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Top 50 cited articles on cardiac rehabilitation: A bibliometric and altmetric analysis study

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Abstract

Background/Aim: Cardiovascular disease (CVD) is the leading cause of death globally, with an estimated 18.6 million deaths each year. Cardiac rehabilitation (CR) has positive effects on reducing the mortality and morbidity of CVD, so there is a growing interest in this field. The aim of this study was to analyze the top 50 cited articles in the field of CR.

Methods: The Web of Science (WoS) database was searched for articles published between 1986 and 2021. A record was made of the following information for the bibliometric analysis: article title, year of publication, number of authors and their names, number of citations, citation index, journal of publication, impact factor, type of article, and source of funding. The altmetric attention score (AAS) was recorded using automatic software calculation.

Results: The majority of articles were published in the journal "Circulation" (n=14) and the "Journal of the American College of Cardiology" (n=8). The country with the highest number of articles was the US (n=27), and the most cited author was P.A. Ades. Studies evaluating exercise-based rehabilitation, key components of CR, and secondary prevention were among the top cited articles. In terms of AAS, in addition to the titles mentioned, mobile health services that rely on communication technologies have also received attention.

Conclusion: This study provides useful information for researchers interested in CR, including trends, topics of interest in the field, and potential research collaborations. It is intended to guide future, more comprehensive, and in-depth studies on CR.

Keywords: cardiac rehabilitation, bibliometric analyses, altmetric analyses, citation

Introduction

Cardiovascular diseases (CVDs) remain a major cause of mortality and morbidity globally. In 2019, over 18.6 million people died from CVD, representing a 17.1% increase from the previous decade [1]. There were also more than 523.2 million cases of CVD in 2019, a 26.6% increase compared to 2010. Experts predict that the global burden of CVD will continue to grow in the coming years due to the long-term effects of the COVID-19 pandemic [2]. According to the National Burden of Disease Study, 8% of the total burden of disease in 2004 was due to CVD, and CVD was the leading cause of morbidity among adults in Turkey [3]. Ischemic heart disease in particular has been the leading cause of the increasing global burden of disease in the past 30 years. Therefore, preventing the occurrence and recurrence of CVD should be a top priority in reducing the burden on public health systems worldwide.

Cardiac rehabilitation (CR) has been shown to improve cardiopulmonary function, reduce cardiovascular risk and mortality, decrease relapses and hospitalizations, and improve quality of life [4-12]. Hence, the steady increase of scientific evidence showing the positive effect of CR on the mortality and morbidity of CVD has attracted the attention of many clinicians in recent years. However, the availability and capacity of CR programs varies greatly by region and country, and many patients do not have access to the benefits of participation [13].

Another study investigating the availability and distribution of CR in Europe found that 90.9% of European countries had a CR program. However, only one spot is available for every seven patients in need, although this density is quite good compared with other regions of the globe [14]. In Turkey, it is estimated that the economic burden of CVD, including direct healthcare costs and indirect costs from loss of productivity, will double to $19.4 billion by 2035 [15].

Bibliometric analysis is a statistical method that can be used to identify trends and changes within a research field, to profile publications on a subject, and to improve the quality of science through a systematic and reproducible review process [16,17]. Bibliometric analysis is a quantitative research technique based on bibliographic data that provides information about the general perspective of a research field based on articles, authors, and journals [18]. In the bibliometric analysis method, a wide variety of analysis techniques, including citation-based and performance-based analysis, are used to classify publications according to countries, universities, research groups, or authors [19]. In recent years, bibliometric analysis has been used to analyze various diseases in different branches of medicine.

When searching for the most valuable articles on a specific topic, researchers usually consider criteria such as the journal of publication, current impact factor, h-index, and number of citations. However, with the widespread use of the internet and social media platforms in recent years, platforms such as Facebook, Linkedin, Twitter, and blogs have become important tools that contribute to the promotion of medical literature [20-22]. Altmetric analysis is used to gather quantitative data and determine the metrics of a particular article on these platforms. In this study, we analyzed the 50 most cited (T50) articles on CR between 1985 and 2021 using these techniques and evaluated the relationship between the total number of citations/citation index and AAS. The aim was to contribute to the development of new study goals and methodologies by providing data on current issues in the field of CR, the most interesting research areas, and any deficiencies.

Materials and methods

The Clarivate Analytics Web of Science (WoS) database (Philadelphia, USA) was used to identify the top 50 articles related to CR. The database was searched using the keywords "Cardiac Rehabilitation" to identify articles published between 1985 and 2021 in English as of December 31, 2021. The articles were then ranked according to the number of citations from highest to lowest using the "Number of citations" option. Ethics committee approval was not needed for this study as the data analyzed were taken from published articles.

The top 50 articles were identified through a search of the WOS database by two reviewers, who searched abstracts and full texts according to the study type and subject. Only original articles and reviews were included as publication types, while letters to the editor, editorial material, corrections, and other types of publications were excluded. Only articles with CR as the main focus were included, whereas articles with a core topic other than CR were also excluded, even if they included information on CR. In cases where the two reviewers had differing opinions, a third reviewer was consulted to reach a consensus. During the bibliometric analysis, the information recorded included the citation index, title of the article, number of authors, names of authors (first authors and corresponding authors), country, publication year, number of citations, type, subject, and funding sources, Q classification of the publication, h-index, and impact factor. If the authors of the article came from multiple countries, the corresponding author's country was considered as the country of origin for the article.

The AAS was used to determine the impact of an article by taking into account the number of citations and the level of engagement on internet-based social platforms, including views and downloads. The "Altmetric it" function on the website https://www.altmetric.com was used to calculate the AAS. The AAS is calculated based on three primary factors: volume, sources, and authors. The number of citations an article receives from different authors is directly related to the AAS.

More references to an article result in a higher submetric attention score. Different citation sources, such as Facebook, blogs, Twitter, and LinkedIn, have varying levels of influence on the score. The characteristics of the authors citing the article also factor into the calculation of the AAS. More information about how the AAS is calculated can be found on the Altmetric website (https://www.altmetric.com).

Statistical analysis

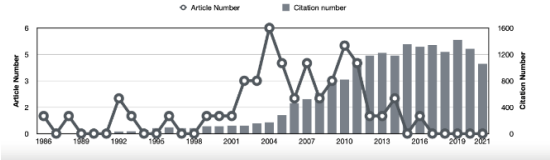
All statistical analyses were conducted using the software IBM SPSS Statistics v. 21.0. The Shapiro-Wilk test was used to determine the distribution of variables. Descriptive statistics were expressed in the form of mean (standard deviation [SD]) for quantitative variables and in the form of "frequency and percentage (n [%])" for categorical variables. Spearman's rank correlation analysis was used to evaluate correlations

between non-normally distributed variables. Relationships were considered highly correlated when the correlation coefficient (r) was ≥0.60, moderately correlated when r was between 0.30 and 0.59, and weakly correlated when r was ≤0.29. A *P*-value of <0.05 was considered statistically significant.

Results

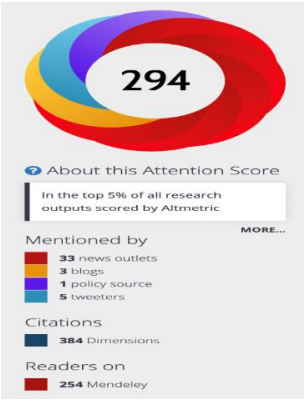
The search yielded 16,971 articles on CR published between 1986 and 2021 in the WoS database. Table 1 shows the top 20 most cited articles from the top 50 articles obtained (#1 and #100 in the supplemental material). The top 50 articles had citation counts ranging from 169 to 1509 with an average of 390.82 (638.36) and a median value of 258.5. The number of articles and citations of the top 50 articles between 1985 and 2021 is shown in Figure 1.

Figure 1: The number of articles and citations of the top 50 articles between 1985 and 2021



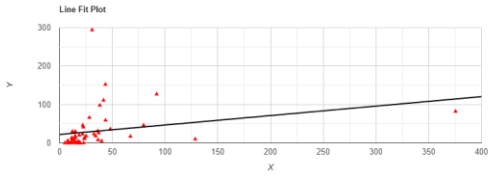
The AAS ranged from 1 to 294. The AAS could not be determined for 12 articles. The average AAS was 22.1 (47.7) with a median value of 8. The most cited article in the top 50 was "Exercise-based rehabilitation for patients with coronary heart disease (CHD): Systematic review and meta-analysis of randomized controlled trials" (#1), which was published by Taylor et al. in 2004. "Exercise-based cardiac rehabilitation for CHD" (#2), another study published by Taylor et al. in 2011, ranked first in the citation index score, although it ranked second in the total number of citations. The study with the highest AAS was "Referral, Enrollment, and Delivery of Cardiac Rehabilitation/Secondary Prevention Programs at Clinical Centers and Beyond: A Presidential Advisory From the American Heart Association" (#15), which was by Balady et al. and published in 2011 (Figure 2).

Figure 2: Altmetric donut of the study entitled "Referral, Enrollment, and Delivery of Cardiac Rehabilitation/Secondary Prevention Programs at Clinical Centers and Beyond A Presidential Advisory From the American Heart Association"



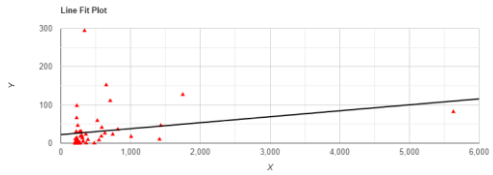
When examining the articles in the top 50 list, it was determined that the most cited were studies examining the three basic components of CR: education, exercise training, psychological support, and secondary prevention [23-25]. The AAS values for the most prominent topics related to CR were highest for referral systems, enrollment and utilization, smartphone-based home care models, and the basic components of CR [26,27]. Exercise-based rehabilitation (n=15), secondary prevention (n=14), and participation and referral to CR (n=7) were the most frequently analyzed topics in the top 50 articles. A significant correlation was found between the citation index and the AAS (P<0.05, r=0.259) (Figure 3). Similarly, a significant correlation was observed between the total number of citations and the AAS (P<0.05, r=0.245) (Figure 4).

Figure 3: Correlation Graphic of Citation Index and The Altmetric Attention Score



Results of the Pearson correlation indicated that there is a non-significant small positive relationship between X and Y, (r(48)=0.259, P=0.069).r=0.2594

Figure 4: Correlation graphic of total number of citations and the altmetric attention score



Results of the Pearson correlation indicated that there is a non-significant small positive relationship between X and Y, (r(48)=0.245, P=0.086).r=0.2454

The most cited articles on CR were mainly published in 2004 (n=6) and 2010 (n=5) (Figure 1). No articles published after 2016 were included in the top 50 list. The top 50 articles were published in 18 journals, with two or more articles published in 10 journals (Table 2). Most of the articles were published in the journal “Circulation” (n=14), the “Journal of the American College of Cardiology” (n=8), and “the European Heart Journal” (n=4) (Table 3).

The countries that contributed the most to T50 articles were the USA (n=27), the United Kingdom (n=8), and Italy (n=8). The number of authors of T50 articles ranged from 1 to 24. The majority of the articles (n=35) had 5 or more authors. P.A. Ades and N. Oldridge were the most frequent authors. Oldridge was also the most highly cited author with a total of 4407 citations. Furthermore, he was the first and corresponding author in one article and contributed to six articles in total.

Table 2: Journals of the T100 articles (n≥2)

Journal	Number of articles
Circulation	14
Journal of The American College of Cardiology	8
European Heart Journal	4
European Journal of Preventive Cardiology	3
Heart	3
American Journal of Medicine	2
European Journal of Cardiovascular Prevention & Rehabilitation	2
JAMA-Journal of The American Medical Association	2
Archives of Internal Medicine	2
Cochrane Database of Systematic Reviews	2

Table 3: Journals with T50 articles, ranked according to times cited

Journal name	Number of articles	IF	H - Index	Q Classification
Circulation	14	6.16	607	Q1
Journal Of The American College Of Cardiology	8	4.75	431	Q1
European Heart Journal	4	5.87	293	Q1
European Journal of Preventive Cardiology	3	1.49	101	Q1
Heart	3	1.33	183	Q1
American Journal of Medicine	2	1.37	229	Q1
European Journal of Cardiovascular Prevention & Rehabilitation	2	1.49	101	Q1
JAMA-Journal of The American Medical Association	2	11.48	680	Q1
Archives of Internal Medicine	2	5.21	342	Q1
Cochrane Database of Systematic Reviews	2	1.31	273	Q1
BMJ-British Medical Journal	1	6.27	429	Q1
British Journal of Health Psychology	1	0.97	88	Q1
Journal of Psychosomatic Research	1	0.80	156	Q1
New England Journal of Medicine	1	26.14	1030	Q1
Stroke	1	1.81	319	Q1
Clinical Rehabilitation	1	1.39	110	Q1
Mayo Clinic Proceedings	1	2.16	179	Q1
American Heart Journal	1	1.11	187	Q1

*IF: Impact factor, Q Classification: Quarter classification of Journal

Table 1: Top 20 cited articles

Title	Authors	Source Title	PY	TC	CI	AS	AT
1-Exercise-based rehabilitation for patients with coronary heart disease: Systematic review and meta-analysis of randomized controlled trials	Ref#25	American Journal of Medicine	2004	1509	83.83	46	Meta-Analysis
2-Exercise-based cardiac rehabilitation for coronary heart disease	Ref#24	Cochrane Database of Systematic Reviews	2011	1479	134.45	10	Meta-Analysis
3-Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol - Consensus statement of the Study Group of Sports Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology	Ref#23	European Heart Journal	2005	851	50.06	36	Review
4-Cardiac Rehabilitation After Myocardial Infarction - Combined Experience Of Randomized Clinical-Trials	Oldridge et al.	JAMA-Journal of The American Medical Association	1988	774	22.76	23	Meta-Analysis
5-Core components of cardiac rehabilitation/secondary prevention programs: 2007 update -	Ref#36	Circulation	2007	704	46.93	152	Guideline
6-Cardiac rehabilitation and secondary prevention of coronary heart disease - An American Heart Association Scientific Statement from the Council on Clinical Cardiology in collaboration with the American Association of Cardiovascular and Pulmonary Rehabilitation	Leon et al.	Circulation	2005	689	40.53	26	Review
7-Recommendations for competitive sports participation in athletes with cardiovascular disease -	Pelliccia et al.	European Heart Journal	2005	604	35.53	18	Review
8-Statement on exercise: Benefits and recommendations for physical activity programs for all Americans - A statement for health professionals by the committee on exercise and cardiac rehabilitation of the council on clinical cardiology, American Heart Association	Fletcher et al.	Circulation	1996	602	23.15	41	Guideline
9-Use of cardiac rehabilitation by Medicare beneficiaries after myocardial infarction or coronary bypass surgery	Suaya Jose et al	Circulation	2007	562	37.47	8	Research Article
10-Secondary prevention through cardiac rehabilitation: from knowledge to implementation. A position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation	Piepoli Massimo et al	European Journal of Cardiovascular Prevention & Rehabilitation	2010	554	46.17	7	Review
11-Medical progress: Cardiac rehabilitation and secondary prevention of coronary heart disease.	Ades	New England Journal of Medicine	2001	501	23.86	0	Review
12-Efficacy of exercise-based cardiac rehabilitation post-myocardial infarction: A systematic review and meta-analysis of randomized controlled trials	Ref#32	American Heart Journal	2011	397	36.09	23	Meta-Analysis
13-Statement On Exercise – Benefits, And Recommendations For Physical-Activity Programs For All Americans	Fletcher et al	Circulation	1992	394	13.13	9	Guideline
14-Prediction of long-term prognosis in 12 169 men referred for cardiac rehabilitation	Kavanagh et al	Circulation	2002	380	19	0	Research Article
15-Referral, Enrollment, and Delivery of Cardiac Rehabilitation/Secondary Prevention Programs at Clinical Centers and Beyond A Presidential Advisory From the American Heart Association	Ref#26	Circulation	2011	355	32.27	294	Guideline
16-Cardiac Rehabilitation and Survival in Older Coronary Patients	Suaya, Jose et al	Journal Of The American College of Cardiology	2009	334	25.69	13	Research Article
17-Secondary prevention in the clinical management of patients with cardiovascular diseases. Core components, standards, and outcome measures for referral and delivery	Piepoli, Massimo et al.	European Journal of Preventive Cardiology	2014	331	41.38	5	Guideline
18-Relationship Between Cardiac Rehabilitation and Long-Term Risks of Death and Myocardial Infarction Among Elderly Medicare Beneficiaries	Hammill, Bradley et al.	Circulation	2010	327	27.25	18	Research Article
19-Action plans and coping plans for physical exercise: A longitudinal intervention study in cardiac rehabilitation	Sniehotta et al.	British Journal of Health Psychology	2006	303	18.94	20	Research Article
20-Global Secondary Prevention Strategies to Limit Event Recurrence After Myocardial Infarction Results of the GOSPEL Study, a Multicenter, Randomized Controlled Trial From the Italian Cardiac Rehabilitation Network	Giannuzzi, Pantaleo et al.	Archives of Internal Medicine	2008	282	20.14	0	Research Article

PY: Publication year, TC: Total citations, AS: Altmetric score, CI: Citation index, AT: Article type

Discussion

Bibliometric analysis is a scientific evaluation method that quantitatively evaluates articles published within a certain time period and the relationships between them. It provides comprehensive information about parameters such as global publication efficiency, trends over the years, the status of countries, and citation data [28]. Altmetric analysis takes into account the impact of a publication on social media and the internet and can be used as a supplement or alternative to traditional evaluation methods such as the impact factor [29]. Altmetrics track the online activity related to research output, allowing us to evaluate the immediate social impact of an article through real-time analysis of its online presence and dissemination. Few studies have used altmetric analysis to evaluate the impact of research on social media and the internet, and to the best of our knowledge, no study has combined bibliometric and altmetric analysis to evaluate the impact of research on CR. In this study, we aimed to present a broad perspective on the field of CR through both bibliometric and altmetric analyses of the top 50 articles in the field of CR.

Bibliometric assessments often involve analyzing the number of citations received by articles, which is a crucial aspect of evaluating the impact and influence of research. Although the article investigating exercise-based rehabilitation in patients with CHD published in 2004 was the most cited article in this study, the article investigating exercise-based cardiac rehabilitation for CHD published in 2011 had the highest citation index. This article is also the second most cited article [24,25]. Along with these two articles, exercise-based rehabilitation was the most frequently researched topic with a total of 15 articles in the T50 list. Exercise is one of the three core modalities of CR, along with education and psychological support, as outlined in international guidelines and expert consensus [30].

High-quality systematic reviews provide important data and scientific evidence for the use of exercise-based CR specifically in the CVD population and confirm that it reduces cardiovascular risk and mortality, as well as reinfarction after myocardial infarction and hospitalizations due to heart failure [24,25,31,32]. Exercise training has been shown to have direct benefits on the heart and blood vessels supplying the heart, including reduction of the heart's oxygen needs, improvement of endothelial function and autonomic tone, modification of coagulation and inflammatory markers, and promotion of the growth of coronary collaterals [33]. However, a previous review of the research on exercise-based CR for CHD found that the decreased mortality rates associated with CR may be due to the indirect effects of exercise, such as improved risk factors for clogged arteries [34]. International guidelines recommend exercise-based CR as a crucial part of comprehensive care for individuals with CHD and heart failure, but a large number of patients globally do not receive this treatment.

The article that received the most attention according to AAS was a guideline that examined the referral, enrollment, and delivery of CR and secondary prevention [26]. "Core components of cardiac rehabilitation/secondary prevention programs: 2007 update" and "Exercise-based cardiac rehabilitation for CHD 2016" ranked second and third,

respectively [35,36]. Although the article with the highest number of citations ranked fifth, the articles that received the most attention according to the altmetric analysis were not those with the most citations. The publications with the top two AASs ranked 15th and 5th in terms of the number of citations they received.

These results illustrate the contrast between bibliometric and altmetric analyses. The T50 list included studies on key components of CR, such as secondary prevention, referral, enrollment and delivery to CR, and the impacts of CR on mortality, a smartphone-based home care model, and home and center-based CR. In particular, studies based on exercise, which is among the main components of CR, were emphasized (n=15). These studies emphasized the efficacy and importance of CR in the prevention of CVD and the reduction of mortality. In recent years, with the widespread use of technology and the internet by patients, smartphone-based CR programs and activities have come to the forefront [27].

Another important issue studied in the top 50 articles was patients' referrals and participation in CR. A few developed Western countries, such as the United States, the United Kingdom, and Canada, have developed mature and well-established CR propulsion systems, as well as systematic and standardized CR models. Despite this, CR awareness and participation are generally low in most developing countries and regions. An international study investigating the worldwide availability of CR found it to be present in 111 of 203 countries [13]. According to data from the World Health Organization, CR programs can be found in the majority of European countries (80.7%), a substantial number of countries in the Americas (70.0%), over half of the countries in Southeast Asia and the Eastern Mediterranean Region (54.5% in both regions), just under half of the countries in the Western Pacific region (42.7%), and a small number of countries in Africa (17.0%) [13].

The articles included in the T50 list, which were drawn from the period of 1986 to 2021, were predominantly published between 2004 and 2010 (n=26). The increase in publications during this period can be explained by the contribution to the development of CR of the physical activity and exercise guideline in CVD patients published by the AHA in 2003, followed by the systematic guideline on CR published jointly by the AHA and AACPR in 2007. No article published after 2016 could enter the T50 list. This is an understandable result as the quoting process is time-consuming. Chen et al. [37] have shown that an article can reach its maximum number of citations in about 3 years from the date of publication. Therefore, the citation counts for articles published in 2016 or more recently may not be accurately reflected in the database search conducted in this study.

Nearly all of the articles with high AASs were published after 2004, with the exception of the 1996 American Heart Association article titled, "Benefits and recommendations for physical activity programs for all Americans." AAS could not be determined for 12 articles, which were mostly published before 2003. This occurred because altmetric analysis has only been actively used for a relatively short period of time, so less data are available for articles published earlier. The AAS of current articles can be expected to be higher. A broad range of data sources were analyzed to identify the T50 articles, and by including more recent articles, this study also evaluated publications that have not yet had the opportunity to receive a significant number of citations. This is believed to be the reason for the moderate to poor correlation observed between the citation index or number of citations and altmetric scores. This factor should be kept in mind when interpreting the study results.

The country that contributed the most to the T50 list was the USA, with 27 articles, as in many branches of medicine. The USA was followed by the UK and Italy with 8 articles each. In bibliometric analyses conducted on different subjects in the field of medicine, the USA is generally the first country. These findings may be the result of the significant number of articles published in the United States, as well as the nation's high level of scientific excellence, or the preponderance of journals based in the United States and Canada in which the articles were published. Previous bibliometric studies have suggested that journals tend to publish articles that originate from their own regions [38,39].

The funding rate for articles on CR was low. Almost all of the funders were public institutions, and almost all of the funded articles were from the USA. This suggests that economic resources may play a significant role in the production of articles that are likely to generate high-quality scientific interest.

The prevalence of CVD is increasing rapidly all over the world due to the aging and growth of populations. There are also increases in survival rates after CVD, depending on both the advances in healthcare and the widespread access of patients to health services [1,4,7]. There is accumulating evidence in the literature that CR, a supervised program that typically includes exercises, health education, and psychological intervention, improves mortality, morbidity, and quality of life for patients following a cardiac event [5,7-12,40]. Despite the positive effects of CR in increasing the quality of life of patients and reducing the health cost burden of countries, its application is not widespread worldwide. Except for a few developed countries (USA, UK, and Canada), few countries have referral and treatment systems with established applicability and efficiency. In our study, both the most highly cited publications and those with the highest altmetric scores were also from these countries. Furthermore, most of the journals in which these publications were published were based in these countries.

Keyword clustering analysis and co-citation analysis of references reflect CR's trends and hotspots. Early studies of CR focused on mainly the efficacy of CR and the disease groups to which it would be applied. With the steady increase of evidence regarding the positive effects of CR on CVD, studies seem to focus more on referral, enrollment, delivery of CR, and secondary prevention. Current hotspots are the three core components of CR that focus on exercise prescription for CR: training, exercise training, and psychological support. In addition, with the spread of the internet and its ease of accessibility, patient-centered remote health applications have also started to emerge and become popular. Since COVID-19 entered our lives in 2019, none of the studies on CR in this field have yet reached the number of citations to enter the T50 list. However, CR is likely to be critically important in the treatment of CVD caused by COVID-19 [41-43].

Limitations

One of the limitations of the study is that the study was based on only a search in the WoS database. Other databases (Scopus, Google Scholar) and articles written in different languages were not included in the analysis. In addition, cross-country citation interaction and dimensions of self-citation have not been explored.

Conclusion

Exercise-based rehabilitation was found to be the most frequently studied topic in the top 50 articles related to CR. The most cited articles were mainly from 2004 and 2010 and were published in journals such as “Circulation”, “the Journal of the American College of Cardiology”, and “the European Heart Journal”. The study found that the countries that contributed the most to the top 50 articles were the USA, the United Kingdom, and Italy. The study also found that there is a correlation between the citation index and the AAS. The results suggest that more research on CR is needed to improve the availability and capacity of CR programs worldwide and to reduce the burden of cardiovascular disease. Additionally, bibliometric and altmetric analysis can provide a more comprehensive view of the state of a particular research area than traditional methods and guide further studies in these areas.

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