

**ANTRENMAN VE EGZERSİZ YAYINLARININ GELİŞİMİ: 1980-2021
DÖNEMİNDE KÜRESEL ÜRETKENLİK VE YAYIN EĞİLİMLERİ**

**THE DEVELOPMENT OF TRAINING AND EXERCISE
PUBLICATIONS: GLOBAL PRODUCTIVITY AND PUBLICATION
TRENDS DURING 1980-2021**

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Antrenman ve Egzersiz Yayınlarının Gelişimi: 1980-2021 Döneminde Küresel Üretkenlik ve Yayın Eğilimleri

ÖZ

Spor bilimleri içinde önemli bir yere sahip olan antrenman ve egzersiz ile ilgili küresel çalışmaların sayısındaki artışa rağmen literatürde halen bibliyometrik çalışmalar bulunmamaktadır. Bu çalışma, antrenman ve egzersiz konusunda yayınlanmış bilimsel makaleleri bibliyometrik yöntemlerle incelemeyi amaçlamaktadır. 1980-2021 yılları arasında yayınlanan antrenman ve egzersiz makaleleri Web of Science'dan (WoS) indirilmiştir. Ülkelerin makale sayıları ile bazı gelişmişlik göstergeleri arasındaki korelasyon analizleri için Spearman korelasyon katsayısı kullanıldı. Üstel düzeltme, sonraki yıllarda yayınlanacak makalelerin sayısını tahmin etmek için kullanıldı. Atıf analizlerini ve trend konularını belirlemek için ağ görselleştirme haritaları kullanıldı. Toplam 37408 makale analiz edildi. Literatüre katkı sağlayan ilk 3 ülke ABD (n=13227), İngiltere (n=4481), Kanada (n=3211) oldu. En aktif dergiler Journal of Applied Physiology (n=4338), Medicine and Science in Sports and Exercise (n=3292), Journal of Strength and Conditioning Research (n=2743) oldu. En aktif ilk 3 kurum University of California System (n=696), University of Copenhagen (n=678) ve University of North Carolina (n=644) idi. Literatüre en aktif katkı yapan kişi William J. Kraemer'dir (Makale Sayısı=223). Antrenman ve egzersizle ilgili bu kapsamlı bibliyometrik çalışmada 37408 makalenin bir özetini paylaştık. Son dekatta (2013-2021) çalışılan konular direnç antrenmanı, futbol, atletik performans, yüksek yoğunluklu interval antrenman, spor, gençler, takım sporları, antrenman yükü, sakatlık önleme, sağlık, yaşam kalitesi, egzersiz terapisi, obezite, aerobik egzersiz, kas gücü, biyomekanik, denge, yürüyüş, kalp hızı değişkenliği ve hipertansiyon olarak belirlendi.

Anahtar Kelimeler: Antrenman, egzersiz, spor, trend konular, bibliyometrik analiz

The Development of Training and Exercise Publications: Global Productivity and Publication Trends During 1980-2021

ABSTRACT

Despite the increase in the number of global studies on training and exercise, which have an important place in sports sciences, there are still no bibliometric studies in the literature. This study aims to analyse the scientific articles that have been published on training and exercising by using bibliometric methods. Articles on training and exercise published between 1980 and 2021 were downloaded from the Web of Science (WoS). Spearman correlation coefficient was used for the correlation analysis between the number of articles and some development indicators of the countries. The exponential smoothing was used to estimate the number of articles to be published in the next years. Network visualization maps were used to identify citation analyses and trending topics. A total of 37408 articles were analysed. The top 3 contributing countries to the literature were USA (n=13227), UK (n=4481), Canada (n=3211). The most active journals were Journal of Applied Physiology (n=4338), Medicine and Science in Sports and Exercise (n=3292), Journal of Strength and Conditioning Research (n=2743). The top 3 most active institutions were University of California System (n=696), University of Copenhagen (n=678), University of North Carolina (n=644). The most active contributor to the literature was William J. Kraemer (Number of articles=223). We shared a summary of 37408 articles in this comprehensive bibliometric study on training and exercise. The topics studied in the last decade were determined as resistance training, football, athletic performance, high-intensity interval training, sports, youth, team sports, training load, injury prevention, health, quality of life, exercise therapy, obesity, aerobic exercise, muscle strength, biomechanics, balance, gait, heart rate variability, and hypertension.

Key Words: Training, exercise, sports, trends, bibliometric analysis

INTRODUCTION

There is a natural emphasis on how training affects performance because the majority of an athlete's preparation is tied to the organization and specifics of the training program. This curiosity dates back to the Italian farmer Milo of Crotona, who became the strongest man in the world and a legend of the ancient Olympics by lifting a bull that grew every day. This narrative offers the historical underpinnings for the quest to comprehend the training response, which is most distinctively characterized by the idea of training load progression and the concept that training loads could be quantified and associated to performance outcomes^{2,3}.

Training has been defined as the process of systematically exercising in order to improve the physical abilities of athletes and to acquire certain sports skills⁴. While endurance training supports an increase in the exercising system and performance in both the cardiovascular and musculoskeletal systems⁵ strength training causes increases in muscular power and strength as a result of the neuromuscular adaptations, increases in muscle CSA and changes in the connective tissue rigidity⁶. An important aspect of all training adaptations, whether it is strength or endurance, is genetics⁷. The literature of recent years includes studies that highlight the genetic differences in planning trainings and exercises⁷⁻⁹. Testing physical abilities and the visual evaluation of competition results and technical performance demonstrate the effectiveness of training⁴. Monitoring the training load is a fundamental aspect of the modern sports science applications. The collection, sweeping, analysis, interpretation and distribution of load data is usually carried out with the aim of improving the athlete performance and managing the risk of injury. To achieve these goals, practitioners try to optimize the load in different stages throughout the training process, such as setting up individual sessions, creating plans for every day, dividing the season into periods, and managing athletes with a long-term perspective¹⁰. As new technologies emerged for measuring athlete performance (e.g., systems for monitoring heartbeats), the desire to utilize and adapt such technologies have also increased in sports sciences and medical disciplines¹¹.

Exercising is the execution of activities that include aerobic and anaerobic exercises for the purposes of improving or maintaining physical condition and staying healthy, which increase cardiovascular endurance, such as stretching exercises, walking and running (aerobic exercises), and increase short-term muscular power, such as weightlifting (anaerobic exercises)¹². Important information has been accumulated over the past 20 years on the importance of exercise as a first-stage treatment of various chronic diseases. It is known that exercises have a positive effect on many diseases.¹³ These are psychiatric disorders (depression, anxiety, stress, schizophrenia); neurological diseases (dementia, Parkinson's disease, multiple sclerosis); metabolic diseases (lipidosis, hyperlipidemia, metabolic syndrome, polycystic ovary syndrome, Type-2 diabetes, Type-1 diabetes); cardiovascular diseases (hypertension, coronary heart disease, heart failure, cerebral apoplexy, and intermittent claudication); lung diseases (chronic obstructive pulmonary disease, asthma, cystic fibrosis); musculoskeletal disorders (osteoarthritis, osteoporosis, back pain, rheumatoid arthritis); and cancer. Research, based on the necessity of exercise as medication for all such diseases and disorders and the manner of application, is being conducted¹⁴. Historically, clinicians have advised cancer patients to rest and avoid activity, however, new research on exercise has challenged this recommendation. It was concluded that exercising was safe during and after cancer

treatment and resulted in improvement in physical functionality, quality of life and fatigue of cancer for a few groups that survived cancer and that even cancer patients who are currently ill or undergo difficult treatment should be recommended "to avoid inactivity"¹⁴.

Bibliometrics is the analysis of many scientific outputs, such as articles and books, using statistical methods¹⁵⁻²⁰. Bibliometric studies can reveal the authors, journals, institutions and countries that are most active in a subject or a field as well as inter-institutional or transnational cooperations^{15,16}. Thanks to bibliometric studies, researchers can master the literature in a short time by reading the abstracts obtained from the analyses of hundreds of articles from past to present¹⁸. Additionally, by observing the current trends, researchers can also develop fresh ideas for new studies that they can design¹⁸. Numerous bibliometric studies on medical subjects have been conducted in response to the growing number of publications in the literature¹¹⁻¹⁶. Bibliometric studies have recently begun to be conducted in the field of sports sciences.^{21,22}

There are still no bibliometric studies in the literature, despite a growth in the number of international studies on training and exercise, which are significant in sports sciences. The goal of this study is to use statistical and bibliometric techniques to analyze the scientific publications on training and exercise that have been published between 1980 and 2021.

MATERIAL AND METHODS

For the literature review, the Web of Science Core Collection (WoS by Clarivate Analytics) database was utilized. The search process was determined as 1980-2021 (access date: 05.01.2022). Training and exercise were utilized as WoS specific keywords. The search was utilized only on the titles of publications indexed under "sports sciences". Codes for repeatability that allow researchers to access related documents: (Title=(training) Or Title=(exercise*)) Refined by: Web of Science Categories: (Sport Sciences) Timespan: 1980-2021. Indexes: SCI-Expanded, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI). Through this search method, all articles published in the field of sports sciences research with training and exercise (including exerciser and exercises) in the title were found and these articles were downloaded from the WoS database. The exponential smoothing from seasonal effect of time series estimator was used in the Microsoft Office Excel program to estimate the number of articles that can be published for the next 5 years based on the number of past articles. The website (<https://app.datawrapper.de>) was used for world map drawing. Bibliometric network visualization maps and citation analysis were conducted using the VOSviewer software tool (version 1.6.16, Leiden University, Leiden, Netherlands)²³. Statistical analysis was utilized using the SPSS software (version 22.0, SPSS Inc., Chicago, IL, USA, Licence: Hitit University). The Kolmogorov-Smirnov test was used to analyze the data for normal distribution. In order to discover the impact of economic power on the global publication productivity on training and exercise, correlation analyses were done between the number of articles generated by the nations and major economic development indicators of the nations (Gross Domestic Product (GDP), Gross Domestic Product per capita (GDP per capita), data sourced from the World Bank²⁴. Spearman's correlation coefficient was used to evaluate

correlation analysis because the data were not normally distributed. $P < 0.05$ was considered as statistically significant difference.

RESULTS

The WoS database contained 438883 publications on training and exercise that were published between 1980 and 2021 as a consequence of the literature review. 61893 of these publications were published in the field of sports sciences. These articles were distributed as follows: Article (37408, 60.4%), Meeting Abstract (16144, 26.0%), Review (3761, 6.0%), Proceedings Paper (1657, 2.6%), Letter (1082, 1.7%), and the rest were in other publication types (Editorial Materials, Corrections, Book, Chapters, Early Access, Notes, Book Reviews, News Items, Books, Retractions, Reprints, Biographical-Items, Retracted Publications, Discussions, Software Reviews, Item Withdrawal). Bibliometric analysis was conducted with 37408 articles in the article publication category in WoS. Of these articles, 95.9% ($n=35879$) were published in English and the rest were published in other languages (Portuguese ($n=432$), German (308), French (244), Spanish (200), Japanese (191), Russian (72), Italian (71), Dutch (7), Catalan (1), Croatian (1)).

Development of Publications by Years on Training and Exercise

The distribution of the number of published articles by years is displayed in Figure 1. The estimation values of the results of the exponential smoothing from seasonal effect of time series estimation model used to predict the number of articles that can be published in 2022-2026 are illustrated in Figure 1. According to the prediction model findings, it was estimated that 2163 (CI%: 2032-2294) and 2465 (CI%: 2148-2782) articles on training and exercise could be published in 2022 (Figure 1).

Active Countries on Training and Exercise

The distribution of the number of articles according to the nations of the world is displayed in Figure 2. The 24 most active countries that have published more than 400 articles on training and exercise were determined as USA ($N=13227$, 35.3%), UK (4481, 9.5%), Canada (3211, 8.5%), Australia (3141, 8.3%), Brazil (2616, 6.9%), France (1825, 4.8%), Spain (1731, 4.6%), Japan (1698, 4.5%), Germany (1545, 4.1%), Italy (1092, 2.9%), Denmark (944, 2.5%), Netherlands, (786, 2.1%), Sweden (786, 2.1%), Finland, (692, 1.8%), New Zealand (685, 1.8%), Poland (665, 1.7%), China (627, 1.6%), Norway (626, 1.6%), Switzerland (594, 1.5%), Iran (540, 1.4%), Portugal, (498, 1.3%), Belgium (492, 1.3%), Greece (475, 1.2%), and Turkey (429, 1.1%).

Cluster analysis was conducted among 68 nations that produced at least 10 papers from the 125 countries whose writers collaborated internationally and published articles on this topic. The network map is presented in Figure 3.a. The clustering analysis' findings showed that there were 7 different clusters for international collaboration (Cluster 1: Austria, Bosnia Herceg, Croatia, Czech Republic, Denmark, Estonia, Finland, Hungary, Iceland, Iran, Israel, Italy, Lithuania, Norway, Poland, Romania, Russia, Ukraine, Serbia, Slovenia, Slovakia, Sweden, Switzerland. Cluster 2: Australia, Egypt, India, Jordan, Lebanon, Malaysia, New Zealand, China, United Arab Emirates, Qatar, Saudi Arabia, Tunisia, Taiwan, Thailand, Singapore. Cluster 3: Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, Portugal, Spain, Cluster 4: Bolivia, Cameroon, Cyprus, France, Greece, Iraq, Turkey, Cluster 5: Canada, Indonesia,

Japan, Netherlands, South Korea, USA, 6: England, Ireland, North Ireland, Scotland, South Africa, Wales (in UK) 7: Belgium, Germany).

Additionally, overall connection strength scores representing the degree of cooperation across 68 nations were computed; the resulting map of international collaboration density is displayed in Figure 3.b. (Top 15 countries with highest scores: USA=3724, England=3011, Australia=2508, Canada=1586, Spain=1423, Brazil=1288, France=991, Germany=919, Italy=874, New Zealand=780, Denmark=719, Switzerland=680, Netherlands=640, Sweden=610, Portugal=551).

Correlation Analysis on Training and Exercise

The number of training and exercise-related articles published by nations and their GDP and GDP per capita values showed a strong and moderate statistically significant correlation ($r=0.703$, $p<0.001$; $r=0.610$, $p<0.001$, respectively).

Active Authors on Training and Exercise

Kraemer WJ. (n=223), Hakkinen K. (187), Noakes TD. (113), Nosaka K. (113), Jones AM. (111), Newton RU. (105), Maresh CM. (102), Volek JS. (95), Schoenfeld BJ. (94), Izquierdo M. (91) Kjaer M. (90), Shephard RJ. (90), Hoffman JR. (88), Ugrinowitsch C. (88). Foster C. (85), Krstrup P. (84), Laughlin MH. (84), Anonymous (81), and Bangsbo J. (80) were the most productive authors, publishing more than 80 papers on training and exercise.

Active Institutions on Training and Exercise

The top 25 most active institutions producing the most articles on Training and Exercise were the University of California System (n=696), University of Copenhagen (678), University of North Carolina (644), Universidade De Sao Paulo (631), State University System of Florida (602), University of Texas System (546), Pennsylvania Commonwealth System of Higher Education Pcshe (532), California State University System (476), University of Wisconsin System (451), University of Jyväskylä (416), McMaster University (409), Edith Cowan University (398), US Department of Veterans Affairs (351), Karolinska Institutet (343), University System of Georgia (343), Veterans Health Administration (337), Liverpool John Moores University (331), University of British Columbia (331), University of Queensland (330), University of Connecticut (325), University of Toronto (320), University of Exeter (312), Loughborough University (311), University of Western Australia (297), and University of Sydney (285).

Active Journals on Training and Exercise

37408 training and exercise-related articles were published in 224 different journals. Table 1 lists the first 63 most popular journals that published 100 or more papers from these journals, as well as the total number of citations the journals received and the mean number of citations per article. Figure 4 displays the visualization map of the citation network between these publications.

Citation Analysis on Training and Exercise

The first 25 papers with the highest number of citations out of the 37408 publications published on training and exercise are listed in Table 2 based on the overall number of citations. The final column of Table 2 lists the average annual number of citations that each article received.

Co-citation Analysis on Training and Exercise

In the reference list of the 37408 articles published on training and exercise, a total of 457694 papers were cited. Borg (1982) (Number of citation, NC:1391), Dill and Costill (1974) (NC:1086), Hopkins et al. (2009) (NC:920), Cohen (1988) (NC:724), Ratamess et al. (2009) (NC:718), Garber et al. (2011) (NC:651), Beaver et al. (1986) (NC:637), Borg (1970) (NC:596), Foster et al. (2001) (NC:550), Jackson and Pollock (1978) (NC:487), and Kraemer et al. (2002) (NC:409) had the 11 studies with the most co-citations, totaling more than 400²⁵⁻³⁵.

Trend topics on Training and Exercise

36283 different keywords were used in the 37408 articles about training and exercise that were published. Table 3 displays 104 different keywords from this list that were used in at least 130 different articles. Figure 5 displays a cluster network visualization map of the outcomes of the clustering analysis carried out between these keywords (Cluster 1: 29 keywords, red color, Cluster 2: 23 keywords, green color, Cluster 3: 18 keywords, blue color, Cluster 4: 15 keywords, yellow color, Cluster 5: 14 keywords, purple color, Cluster 6: 7 keywords, turquoise color). Figure 6 displays a trend network visualization map that was created to revealed trend topics, while Figure 7 displays a citation network visualization map that was created to revealed the most-cited topics.

Table 1. The 63 Most Active Journals That Have Published More Than 100 Articles on Training and Exercise

Journals	RC	C	AC	Journals	RC	C	AC
Journal of Applied Physiology	4338	247976	57.2	Medicina Dello Sport	239	335	1.4
Medicine and Science in Sports and Exercise	3292	164414	49.9	Sports Medicine	239	11959	50.0
Journal of Strength and Conditioning Research	2743	70195	25.6	Journal of Orthopaedic & Sports Physical Therapy	234	10887	46.5
European Journal of Applied Physiology	2687	74842	27.9	Journal of Sport & Exercise Psychology	229	11786	51.5
International Journal of Sports Medicine	1872	55741	29.8	Sports	229	971	4.2
Journal of Sports Medicine and Physical Fitness	1274	13935	10.9	Pediatric Exercise Science	226	2583	11.4
European Journal of Applied Physiology and Occupational Physiology	989	35130	35.5	American Journal of Sports Medicine	224	15574	69.5
Journal of Sports Sciences	966	24737	25.6	Journal of Sport Rehabilitation	222	1984	8.9
Archives of Physical Medicine and Rehabilitation	817	37225	45.6	RBNE-Revista Brasileira de Nutricao Esportiva	215	409	1.9
Scandinavian Journal of Medicine & Science in Sports	764	21714	28.4	Clinical Journal of Sport Medicine	205	5507	26.9
Applied Physiology Nutrition and Metabolism	723	11691	16.2	Journal of Electromyography and Kinesiology	205	4041	19.7
British Journal of Sports Medicine	576	23661	41.1	ACSMS Health & Fitness Journal	199	659	3.3

International Journal of Sports Physiology and Performance	576	10349	18.0	Journal of Rehabilitation Medicine	197	5823	29.6
Strength and Conditioning Journal	489	4559	9.3	Isokinetics and Exercise Science	197	1051	5.3
Journal of Sports Science and Medicine	483	7848	16.2	Gait & Posture	192	3508	18.3
International Journal of Sport Nutrition and Exercise Metabolism	446	10123	22.7	International Journal of Applied Exercise Physiology	186	227	1.2
Science & Sports	417	1301	3.1	Canadian Journal of Applied Physiology-Revue Canadienne de Physiologie Appliquee	166	4721	28.4
Revista Brasileira de Medicina do Esporte	407	1065	2.6	Bewegungstherapie und Gesundheitssport	127	152	1.2
European Journal of Sport Science	405	5030	12.4	Physical Therapy in Sport	127	1439	11.3
Physician and Sportsmedicine	401	3206	8.0	Sport Sciences for Health	123	112	0.9
Aviation Space and Environmental Medicine	394	6568	16.7	International Journal of Sport Psychology	123	2745	22.3
Journal of Science and Medicine in Sport	384	8548	22.3	Research in Sports Medicine	122	1295	10.6
Biology of Sport	366	2396	6.5	BMC Sports Science Medicine and Rehabilitation	121	702	5.8
Journal of Aging and Physical Activity	356	5685	16.0	Pm&R	120	1918	16.0
American Journal of Physical Medicine & Rehabilitation	344	8647	25.1	Applied Physiology Nutrition And Metabolism-Physiologie Appliquee Nutrition et Metabolisme	118	2501	21.2
Journal of Human Kinetics	325	2835	8.7	International Journal of Sports Physical Therapy	117	1028	8.8
Research Quarterly For Exercise and Sport	322	7857	24.4	Journal of Exercise Science & Fitness	115	838	7.3
Journal of Athletic Training	311	5882	18.9	Frontiers in Sports and Active Living	111	155	1.4
Journal of The International Society of Sports Nutrition	292	4628	15.8	Clinical Biomechanics	110	2442	22.2
Psychology of Sport and Exercise	286	8378	29.3	Athletic Therapy Today	106	228	2.2
Journal of Human Sport and Exercise	253	606	2.4	International Journal of Sport Nutrition	103	3198	31.0
Japanese Journal of Physical Fitness and Sports Medicine	252	317	1.3				

RC: Record count, C: Number of citation, AC: Average citation per document

Table 2. The Top 25 Most Cited Articles on Training and Exercise by Total Number of Citations

No	Article	Author	Journal	PY	TC	AC
1	Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise	Garber CE. et al.	Medicine and Science in Sports and Exercise	2011	4680	390
2	Progressive statistics for studies in sports medicine and exercise science	Hopkins WG. et al.	Medicine and Science in Sports and Exercise	2009	4532	323.71
3	American College of sports medicine roundtable on exercise guidelines for cancer survivors	Schmitz KH. et al.	Medicine and Science in Sports and Exercise	2010	1623	124.85
4	A new approach to monitoring exercise training	Foster, C. et al.	Journal of Strength and Conditioning Research	2001	1502	68.27
5	Self-efficacy and the stages of exercise behavior-change	Marcus BH. et al.	Research Quarterly For Exercise and Sport	1992	1127	36.35
6	Increased rate of force development and neural drive of human skeletal muscle following resistance training	Aagaard P. et al.	Journal of Applied Physiology	2002	971	46.24
7	The effect of neuromuscular training on the incidence of knee injury in female athletes - A prospective study	Hewett TE. et al.	American Journal of Sports Medicine	1999	970	40.42
8	Exercise-induced muscle damage in humans	Clarkson PM. and Hubal MJ.	American Journal of Physical Medicine & Rehabilitation	2002	817	38.9
9	Exercise as medicine - evidence for prescribing exercise as therapy in 26 different chronic diseases	Pedersen BK. and Saltin B.	Scandinavian Journal of Medicine & Science in Sports	2015	783	97.88
10	Myofibrillar damage following intense eccentric exercise in man	Friden J. et al.	International Journal of Sports Medicine	1983	778	19.45
11	The effects of exercise training on elderly persons with cognitive impairment and dementia: A meta-analysis	Heyn, P. et al.	Archives of Physical Medicine and Rehabilitation	2004	775	40.79
12	Not what, but how one feels - the measurement of affect during exercise	Hardy, C.J. and rejeski, WJ	Journal of Sport & Exercise Psychology	1989	751	22.09
13	Neural adaptation to resistance training	Sale, DG.	Medicine and Science in Sports and Exercise	1988	743	21.23
14	Muscle glycogen utilization during prolonged strenuous exercise when fed carbohydrate	Coyle, EF. et al.	Journal of Applied Physiology	1986	728	19.68
15	Aerobic high-intensity intervals improve VO2max more than moderate training	Helgerud, J. et al.	Medicine and Science in Sports and Exercise	2007	719	44.94
16	Robot-assisted movement training compared with conventional therapy techniques for the	Lum, PS. et al.	Archives of Physical Medicine and Rehabilitation	2002	713	33.95

	rehabilitation of upper-limb motor function after stroke					
17	Muscle function after exercise-induced muscle damage and rapid adaptation	Clarkson, PM. et al.	Medicine and Science in Sports and Exercise	1992	712	22.97
18	Influence of body temperature on the development of fatigue during prolonged exercise in the heat	Gonzalez-Alonso, J. et al.	Journal of Applied Physiology	1999	698	29.08
19	A modification to the behavioural regulation in exercise questionnaire to include an assessment of amotivation	Markland D. and Tobin V	Journal of Sport & Exercise Psychology	2004	688	36.21
20	Plyometric training in female athletes - Decreased impact forces and increased hamstring torques	Hewett, TE. et al.	American Journal of Sports Medicine	1996	658	24.37
21	Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes - 2-year follow-up	Mandelbaum, BR. et al.	American Journal of Sports Medicine	2005	652	36.22
22	Use of RPE-based training load in soccer	Impellizzeri, FM. et al.	Medicine and Science in Sports and Exercise	2004	650	34.21
23	Monitoring training in athletes with reference to overtraining syndrome	Foster, C.	Medicine and Science in Sports and Exercise	1998	647	25.88
24	Determining the magnitude of treatment effects in strength training research through the use of the effect size	Rhea, MR.	Journal of Strength and Conditioning Research	2004	645	33.95
25	Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis	Alfredson, H. et al.	American Journal of Sports Medicine	1998	645	25.8

PY: Publication year, TC: Total citation, AC: Average citations per year

Table 3. The 69 Most Frequently Used Keywords in Articles on Training and Exercise

Keywords	Number of uses	Keywords	Number of uses	Keywords	Number of uses
Exercise	4140	metabolism	277	stroke	172
Resistance Training	1239	cortisol	272	health	170
Rehabilitation	1131	hypoxia	265	perceived exertion	166
Physical Activity	1042	testosterone	254	sports	164
Training	826	biomechanics	249	near-infrared spectroscopy	161
Strength Training	821	football	243	gait	160
Strength	734	muscle	238	maximal oxygen uptake	159
Performance	718	women	236	periodization	159
Fatigue	694	creatine kinase	234	exercise test	158
Heart Rate	678	physical exercise	229	carbohydrate	156
Aging	647	EMG	223	muscle hypertrophy	155
Electromyography	624	balance	221	gender	154
Muscle Strength	539	athletic performance	217	team sports	154
Skeletal Muscle	453	children	215	blood flow	152
Blood Pressure	441	inflammation	213	nitric oxide	152
Recovery	437	nutrition	209	insulin	149
Obesity	428	exercise therapy	208	sport	147
Resistance Exercise	420	heart rate variability	205	lactate threshold	146
Cycling	405	thermoregulation	204	motivation	145
Lactate	400	elderly	203	stress	141
Body Composition	399	fitness	198	team sport	140
Endurance	388	blood lactate	194	muscle soreness	139
Muscle Damage	386	quality of life	194	hypertension	138
Athletes	365	high-intensity interval training	193	knee	138
Exercise Training	359	weight training	193	RPE	138
Power	346	exercise intensity	192	anaerobic threshold	137
Running	340	cytokines	187	cognition	137
Oxygen Uptake	330	cardiac output	184	dehydration	136
Endurance Training	326	energy expenditure	184	exercise prescription	136
Oxidative Stress	317	glucose	184	exercise performance	135
Physical Fitness	310	endurance exercise	181	injury prevention	135
Aerobic Exercise	295	swimming	180	muscle fatigue	135
Soccer	295	autonomic nervous system	179	growth hormone	134
Oxygen Consumption	285	training load	176	youth	133
Hypertrophy	284	eccentric exercise	172		

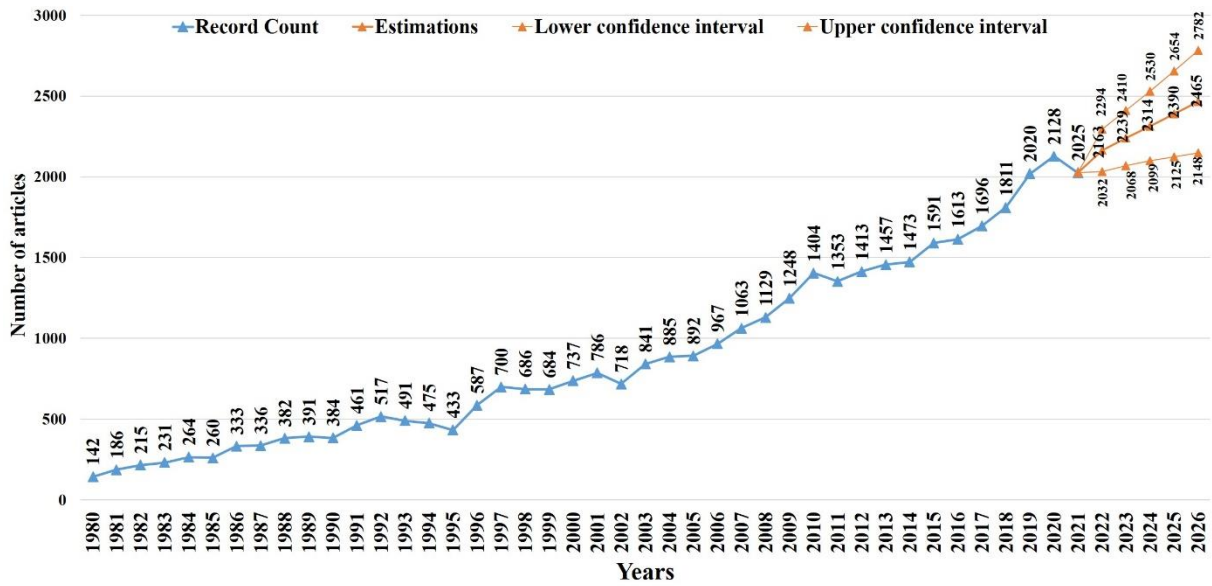


Figure 1. Distribution of Articles Published on Training and Exercise by Years and Estimated Number of Articles for Future Years



Figure 2. World Map Showing the Distribution of Articles Published on Training and Exercise by Countries

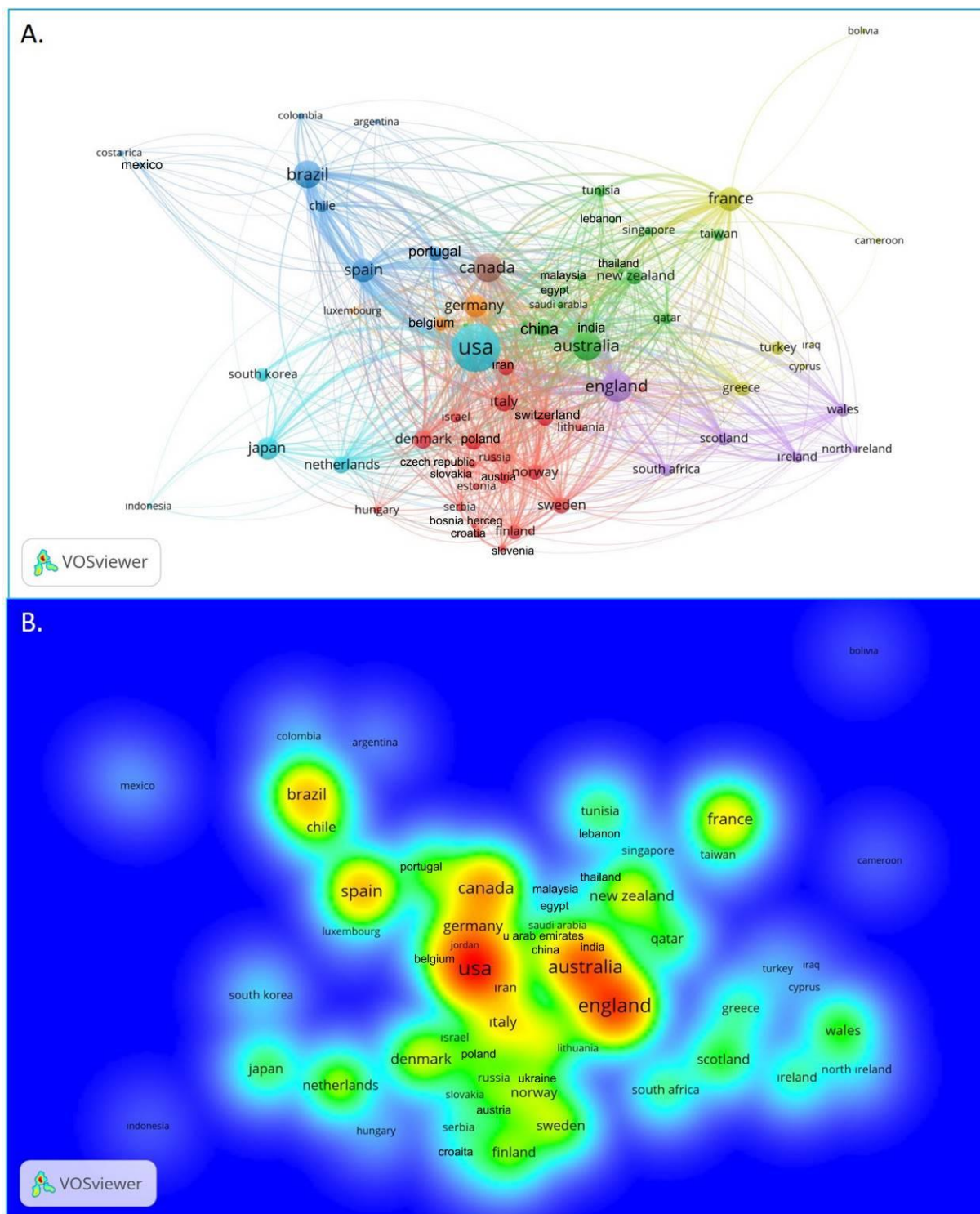


Figure 3. a. Network visualization map of cluster analysis on international collaboration between countries on training and exercise. Footnote: Colors indicate clustering. The size of the circle indicates the large number of articles. b. Density map for international collaboration of countries on training and exercise. Footnote: The strength of international collaboration score increases from blue to red (blue-green-yellow-red)

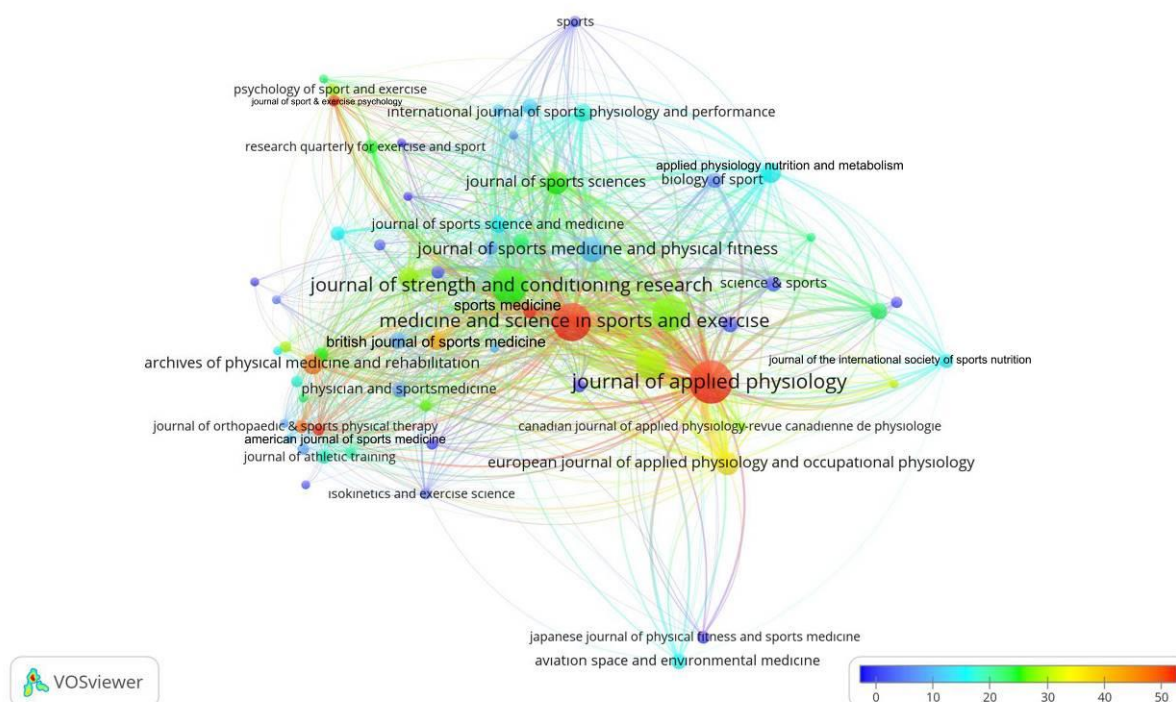


Figure 4. Network visualization map for citation analysis of active journals on training and exercise. Footnote: The average number of citations per article by journals increases from blue to red (blue-green-yellow-red). The size of the circle indicates the large number of articles.

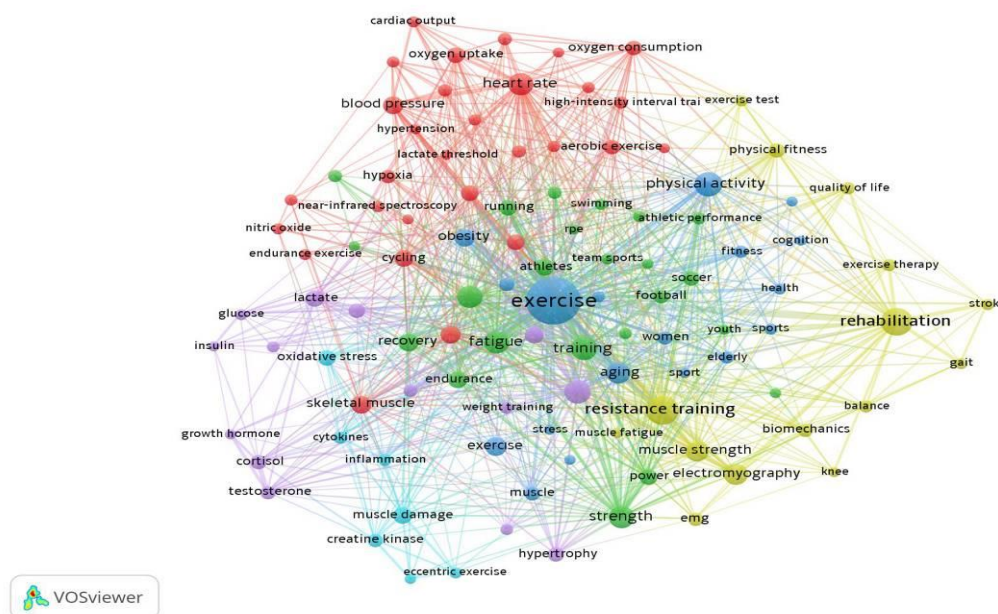


Figure 5. Network visualization map for cluster analysis based on keyword analysis on training and exercise. Footnote: Colors indicate clustering. Keywords in the same cluster are of the same color. The size of the circle indicates the number of uses of the keyword

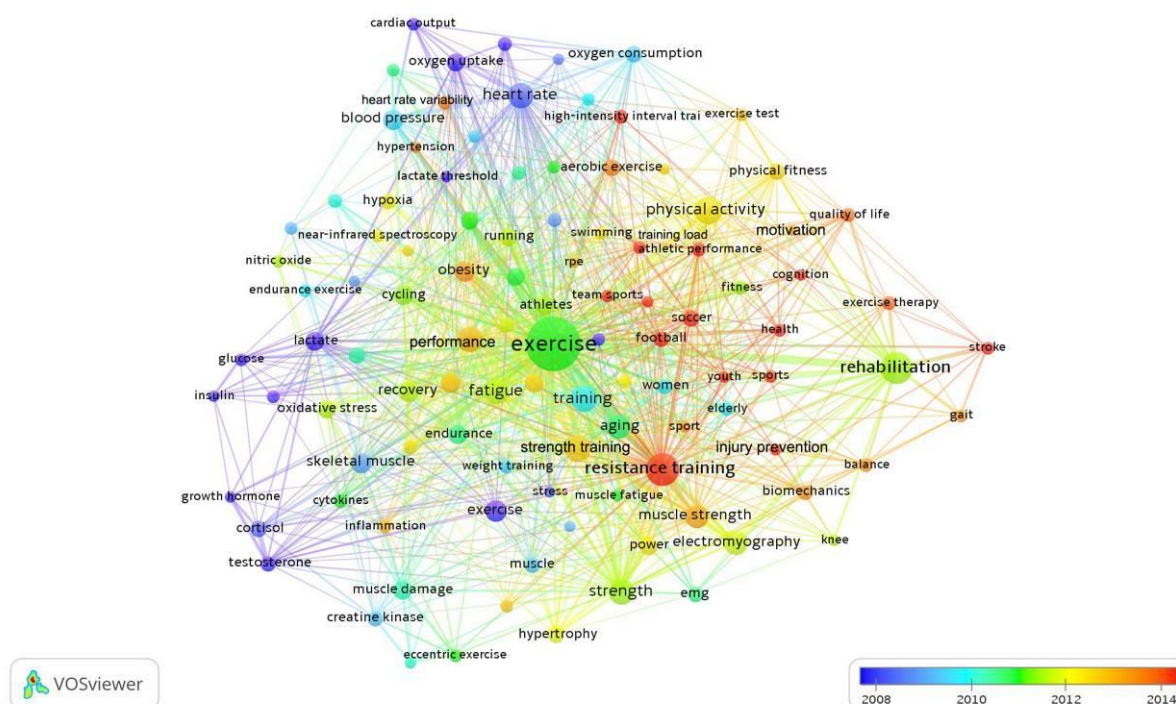


Figure 6. Network visualization map for trends on training and exercise. Footnote: In the indicator given in the lower right corner of the figure, the topicality of the article increases from blue to red (blue-green-yellow-red). The size of the circle indicates the number of uses of the keyword

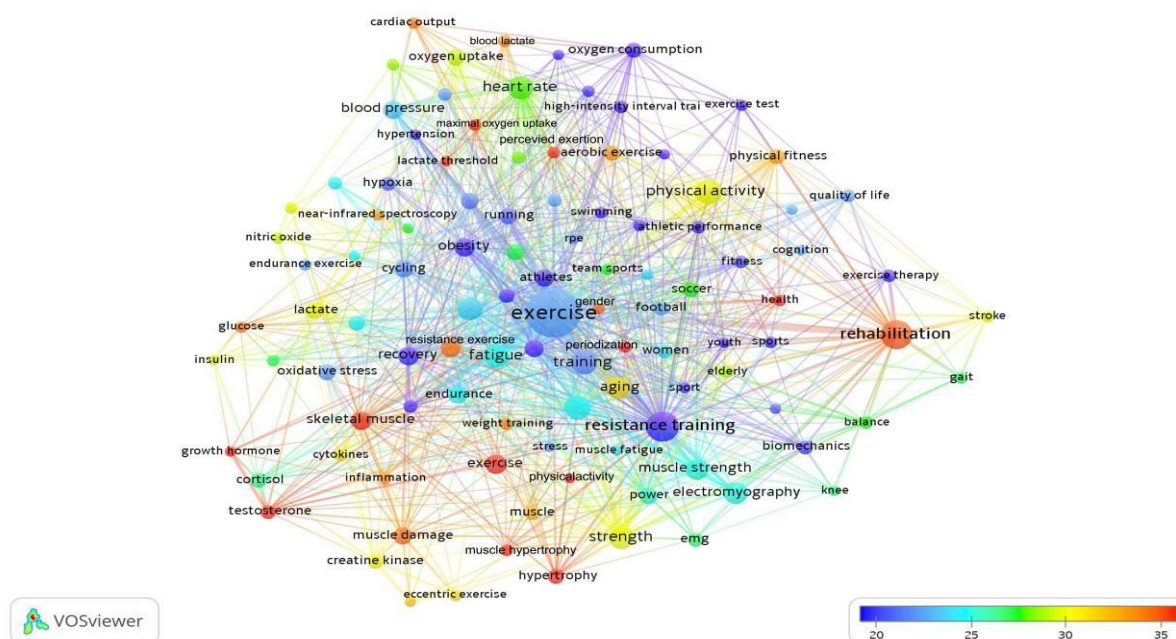


Figure 7. Network visualization map of the most frequently cited topics on training and exercise. Footnote: In the indicator given in the lower right corner of the figure, the number of citations received by the topic increases from blue to red (blue-green-yellow-red). The size of the circle indicates the number of uses of the keyword

DISCUSSION

Between 1980 and 1995, a minimum of 142 and a maximum of 557 (average of 343 articles) were published on training and exercise. A minimum of 587 and a maximum of 1591 (average 1031 articles) articles were published between 1996 and 2015, and a minimum of 1613 and maximum 2128 (average 1882 articles) articles were published between 2016-2021. In particular, a remarkable increase trend was observed in the number of articles published between 2016 and 2021. There were 2128 articles in 2020 and 2025 articles in 2021. When the estimation results were evaluated, it was seen that the number of articles would continue with an increasing trend.

When the countries' training and exercise publications were analyzed, it was found that 20 of the 24 most active nations were industrialized nations (USA, UK, Canada, Australia, France, Spain, Japan, Germany, Italy, Denmark, Netherlands, Sweden, Finland, New Zealand, Poland, Norway, Switzerland, Portugal, Belgium, Greece). The other 4 countries (Brazil, China, Iran, Turkey) were developing countries (developing countries) with large economies. As a result of the correlation analysis we conducted in our study, the high level of correlation between article productivity and GDP and the moderate correlation between GDP per capita shows that the economic size of the countries is primarily effective in the productivity of publications on training and exercise. In the literature, it has been stated that economic development has an effect on publication productivity in many bibliometric studies conducted on medical subjects^{15,16,18}.

The top 10 countries with the most intense collaboration were found to be the USA (international cooperation score: 3724), England (in UK) (3011), Australia (2508), Canada, (1586), Spain (1423), Brazil (1288), France (991), Germany (919), Italy (874) and New Zealand (780) when the density map developed based on the countries' overall cooperation score was analyzed. When the co-authorship cooperation of countries on training and exercise was examined, it was seen that international collaborations based on geographical neighborhood were effective in the production of articles (Countries with geographical proximity and in the same cluster: (Austria, Bosnia Herceg, Croatia, Czech Republic, Denmark, Estonia, Finland, Hungary, Iceland, Italy, Lithuania, Norway, Poland, Romania, Serbia, Slovakia, Slovenia, Sweden, Switzerland), (Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico), (Portugal, Spain), (Canada, USA), (Indonesia, Japon, South Korea), (England, Ireland, North Ireland, Scotland, Wales), (Australia, Malaysia, New Zealand, Singapore, Taiwan, Thailand), (Egypt, Jordan, Lebanon, Qatar, Saudi Arabia, Tunisia, United Arab Emirates), (India, China), (Belgium, Germany), (Cyprus, Greece, Iraq, Turkey)).

The journals that published the most articles on training and exercise were determined as Journal of Applied Physiology, Medicine and Science in Sports and Exercise, Journal of Strength and Conditioning Research, European Journal of Applied Physiology, International Journal of Sports Medicine, Journal of Sports Medicine and Physical Fitness, European Journal of Applied Physiology and Occupational Physiology, Journal of Sports Sciences, Archives of Physical Medicine and Rehabilitation, Scandinavian Journal of Medicine & Science in Sports, and Applied Physiology Nutrition and Metabolism, respectively. We can advise writers who desire to write on training and exercise to first think about these journals. The American Journal of Sports Medicine, Journal of Applied Physiology, Journal of Sport & Exercise Psychology, Sports Medicine, Medicine and Science in Sports and Exercise, Journal

of Orthopaedic & Sports Physical Therapy, Archives of Physical Medicine and Rehabilitation, British Journal of Sports Medicine, European Journal of Applied Physiology and Occupational Physiology, and International Journal of Sport Nutrition were found to have the highest average amount of citations per article when the journals' citation analyses were analyzed. We can advise researchers to prioritize these publications if they want their articles to be cited more frequently.

When the examined papers were assessed based on the overall amount of citations they had, it was determined that the most influential study with the highest number of citations was the study titled "Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise" published in *Medicine and Science in Sports and Exercise* by Garber et al. (2011)³⁰. The second most influential study was the study titled "Progressive statistics for studies in sports medicine and exercise science" published in *Medicine and Science in Sports and Exercise* by Hopkins et al. (2009)²⁷. The third most influential study was the study titled "American college of sports medicine roundtable on exercise guidelines for cancer survivors" published in *Medicine and Science in Sports and Exercise* by Schmitz et al. (2010)¹⁴. The fourth most influential study was the study titled "A new approach to monitoring exercise training" published in *Journal of Strength and Conditioning Research* by Foster et al. (2001)³³. The fifth most influential study was the study titled "Self-efficacy and the stages of exercise behavior-change" published in *Research Quarterly for Exercise and Sport* by Marcus et al. (1992)³⁶.

The first article by Garber et al. (2011)³⁰ had the highest impact when the studies were ranked according to the average annual amount of citations. The study by Hopkins et al. (2009)²⁷ was the second-most important paper. The study by Schmitz et al. (2010)¹⁴ was the third-most influential paper. The study by Campbell et al. (2019)³⁷ was the fourth-most influential paper. The study by Pedersen and Saltin (2015)¹³ was the fifth-most influential paper.

According to the co-citation numbers of all analysed articles, Borg (1982), Dill and Costill (1974), Hopkins et al. (2009), Cohen (1988), Ratamess et al. (2009), Garber et al. (2011), Beaver et al. (1986), Borg (1970), Foster et al. (2001), Jackson and Pollock (1978), and Kraemer et al. (2002) were determined as the most effective studies²⁵⁻³⁵. We can advise sports scientists and researchers who are interested in this topic to start by reading these works.

When the results of the keyword analysis were analyzed, it was discovered that the cluster analysis generated clusters of training and exercise subjects in 6 different colors. The most cited keywords were determined as testosterone, growth hormone, skeletal muscle, lactate threshold, maximal oxygen uptake, perceived exertion, periodization, hypertrophy, muscle hypertrophy, health, rehabilitation, exercise, resistance exercise, aerobic exercise, physical fitness, and blood lactate. According to the results of the analysis carried out to determine the trend topics, it was determined that the keywords studied in recent years are resistance training, football, soccer, athletic performance, high-intensity interval training, sports, youth, stroke, team sports, team sport, training load, cognition, injury prevention, health, quality of life, exercise therapy, obesity, aerobic exercise, muscle strength, biomechanics, balance, gait, heart rate variability, hypertension.

We conducted a literature review on training and exercise, however we were unable to find any bibliometric studies. This comprehensive investigation on training and exercise can be referred to as the first bibliometric study. We used only the WoS database in the literature review, which can be said as a limitation in our research. Citation and co-citation analyses are not available in PubMed database. Therefore, we did not prefer PubMed database for literature review. Because the Scopus database also indexes journals with low impact, we didn't use it. Compared to other databases, the WoS database indexes articles from journals with a high impact factor^{15,16,18}. It can be said that the WoS database is more commonly preferred in bibliometric analyses conducted in recent years^{15,16,18,19}.

CONCLUSION

In this extensive bibliometric study on training and exercise, which has a growing tendency in the number of publications in recent years, we provided a summary of 37408 articles published between 1980 and 2021. It can be said that the number of articles on training and exercise will continue with an increasing trend. According to the findings of the analysis carried out to reveal the trend topics, it can be said that the keywords studied in recent years are resistance training, football, soccer, athletic performance, high-intensity interval training, sports, youth, stroke, team sports, team sport, training load, cognition, injury prevention, health, quality of life, exercise therapy, obesity, aerobic exercise, muscle strength, biomechanics, balance, gait, heart rate variability, and hypertension. This article on worldwide outcomes in training and exercise might be a helpful resource for researchers and students of sports science.

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