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Mapping the 25 top-cited research papers in plantar fasciitis in runners

Mapeo de los 25 artículos más citados sobre fascitis plantar en corredores

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Palabras clave:

Fascitis plantar, lesiones musculoesqueléticas, running, atleta, bibliometría, análisis de citas, mapas de la ciencia.

Resumen

Introducción: Las citas que recibe un artículo es el método más utilizado para valorar su impacto en un campo científico determinado. La fascitis plantar es una de las cinco lesiones músculoesqueléticas más frecuentes en corredores, de etiología multifactorial, que se caracteriza por ser un proceso degenerativo de la fascia plantar y ocurre cuando está expuesta de manera repetitiva a sobrecargas tensiles. El objetivo es analizar las características de los 25 artículos más citados sobre fascitis plantar en corredores.

Material y métodos: Para identificar los artículos más citados se utilizó la base de datos Web of Science (1945-2016). Se analizó la información en relación con el número de citas recibidas, años de publicación, revista, área de investigación, autoría, institución, país y referencias bibliográficas de dichos artículos.

Resultados: Los 25 artículos más citados se publicaron entre 1983 y 2009. La década del 2000 es la más productiva en cuanto al número de artículos. El 84 % de estos artículos son originarios de EE. UU. y fueron publicados en 11 revistas diferentes. Recibieron una media de 78,5 citas por artículo. Las áreas de investigación en las que se han desarrollado principalmente estos estudios son Ortopedia y Ciencias del Deporte.

Conclusiones: Los resultados de esta investigación permiten identificar los artículos más relevantes que han contribuido en mayor medida al desarrollo del conocimiento científico sobre la etiología, diagnóstico, prevención y tratamiento de la fascitis plantar in corredores y su evolución en el tiempo. Permite reconocer a los autores e instituciones que han hecho contribuciones destacables en este ámbito y liderado el camino en el crecimiento de estas investigaciones y los autores más influyentes para ellos.

Keywords:

Plantar fasciitis, skeletal muscle injuries, running, athlete, bibliometrics, citation analysis, scientific maps.

Abstract

Introduction: The cites received by a paper is the most common method used to determine its impact in a particular scientific field. Plantar fasciitis is one of the five most common skeletal muscle injuries in runners. With a multi-factor aetiology, this degenerative process of the plantar fascia occurs when it is repetitively exposed to tensile overload. This research aims to analyse the characteristics of the 25 most-cited papers on plantar fasciitis in runners.

Material and methods: To find the top-cited articles, the Web of Science database was used. Data was analysed regarding the number of citations, year of publication, publishing journal, research area, authorship, institution, country, and bibliographic references.

Results: The 25 most cited articles were published between 1983 and 2009. The 2000s is the most productive decade, paper-wise. 84 % of these articles are from the US. They were published in 11 journals. On average, they had 78.5 citations per article. The main research areas in which the papers were developed were Orthopaedics and Sport Science.

Conclusion: The results of this research facilitate the identification of the most relevant research papers contributing to the development of scientific knowledge in the aetiology, diagnosis, prevention and treatment of plantar fasciitis in runners, and help to determine how it has evolved over time. It is also a way of acknowledging authors and institutions with outstanding contributions and leadership in this research area, as well as their most influential authors.

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INTRODUCTION

As from the 1970s, running became the most popular recreational physical activity due to its clear health benefits, easy-to-practice nature and low cost. The number of runners and running events has considerably raised ever since 2000. The disadvantage of this sport, however, is the high risk of lower limb injury, incidence ranging from 19 to 79 %[1-3]. Several studies have reported a 27 to 70 % injury rate in runners in their first running year as a result skeletal-muscle overload[4].

Plantar fasciitis is one of the five most common skeletal muscle injuries in runners. This degenerative process occurs when the plantar fascia is exposed to repeated strain. The aetiology of plantar fasciitis is related to multiple factors that can be grouped into three general categories: training, anatomical/anthropometric factors, and biomechanical variables[1,4-7]. In runners, this injury has an incidence that ranges from 4.5 to 10 %, and a revalence between 5.2 % to 17.5 %[1].

The bibliometric analysis of bibliographic references in scientific papers contributes to the reconstruction of the intellectual process that gives way to new knowledge, the identification of current research areas, the determination of the influence of papers on subsequent literature, and the evaluation of the reach of a scientific publication. Three methods are used in the identification and analysis of bibliographic references: direct citation, co-citation analysis, and bibliographic coupling[8].

In a paper, a bibliographic citation acknowledges the work done in a specific area by another author. Direct citation is the most common method for the evaluation of the impact of a document on the scientific community.

The higher the number of citations of a paper, the more valuable the paper is in its field[9]. Co-citation quantifies the frequency of two documents being cited together in the literature, which allows identify the most influential papers and authors in a discipline. Bibliographic coupling identifies and quantifies the cases in which papers cite the same references. Two documents citing the same papers is indicative of the existence of links between them; the higher the number of shared references, the greater their thematic proximity[8]. Knowledge maps generated with this type of data are useful to better visualize this information[10].

The Institute for Scientific Information (ISI) has carried out the most relevant bibliographic compilation of scientific papers ever since 1960. The Web of Science is one of the most important databases for the categorisation of data relative to citation and the academic impact of information[9,11,12].

This study aims to identify the 25 most cited running-related plantar fasciitis research papers and analyse their main characteristics by means of bibliometric analysis.

MATERIAL AND METHODS

Data was retrieved on 3 February 2016 by searching the Web of Science Core Collection (WOS-CC). This particular database was chosen for its characteristics: list of names of all paper authors; inclusion of all of the authors' workplace (this piece of information is key for scientific collaboration analysis); it specifies the number of citations received by each paper and includes the references cited by each paper[11,13,14]. The search equation was performed using the following English terms: [(*plantar fasciitis*)] AND [runn* OR athlet*] in the "Topic" field. Synonyms of the terms did not retrieve different records.

Once the search was completed, the 25 most cited research papers related to the study of this pathology in both professional and amateur runners were selected. Documents other than *articles* were ruled out. Records including some of the search terms but not showing a relationship with the subject were also eliminated.

Basic data were recorded and analysed, including abstract, title, authors, year of publication, paper type, journal, organisation, country, research area, number of citations, citation density (average number of citations/year), bibliographic references, impact factor, quartile, and WOS category.

The different denominations of authors and institutions were standardised, this being essential to ensuring more accurate results. Where two or more variants were found for the same name, coincidence in institutional affiliation for each of them was verified. To standardise institutions were identified in the original scientific document or in their respective websites.

The software used for co-occurrence (co-authored and co-citation) networks and for bibliographic coupling network was Bibexcel version 2014-03-25 and Pajek version 4.08[15,16]. For the geolocation of authors, the online tool GPS Visualizer was used.

RESULTS

Table I includes the 25 most cited research papers and their number of citations. Altogether, the articles had 1,962 citations including self-citation. The number of citations per article varies from 410 to 29. The average for the top 25 is 78.5.

The oldest article was published in 1983. It ranks sixth on the 'most-cited' list, while the most recent one dates back to 2009 and ranks twelfth. All the articles were published in English.

The 'hot paper' is *A retrospective case-control injuries analysis of 2002 running injuries,* with 410 citations. It was published in the *British Journal of Sports Medicine* in 2002 by 6 authors from the University of British Columbia: Taunton, JE; Ryan, MB; Clement, DB; McKenzie, DC; Lloyd-Smith, DR; Zumbo, BD. It is a case-control analysis of running injuries, risk factors and gender diversity[17]; the second hot paper is *Risk factors for plantar fasciitis: A matched case-control study,* with 185 citations. It was published in 2003 in *The Journal of Bone & Joint Surgery* by 4 authors from the same institution, Virgin-

Table I. The 25 most cited articles in plantar fasciitis in runners

Title and year of publication	Authors	No. of citations (citation density)
A retrospective case-control analysis of 2002 running injuries (2002)	Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD	410 (27,3)
Risk factors for plantar fasciitis: a matched case-control study (2003)	Riddle DL, Pulisic M, Pidcoe P, Johnson RE	185 (13,21)
Functional biomechanical deficits in running athletes with plantar fasciitis (1991)	Kibler WB, Goldberg C, Chandler TJ	109 (4,19)
Effectiveness of orthotic shoe inserts in the long-distance runner (1991)	Gross ML, Davlin LB, Evanski PM	84 (3,23)
Effectiveness of foot orthoses to treat plantar fasciitis - A randomized trial (2006)	Landorf KB, Keenan AM, Herbert RD	81 (7,36)
Plantar fascia release for chronic plantar fasciitis in runners (1983)	Snider MP, Clancy WG, Mcbeath, AA	79 (2,32)
Anatomical factors associated with overuse sports injuries (1997)	Krivickas LS	78 (3,9)
Results of surgery in athletes with plantar fasciitis (1986)	Leach RE, Seavey MS, Salter, DK	74 (2,39)
Shock wave application for chronic plantar fasciitis in running athletes - A prospective, randomized, placebo-controlled trial (2003)	Rompe JD, Decking J, Schoellner C, Nafe B	73 (5,21)
Treatment of plantar fasciitis by lontophoresis of 0.4 % dexamethasone - A randomized, double-blind, placebo-controlled study (1997)	Gudeman SD, Eisele SA, Heidt RS, Colosimo AJ, Stroupe AL	71 (3,55)
Strains in the metatarsals during the stance phase of gait: Implications for stress fractures (1999)	Donahue SW, Sharkey NA	68 (3,78)
Biomechanical and anatomic factors associated with a history of plantar fasciitis in female runners (2009)	Pohl MB, Hamill J, Davis IS	65 (8,12)
Outcome of nonsurgical treatment for plantar fasciitis (1996)	Gill LH, Kiebzak GM	63 (3)
Acute and overuse injuries correlated to hours of training in master running athletes (2008)	Knobloch K, Yoon U, Vogt PM	60 (6,67)
Biomechanics of longitudinal arch support mechanisms in foot orthoses and their effect on plantar aponeurosis strain (1996)	Kogler GF, Solomonidis SE, Paul JP	57 (2,71)
Plantar fasciitis: Evidence-based review of diagnosis and therapy (2005)	Cole C, Seto C, Gazewood J	53 (4,42)
Mechanical treatment of plantar fasciitis - A prospective study (2001)	Martin JE, Hosch JC, Goforth WP, Murff RT, Lynch DM, Odom RD	51 (3,19)
A biomechanical approach to the prevention, treatment and rehabilitation of plantar fasciitis (1993)	Chandler TJ, Kibler WB	49 (2,04)
Epidemiology and aetiology of marathon running injuries (2007)	Fredericson M, Misra AK	44 (4,4)
Predicting plantar fasciitis in runners (1987)	Warren BL, Jones CJ	43 (1,43)
Plantar fasciitis: A prospective randomized clinical trial of the tension night splint (1996)	Batt ME, Tanji JL, Skattum N	39 (1,86)
Plantar fasciitis in runners treatment and prevention (1990)	Warren BL	36 (1,33)
Impact of demographic and impairment-related variables on disability associated with plantar fasciitis (2004)	Riddle DL, Pulisic M, Sparrow, K	31 (2,38)
Anatomical factors associated with predicting plantar fasciitis in long-distance runners (1984)	Warren BL	30 (0,91)
Current concepts review: Plantar fasciitis (2008)	League AC	29 (3,22)

ia Commonwealth University: Riddle, DL; Pulisic, M; Pidcoe, P; Johnson, RE. With an epidemiological design, their paper seeks to determine whether plantar fasciitis risk factors can be identified. More particularly, the authors examined risk factors such as ankle dorsiflexion with the knee extended, obesity, and time spent weight-bearing[7]; the third most cited paper is *Functional biomechanical deficits in running athletes with plantar fasciitis,* with 109 citations and published in 1991 in the American Journal of Sport Medicine by 3 authors from Lexington Clinic: Kibler, WB; Goldberg, C; Chandler, TJ. Their study was designed to examine the strength and flexibility findings in the muscles that are put on tensile load while running, and which are responsible for controlling the forces on the foot during stance and push-off[18].

The 3 articles with the greatest citation density are *A retrospective case-control injuries analysis of 2002 running injuries, Risk factors for plantar fasciitis: A matched case-control stud* and *Biomechanical* and *Anatomic factors associated with a history of plantar fasciitis in female runners,* with 27.33, 13.21 and 8.12 citations per year, respectively.

Figure 1 shows the overall number of citations received by the articles, per 5-year period, and the cumulative citation figure. Period 2010-2014 has the highest number of citations (n = 771). From period 1995-1999 to period 2010-2014, the cumulative number has kept on doubling.

All along three decades, Figure 2 shows the distribution of publications and the cumulative number of articles, differentiating one-author articles from co-authored ones. The decade with more published papers is 2000-2009, with a total of 11. 84% of the most cited articles were written by more than one author.

Warren BL (n = 3) is the author with more articles. He is followed by Chandler TJ, Kibler WB, Pulisic M, and Riddle DL (n = 2) (Table I), who are the authors who collaborated in 2 articles each (Chandler TJ with Kibler WB, and Pulisic M with Riddle DL). The rest of authors publishing in cooperation only have one co-authorship with some of the authors.

The 25 most cited articles were published by researchers from 6 different countries. In terms of country of origin, the leading publishing nation is the US (n = 21), followed by Canada and Germany (n = 2), and Australia, England and Scotland (n = 1). 24 % of articles are the result of national collaboration. Only 2 articles involved international collaboration, the participating countries being USA with Scotland, and Australia with England.

The geolocation of the authors of the 25 most cited research papers and the collaboration links between their countries can be seen on the map in Figure 3.

32 institutions participate in the articles (Table II). Lexington Clinic, University of California Davis, University of New Orleans, and Virginia Commonwealth University have 2 high-impact articles each.

Figure 4 shows the institutions' collaboration network. 28.1 % of the organisations collaborate with 2 institutions, and 31.2 % cooperate with one institution only. Collaboration between institutions from the same continent is more frequent than with institutions from a different continent.

The most cited articles were published in 11 journals (Table III). The journals publishing the most articles were the *American Journal of Sports Medicine* and *Foot and Ankle International*, 5 articles each, followed by *Sports Medicine,* 4 articles.

The journals where the 25 most cited articles are published have an impact factor between 17.333-0.650. The journal that published the most cited article was the *Bristish Journal of Sports Medicine;* its IF is 5.025, which makes it the second journal with the greatest impact in the Sport Science category of the *Journal Citation Report* Science Edition. The highest impact factor is that of *Archives of Internal Medicine* (IF = 17.333), the journal that published the fifth most-cited article in the rank.

Articles are classified into 7 different WOS categories. 44 % of them are published in journals classified in more than 1 category. The two research areas contributing to the knowledge of plantar fasciitis in runners to a greater extent are orthopaedics (n = 16) and sport science (n = 15).

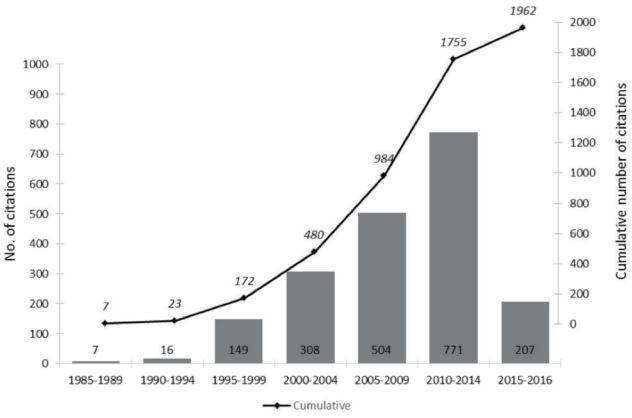

Figure 1. Quinquennial frequency and cumulative number of citations. The last column does not span five years. It only includes citations for 2015 and the first month in 2016.

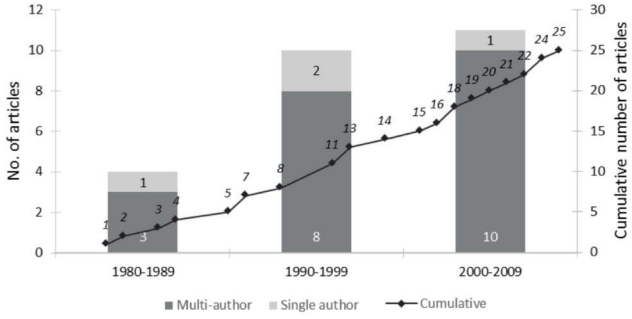

Figure 2. Productivity and collaboration per decade, and cumulative number of articles per year.

Figure 3. Author geolocation map. The size of the nodes represents the higher or lower number of authors publishing on the topic in that particular location. The thickness of the line shows the greater or smaller collaboration frequency between authors from different institutions.

Table II. Top institutions of origin

Institution	No. of articles
Lexington Clinic	2
University of California Davis	2
University of New Orleans	2
Virginia Commonwealth University	2
Boston Univiversity	1
Drayer Physical Therapy Institute	1
Hannover Medical School	1
Harvard University	1
Illinois Bone & Joint Institute	1
Indiana University	1
La Trobe University	1
Miller Orthopaedic Clinic	1
Orthopaedic & Sports Medicine Associates	1
Pennsylvania State University	1
Richmond Physical Therapy	1
Scott and White Hospital	1
Southern Illinois University	1
Specialty Center of Orthopaedics and Rehabilitation Excellence	1
St Mary's Hospital	1
Stanford University	1
Texas A&M University	1
University of British Columbia	1
University of Calgary	1
University of Cincinnati	1
University of Leeds	1
University of Mainz	1
University of Massachusetts	1
University of Strathclyde	1
University of Sydney	1
University of Virginia	1
University of Wisconsin	1
Wellington Orthopaedic & Sports Medicine	1

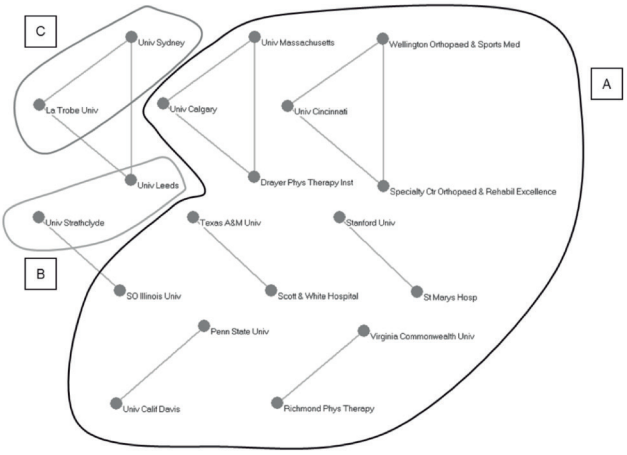

Figure 4. Institutional collaboration network. A: America; B: Europe; C: Oceania

Figure 5 shows the network of citations between the 25 most cited articles. 68% of articles were cited by some of the remaining 24, the article most cited between them being *Functional biomechanical deficits in running athletes with plantar fasciitis* by Kibler WB, 1991 (n = 9), followed by *Plantar fascia release for chronic plantar fasciitis in runners* de Snider MP, 1983 (n = 7) and *Risk factors for plantar fasciitis: A matched case-control study* by Riddle DL, 2003 (n = 5).

After a citation analysis, Figure 6 shows that the most influential authors/articles on the most cited authors are Kibler WB, 1991, V19, P66, Am J Sport Med -cited in 9 articles-, followed by Pfeffer G, 1999, V20, P214, Foot Ankle Int, Kwong PK, 1988, V7, P119, Clin Sport Med, and Snider MP, 1983, V11, P215, Am J Sport Med, each being cited in 7 articles. The figure also shows the co-citation network for the pairs of authors/articles jointly cited in 4 or more articles.

The bibliographic coupling analysis is illustrated in Figure 7. The articles that coincide in the highest number of cited papers are *Current concepts review: Plantar fasciitis* by League AC (2008) and *Shock wave application for chronic plantar fasciitis in running athletes - A prospective, randomized, placebo-controlled trial* by Rompe JD (2003), with 11 in total. *Mechanical treatment of plantar fasciitis - A prospective study* by Martin JE (2001) and *Current concepts review: Plantar fasciitis* by League AC (2008), as well as *Outcome of nonsurgical treatment for plantar fasciitis* by Gill LH (1996) and *Plantar fasciitis: A prospective randomized clinical trial of the tension night splint* by Batt ME (1996), with 9 references in common.

DISCUSSION

Plantar fasciitis is a broadly addressed pathology in scientific literature; the WOS-CC (February 2016) includes 1,008 bibliographic records (729 original articles) published from 42

Table III Journals publishing the 25 most cited articles

Journal	No. of articles	Impact Factor (Year: 2014)	Category WOS	Quartile (JCR)	Position
American Journal of Sports Medicine	5	4,362	Orthopedics	Q1	2
			Sport Sciences	Q1	3
Foot Ankle International	5	1,506	Orthopedics	Q3	36
Sports Medicine	4	5,038	Sport Sciences	Q1	1
Clinical Journal of Sport Medicine	2	2,268	Orthopedics	Q2	19
			Physiology	Q3	43
			Sport Sciences	Q1	18
Journal of Bone and Joint Surgery American Volume	2	5,280	Orthopedics	Q1	1
			Surgery	Q1	6
Medicine and Science in Sports and Exercise	2	3,983	Sport Sciences	Q1	6
American Family Physician	1	2,175	Medicine, General & Internal	Q2	43
			Primary Health Care	Q1	4
Archives of Internal Medicine	1	17,333	Medicine, General & Internal	Q1	6
British Journal of Sports Medicine	1	5,025	Sport Sciences	Q1	2
Clinical Biomechanics	1	1,970	Engineering, Biomedical	Q2	33
			Orthopedics	Q2	26
			Sport Sciences	Q2	26
Journal of the American Podiatric Medical Association	1	0,654	Orthopedics	Q4	58

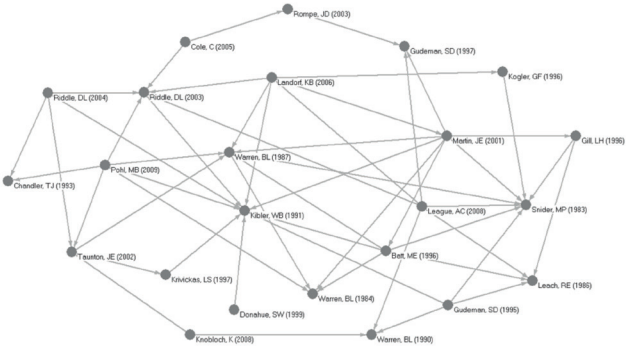

Figure 5. Citation network for the 25 top cited articles. The arrow → indicates that the work of author A cites the work of author B. The name on each node is the first author's name, with the year of publication.

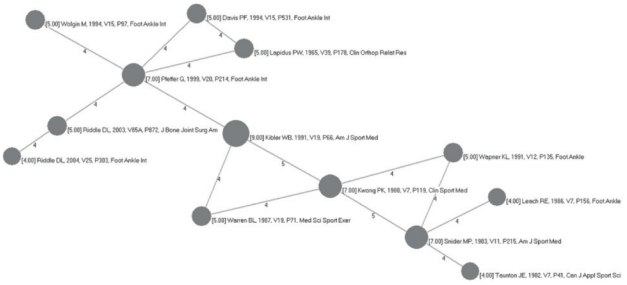

Figure 6. Co-citation network. The values on the lines reflect the frequency of references shared by a pair of nodes (documents). The name on each node is the first author's name, with the year of publication, issue, page and journal. The weight of the node reflects the frequency of citation.

different research areas; yet, the specific study of running-related plantar fasciitis only accounts for 14 % of that literature. In both cases, orthopaedics and sport science are the research areas contributing to the development of the discipline to a greater extent.

In spite of being the most prevalent injury in runners [19], the literature found in the WOS-CC on the same date shows a greater proportion of specialised publications for other more frequent lower-limb injuries caused by skeletal muscle overload in runners, such as Medial tibial stress syndrome, Patellar tendinopathy, Achilles tendinopathy, or Patellofemoral syndrome[1,2], which account for 61.4 %, 37.7 %, 24.7 %, and 23.9 % respectively of the studies conducted on these pathologies in general.

The 25 most cited articles were published between 1983 and 2009. It is worth noting that the publication of arti-

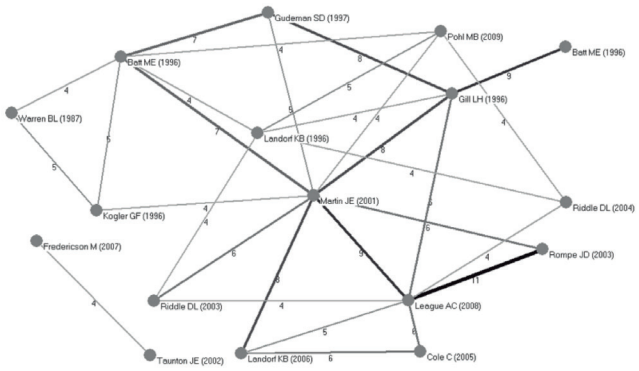

Figure 7. Network of bibliographic coupling. The thickness of the lines and the value reflect the frequency of references shared by a pair of nodes (documents). The name on each node is the first author's name, with the year of publication.

cles focused on plantar fasciitis in runners started with US researchers, following the 1980s boom -about 25 million Americans started running for the first time between November 1984 and November 1986[17].

Although a total of 6 countries contribute to the top-25 list, 84% of articles come from the US. This could be attributed to the United States' large scientific community and sufficient funding[9,11,20].

The decade starting in 2000 is the most productive one, paper-wise. The most cited articles are also from that period. This finding illustrates the researchers' growing interest in this injury, especially as of 2000, with the ever-increasing popularity of running, the organisation of running events and the subsequent injury incidence and the need to prevent it[3,21,22].

Published in the *British Journal of Sports Medicine* in 2002, the article *A retrospective case-control injuries analysis of 2002 running injuries* is also the most cited of all articles on plantar fasciitis in general and could therefore be said to be the most influential for the scientific community studying this particular pathology.

The 25 most cited research papers were cited between 29 and 410 times. Citation density is a measure that shows the relative importance of a paper regardless of the time elapsed since publication. Although it is possible for papers with a higher citation density not to have been included in this study, the method considering the number of absolute citations helps identify the papers more frequently used by researchers as a basis for the own studies[11]. The citation rate gradually increased over the past decade, which points to a higher degree of consideration of this study field.

The articles were published in 11 journals. The most productive journals were: *American Journal of Sports Medicine*, with 5 of the most cited articles, followed by *Foot and Ankle International* and Sports Medicine, both of them with 4 articles. Previous studies found a journal's impact factor to be the strongest indicator for citation, and that most top-cited articles are published in journals with high impact factors[9,23]. Yet, our results suggest that citing the most cited articles is not conditioned by the impact factor of the journal.

The limitations of this study must be noted. Though a well-defined method was used in the identification of the 25 most cited articles, some reviews with a high number of citations were not included because they did not fall under the object of study; likewise, some relevant and influential papers with a lower number of citations were not included, as not enough years have elapsed for them to be further cited. It could be the case that some papers may have been more cited simply because their citation period was longer. In other words, this method favours the oldest papers, which have managed to have a greater number of citations over time. Additionally, a snowball effect might be present: some authors are more likely to cite certain papers only because they are highly cited and not because of what they are worth[24].

In conclusion, this study provides detailed information on the characteristics of the 25 most cited research papers. It sheds some light on the history and development of scientific knowledge as regards the aetiology, diagnosis, prevention and treatment of plantar fasciitis in runners, and it gives an insight into the authors and institutions contributing to the development of this field to a greater extent, who have become world references. The study helps determine the importance of the articles and their impact on the scientific community.

INTEREST CONFLICT

María Ayala-Gascón, Fernanda Garzón-Farinós, Javier Torralba-Estelles y Javier Ferrer-Torregrosa declare that they have no conflicts of interest relevant to the content of this review. It has not been presented anywhere.

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AUTHOR CONTRIBUTIONS

M.A. and J.T. were responsible for project design. M.A., J.F., F.G. and J.T. were responsible for data analysis, writing, and preparation of the manuscript. M.A., J.F., F.G. and J.T. edited and revised the paper. All authors have seen and approved the final submitted manuscript.

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