A Bibliometric Analysis of the Top Cited Articles in Sports and Exercise Medicine

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Background: Although citation analysis is common in many areas of medicine, there is a lack of similar research in sports and exercise medicine.

Purpose: To identify and examine the characteristics of the 100 top cited articles in the field of sports and exercise medicine in an effort to determine what components make an article highly influential.

Study Design: Cross-sectional study.

Methods: The Web of Science, Scopus, and PubMed databases were used to determine the 100 top cited articles from 46 journals in the field of sports and exercise medicine. Each of the 100 articles was then analyzed by 2 independent reviewers, and results were compared. Basic information was collected, including journal title, country of origin, and study type. Different categories were compared using descriptive statistics of counts or percentages.

Results: The 100 top cited articles were published in 15 of the 46 identified sports and exercise medicine journals, with the most prolific being *Medicine and Science in Sports and Exercise* (n = 49), *American Journal of Sports Medicine* (n = 18), and *Sports Medicine* (n = 7). In terms of country of origin, the top 3 contributors were the United States (n = 65), Canada (n = 9), and Sweden (n = 8). The most commonly researched anatomic areas were the knee (n = 15) and the brain (n = 3). Narrative reviews were the most common study type (n = 38), and only a single study on the 100 top cited articles list used a randomized controlled trial design. The most prevalent fields of study were exercise science (55% of articles) and well-being (16% of articles).

Conclusion: Narrative reviews from the United States and published in English-language journals were the most likely to be highly cited. In addition, the knee was a common anatomic area of study on the top cited list of research in sports and exercise medicine

Keywords: citation analysis; citation counts; top cited articles; sports medicine; exercise medicine

Citation analysis is a bibliometric method to evaluate research performance in a specific field by examining the frequency and patterns of citations in scientific literature.[26,36] It is one effective method of determining an article's effect on a particular site of study.[12,19,20,29,31] It is also commonly used by academic institutions and government bodies to recognize scholarly excellence for the purposes of allocation of funding and determination of awards, as well as for tenure decisions. Within medicine, there are numerous examples of the use of citation analysis to identify scholarly work of particular significance in a specialty of interest.[3,5,6,26,28,34,36,41]

Sports and exercise medicine is a broad and rapidly growing discipline involving the following: (1) management of sports injuries and medical conditions in exercising individuals; (2) the biomechanics and optimization of athletic performance; and (3) the use of exercise as a medical intervention in the treatment, rehabilitation, and prevention of illness at the individual and population level.[30] This breadth and growth is evidenced in part by the increasing number of articles published by researchers in a variety of journals related to this topic. At the time of this study, there were 46 journals related to sports and exercise medicine in the combined databases of Web of Science, Scopus, and PubMed. One area of sports and exercise medicine is orthopaedic sports medicine, which mainly involves prevention and treatment of musculoskeletal conditions in sports.

Web of Science is a subscription-based platform that provides access to 15 citation indexes.[15] This encompasses >34,385 journals, books, proceedings, patents, and data sets, which extend from 1800 to present day. Web of Science was originally produced by the Institute for Scientific Information and is currently maintained by Clarivate Analytics. Scopus is a subscription-based abstract and indexing database that was produced by Elsevier.[10] It indexes >14,000 titles from 4000 publishers. Scopus contains 27 million abstracts with citations dating back to 1966. PubMed is a free database administered by the National Center for

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Biotechnology Information at the US National Library of Medicine that contains >30 million citations and abstracts of peer-reviewed biomedical literature.[44] It does not include full-text journal articles; however, links to full-text articles from other sources are provided when available.

Although citation analysis is common in many areas of medicine,[5,6,26,28,34,36,41] there is a lack of similar research in sports and exercise medicine. The only previous effort of a citation analysis of the literature in its entirety was by Garfield,[21] who looked at data between 1981 and 1996 and presented his findings at the 44th Annual Meeting of the American College of Sports Medicine on May 13, 1997. However, his findings remained unpublished. Nayar et al[33] also performed a citation analysis, but it focused on the subspecialty of orthopaedic sports medicine. The purpose of this study was therefore to fill this void by identifying the 100 top cited articles published in journals related to sports and exercise medicine and analyzing key characteristics, such as year of publication, country of origin, source journal, and level of evidence. We hypothesized that factors, such as language, topic, level of evidence, and country of origin, would be among the key determinants of scientific effect.

We believe that this study will provide valuable information about the evidence basis for specific aspects of current clinical practice in sports and exercise medicine and help inform practitioners, researchers, and policy makers about potential research and funding priorities.[4] The analysis can also assist researchers in finding appropriate strategies for achieving the highest scientific effect.

METHODS

The first step in our analysis was to identify and create a list of journals with a focus on sports and exercise medicine. Citation analyses in the past used a single database to create this list of journals.[23,25,26] To create a more comprehensive list, we used the combined databases of Web of Science, Scopus, and PubMed. In May 2019, we searched the Web of Science category "sport sciences," which yielded 316,740 publications. The source journals of these publications were determined and comprised a list of 100 journals. From this list, we removed those that were not closely related to sports and exercise medicine, leaving us with 35 journals. Next, we searched Scopus using the subject category "orthopaedics and sports medicine." This provided us a citation rank list of 334 journals, which was reduced to 44 journals after removal of those not closely related to sports and exercise medicine. Next, we searched PubMed using the term "sports medicine." This search yielded 10,578 articles. We identified the journals of origin and selected those that were related to sports and exercise medicine, yielding a total of 27 journals. Finally, we combined the selected journals from the 3 sources and removed any duplicate entries, thus creating a master list of 46 sports and exercise medicine–related journals (Appendix Table A1).

The second step in our analysis was to determine the 100 top cited articles from our comprehensive list of journals. We performed a complete search of all the journals on Web of Science, which generated 154,492 publications. These publications were then ranked by number of times cited, and the 100 top cited articles were recorded. Each of these 100 articles was then analyzed by 2 independent reviewers (O.K. and B.S.) using a standardized questionnaire, and the results were compared. Basic information was collected, including source journal, publication year, H-index, Altmetric score, language of publication, study participants, research design, research methods, study design, level of evidence, authors, age group, field of study, and study conclusions. The H-index, proposed by J.E. Hirsch in 2005, is an author-specific value that captures output based on the total number of publications and the total number of citations.[42] It provides a focused assessment of an individual's research performance. The Altmetric score is a weighted count of all the online attention that a research output has received.[43] This includes mentions in public policy documents and references in Wikipedia, the mainstream news, social networks, and blogs.

The different categories of information were compared using descriptive statistics of counts or percentages. Statistical analysis was performed using jamovi Version 1.0.8.0 (The jamovi project). A chi-square test of association and linear regression test were used to compare groups. $P \leq .05$ was considered significant.

RESULTS

The 100 top cited articles are listed in Appendix Table A2. The top 28 articles were cited >1000 times, and the range in the top 100 was from 7228 to 534 citations. They were published in 15 of the 46 identified sports and exercise medicine–related journals; the 3 journals with the majority of articles in the top 100 were the *American Journal of Sports*

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Ethical approval was not sought for the present study.

TABLE 1
Number of Articles in 100 Top Cited Articles List by Source Journal

Journal	No. of Articles
Medicine and Science in Sports and Exercise	49
American Journal of Sports Medicine	18
Sports Medicine	7
Research Quarterly for Exercise and Sport	4
British Journal of Sports Medicine	3
Journal of Athletic Training	3
Journal of Sports Sciences	3
Canadian Journal of Sports Sciences	3
Exercise and Sport Sciences Review	2
International Journal of Sports Medicine	2
Journal of Strength and Conditioning Research	2
Clinical Journal of Sport Medicine	1
International Journal of Sports Physiology and Performance	1
Journal of Orthopaedic and Sports Physical Therapy	1
The Physician and Sportsmedicine	1

Medicine (n = 18), *Medicine and Science in Sports and Exercise* (n = 49), and *Sports Medicine* (n = 7), as seen in Table 1.

The publication dates of the 100 top cited articles spanned between 1973 and 2013. The 5 top cited articles[1,9,13,18,38] were published in the years 1982, 2000, 2003, 2007, and 2011. The decade with the greatest number of articles in the top 100 was the 2000-2009 period (n = 51), and only 1 article[8] was published in the 1970s (Figure 1A). There was less variation in the mean number of citations in each decade, as seen in Figure 1B.

Although all of the top 100 articles were published in English, there was some diversity in terms of the country of origin. The top 3 contributors were the United States (n = 65), Canada (n = 9), and Sweden (n = 8). The most prominent institution was the University of South Carolina, with 4 articles[1,35,39,40] in the top 100. In terms of contributions from outside the United States, the University of Copenhagen and the University of Queensland also had substantial influence, with 3 articles each.[7,24,32] The most frequent author was S.G. Trost, with 5 lead authorships. The number of authors per article ranged from 1 to 10, with 10 articles being published by a single author.

Of the 100 top cited articles, 22 focused on a specific anatomic zone, such as the knee (n = 15), brain (n = 3), or ankle (n = 2) (Figure 2), with the remainder being more general in scope.

Many of the articles studying the knee were related to the biomechanics, consequences, and prevention of ACL injury. All articles focusing on the brain discussed sports-related concussion. In terms of the age demographic evaluated, the largest proportion of articles were general and not focused on any specific population (n = 44). However, a significant number investigated a pediatric (n = 16) or an adult (n = 31) population. Similar age groups were studied regardless of decade of publication ($P = .64$; $\chi^2 = 23.3$; χ^2 test of association). In terms of field of study, 69 articles had a single focus, and 31 were multifocus (Figure 3A). The most common field of study was exercise science, with

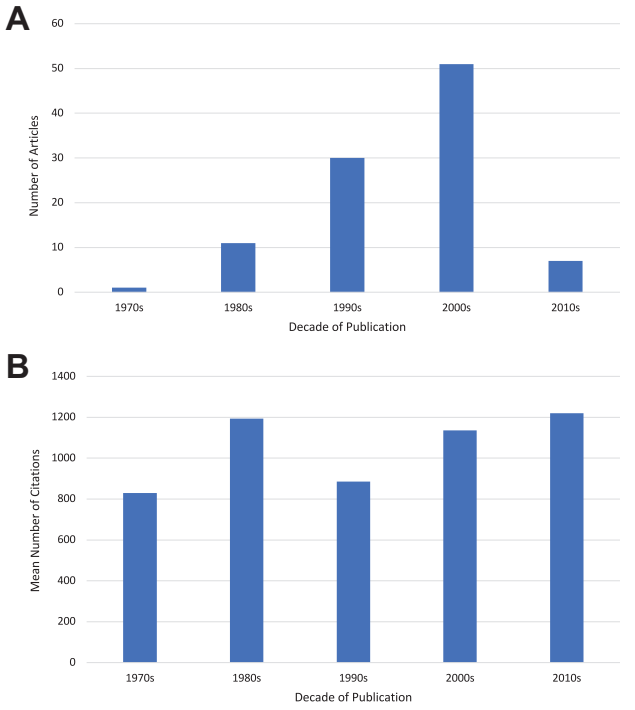

Figure 1. (A) Number of articles on the 100 top cited articles list by decade of publication. (B) Mean number of citations by decade of publication for articles on the 100 top cited articles list.

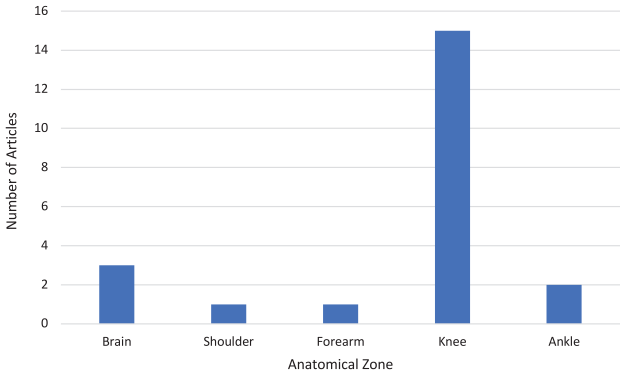

Figure 2. Breakdown of the 100 top cited articles based on anatomic area of focus.

55% of articles featuring it as at least a partial focus (Figure 3B).

Well-being and clinical injury studies were also quite common, as they were areas of interest in 16% and 13% of articles, respectively. Of the 100 top cited articles, 10 were sport-specific studies, with soccer being the most common sport of interest (n = 6).

The 3 most common study types from the 100 top cited articles were narrative review (n = 38), cohort (n = 20), and methodological (n = 16). Case series accounted for only 10% of the top 100 top cited articles. Only 1 article in the top 100 was a randomized controlled trial.[37] The most common level of evidence was level 4 (n = 68), which is consistent

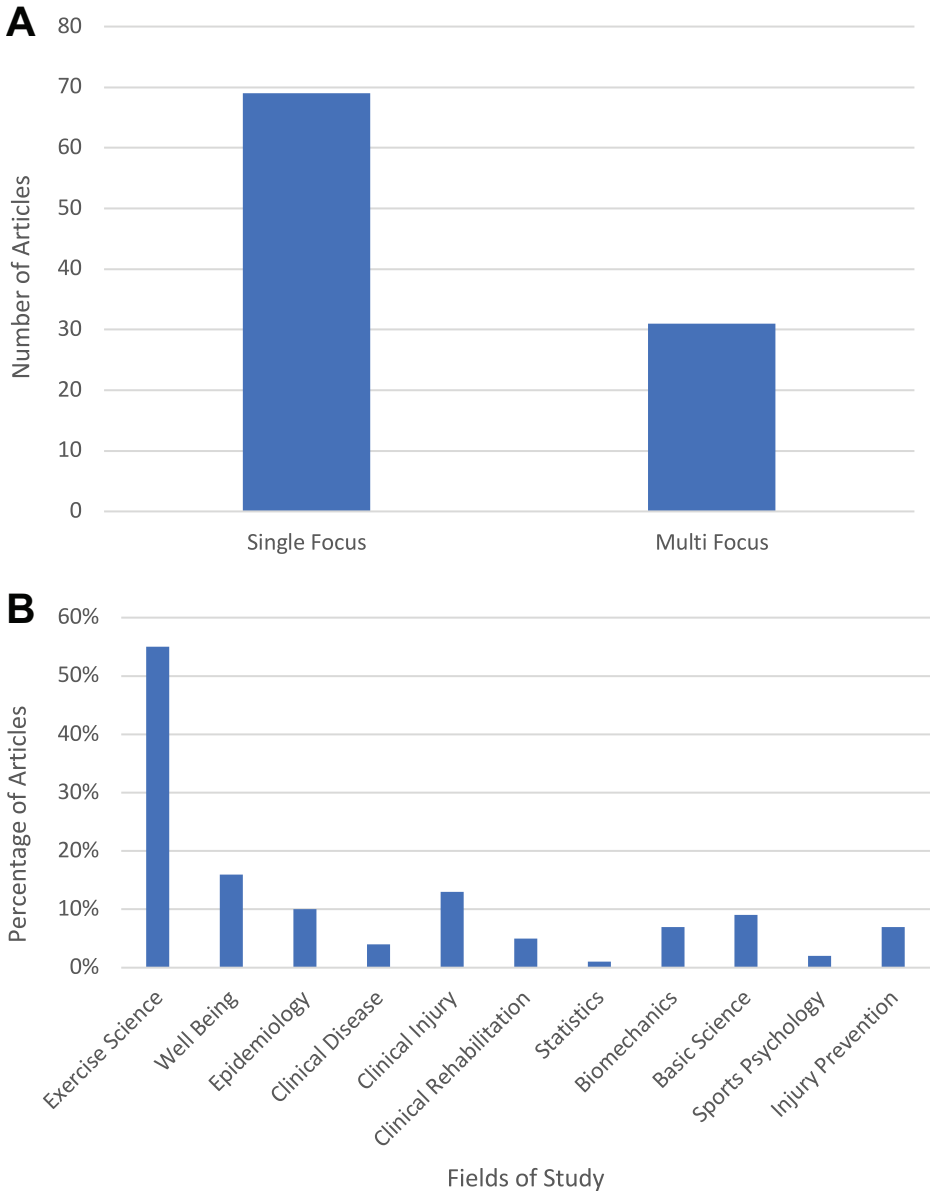

Figure 3. Breakdown of articles on the 100 top cited articles list based on (A) singular or multiple fields of study and (B) field of study by percentage of all articles.

with the most frequent study design types. There was no significant difference in level of evidence based on decade of publication ($P = .85$; $\chi^2 = 10.1$; χ^2 test of association).

We found no correlation between an article's Altmetric score and the number of times that it was cited ($r = 0.08$; linear regression test; $P \leq .05$). We also found no correlation between the H-index of the lead author of an article and the number of times that it was cited ($r = 0.05$; linear regression test; $\leq .05$).

DISCUSSION

The purpose of this article was to identify the 100 top cited articles in the field of sports and exercise medicine and examine their characteristics in an effort to determine what elements of an article make it highly influential.

The top cited article in our list had 7228 citations[9] (Appendix Table A2). Comparatively, this is much greater than that of the top cited article in similar reviews of other subspecialties, such as orthopaedic surgery (1748 citations),[26] rehabilitation (1109 citations),[36] and emergency medicine (335 citations).[41] In terms of the temporal distribution of citations, the 2000-2009 period had by far the greatest number of citations on our 100 top cited articles list (n = 51); this appears in line with a similar study on spinal deformity.[45] The earliest article was published in 1973 and was the only article[8] on the list from the 1970s (Figure 1A). In a similar citation analysis in orthopaedic

surgery, a substantial number of top cited articles were published in the 1940s to 1970s.[26] This unique citation pattern in sports and exercise medicine is likely secondary to several key assertions. First, as shown in previous studies, it generally requires 10 to 20 years for prominent articles to receive their maximal recognition and reach their peak in terms of number of citations.[2,20,22] Second, sports and exercise medicine is a relatively novel medical discipline, especially in comparison with orthopaedic surgery. Third, there has been a rapid growth in the field of sports and exercise medicine, with increased formal fellowship training opportunities over the past 2 decades, which has in turn vastly increased the amount of research output from the speciality.[3,14]

Nearly two-thirds of the 100 top cited sports and exercise medicine–related articles were from the United States. Although this makes up the majority, it is actually a smaller proportion when compared with other medical subspecialties, such as general surgery (78%),[34] orthopaedic surgery (76%),[26] and otolaryngology (85%).[16] This preponderance of US-based publications is secondary to several factors: (1) the American scientific community is sizably larger than that of anywhere else in the world; (2) the United States has the most available funding for research; and (3) American authors tend to preferentially cite American articles and publish their articles in American journals.[11] As a result, US authors have an inherent advantage when attempting to publish highly cited and influential articles, although it seems that this advantage is slightly mitigated in sports and exercise medicine.

We found that 68% of the top cited articles were classified as level 4 evidence, which is reflected in the most common study type of narrative review. Case series, which were very common in previous citation analyses in orthopaedic surgery and rehabilitation,[26,36] accounted for only 10% of the 100 top cited articles. This difference may partially be attributable to the multitude of institutional reviews, especially by the American College of Sports Medicine, which have been highly influential in sports and exercise medicine literature and are found throughout our 100 top cited articles list.

The knee was by far the most common anatomic site of study, accounting for 15 articles on the 100 top cited articles list (Figure 2). A majority of these articles focused on the anterior cruciate ligament. Areas of focus included injury prevention, short- and long-term consequences of injury, epidemiology, rehabilitation, and biomechanics. There was also a preponderance of female athlete studies in the ACL-related publications. These articles were published across a broad time span, extending from 1988 to 2005, and may serve as a possible area of focus for future researchers who hope to publish articles that affect the field of sports and exercise medicine.

Overall, 10% of the articles on the 100 top cited articles list were sport-specific studies, with the majority focusing on soccer. This was somewhat of a surprise because the United States was responsible for the majority of articles and soccer is of relatively lower popularity in this country in comparison with other major sports, such as football, baseball, and basketball.[17] It may point to alternative explanations for this predisposition to soccer, such as ease of research, interest from highly influential or highly cited authors, increased acceptance of research groups into professional and semiprofessional soccer teams, sport-specific injury patterns, or possibly the popularity of the sport worldwide.

We found no correlation between the number of times that an article was cited and its Altmetric score. This may highlight a discrepancy between an article's effect within the scientific community, which can be gauged by the number of times that it is cited, and its influence on the community at large, which is what the Altmetric score aims to capture.

As is the case with other citation analyses, several limitations to this study should be acknowledged. First and possibly the most significant is that, although we strived to create the most comprehensive list of journals possible using the combined databases of Web of Science, Scopus, and PubMed, articles published in general medical and basic science journals were not considered in this study, possibly leaving out influential works. A second limitation relates to the time of publication, with more recently published articles having an inherent disadvantage in terms of citation count. Given this disadvantage, potentially more relevant and highly influential articles published more recently[27] may not have made the 100 top cited articles list because they have not had enough time to accumulate the necessary number of citations. This type of citation analysis also does not account for self-citation, citation in textbooks or lectures, and the predilection of authors to cite articles that are published in the journals in which they hope to publish their own work. There may also be confounding attributed to biases related to the tendency to cite articles generated by prolific researchers or colleagues, as well as a tendency to cite an article because it has previously been highly cited, in a type of "snowball effect."

CONCLUSION

To our knowledge, this is the first comprehensive published citation analysis in sports and exercise medicine. Our findings indicated that narrative reviews focused on exercise science that were from the United States and were published in English-language, US-based journals were the most likely to be highly cited. We also found that the knee was a common anatomic site of study in these highly cited articles.

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APPENDIX

TABLE A1
Sports and Exercise Medicine–Related Journals on Web of Science, Scopus, and PubMed

Journal Name
American Journal of Sports Medicine
Annals of Applied Sport Science
Apunts Medcina de l'Esport
Biology of Sport
BMC Sports Science, Medicine and Rehabilitation
British Journal of Sports Medicine
Canadian Journal of Sports Sciences
Clinical Journal of Sports Medicine
Clinics in Sport Medicine
Current Sports Medicine Reports
Deutsche Zeitschrift fur Sportmedizin
European Journal of Sport Science
European Journal of Sports Traumatology and Related Research
Exercise and Sports Sciences Reviews
German Journal of Exercise and Sport Research
International Journal of Performance Analysis in Sport
International Journal of Sport Nutrition and Exercise Metabolism
International Journal of Sports Medicine
International Journal of Sports Physiology and Performance
Japanese Journal of Physical Fitness and Sports Medicine
Journal of Athletic Training
Journal of Orthopaedic and Sports Physical Therapy
Journal of Science and Medicine in Sport
Journal of Sport and Health Science
Journal of Sport Rehabilitation
Journal of Sports Medicine and Physical Fitness
Journal of Sports Science and Medicine
Journal of Sports Sciences
Journal of Strength and Conditioning Research
Knee Surgery, Sports Traumatology, Arthroscopy
Medicina dello Sport
Medicine and Science in Sports and Exercise
Medicine and Sport Science
Montenegrin Journal of Sports Science and Medicine
Operative Techniques in Sports Medicine
Orthopaedic Journal of Sports Medicine
Physical Therapy in Sport
Research in Sports Medicine
Research Quarterly for Exercise and Sport
Revista Brasileira de Medicina do Esporte
Sports Biomechanics
Sports Health: A Multidisciplinary Approach
Sports Medicine
Sports Medicine and Arthroscopy Review
Sportverletzung Sportschaden
The Physician and Sportsmedicine

TABLE A2
Top 100 Cited Articles Published in Sports and Exercise Medicine–Related Journals on Web of Science, Scopus, and PubMed

Rank	Article	No. of Citations
1	Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982;14(5):377-381.	7228
2	Craig CL, Marshall AL, Sjostrom M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc.* 2003;35(8):1381-1395.	6193
3	Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc.* 2000;32(9):498-504.	4055
4	Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc.* 2007;40(1):181-188.	3584
5	Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand: quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults. Guidance for prescribing exercise. *Med Sci Sports Exerc.* 2011;43(7):1334-1359.	2803
6	Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc.* 2007;39(8):1423-1434.	2748
7	Ainsworth BE, Haskell WL, Leon AS, et al. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc.* 1992;25(1):71-80.	2712
8	Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc.* 1999;32(5):963-975.	2513
9	Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc.* 2008;41(1):3-13.	2346
10	Hopkins WG. Measures of reliability in sports medicine and science. *Sports Med.* 2000;30(1):1-15.	2099
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