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Bibliometric and Altimetric Analysis of Research Relating to Percutaneous Electrolysis

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SUMMARY

Objective. Percutaneous electrolysis is a new treatment modality whose benefits have been described in recent years. The aim of this study was to analyze the articles published on percutaneous electrolysis and to compare bibliometric and altimetric analyses.

Methods. Using the keywords "percutaneous electrolysis", all articles published in Web of Science were identified. For bibliometric analysis, article title, number and names of authors, h-index of authors, article citation count, citation index, journal names, impact factors, h- and q-indices, and types of articles were determined. For altimetric analysis, the "Altmetric Attention Score" (AAS) was recorded with a software automatically calculating the score. Correlation analyses between bibliometrics and altimetrics were performed.

Results. The total number of citations in the list was between 0 and 48. The country that produced the most articles was Spain and the most cited author was Fernandez-de-las-Penas. The journals that published the highest number of articles had each published four articles. The majority of the articles consisted of clinical trials. According to Pearson correlation coefficients, there was a moderate and significant correlation between the number of citations and the AASs ($p < 0.005$, $r = 0.561$).

Conclusions. This study provides a general overview of the level of interest shown in articles related to percutaneous electrolysis within the scientific community and on social media platforms. The findings can assist researchers in understanding the current state of research on percutaneous electrolysis and in identifying new directions for future research as promptly as possible. However, more research and collaboration are needed on a global scale.

KEY WORDS

Altmetric analysis; bibliometric analysis; citation; percutaneous electrolysis; galvanic current.

INTRODUCTION

Percutaneous Electrolysis is a medical technique that utilizes a cathode flow to generate a non-thermal electrochemical ablation, triggering a controlled and localized inflammatory response, enabling the activation of cellular mechanisms involved in the healing and regeneration of damaged soft tissue (1-3). It has been successfully applied, particularly in the treatment of chronic tendinopathy in recent years (3). Percutaneous electrolysis utilizes a combination of mechanical (needle) and electrical (galvanic current) stimulation to provide controlled microtrauma and non-thermal electrochemical ablation directly to the degenerated tendon area. This leads to the production of sodium hydroxide molecules, changes in pH, and an increase in oxygen in the treatment area, enabling cellular phagocytosis and activating tendon repair (3, 4). Scientific evidence regarding percutaneous electrolysis has increased in the last decade, and the method has become increasingly popular. Hence, there is a need for bibliometric and altimetric analyses that provide a comprehensive overview of percutaneous electrolysis.

Bibliometric analysis is an analytical method applied to assess the academic productivity of a field within a specific time frame (5). It is used to analyze influential articles, countries, journals, and authors or organizations within a field. Bibliometric analysis results can identify the deficiencies that need consideration in future research and provide guidance for further studies (6). Academics frequently use bibliometric analysis to identify the most valuable publications within their respective fields (7).

Due to the widespread use of the internet and the increased utilization of social media platforms in various aspects of life, alternative metrics have begun to be applied to measure the impact of research. Various internet-based tools allow for the rapid tracking of the social impact of a scientific publication by assessing social media shares, comments on platforms like YouTube, Facebook, Twitter, mentions in news outlets, and academic platforms (8). One of these tools, the "Altmetric Attention Score" (AAS), is a weighted score that assesses and measures the online impact of an article on various platforms, including social media, mainstream news, blogs, and forums (9, 10). AASs are calculated automatically using an algorithm based on the weighted count of all online attention received by a research paper. The concept of "Altmetric Attention Score" gained prominence when Altmetric Explorer (Altmetric, London, UK) began conducting analyses in 2011. Although the concept is still in its infancy, there are articles using and analyzing AASs (11, 12).

The aim of the present study was to analyze all previously published articles related to percutaneous electrolysis using the aforementioned techniques and to assess the relationship between total citation count/citation index and the AAS. Hence, the aim is to contribute to the identification of hypotheses and methodologies for new studies through the data, such as popular topics or deficiencies in this field.

MATERIALS AND METHODS

Study design and search strategy

Similar studies in the literature were reviewed before the study, and the methodology was developed based on these studies (6). The Web of Science database (Clarivate, Analytics, Philadelphia, USA) was used to search for articles. On July 5, 2023, a search was conducted in the Web of Science database for articles published in English between 1975 and 2023 using the keyword "percutaneous electrolysis". Then, using the "Number of Citations" option, the articles were ranked according to the number of citations from highest to lowest. Since the data used in this study were obtained from published articles, ethical approval was not required.

Article selection

The articles were identified through independent screening of abstracts/full texts by two reviewers (F.B. and B.A.) in the Web of Science database according to study type and subject. In case of any disagreement, a third researcher (M.Y.) assisted in reaching a consensus for the final decision. Only articles with a primary focus on percutaneous electrolysis were included in the study. Articles with a primary focus other than percutaneous electrolysis were excluded. Case report or case series, randomized controlled study, case-control study, retrospective study, cohort study, meta-analysis, editorial, prospective study, systematic review, and animal and laboratory study were included. Other types of publications were excluded.

Data extraction

All articles were read by the authors, and parameters such as article title, publication year, number of authors, author names (first and corresponding author), author's country, author's h-index, citation count, citation index, publication type, journal name, journal impact factor, journal's h-index, and q-index were recorded for bibliometric analysis. For articles with authors from different countries, the country of the first author was selected as the country of publication. Citation index is a parameter obtained by calculating the number of citations on an annual basis. It is determined by the ratio of the total number of citations of the article to the number of years elapsed since its publication (13).

The Altmetric Attention Score was obtained through the "Altmetric it" function available on the altmetric.com website. It evaluates the impact of an article by considering not only the citation count but also the views and downloads on social platforms. This includes social media visibility (such as newspapers, Twitter, and Facebook), mentions in research blogs, bookmarks in reference managers like Mendeley, news coverage, and more. The more an article is cited by different authors, the higher the AAS (14). Additionally, the characteristics of the citing authors are also influential in the calculation of the AAS. Details on the calculation method can be found on the aforementioned website.

Statistical analysis

To perform all statistical analyses, IBM SPSS Statistics v. 21.0 statistical software (Armonk, NY, USA) was used. Shapiro-Wilk test was used to determine the distribution of the variables. Descriptive statistics were expressed as "mean ± standard deviation" and "median, minimum-maximum" for quantitative variables and "frequency and percentage (n (%))" for categorical variables. Spearman's rho test was used to evaluate the correlations between variables that did not follow a normal distribution. Accordingly, the correla-

tions were categorized as strong for rho score (r) ≥ 0.60, moderate for r between 0.30 and 0.60, and weak for r ≤ 0.30. $p < 0.05$ was considered statistically significant in all analyses (15).

RESULTS

A search of the Web of Science database between 1975 and 2023 using the keyword "percutaneous electrolysis" revealed a total of 56 articles published between 2010 and 2023. The articles, ranked from the most cited to the least cited, are presented in **table I**. The total number of citations varies between 0 and 48. The mean number of citations was 8.35 ± 10.25 and the median number of citations was 6. For the citation index, the mean value was 1.59 ± 1.49 and the median value was 1.35. The most cited article was "Clinical results after ultrasound-guided intratissue percutaneous electrolysis (EPI®) and eccentric exercise in the treatment of patellar tendinopathy". Published by Abat *et al.* (3) in 2015, the article had 48 citations and a citation index of 5.33. The total number of citations and articles published by year are illustrated in **figure 1**.

AAS of the articles ranged from 1 to 45. For 7 articles, the AAS could not be calculated. The mean AAS was 7.67 ± 9.38 and the median value was 4. The article with the highest AAS was published by Valtierra *et al.* (16) in 2018 with the title "Ultrasound-Guided Application of Percutaneous Electrolysis as an Adjunct to Exercise and Manual Therapy for Subacromial Pain Syndrome: A Randomized Clinical Trial" (**figure 2**). The top three studies with the highest citation counts and AASs were studies examining treatment efficacy (3, 16, 17).

The most cited articles on percutaneous electrolysis were mostly published in 2022 (n = 12), 2020 and 2021 (n = 10) (**figure 1**). Articles on percutaneous electrolysis were published in a total of 39 journals. Two or more articles were published in 10 journals. The highest number of articles were published in Acupuncture in Medicine (n = 4),

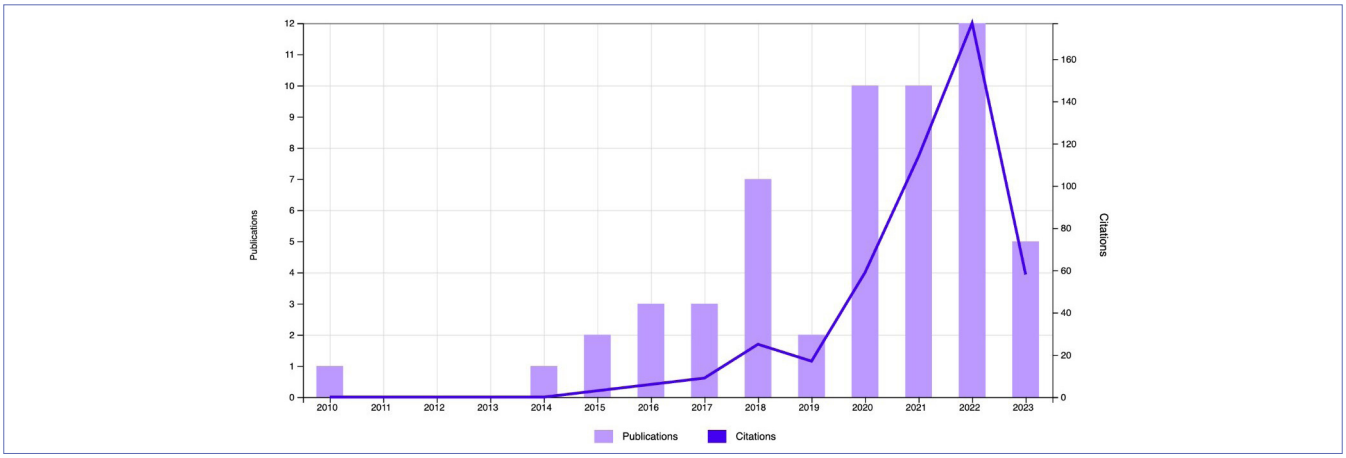

Figure 1. The number of articles and citations are shown by year.

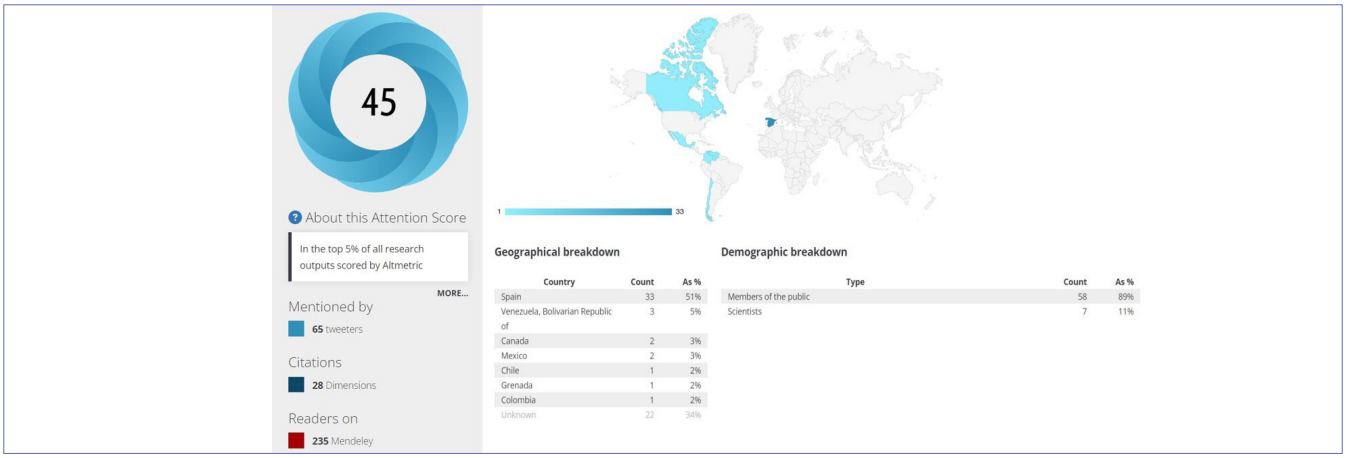

Figure 2. Geographic distribution of the article with the highest altmetric score.

Table I. All articles related to percutaneous electrolysis.

No	Title	Authors	CA	Country	ST	PY	TC	CI	AS	NA
1	Clinical results after ultrasound-guided intratissue percutaneous electrolysis (EPI®) and eccentric exercise in the treatment of patellar tendinopathy	Abat *et al.*	Abat	Spain	Knee Surgery, Sports Traumatology, Arthroscopy	2015	48	5.33	22	5
2	Ultrasound-guided percutaneous needle electrolysis in chronic lateral epicondylitis: short-term and long-term results	Valera-Garrido *et al.*	Valera-Garrido	Spain	Acupuncture in Medicine	2014	43	4.3	31	3
3	Randomized, double-blind study comparing percutaneous electrolysis and dry needling for the management of temporomandibular myofascial pain	Lopez-Martos *et al.*	Gonzalez-Perez	Spain	Medicina Oral, Patología Oral y Cirugía Bucal	2018	33	5.5	13	6
4	Ultrasound-Guided Percutaneous Electrolysis and Eccentric Exercises for Subacromial Pain Syndrome: A Randomized Clinical Trial	Arias-Buria *et al.*	Fernandez-de-las-Penas	Spain	Evidence-Based Complementary and Alternative Medicine	2015	26	2.89	3	6
5	Ultrasound-Guided Application of Percutaneous Electrolysis as an Adjunct to Exercise and Manual Therapy for Subacromial Pain Syndrome: A Randomized Clinical Trial	Valtierra *et al.*	Fernandez-de-las-Penas	Spain	Journal of Pain	2018	23	3.83	47	5
6	Autonomic responses to ultrasound-guided percutaneous needle electrolysis of the patellar tendon in healthy male footballers	De-la-Cruz-Torres *et al.*	De-la-Cruz-Torres	Spain	Acupuncture in Medicine	2016	23	2.88	13	4
7	Percutaneous Electrolysis in the Treatment of Lateral Epicondylalgia: A Single-Blind Randomized Controlled Trial	Rodriguez-Huguet *et al.*	Fernandez-de-las-Penas	Spain	Journal of Clinical Medicine	2020	17	4.25	5	8
8	Effectiveness of Ultrasound-Guided Percutaneous Electrolysis for Musculoskeletal Pain: A Systematic Review and Meta-Analysis	Gomez-Chiguano *et al.*	Fernandez-de-las-Penas	Spain	Pain Medicine	2021	16	5.33	11	7
9	Intratissue percutaneous electolysis combined with active physical therapy for the treatment of adductor longus enthesopathy-related groin pain: a randomized trial	Moreno *et al.*	Moreno	Italy	Journal of Sports Medicine and Physical Fitness	2017	15	2.14	17	5
10	Effectiveness of Percutaneous Electrolysis in Supraspinatus Tendinopathy: A Single-Blinded Randomized Controlled Trial	Rodriguez-Huguet *et al.*	Ibanez-Vera	Spain	Journal of Clinical Medicine	2020	14	3.5	8	8
11	Minimally invasive non-surgical management of plantar fasciitis: A systematic review	Al-Boloushi *et al.*	Herrero	Kuwait	Journal of Bodywork and Movement Therapies	2019	14	2.8	8	5
12	Changes in Gene Expression Associated with Collagen Regeneration and Remodeling of Extracellular Matrix after Percutaneous Electrolysis on Collagenase-Induced Achilles Tendinopathy in an Experimental Animal Model: A Pilot Study	Sanchez-Sanchez *et al.*	Fernandez-de-las-Penas	Spain	Journal of Clinical Medicine	2020	12	3	28	6
13	Autonomic Responses to Ultrasound-Guided Percutaneous Needle Electrolysis: Effect of Needle Puncture or Electrical Current?	Bermejo *et al.*	De-la-Cruz-Torres	Spain	Journal of Alternative and Complementary Medicine	2018	12	2	2	4

No	Title	Authors	CA	Country	ST	PY	TC	CI	AS	NA
14	A novel approach in the treatment of acute whiplash syndrome: Ultrasound-guided needle percutaneous electrolysis. A randomized controlled trial	Naranjo *et al.*	Rosa	Spain	Orthopaedics & Traumatology: Surgery & Research	2017	12	1.71	4	5
15	Treatment of proximal hamstring tendinopathy-related sciatic nerve entrapment: presentation of an ultrasound-guided Intratissue Percutaneous Electrolysis application	Mattiussi *et al.*	Moreno	Italy	Muscles, Ligaments and Tendons Journal	2016	11	1.38	3	2
16	A Comparative Study of Treatment Interventions for Patellar Tendinopathy: A Randomized Controlled Trial	Lopez-Royo *et al.*	Herrero	Spain	Archives of Physical Medicine and Rehabilitation	2021	10	3.33	15	5
17	Current advances and novel research on minimal invasive techniques for musculoskeletal disorders	Romero-Morales *et al.*	Lopez-Lopez	Spain	Disease-a-Month	2021	9	3	3	8
18	Ultrasound-Guided Percutaneous Needle Electrolysis in Dancers with Chronic Soleus Injury: A Randomized Clinical Trial	De-la-Cruz-Torres *et al.*	De-la-Cruz-Torres	Spain	Evidence-Based Complementary and Alternative Medicine	2020	9	2.25	8	5
19	Comparing two dry needling interventions for plantar heel pain: a randomised controlled trial	Al-Boloushi *et al.*	Herrero	Spain	BMJ Open	2020	9	2.25	4	6
20	Prospective Randomized Trial of Electrolysis for Chronic Plantar Heel Pain	Fernandez-Rodriguez *et al.*	Fernandez-Rodriguez	Spain	Foot & Ankle International	2018	9	1.5	21	5
21	Intratissue Percutaneous Electrolysis vs Corticosteroid Infiltration for the Treatment of Plantar Fasciosis	Iborra-Marcos *et al.*	Ramos-Alvarez	Spain	Foot & Ankle International	2018	9	1.5	11	7
22	Autonomic activity in women during percutaneous needle electrolysis	Bermejo *et al.*	De-la-Cruz-Torres	Spain	European Journal of Integrative Medicine	2017	9	1.29	0	4
23	Comparing two dry needling interventions for plantar heel pain: a protocol for a randomized controlled trial	Al-Boloushi *et al.*	Herrero	Spain	Journal of Orthopaedic Surgery and Research	2019	8	1.6	4	6
24	The conservative treatment of longstanding adductor-related groin pain syndrome: a critical and systematic review	Bisciotti *et al.*	Bisciotti	Qatar	Biology of Sport	2021	7	2.33	8	10
25	Rehabilitation of patellar tendinopathy	Muaidi *et al.*	Muaidi	Saudi Arabia	Journal of Musculoskeletal Neuronal Interactions	2020	6	1.5	1	1
26	Ultrasound-Guided Percutaneous Needle Electrolysis and Rehab and Reconditioning Program for Rectus Femoris Muscle Injuries: A Cohort Study with Professional Soccer Players and a 20-Week Follow-Up	Valera-Garrido *et al.*	Valera-Garrido	Spain	Applied Sciences (Basel)	2020	6	1.5	13	5
27	The Effectiveness of Minimally Invasive Techniques in the Treatment of Patellar Tendinopathy: A Systematic Review and Meta-Analysis of Randomized Controlled Trials	Lopez-Royo *et al.*	Ortiz-Lucas	Spain	Evidence-Based Complementary and Alternative Medicine	2020	6	1.5	0	4
28	Comparative study of treatment interventions for patellar tendinopathy: a protocol for a randomised controlled trial	Lopez-Royo *et al.*	Herrero	Spain	BMJ Open	2020	6	1.5	4	8

No	Title	Authors	CA	Country	ST	PY	TC	CI	AS	NA
29	Therapeutic results after ultrasound-guided intratissue percutaneous electrolysis (EPI®) in the treatment of rectus abdominis-related groin pain in professional footballers: a pilot study	Moreno *et al.*	Moreno	Italy	Journal of Sports Medicine and Physical Fitness	2016	6	0.75	15	3
30	Galvanic current activates the NLRP3 inflammasome to promote Type I collagen production in tendon	Penin-Franch *et al.*	Pelegrin	Spain	Elife	2022	4	2	15	11
31	A new ultrasound-guided percutaneous electrolysis and exercise treatment in patellar tendinopathy: three case reports	Fernandez *et al.*	Romero	Spain	Frontiers in Bioscience-Landmark	2021	4	1.33	1	8
32	Short-term effectiveness of high- and low-intensity percutaneous electrolysis in patients with patellofemoral pain syndrome: A pilot study	Valera-Calero *et al.*	Valera-Calero	Spain	World Journal of Orthopedics	2021	4	1.33	1	3
33	Cost-Effectiveness of Two Dry Needling Interventions for Plantar Heel Pain: A Secondary Analysis of an RCT	Fernandez *et al.*	Herrero	Spain	International Journal of Environmental Research and Public Health	2021	4	1.33	2	6
34	Percutaneous Needle Electrolysis Reverses Neurographic Signs of Nerve Entrapment by Induced Fibrosis in Mice	Margalef *et al.*	Santafe	Spain	Evidence-Based Complementary and Alternative Medicine	2020	4	1	5	6
35	Ultrasound-guided percutaneous electrolysis: A new therapeutic option for mammary fistulas	Berna-Serna *et al.*	Berna-Serna	Spain	Medical Hypotheses	2018	4	0.67	1	4
36	Percutaneous Electrochemical Debridement of the Plantaris Tendon A Novel Option in the Treatment of Midportion Achilles Tendinopathy	Mattiussi *et al.*	Moreno	Italy	Journal of the American Podiatric Medical Association	2018	3	0.5	0	2
37	Effectiveness of electrolysis percutaneous intratisular (EPI®) in chronic insertional patellar tendinopathy	Valera-Garrido *et al.*	Valera-Garrido	Spain	Trauma (Spain)	2010	3	0.21	29	3
38	A comparative study of treatment interventions for patellar tendinopathy: a secondary cost-effectiveness analysis	Fernandez-Sanchis *et al.*	Herrero	Spain	Acupuncture in Medicine	2022	2	1	0	6
39	Endogenous Pain Modulation in Response to a Single Session of Percutaneous Electrolysis in Healthy Population: A Double-Blinded Randomized Clinical Trial	Varela-Rodriguez *et al.*	Varela-Rodriguez	Spain	Journal of Clinical Medicine	2021	2	1	1	5
40	Effects of Percutaneous Electrolysis on Endogenous Pain Modulation: A Randomized Controlled Trial Study Protocol	Varela-Rodriguez *et al.*	Fernandez-de-las-Penas	Spain	Brain Sciences	2021	2	0.67	1	7
41	Efficacy of percutaneous electrolysis for the treatment of tendinopathies: A systematic review and meta-analysis	Asensio-Olea *et al.*	Leiros-Rodriguez	Spain	Clinical Rehabilitation	2023	1	0.5	0	5
42	Clinical use of percutaneous needle electrolysis in musculoskeletal injuries: A critical and systematic review of the literature	Martinez-Silvan *et al.*	Martinez-Silvan	Spain	Apunts Sports Medicine	2022	1	0.5	15	14
43	Galvanic current dosage and bacterial concentration are determinants of the bactericidal effect of percutaneous needle electrolysis: an in vitro study	Garcia-Vidal *et al.*	Garcia-Vidal	Spain	Scientific Reports	2021	1	0.33	2	9

No	Title	Authors	CA	Country	ST	PY	TC	CI	AS	NA
44	Safety analysis of percutaneous needle electrolysis: a study of needle composition, morphology, and electrical resistance	Margalef *et al.*	Santafe	Spain	Acupuncture in Medicine	2021	1	0.33	12	5
45	Efficacy of Deep Dry Needling versus Percutaneous Electrolysis in Ultrasound-Guided Treatment of Active Myofascial Trigger Points of the Levator Scapulae in Short-Term: A Randomized Controlled Trial	Benito-de-Pedro *et al.*	Calvo-Lobo	Spain	Life (Basel)	2023	0	0	7	6
46	Botulinum Toxin and Percutaneous Needle Electrolysis for the Treatment of Chronic Masticatory Myalgia	Gonzalez-Perez *et al.*	Infante-Cossio	Spain	Toxins	2023	0	0	1	5
47	Ultrasound-Guided Percutaneous Needle Electrolysis Combined With Therapeutic Exercise May Add Benefit in the Management of Soleus Injury in Female Soccer Players: A Pilot Study	De-la-Cruz-Torres *et al.*	De-la-Cruz-Torres	Spain	Journal of Sport Rehabilitation	2023	0	0	2	3
48	Efficacy of different intensities of percutaneous electrolysis for musculoskeletal pain: A systematic review and meta-analysis	Sanchez-Gonzalez *et al.*	Vinaspre-Hernandez	Spain	Frontiers in Medicine	2023	0	0	0	6
49	Percutaneous Electrolysis (EPI®), a Promising Technology in the Treatment of Insertional Patellar Tendinopathy in Soccer Players	Calderon-Diez *et al.*	Calderon-Diez	Spain	Ambient Intelligence—Software and Applications—13th International Symposium on Ambient Intelligence	2023	0	0	0	4
50	Application of Percutaneous Needle Electrolysis Does Not Elicit Temperature Changes: An In Vitro Cadaveric Study	Borrella-Andres *et al.*	Fernandez-de-las-Penas	Spain	International Journal of Environmental Research and Public Health	2022	0	0	7	10
51	Cadaveric and Ultrasound Validation of Percutaneous Electrolysis Approach at the Distal Biceps Tendon: A Potential Treatment for Biceps Tendinopathy	Calderon-Diez *et al.*	Fernandez-de-las-Penas	Spain	Diagnostics	2022	0	0	1	6
52	Cadaveric and Ultrasound Validation of Percutaneous Electrolysis Approach at the Achilles Tendon as a Potential Treatment for Achilles Tendinopathy: A Pilot Study	Calderon-Diez *et al.*	Fernandez-de-las-Penas	Spain	International Journal of Environmental Research and Public Health	2022	0	0	1	5
53	Percutaneous Needle Electrolysis Accelerates Functional Muscle Regeneration in Mice	Valera-Garrido *et al.*	Santafe	Spain	Applied Sciences (Basel)	2022	0	0	3	5
54	In vitro bacteriological effect of tri-beveled needle electrolysis against Staphylococcus aureus	Garcia-Vidal *et al.*	Garcia-Vidal	Spain	Scientific Reports	2022	0	0	1	6
55	A new ultrasound-guided percutaneous electrolysis and exercise treatment in patellar tendinopathy: three case reports	Fernandez *et al.*	Romero	Spain	Frontiers in Bioscience-Landmark	2022	0	0	1	8
56	Cadaveric and Ultrasound Validation of Percutaneous Electrolysis Approaches at the Arcade of Frohse: A Potential Treatment for Radial Tunnel Syndrome	Belon-Perez *et al.*	Fernandez-de-las-Penas	Spain	International Journal of Environmental Research and Public Health	2022	0	0	1	6

CA: Corresponding author; ST: Source title; PY: Publication year; TC: Total citations; AS: Altmetric score; CI: Citation index; NA: Number of authors.

Evidence-Based Complementary and Alternative Medicine (n = 4), Journal of Clinical Medicine (n = 4), and International Journal of Environmental Research and Public Health (n = 4) journals. **Table II** outlines the top 10 journals by the number of articles published, publishing companies, Q ranking of journals, h-index, and impact factor (IF) data. The majority of articles related to percutaneous electrolysis have originated from Spain (n = 49). Other contributing countries were Italy (n = 4), Qatar (n = 1), Kuwait (n = 1), and Saudi Arabia (n = 1). The number of authors for these articles varies between 1 and 14. In contrast, the majority of the articles (n = 38) were written by 5 or more authors. Authors with the most published articles were Fernandez-de-las-Penas (n = 9), Valera-Garrido (n = 9), and Herrero (n = 8). These three authors were the corresponding author in 20 articles and the first author in 4 articles (**table III**).

The majority of the articles were clinical studies (n = 45), the majority of which were randomized controlled trials. The remaining articles consisted of reviews (n = 8), case reports (n = 1), corrections (n = 1) and proceeding papers (n = 1) (**figure 3**). Nine articles were experimental studies on animals, cadavers or bacteria. A significant and moderate correlation was found between the total citation count and the AAS ($p < 0.005$, $r = 0.561$). There was a significant and moderate correlation between the citation index and the AAS ($p < 0.005$, $r = 0.559$) (**figure 4**).

DISCUSSION

Bibliometric analysis is a research method that employs quantitative methods such as mathematics and statistics to analyze relevant information about the number of articles, their distribution, changes, and quality within a specific time frame and region (5). Traditional bibliometrics is still recognized as a reliable tool. With the help of bibliometric analysis, it is possible to summarize key articles and general publication patterns on a precise scientific topic.

However, there has been a growing interest in altimetric analysis in recent years. Due to the widespread use of social media, it is stated that citations from web-based journals cannot be accepted as the sole criterion for impact factor and that altimetric analysis can be used as an alternative to citation count, impact factor and similar evaluation methods (18). The AAS is generated by calculating the amount

Table II. Journals of the T100 articles (n ≥ 2).

Journals	Number of articles	Citations	IF*	Q category**	H index**	Publishers
Acupuncture in Medicine	4	69	2.267	Q2	51	Sage Publications
Evidence-Based Complementary and Alternative Medicine	4	45	2.629	Q2	112	Sage Publications
Journal of Clinical Medicine	4	45	3.39	Q2	167	MDPI
International Journal of Environmental Research and Public Health	4	4	4.241	Q1	95	Taylor & Francis
Journal of Sports Medicine and Physical Fitness	2	21	NA	Q2	101	Edizioni Minerva Medica
Foot & Ankle International	2	18	2.692	Q1	139	Sage Publications
BMJ Open	2	15	2.827	Q1	120	BMJ Publishing Group
Applied Sciences-Basel	2	6	4.009	Q2	156	MDPI
Frontiers in Bioscience-Landmark	2	4	1.637	Q2	74	IMR Press
Scientific Reports	2	1	4.379	Q1	282	Nature

*IF: Impact factor, 2022 Journal Citation Reports, Web of Science Group; **2022 SCImago Journal and Country Rank; NA: not available.

Table III. Data on the 10 most cited authors are shown.

Rank	Author	Article number	Total Citation	H-index	Country	Affiliation
1	Fernandez-de-las-Penas	9	79	66	Spain	King Juan Carlos University
2	Valera-Garrido	9	71	6	Spain	San Pablo CEU University
3	Herrero	8	59	14	Spain	University of Zaragoza
4	Minaya-Munoz	8	70	5	Spain	San Pablo CEU University
5	Sanchez-Sanchez	7	16	3	Spain	University of Salamanca
6	Calderon-Diez	6	14	2	Spain	University of Salamanca
7	Gomez-Trullen	6	53	10	Spain	University of Zaragoza
8	Lopez-Royo	6	46	6	Spain	San Jorge University
9	Al-Boloushi	5	41	4	Kuwait	Ministry of Health
10	Arias-Buria	5	77	15	Spain	King Juan Carlos University

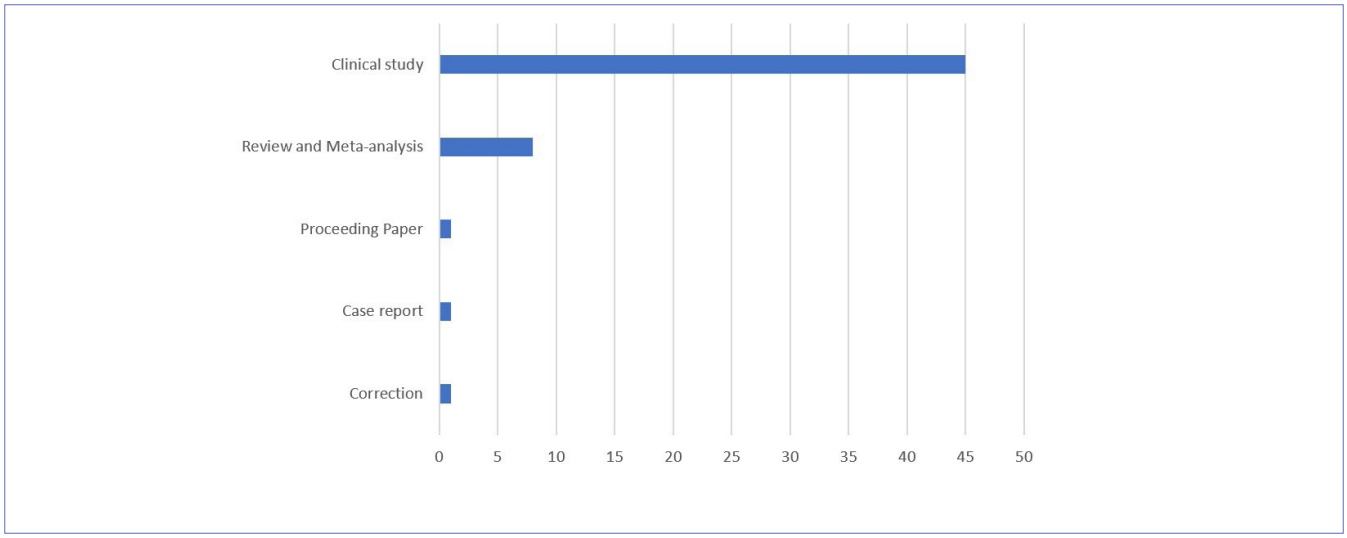

Figure 3. Distribution of article type.

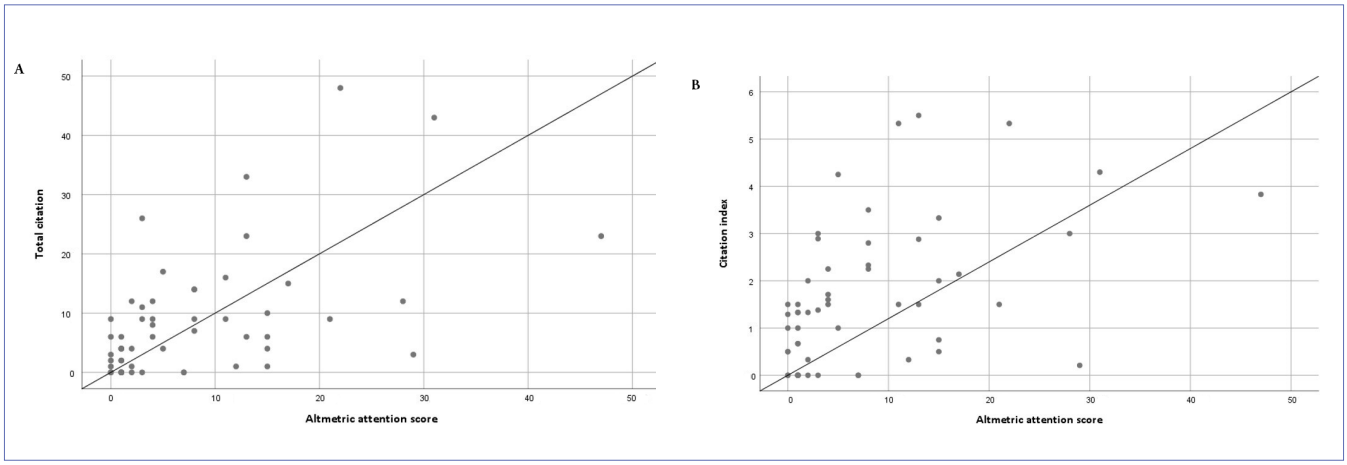

Figure 4. Scatter plot between total citation count and altmetric attention score **(A)**; Scatter plot between citation index and altmetric attention score **(B)**.

of interest in research studies with an automatic algorithm (19). Due to the increasing popularity of altimetric analysis, journals now offer AAS to researchers in addition to the traditional citation score of their articles. Similar to citation-based bibliometric measurements, altimetric measurements do not reflect the quality of a research; they solely measure the online interest in the research.

It has been suggested that traditional bibliometric methods and altimetric analysis cannot be used interchangeably when assessing the online impact and dissemination of articles, but it can instead be used complementarily (20). To the best of our knowledge, there is no study in the literature on percutaneous electrolysis that includes both bibliometric and altimetric analyses. Therefore, a comprehensive, systematic, scientific, and objective research methodology has been employed to comprehensively understand the background and development trends of percutaneous electrolysis treatment, evaluate the current status of research, and explore the hotspots and limitations by combining bibliometric and altimetric analyses. Percutaneous electrolysis is a relatively new treatment modality. The first publication related to percutaneous electrolysis was made in 2010, and in the subsequent years, there has been a significant increasing trend in the number of publications regarding this topic. After the initial publication in 2010, the absence of publications in 2011, 2012, and 2013 is particularly noteworthy. It can be said that it took a certain amount of time for researchers to notice this study. In the following years, the topic attracted attention and the number of publications gradually increased. In 2022, it reached its peak. This trend indicates an increasing interest in percutaneous electrolysis treatment. We believe that the number of publications will continue to increase in the following years.

The highest contribution came from Spain with 49 articles, accounting for 87.5% of the articles published. This may be because percutaneous electrolysis was initially developed in Spain, attracting the interest of other researchers in the country. Usually, in previous bibliometric analyses, United States has been identified as the country with the most contribution (7, 21, 22), and this can be generalized for the entire medical literature. Although there are no previous bibliometric analyses on percutaneous electrolysis, the findings of this study are similar to previous bibliometric reviews on dry needling. In a bibliometric analysis of dry needling, it was observed that Spain was one of the two countries with the most contribution, similar to percutaneous electrolysis (23). Furthermore, similar to the present study, the author with the most publications was "Fernandez-de-las-Penas". According to these results, both dry needling and percutaneous electrolysis topics hold a significant position in Spain.

The journals publishing the most articles, with 4 articles each, were Acupuncture in Medicine, Evidence-Based Complementary and Alternative Medicine, Journal of Clinical Medicine, and International Journal of Environmental Research and Public Health. Two of the journals were of British origin, while the other two were from Switzerland. In general, researchers tend to publish their publications in their own countries (22). Interestingly, in the present study, the top 10 contributing journals were not of Spanish origin. We believe that one reason for this is researchers' desire to publish their research in journals with higher publication value and accessibility to reach a wider audience.

The article titled "Clinical results after ultrasound-guided intratissue percutaneous electrolysis (EPI®) and eccentric exercise in the treatment of patellar tendinopathy", published by Abat *et al.* in Knee Surgery, Sports Traumatology, Arthroscopy in 2015, was the most cited article with 48 citations (3). It had a citation index of 5.33. The article was a prospective study with a Level IV evidence that evaluated 40 patients with patellar tendinopathy over a 10-year follow-up period. The study emphasized that percutaneous electrolysis and eccentric exercises in patellar tendinopathy provided a rapid return to previous activity levels and highlighted their continued benefits during long-term follow-ups. No relapses or adverse events were reported during the 10-year follow-up.

The article titled "Ultrasound-guided percutaneous needle electrolysis in chronic lateral epicondylitis: short-term and long-term results" published by Valera-Garrido *et al.* in Acupuncture in Medicine in 2014 was the second most cited article with 43 citations (17). With an AAS of 31, it was also the study with the second highest AAS. This article had a citation index of 4.3. The effectiveness of percutaneous electrolysis was also emphasized in this prospective study reporting the efficacy of percutaneous electrolysis and eccentric exercise therapy in 36 patients with lateral epicondylitis. The study evaluated structural tendon changes and vascularity using ultrasonographic techniques. During the 52-week follow-up period, no relapse or adverse events were reported. It is noteworthy that the two most cited articles are not randomized controlled trials. In addition, eccentric exercise therapy was applied with percutaneous electrolysis treatment. It is not known how much treatment efficacy depended on either of the treatments. Due to the concurrent application of exercise therapy with percutaneous electrolysis, the efficacy of percutaneous electrolysis treatment could not be clearly established. Therefore, large randomized controlled trials comparing percutaneous electrolysis with control groups are needed.

The third most cited article was "Randomized, double-blind study comparing percutaneous electrolysis and dry needling

for the management of temporomandibular myofascial pain" by Lopez-Martos *et al.* published in Medicina Oral Pathologia Oral y Cirugia Bucal in 2018 (24). This article had 33 citations. It had a citation index of 5.5 and was the article with the highest citation index. Unlike the two most cited articles, this was a randomized controlled double-blind study. The study compared percutaneous electrolysis and dry needling in the treatment of temporomandibular myofascial pain. In this treatment applied on the trigger points of the lateral pterygoid muscle, 60 patients were divided into three groups and the control group underwent a sham needling procedure. Both dry needling and percutaneous electrolysis demonstrated benefits. Improvements were observed earlier in the percutaneous electrolysis group. Percutaneous electrolysis also uses acupuncture needles used in dry needling therapy. Therefore, the mechanical effect of both treatments in the area where they are applied is similar. The additional use of galvanic current may be the beneficial factor here.

Top three articles with the highest AASs ranked 5th, 2nd, and 37th in terms of citation count. These findings also significantly emphasize the difference between bibliometric and altimetric analyses. According to AASs, the article with the highest AAS of 45 was published in The Journal of Pain titled "Ultrasound-Guided Application of Percutaneous Electrolysis as an Adjunct to Exercise and Manual Therapy for Subacromial Pain Syndrome: A Randomized Clinical Trial" (16). The article was published by Valtierra *et al.* in 2018. The findings of this randomized controlled study showed that adding percutaneous electrolysis treatment to exercise and manual therapy treatment was beneficial in subacromial pain syndrome. With 23 citations and a citation index of 3.83, this article was also the fifth article with the highest number of citations. The randomized controlled design was a strength of this study.

"Effectiveness of electrolysis percutaneous intratisular (EPI®) in chronic insertional patellar tendinopathy", the first published article on percutaneous electrolysis, had the third highest AAS with 29 points. It was published by Valera-Garrido *et al.* in the Trauma (Spain) journal in 2010 (25). The effectiveness of percutaneous electrolysis combined with eccentric exercises was evaluated in 32 patients with patellar tendinopathy, and the treatment's efficacy was emphasized. Interestingly, this article has only three citations and ranks 37th in the citation count. This finding further emphasizes the difference between citation count and altimetric score. The article also has a citation index of 0.21. The most significant limitation of this study was that it was not a randomized controlled trial.

Interestingly, the fourth-highest article in terms of altimetric score, with an AAS of 28, was the one published in 2020 by Sanchez-Sanchez *et al.* titled "Changes in Gene Expression Associated with Collagen Regeneration and Remodeling of Extracellular Matrix after Percutaneous Electrolysis on Collagenase-Induced Achilles Tendinopathy in an Experimental Animal Model: A Pilot Study" (26). This animal study focused on histological and gene expression changes after percutaneous electrolysis in experimentally induced Achilles tendinopathy. The authors identified a significant increase in the molecular expression of COX2, MMP9 and VEGF genes in Achilles tendons treated with percutaneous electrolysis. They stated that these changes in gene expression could enhance collagen regeneration and remodeling of the extracellular matrix. These findings indicate that the effects of percutaneous electrolysis treatment at the tissue level have garnered attention in social media. The effects of galvanic current at the cellular and tissue level will be further investigated as percutaneous electrolysis therapy becomes more widespread and its benefits are demonstrated.

Articles related to percutaneous electrolysis were studies investigating its effectiveness, mechanisms of action, physiological effects, and reliability. Studies evaluating treatment efficacy were particularly prominent (n = 40). In the vast majority of these studies, the effectiveness of percutaneous electrolysis has been investigated in the treatment of chronic tendinopathy patients, both as a standalone treatment and in addition to exercise therapy. There are also publications investigating the effectiveness of percutaneous electrolysis in myofascial pain syndrome, breast fistula, and acute whiplash syndrome (17, 27, 28). The general message conveyed by these studies is that percutaneous electrolysis treatment is beneficial. However, it has also been indicated that long-term randomized controlled trials are needed to demonstrate that this benefit persists over time (29). Additionally, it has been mentioned that applying percutaneous electrolysis under ultrasound guidance would provide maximum precision while minimizing damage to other structures (30). Although articles on this topic initially began to be published in 2010, the increasing number of studies resulted in the highest number of articles entering the list between 2020 and 2023. Upon evaluating the pool of articles included in the study based on the years, as expected, the largest number of citations was made to articles published in 2022. Upon examining other studies in the literature that combine bibliometric and altimetric analyses, although there are studies indicating a high correlation between AAS and citation count (5), most of the studies we reviewed show a moderate to weak correlation (6, 14, 22, 31, 32). Similarly, in the present study, the correlation between citation count and altimetric score was not completely consistent and the correlation level was moderate. Social media trends and traditional bibliometric data are often inconsistent. This is because AAS is calculated based on current interactions from social

media platforms, news, policy documents, blogs, and more. It therefore reflects the influence of individual users rather than professional researchers (6). Therefore, bibliometric and altimetric analyses should be considered complementary to each other.

From the articles included in this study, we found that 10 were published in journals focusing on Complementary and Integrative Medicine, 10 articles were published in general medical journals, 8 in orthopedic journals, and 7 in sports science journals. This is another finding showing the usage of percutaneous electrolysis treatment across various medical fields and pathologies.

Being the first study to assess the research productivity related to percutaneous electrolysis is a fundamental strength of this study. Bibliometric analysis provides researchers with precise information for constructing new research. In this regard, we believe that this analysis will serve as a reference point to attract researchers' attention and shed light on new research interests related to percutaneous electrolysis. Among other strengths of our study, the analysis we conducted to provide a comprehensive perspective on percutaneous electrolysis was not solely based on social media and public platform interactions or solely on citation counts. Instead, these methods were used together to provide a clearer perspective, and the correlation between altimetric and bibliometric data was also evaluated. It is believed that such a measurement combination could provide the most robust insight into research productivity within a medical field.

This study also has some limitations. The research was conducted only within the Web of Science database, excluding other databases such as Google Scholar, Scopus, and PubMed, which might have affected the number of articles analyzed. However, Web of Science is one of the most popular databases and it covers a relatively comprehensive literature, has strong reliability and authority, and is widely cited in bibliometric analyses (33). Only English articles were included in the study. The inclusion of articles in other languages could provide a broader perspective. The citation analysis did not examine self-citations and interactions between citations. Parameters that may affect science, such as income levels of countries, were also excluded from the study. Some of the articles had no AAS. This is due to both AAS being a newer measurement in terms of research impact and potential reach, and the emergence and increasing popularity of percutaneous electrolysis in recent years. We believe that the popularity of percutaneous electrolysis will continue to increase on social media in the coming years. Daily changes in social media, fluctuations over time periods or with respect to certain events can alter the results. With the rapid changes in social media, the results also tend to be highly variable. This is one of the limitations of altimetric analysis. In addition, some social media outlets are not covered by Altmetric. Although the most popular and widely used social media tools are covered by Altmetric, this is also a limitation. There is a need for more comprehensive studies that analyze larger databases, include articles in other languages, identify links between authors and countries, examine financial support, and conduct self-citation analysis.

CONCLUSIONS

Using bibliometric and altimetric analysis methods, we revealed the global productivity characteristics of articles on percutaneous electrolysis. Bibliometric and altimetric analyses help uncover research trends in the respective field, aid in understanding current topics, highlight gaps in the field, and guide researchers for potential future research. In this regard, the present study may contribute to new developments in percutaneous electrolysis.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

All authors contributed equally to this article.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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