quantifying the quality of studies and also identify



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The articles were further independently characterised by two investigators (JB and PF) and discussed in the case of discrepancies. Then, a third investigator (ATS) re-analysed all the articles, and a discussion was employed until a consensus was achieved. Each article was characterised according to category (original research, review article, case study, short communication/technical report, letter to the editors, point-counterpoint, editorial and thesis), main research topic area (physiology, biomechanics, nutrition, training and testing, sports medicine, performance analysis, sport psychology, coaching and social sciences) and type of study (observational, experimental and review). Also, sex (male, female and both), competitive level (elite, non-elite and both) and age group (youth, adult, all) were extracted for the original research articles (ie, observational and experimental studies). For the purpose of our study, competitive levels were defined as elite (when participants were classified as professional, elite or first division) and non-elite (for amateur, non-elite, college or high-school players), and age groups as youth when <18 years old and adult when >18 years old. When the information was not evidently provided in the article, these categories were considered unclear.

The data analysis was performed using R.<sup>6</sup> An open-source bibliometrix R-package for performing comprehensive bibliometric analyses was used.<sup>7</sup> Also, a network creation for bibliographic collaboration was performed. A scientific collaboration network is a network where nodes are authors and links are co-authorships; it is one of the most well-documented forms of scientific collaboration.<sup>8</sup> An author collaboration network can be obtained computing  $B_{coll} = A \times A'$ , where  $A$  is a Document $\times$ Author matrix. Element  $b_{ij}$  indicates how many collaborations exist between authors  $i$  and  $j$ . The diagonal element  $b_{ii}$  is the number of documents authored or coauthored by researcher  $i$  (for details, see Aria and Cuccurullo<sup>7</sup>).

The distribution of a parameter (eg, number of citations) was characterised by the median (IQR). The  $\chi^2$  test was used to compare two categorical variables. To test the hypothesis if three or more samples characterised by their medians originated from the same distribution, the Kruskal-Wallis test was conducted. The significance level was set to  $p$  value <0.05.

## RESULTS

The top 50 most frequently cited articles in medicine and science in football are shown in table 1. All articles were published in English. The number of citations ranged from 251 to 869, with a median of 323 and an IQR of 125. The number of citations per year ranged from 8 to 54, with a median of 26 and an IQR of 11. Most of the articles (38) were of level III of evidence, while five articles were level II, and seven articles were level IV ( $\chi^2=41.08$ ;  $p<0.001$ ). No significant differences ( $\chi^2=1.57$ ;  $p=0.46$ ) were found between the citation medians of the articles and the level of evidence.

Of the top 50 most-cited articles, 40 articles were original research (37 observational and three experimental studies), nine were review articles (eight narrative reviews and one meta-analysis) and one article was a thesis encompassing 14 original articles and a summarising review ( $\chi^2=50.92$ ;  $p<0.001$ ). No significant differences were detected for the number of citations according to the type of article ( $\chi^2=0.751$ ;  $p=0.687$ ; figure 1). The distribution of original research articles varied according to sex ( $\chi^2=49.4$ ;  $p>0.001$ ), age group ( $\chi^2=66.2$ ;  $p<0.001$ ) and competitive level ( $\chi^2=15.8$ ;  $p=0.001$ ) of the participants.

The majority ( $n=29$ ) of the 40 original research articles investigated male players, and only four studies were exclusively dedicated to female players. Six studies included both male and female players, and the sex of the participants was unclear in one study. However, no significant differences were detected for the number of citations according to the sex of the studied population ( $\chi^2=1.527$ ;  $p=0.676$ ).

Similarly, 32 original research articles investigated adult players, and only six articles were dedicated to youth players. One study included both adult and youth players, and the age group was unclear in one study. No significant differences were detected for the number of citations according to the age group of the studied population ( $\chi^2=3.066$ ;  $p=0.382$ ).

Half of the original research articles ( $n=20$ ) investigated elite players, and 10 articles were conducted with non-elite players. Seven articles included both elite and non-elite players, and the competitive level was unclear in three studies. No significant differences were detected for the number of citations according to the competitive level of the studied population ( $\chi^2=4.599$ ;  $p=0.204$ ).

The topic area with the highest number of articles ( $\chi^2=15.12$ ,  $p<0.01$ ) in the top 50 most frequently cited articles was sports medicine ( $n=22$ ), followed by training and testing ( $n=16$ ), performance analysis ( $n=7$ ) and physiology ( $n=5$ ). No differences were detected for the number of citations per topic area ( $\chi^2=1.133$ ;  $p=0.769$ ; figure 2).

Within the original research articles, the samples sizes ranged from 14 to 2376 players. Eleven articles involved less than 30 players, and 18 articles had a sample size above 50 participants. The sample size was unclear in five original research articles. The majority ( $n=33$ ) of the original research articles were exclusively dedicated to football, but seven articles were multisports investigations.

The top 50 most frequently cited articles were published in 17 journals (table 1), with 68% of the articles published by five journals: *Journal of Sports Sciences* ( $n=8$ ), *American Journal of Sports Medicine* ( $n=8$ ), *Medicine and Science in Sports and Exercise* ( $n=7$ ), *British Journal of Sports Medicine* ( $n=6$ ) and *International Journal of Sports Medicine* ( $n=5$ ). The articles were published during the time period 1983–2011 (figure 3). The oldest article was published in 1983 in *Medicine and Science in Sports and Exercise*, and the

**Table 1** List of the top 50 most-cited articles in football

| Ranking | Authors                   | Year | Title   | Journal                                    | Citations (n) |
|---------|---------------------------|------|---|--|---------------|
| 1       | Arendt <i>et al</i>       | 1995 | Knee injury patterns among men and women in collegiate basketball and soccer. NCAA data and review of literature  | <i>Am J Sports Med</i>                     | 869           |
| 2       | Mohr <i>et al</i>         | 2003 | Match performance of high-standard soccer players with special reference to development of fatigue  | <i>J Sports Sci</i>                        | 737           |
| 3       | Stølen <i>et al</i>       | 2005 | Physiology of soccer—an update  | <i>Sports Med</i>                          | 701           |
| 4       | Lohmander <i>et al</i>    | 2004 | High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury            | <i>Arthritis Rheum</i>                     | 689           |
| 5       | Bangsbo <i>et al</i>      | 1991 | Activity profile of competition soccer  | <i>Can J Sport Sci</i>                     | 514           |
| 6       | Helgerud <i>et al</i>     | 2001 | Aerobic endurance training improves soccer performance  | <i>Med Sci Sports Exerc</i>                | 507           |
| 7       | Mandelbaum <i>et al</i>   | 2005 | Effectiveness of a neuromuscular and proprioceptive training programme in preventing anterior cruciate ligament injuries in female athletes—2 year follow-up      | <i>Am J Sports Med</i>                     | 499           |
| 8       | Krustrup <i>et al</i>     | 2003 | The Yo-Yo intermittent recovery test: physiological response, reliability, and validity   | <i>Med Sci Sports Exerc</i>                | 471           |
| 9       | Ekin <i>et al</i>         | 2003 | Automatic soccer video analysis and summarization   | <i>IEEE Trans Image Process</i>            | 423           |
| 10      | Bangsbo <i>et al</i>      | 2008 | The Yo-Yo intermittent recovery test—a useful tool for evaluation of physical performance in intermittent sports  | <i>Sports Med</i>                          | 419           |
|         | Reilly <i>et al</i>       | 2000 | Anthropometric and physiological predispositions for elite soccer   | <i>J Sports Sci</i>                        | 419           |
| 12      | Caraffa <i>et al</i>      | 1996 | Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training  | <i>Knee Surg Sports Traumatol Arthrosc</i> | 400           |
| 13      | von Porat <i>et al</i>    | 2004 | High prevalence of osteoarthritis 14 years after an anterior cruciate ligament tear in male soccer players: a study of radiographic and patient relevant outcomes | <i>Ann Rheum Dis</i>                       | 396           |
| 14      | Agel <i>et al</i>         | 2005 | Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer—a 13 year review  | <i>Am J Sports Med</i>                     | 390           |
| 15      | Impellizzeri <i>et al</i> | 2004 | Use of RPE-based training load in soccer  | <i>Med Sci Sports Exerc</i>                | 383           |
| 16      | Wisløff <i>et al</i>      | 2004 | Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players   | <i>Br J Sports Med</i>                     | 381           |
| 17      | di Salvo <i>et al</i>     | 2007 | Performance characteristics according to playing position in elite soccer   | <i>Int J Sports Med</i>                    | 377           |
| 18      | Fuller <i>et al</i>       | 2006 | Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries   | <i>Br J Sports Med</i>                     | 373           |
| 19      | Reilly <i>et al</i>       | 2000 | A multidisciplinary approach to talent identification in soccer   | <i>J Sports Sci</i>                        | 359           |
| 20      | Bangsbo <i>et al</i>      | 2006 | Physical and metabolic demands of training and match-play in the elite football player  | <i>J Sports Sci</i>                        | 352           |
|         | Hawkins <i>et al</i>      | 2001 | The association football medical research programme: an audit of injuries in professional football  | <i>Br J Sports Med</i>                     | 352           |
| 22      | Woods <i>et al</i>        | 2004 | The football association medical research programme: an audit of injuries in professional football—analysis of hamstring injuries                                 | <i>Br J Sports Med</i>                     | 351           |
|         | Ekblom                    | 1986 | Applied physiology of soccer  | <i>Sports Med</i>                          | 351           |
| 24      | Beilock <i>et al</i>      | 2002 | When paying attention becomes counterproductive: impact of divided vs skill-focused attention on novice and experienced performance of sensorimotor skills        | <i>J Exp Psychol Appl</i>                  | 349           |
| 25      | Hawkins <i>et al</i>      | 1999 | A prospective epidemiological study of injuries in four English professional football clubs   | <i>Br J Sports Med</i>                     | 325           |
| 26      | Arendt <i>et al</i>       | 1999 | Anterior cruciate ligament injury patterns among collegiate men and women   | <i>J Athl Train</i>                        | 320           |
| 27      | Ekstrand <i>et al</i>     | 1983 | Soccer injuries and their mechanisms: a prospective study   | <i>Med Sci Sports Exerc</i>                | 312           |
| 28      | Krustrup <i>et al</i>     | 2006 | Muscle and blood metabolites during a soccer game: implications for sprint performance  | <i>Med Sci Sports Exerc</i>                | 310           |
| 29      | Bangsbo                   | 1994 | The physiology of soccer—with special reference to intense intermittent exercise.   | <i>Acta Physiol Scand</i>                  | 305           |

Continued

Table 1 Continued

| Ranking | Authors                    | Year | Title   | Journal                                    | Citations (n) |
|---------|----------------------------|------|---|--|---------------|
| 30      | Impellizzeri <i>et al</i>  | 2006 | Physiological and performance effects of generic versus specific aerobic training in soccer players                                       | <i>Int J Sports Med</i>                    | 300           |
|         | Askling <i>et al</i>       | 2003 | Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload                             | <i>Scand J Med Sci Sports</i>              | 300           |
| 32      | Ekstrand <i>et al</i>      | 2011 | Injury incidence and injury patterns in professional football: the UEFA injury study  | <i>Br J Sports Med</i>                     | 296           |
| 33      | Rampinini <i>et al</i>     | 2007 | Variation in top level soccer match performance   | <i>Int J Sports Med</i>                    | 294           |
| 34      | Williams <i>et al</i>      | 2000 | Talent identification and development in soccer   | <i>J Sports Sci</i>                        | 291           |
| 35      | Savelsbergh <i>et al</i>   | 2002 | Visual search, anticipation and expertise in soccer goalkeepers   | <i>J Sports Sci</i>                        | 278           |
| 36      | Croisier <i>et al</i>      | 2008 | Strength imbalances and prevention of hamstring injury in professional soccer players—a prospective study                                 | <i>Am J Sports Med</i>                     | 273           |
| 37      | Lian <i>et al</i>          | 2005 | Prevalence of jumper's knee among elite athletes from different sports—a cross-sectional study  | <i>Am J Sports Med</i>                     | 272           |
| 38      | Alentorn-Geli <i>et al</i> | 2009 | Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: mechanisms of injury and underlying risk factors | <i>Knee Surg Sports Traumatol Arthrosc</i> | 269           |
| 39      | Prodromos <i>et al</i>     | 2007 | A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen  | <i>Arthroscopy</i>                         | 268           |
| 40      | Ekstrand <i>et al</i>      | 2011 | Epidemiology of muscle injuries in professional football (soccer)   | <i>Am J Sports Med</i>                     | 267           |
| 41      | Rampinini <i>et al</i>     | 2007 | Factors influencing physiological responses to small-sided soccer games   | <i>J Sports Sci</i>                        | 266           |
| 42      | Dehaven <i>et al</i>       | 1986 | Athletic injuries: comparison by age, sport, and gender   | <i>Am J Sports Med</i>                     | 265           |
| 43      | Kujala <i>et al</i>        | 1995 | Knee osteoarthritis in former runners, soccer players, weight lifters, and shooters   | <i>Arthritis Rheum</i>                     | 262           |
| 44      | Krustrup <i>et al</i>      | 2005 | Physical demands during an elite female soccer game: importance of training status  | <i>Med Sci Sports Exerc</i>                | 261           |
| 45      | di Salvo <i>et al</i>      | 2009 | Analysis of high intensity activity in premier league soccer  | <i>Int J Sports Med</i>                    | 259           |
| 46      | Heidt <i>et al</i>         | 2000 | Avoidance of soccer injuries with preseason conditioning  | <i>Am J Sports Med</i>                     | 253           |
| 47      | Bradley <i>et al</i>       | 2009 | High-intensity running in English FA Premier League soccer matches  | <i>J Sports Sci</i>                        | 252           |
|         | Rampinini <i>et al</i>     | 2009 | Technical performance during soccer matches of the Italian Serie A league: effect of fatigue and competitive level                        | <i>J Sci Med Sport</i>                     | 252           |
|         | Wisløff <i>et al</i>       | 1998 | Strength and endurance of elite soccer players  | <i>Med Sci Sports Exerc</i>                | 252           |
| 50      | Rampinini <i>et al</i>     | 2007 | Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players               | <i>Int J Sports Med</i>                    | 251           |

most recent ones in 2011 in *British Journal of Sports Medicine* and *American Journal of Sports Medicine*.

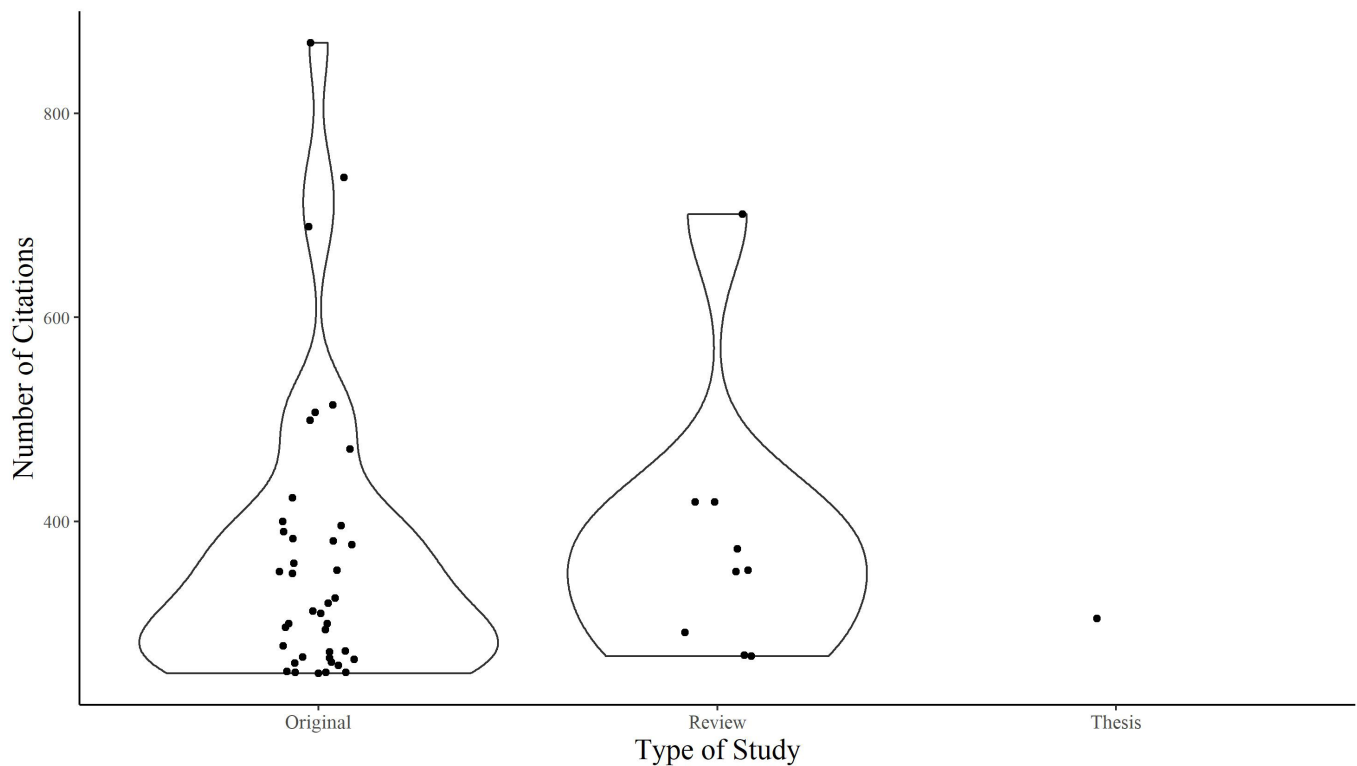
Overall, the top 50 most-cited articles encompassed 139 authors in total, with an average number of 2.8 authors per article. There were two single-author articles. The maximum number of coauthors in an article was 9. The list of authors with three or more articles in the top 50 is presented in table 2. Additionally, a clustered-network of coauthorship collaborations within the 18 authors with three or more articles in the top 50 is presented in figure 4. Seven clusters of co-authorship collaborations were identified.

## DISCUSSION

Over the last decades, the scientific literature available in football has dramatically increased both in terms of quantity and quality. However, to our knowledge, this

is the first bibliometric analysis conducted in football. Here, we show that the number of citations for the 50 most frequently cited articles in medicine and science in football ranged from 251 to 869.

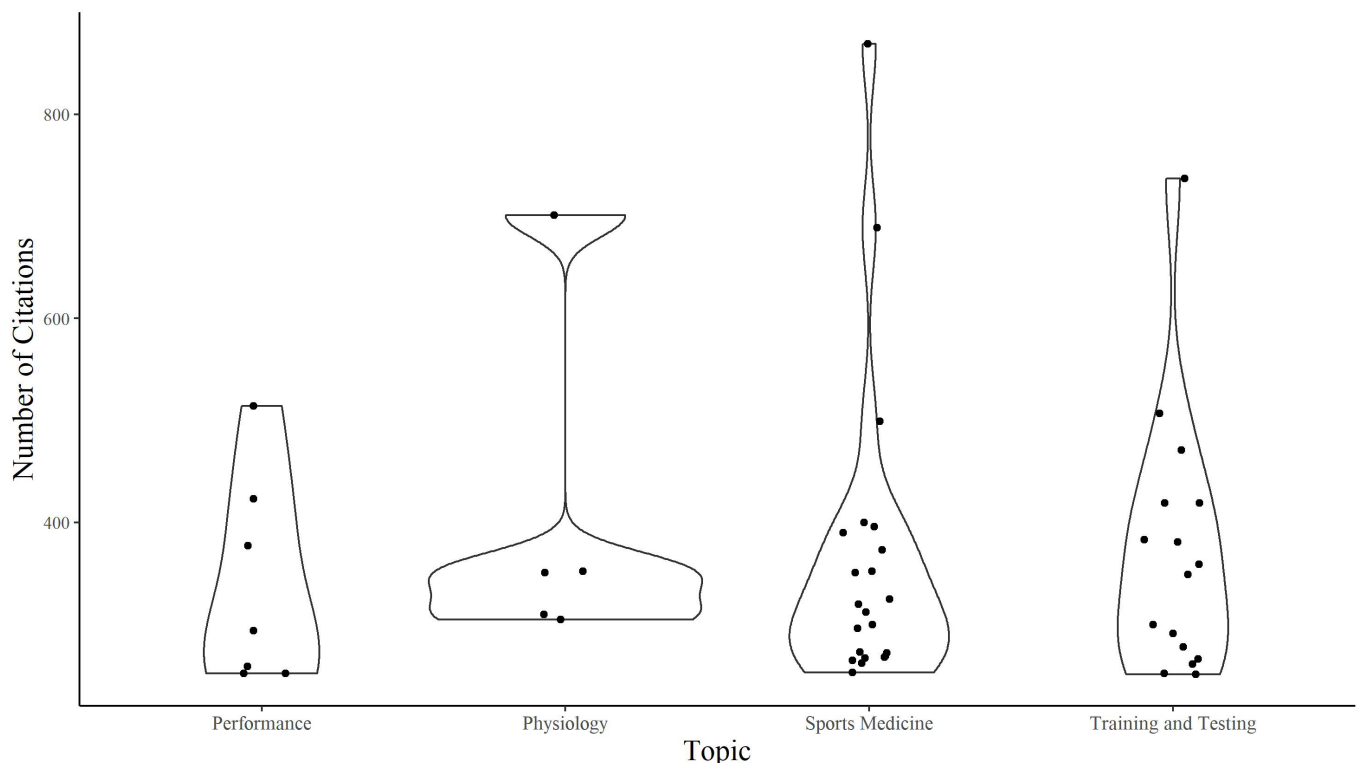
A bibliometric analysis is an extraction of statistics on journal articles in a research field. Its structure resembles the design of a systematic review.<sup>9</sup> Bibliometric analyses are commonly used to measure the impact of scientific articles, but should not be considered as the standard reference of scientific quality of the investigations. Citation rankings may also provide an estimate for trends for the research undertaken worldwide in a specific research subject (eg, football). We observed that 80% of the articles presented in the current ranking were original research, but only three articles had a clear experimental design. Observational studies (eg, notational analysis of performance) have a long tradition in football research,



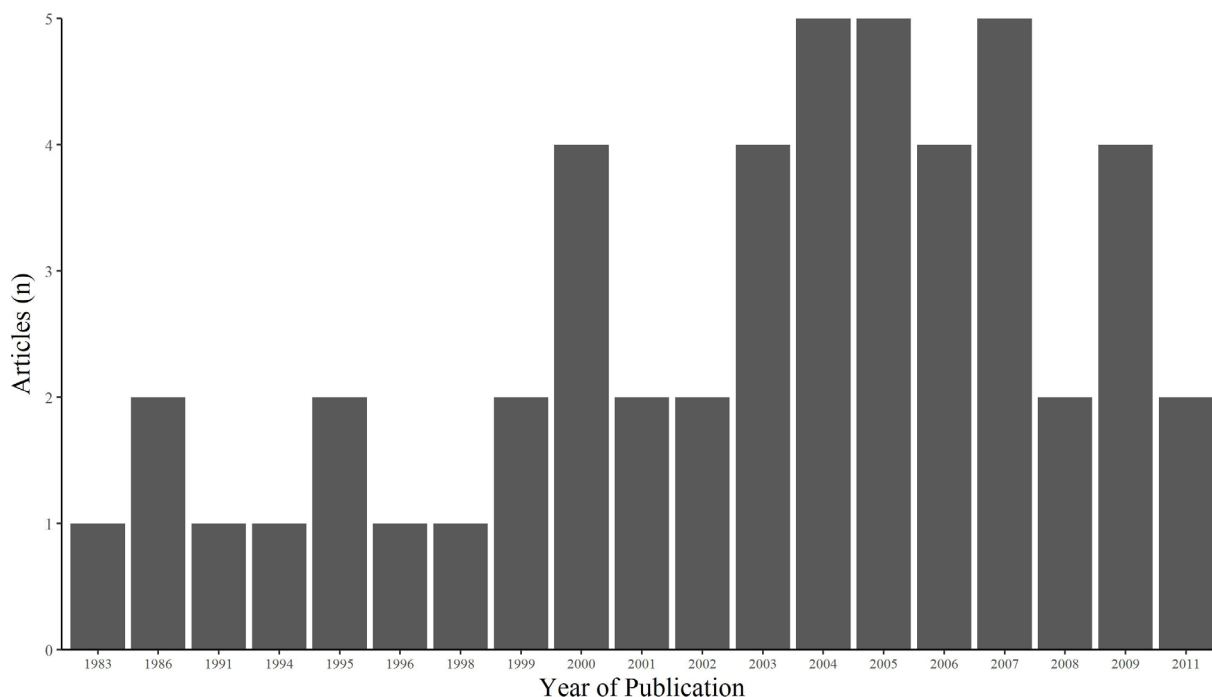
**Figure 1** Distribution of top 50 most-cited articles in medicine and science in football per type of study.

aiming the identification of critical events (often referred as performance indicators) that are thought to be the keys to success in the sport.<sup>10</sup> In fact, observation studies are essential for a comprehensive awareness of the

distinct individual and team performance components. Notwithstanding, the lack of experimental studies within the top 50 most cited articles in football clearly underpins how far we still are from establishing the theoretical



**Figure 2** Distribution of top 50 most-cited articles in medicine and science in football per topic area of research.



**Figure 3** Chronological distribution according to year of publication of the top 50 most-cited articles in medicine and science in football.

and methodological guidelines for the applied science and medicine in football.

Nine review articles, but only one meta-analysis, were included in the current ranking. Meta-analyses characterise and combine findings of prior studies in order to

increase statistical power, provide quantitative summary estimates, and identify data gaps and biases.<sup>11</sup>

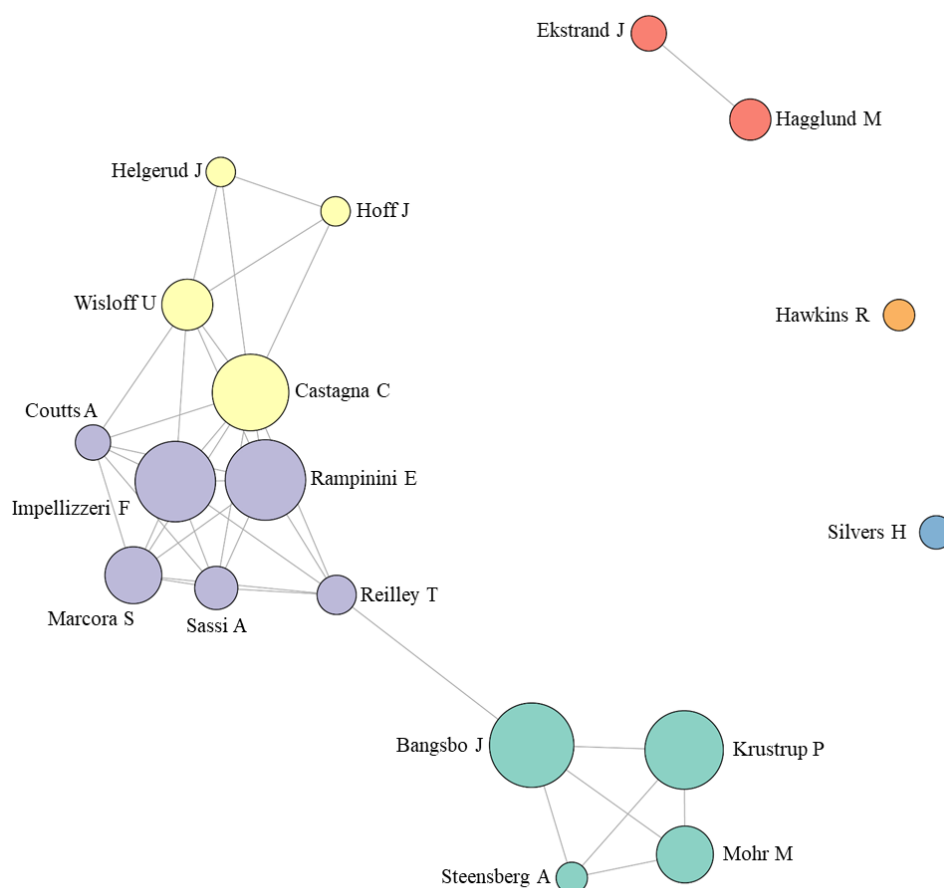
Some of the limitations for conducting scientific studies in football are well known: it is difficult to have access to large sample sizes of top-level players, longitudinal training studies are arduous and laborious, and studies that address and replicate appropriate real-world methodological issues are rare. However, despite the important role of narrative review articles, the debate within the community dealing with medicine and science in football might still be far from high levels of evidence.

Still, the theoretical knowledge, methodological approaches and professional practice in football are supported by comprehensive and complex contributions from a variety of sources.<sup>12</sup> In this line, the input of individuals involved in sports medicine, both from a clinical and scientific perspective, should be highlighted. It is noteworthy that 44% of the articles presented in the current ranking were related to sports medicine. The other topics main topic areas were training and testing, performance analysis and physiology, but no study within the top 50 most-cited was devoted to biomechanics, nutrition, sport psychology, coaching or social sciences.

The articles presented here were all published between 1983 and 2011. Online databases have limitations in tracking older articles, especially for articles published in alternate media, textbooks or meeting symposia,<sup>4</sup> which may have been missed in the current analysis. In addition, it can also be argued that old data are of limited value in the current rapidly changing sports environment. It should be noted that the impact of recent studies could not be captured with the current analysis.

**Table 2** List of authors with three or more articles in the top 50 most-cited articles in football

| Authors        | Articles (n) |
|----------------|--------------|
| Bangsbo J      | 9            |
| Krustrup P     | 7            |
| Castagna C     | 6            |
| Impellizzeri F | 6            |
| Rampinini E    | 6            |
| Mohr M         | 5            |
| Wisløff U      | 5            |
| Ekstrand J     | 4            |
| Marcora S      | 4            |
| Reilly T       | 4            |
| Arendt E       | 3            |
| Coutts A       | 3            |
| Häggglund M    | 3            |
| Hawkins R      | 3            |
| Helgerud J     | 3            |
| Hoff J         | 3            |
| Sassi A        | 3            |
| Williams A     | 3            |



**Figure 4** Clustered network of coauthorship collaborations within the 18 authors with three or more articles in the top 50 most-cited articles in medicine and science in football.

Any article needs some time after publication to receive enough number of citations. However, this is common in all research fields and does not negate the trend and conclusions presented here. We might expect a relative emergence of systematic research analysis and experimental studies in medicine and science in football over the last few years, underpinning the recent growing interest in those areas and, at the same time, highlighting the need for more research in the future. Still, the current study may also be limited by other research publication dynamics, which can include publication biases, as language, predominance of positive results, journal preferences when citing and self-citation.<sup>13 14</sup>

In the current manuscript, we present a network of authors' collaborations within the scope of medicine and science in football. This network underpins the most prolific scientific collaborations within medicine and science in football. Five main clusters of network collaborations were identified. We hope the current manuscript can establish an historical, comprehensive analysis to the most influential scientific literature published within the area of medicine and science in football, helping researchers, sports scientists, clinicians and practitioners on developing new insights to the original theoretical and methodological understanding of the game of football.

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## Correction: Top 50 most-cited articles in medicine and science in football

Brito J, Nassis GP, Seabra AT, *et al.* Top 50 most-cited articles in medicine and science in football. *BMJ Open Sport Exerc Med* 2018;4:e000388. doi: 10.1136/bmjsem-2018-000388

The authors want to alert readers to the following two errors identified in the published version.

In the Results section, the second last sentence of the last paragraph, should read as: “Additionally, a clustered-network with 18 vertices of coauthorship collaborations in the top 50 is presented in figure 4”

Also, the caption of figure 4, has been modified to “Clustered network with 18 vertices of coauthorship collaborations in the top 50 most-cited articles in medicine and science in football.”

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