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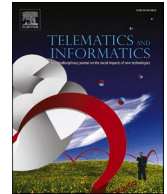
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Status of the research in fitness apps: A bibliometric analysis

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ABSTRACT

Fitness applications have undergone considerable development in the last few years and becoming popular and significant in both academic and practical areas. However, contributions to the systematic mapping of this field continue to be lacking. This paper constitutes the first bibliometric study in this field to better understand the current state of research. We examined 481 records from databases Scopus and Web of Science (Core Collection) using several bibliometric analysis methods. All the records on this emerging topic were published between 2011 and 2019. We processed these records using statistical analysis and science mapping. The bibliometric analysis included the year of publication, journal name, citation, author, country, and particularly, research methodology. Additionally, we used the VOSviewer software to perform bibliometric mapping of co-authorship, co-citation of authors, and co-occurrence of keywords. This field of study, it was found, is currently in its precursor stage, contributing primarily to the fields of medicine, computer science, and health sciences. The United States appeared to have made the largest contribution to this field. However, author productivity, number of citations, and number of core journals all indicated a high degree of fragmentation of research in this field. Remarkably, scientific research in this area is expected to progress tremendously over time. Overall, this study provides basic data and research classifications for the initial phase of research and research direction for future research in this area.

1. Introduction

With the global outbreak of the COVID-19 pandemic in 2020, almost every country is facing problems concerning the shortage of medical and healthcare resources, and people have become more aware of the importance of following a healthy lifestyle and incorporating physical exercise into their daily lives. As the most downloaded type of mobile health applications (mHealth apps), fitness apps can help people manage their nutritional intake, assist their participation in fitness and physical activities, and promote a healthy lifestyle. Therefore, these apps are gradually occupying the commercial mobile app market (Beldad and Hegner, 2018).

Nowadays, fitness apps are rapidly developing in the commercial application market and are attracting the attention of academia (Beldad and Hegner, 2018). Numerous studies have implemented empirical protocols to verify the results of using fitness apps for improving the level of physical activity and/or diet in users (Schoeppe et al., 2017). However, from the academic side, it is still a novel and young area of research.

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As a diverse field of research that is related to an emerging phenomenon, and with the integration of new technologies, the research available on fitness apps is still scarce. Both empirical research and theoretical orientation reviews, mostly focus on summarizing the functions and features of fitness apps and user perspectives. As a result, there appears to be a lack of more macro and objective quantitative research in this field. And the various types of literature are not as substantial or abundant compared to other mature areas of research. It is necessary to carry out a bibliometric study to know the main empirical and theoretical orientations in this case. The data obtained from the bibliometric analysis will be essential to assess the intensity and orientation of new lines of research (Bartoli and Medvet, 2014). Moreover, it is essential to classify the existing research in the research field to track the research progress and research trends in the field (Gaviria-Marin et al., 2019). Bibliometrics study can achieve this objective. It helps display past academic research activities and achievements visually.

To our knowledge, there is no bibliometric study in the field of fitness app research, even though this type of literature has been used widely in other fields in recent years (Zanjirchi et al., 2019). Bibliometrics can supplement existing experiments and review studies, help researchers identify hidden research lines, hot issues, and research methods in the field, and reduce the problems of neglecting certain excellent articles due to the deviation of researchers' subjective judgments (Zanjirchi et al., 2019; Veloutsou and Mafe, 2020).

Therefore, this study offers a bibliometric study of the advancements in research on the mobile-fitness app. It is based on data from a bibliometric analysis. It seeks to assess the intensity and research topics dominant in the scientific community when it comes to this emerging phenomenon, focusing explicitly on the fitness segment of mHealth. This study also aims to provide relevant data and bibliometric indicators for the initial stage of fitness application research and provide primary data for advancing future research in this field. The data used in this study is obtained from two leading databases for scientific research: Scopus and Web of Science.

The research is organized as follows. First, a research background is provided. Second, the research methods and the sources of research data are outlined. Third, the results are presented and discussed. Finally, the main conclusions, limitations, and further opportunities for research are stated.

2. Background

2.1. mHealth apps and fitness apps

Nowadays, mobile apps pertain to a wide range of topics and areas of users' personal and social lives and fulfill various purposes. The use of advanced medical information systems and telematics applications is one of them, which has resulted in the increased availability of medical services at lower overall costs (Kao et al., 2018). Medical and sanitary institutions have begun to appreciate the potential of mHealth apps for communication with patients as well as for the utilization of mobile devices that are specifically designed to monitor specific biomedical data. mHealth is defined as the provision of medical care and health-related services through mobile communication devices that enable user-interaction capability (Cumiskey, 2011; Lupton, 2013). "Mobile Health (mHealth) has become an essential field for disease management, assessment of healthy behaviors, and for interventions on healthy behaviors" (Mas et al., 2016, p. 32).

There are two main areas of implementation of mHealth apps: in professional medical practices (both on the side of doctors and patients; e.g., Skyscape, MySugr), and self-monitoring of healthy habits (e.g., MyFitnessPal). The first area has a field of an app exclusively in the healthcare field, involving the relationships between doctors and their patients. The second area represents fitness apps, which is the subject of this study, is concerned with the personal monitoring of the activities of individuals within the framework of adopting healthy lifestyles or disease prevention habits, and this category is often implemented through commercial apps that are developed without the supervision of medical administrations.

The term "fitness" has a wide semantic field: on the one hand, it refers to the practice of physical exercise to obtain or maintain good body shape and composition; on the other hand, more generally, it refers to a good state of vitality and physical well-being (Corbin et al., 2000). Since the 1980s, academic as well as medical attention to Health-Related Physical Fitness (HRPF) has increased considerably. Fitness is understood within the HRPF framework, which is defined as a set of people's abilities to perform certain physical activities, their energy level to perform daily tasks, and their capacity to reduce the risk of diseases related to sedentarism (Cheng and Chen, 2018).

2.2. Importance of fitness apps

The WHO warns of the development of non-communicable diseases, the pathologies of which are associated with unhealthy lifestyles and diets, as these diseases currently constitute a serious cause of death worldwide (WHO, 2018). In particular, the WHO has established a set of minimum criteria for physical activity for different age groups as well as balanced dietary patterns to maintain optimal health conditions such that people can achieve a reduction in risk factors for non-communicable diseases, including cancer, cardiovascular ailments, and diabetes.

The high rate of obesity is one of the most worrying factors for health globally, particularly in developed countries, but also in emerging countries, with a drastic growth among children (Anderson et al., 2019). For this reason, the WHO recommends avoiding a sedentary lifestyle and following balanced diets for all age groups. Interventions for population self-management, based on changes in lifestyle, are effective in reducing risk factors and the incidence of non-communicable diseases (Burke et al., 2011).

The use of applications on mobile devices has become a key factor in helping and advising people on the adoption of healthy lifestyles in the 21st century. Although some clinicians lack confidence in the protocols and recommendations of fitness apps, these

fitness apps have a great potential to be effective due to their ability to educate a large portion of the population on healthy habits at a low operating cost (Blackman et al., 2013).

3. Methodology

The methodology used in this research work is depicted in Fig. 1. It consists of four steps.

3.1. Step 1: Determining the field of study and database used

We identified “fitness app” as the field for this study with the aim of finding as many articles as possible on fitness-related apps closer to health behaviors than to a professional medical approach. However, in the compilation of the final set of articles, we also included those that, without being strictly articles on fitness apps, contained relevant keywords linked to the subject of study, even though they were papers dealing with other types of mHealth apps.

The data was obtained from two databases: Scopus and Web of Science Core Collection (WoS). These two databases are currently the leading sources for indexing scientific articles and allow for the collection of data from a large number of journals (Adriaanse and Rensleigh, 2013).

Scopus owns high-quality and reliable coverage and complete data for each reference. It is the largest abstract and citation database for peer-review literature (Zanjirchi et al., 2019). The WoS is also recognized by the scientific community as a digital bibliometric platform with high-quality literature, which can also provide metadata for bibliometric analysis and covers a wide range of disciplines (Gaviria-Marin et al., 2019; Hew, 2017).

The combination of more than one database for mining scientific data can provide more robust results for the bibliometric analysis (de Oliveira et al., 2019) even though it makes it necessary to integrate the information from both databases with different structures and review the articles one by one.

3.2. Step 2: Mining of bibliometric data

Mining the data is the most basic and crucial step to obtain valuable and credible research results. The search for this study was conducted in April 2020 and included all relevant publications until the end of December 2019.

The study focused on scientific research related to personal care applications of fitness, using the keywords “fitness app” and its plural form in English for searching through titles, abstracts, keywords, or topics. Our search criteria are detailed in Table 1. These two keywords represent the technological concept (app) associated with the lifestyle (fitness), whose specific relationship makes the object of the present investigation. No more keywords related to the fitness industry were used (e.g., weight loss/running, dieting) since we wanted to examine which other specific categories were reviewed under the category of fitness apps in general. Our search does not have a low-time frame limit, and the aim is to learn about the starting time of research in this field (Table 1).

After searching in the two databases separately, we performed a manual review of the titles and abstracts (also full text if necessary), excluding articles whose topics did not meet the criteria of the study, and subsequently removing duplicate literature. When the same article appeared in both databases, we opted to keep the references in Scopus because Scopus provides broader

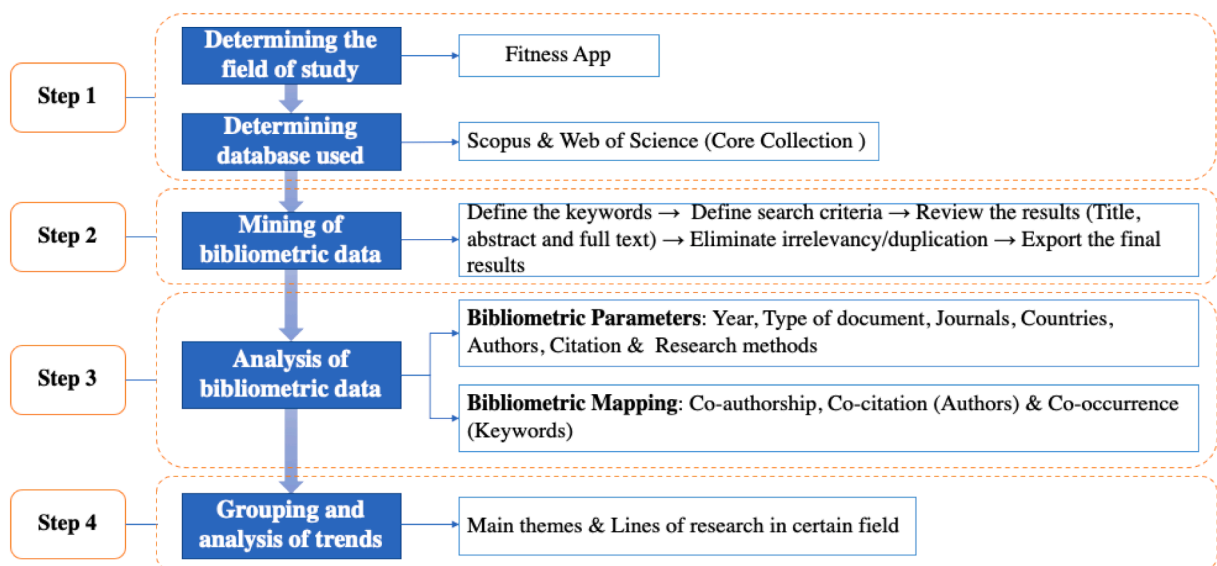


Fig. 1. The general framework of methodology.

Table 1
Search criteria for the study field “fitness apps”.

Database	Scopus	Web of Science
Searched for	TOPIC: (fitness app) OR TOPIC: (fitness apps)	TITLE-ABS-KEY (“fitness” AND “app” OR “apps”)
Publication period*	Until 2019	Until 2019
Document type	Article, Review, and Conference Paper	Article, Review, Proceedings paper, and Meeting abstract
Language	English	English

*No low time frame limit was set, but articles published before 2010, while containing relevant keywords, were seen not to be relevant to the field.

bibliographic information than WoS. The search returned 1095 records. We decided to keep the conference papers and meeting abstracts due to the youth and relative novelty of the field of study. After filtering out the irrelevant and incomplete records, we ended up with a total sample of 481 records (Table 2).

3.3. Step 3: Analysis of bibliometric data

The records were then analyzed using bibliometric analysis. Bibliometrics is “the quantitative study of physical published units, or bibliographic units, or of the surrogates for either” (Broadus, 1987, p. 376). The bibliometric analysis allows us to understand the intensity of the research available on a topic as well as the different research fields explored by the academic community.

The variables analyzed for the bibliometric study were the year of publication, author, country of institutional origin, language of publication, type of document, journal, number of citations, area of research, topics analyzed, and the research method used.

Additionally, bibliometric mapping was also conducted. The construction of bibliometric maps has always received attention in bibliometric studies (Van Eck and Waltman, 2010). We used Vosviewer software to present the relation of co-citation, co-occurrence of keywords, etc.

3.4. Step 4: Grouping and analysis of trends

Finally, we summarized the current research hotspots and trends in this field, based on the content of these 481 articles and the information presented by the keywords of their authors, to inform and inspire further studies.

4. Results

4.1. Publication frequency per year

The first article on fitness apps was published in 2011, and until 2014, the intensity of research was very low. 95.2% of the articles are published from 2014 onwards. In 2014, there was a significant increase in the number of publications, doubling the number of 2013 (Table 3).

These results represent a Price’s Index of 89.4% until the end of 2019. Price’s Index (Price, 1970) refers to the percentage of references less than five-year-old. As the Price Index’s value is relatively high, this area is considered to be novel and dynamic.

Price’s Law (Price, 1963) proposes that the development of the scientific field follows an exponential growth, which doubles in size every 10–15 years. The development of the scientific field goes through four stages: the precursor stage, the exponential growth stage, the consolidation of the body knowledge stage, and the decrease in the production stage. As shown in Fig. 2, publications in related fields underwent a growth process from 2011 to 2019. A linear mathematical adjustment of the measured values provided us with a correlation coefficient $r = 0.964$, which implies that 7.07% of variance failed to explain this fitting. In contrast, a mathematical adjustment to the exponential curve provides a coefficient $r = 0.788$, indicating an unexplained variance of 37.86%. This reveals that the data analyzed is more consistent with a linear fitting rather than an exponential one (Fig. 2).

While the third stage of growth also showed a linear trend, the first contribution in this field was produced in 2011, and the exponential growth trend stage was not detected. So, research in this field is still in its precursor stage. Additionally, the number of publications in 2018–2019 was close to 50% of the total, exhibiting rapid growth. Although there was a small decline in 2019 compared to 2018, we expect the scientific production in this field to enter the exponential growth stage in the coming years.

Table 2
Search results in academic databases.

Database	Scopus	WoS	Total Records
Number of records obtained without filtering	603	492	1095
Number of records obtained after filtering	393	321	714
Number of records obtained after eliminating duplications	378	103	481

Table 3
Frequency of publication of articles related to fitness apps per year.

Year	Frequency	Percentage	Accumulated percentage
2019	113	23.5%	100.0%
2018	122	25.4%	76.5%
2017	71	14.8%	51.1%
2016	70	14.6%	36.4%
2015	54	11.2%	21.8%
2014	28	5.8%	10.6%
2013	11	2.3%	4.8%
2012	6	1.2%	2.5%
2011	6	1.2%	1.2%
Total	481	100%	

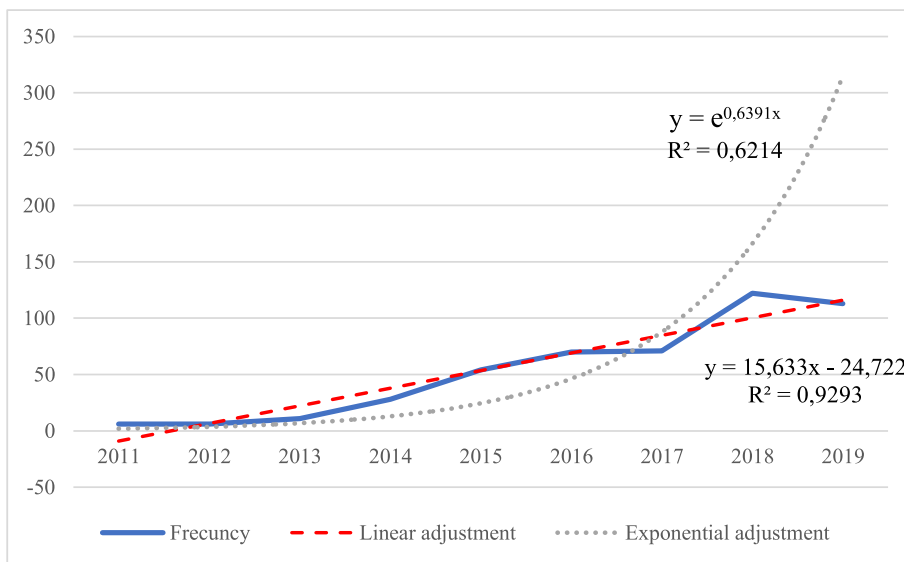


Fig. 2. Growth of scientific production in fitness apps.

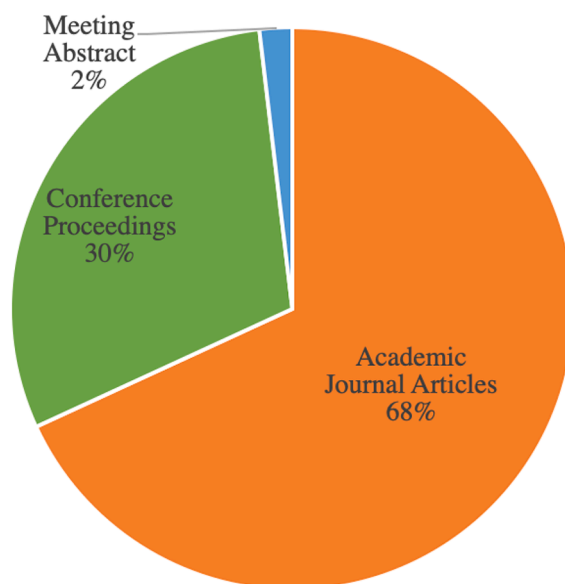


Fig. 3. Type of documents.

4.2. Most productive and influential journals/conferences and type of documents

Articles on fitness apps are published in a wide range of journals, from medical and health-related ones to computer science-related ones. Out of the 481 records, 328 were published in academic journals, and 153 were published as conference proceedings. The publication source also indicates a great dispersion: there were 189 journals and 109 different conference proceedings in total [Fig. 3](#).

Among all the relevant journals, eight journals have published three or more articles. However, only nine conference proceedings had more than one article. Compared to other fields of study, this number seems very small and indicates a low level of source concentration.

[Table 4](#) presents the field's 18 most productive and influential journals, and [Table 5](#) outlines the nine most productive conference proceedings.

JMIR mHealth and uHealth and *Journal of Medical Internet Research* have achieved a prominent position here, with a relatively high number of articles. Both are sister journals of JMIR Publications. It is worth noting that although only three articles were sourced from the International Journal of Behavioral Nutrition and Physical Activity, it ranked third overall in the number of citations.

Besides, 30% of the publications were from conference proceedings. The first and second positions by the number of publications came from the field of computer science. The high proportion may be explained by the fact that, although the importance of conference proceedings in areas such as the natural sciences is decreasing, they still play an important role in computer science, with nearly 20% of citations also distributed in the proceedings ([Michels and Fu, 2014](#); [Lisée et al., 2008](#)). It also shows the importance of the development of fitness apps in the domain of computer applications.

Bradford's Law ([Bradford, 1934](#)) is a tool used in bibliometric studies to evaluate the concentration/dispersion factor of a set of publications. In essence, it allows the determination of the most productive nucleus in a particular subject. It postulates the existence of a small nucleus of journals that address the topic more broadly as well as a vast peripheral region that is divided into several zones with journals that have a decreasing representation in the subject studied ([Alvarado, 2016](#)). The number of journals in the core and the number in the successive zones are in a ratio of 1: n: n².

Therefore, journals included in the core have a comparatively high concentration of publication, while those involved in the surrounding areas are increasingly dispersed. Thus, we can see that there is an unequal distribution of articles in the journals. A large number of articles are found in a small number of journals. As shown in [Fig. 4](#) and [Table 6](#), within the core of the ring, only 10 journals contained one-third of all published articles (109 records). Zone 1 comprises 70 journals, and zone 2 comprises 109 journals. Zone 2 contains a much smaller number of journals than the theoretical value (570). This result suggests the innovative and youthful nature of the field under study, which has not been considered in depth by many journals.

4.3. Most cited articles

The number of citations is an important indicator of the influence and the attention presented by the scientific community. According to the results shown in [Table 7](#), a total of 28 articles received more than 60 citations—all from academic journals. This number is relatively low compared to other more mature fields of research.

The most cited article (598 citations) is a multidisciplinary review by Boulos M.N.K. et al., published in 2011, one of the first published articles in the field, followed by the research by Krebs P., Duncan D.T., published in 2015 with 316 citations.

4.4. Most productive and influential authors

A total of 1,776 authors have contributed to this field. The average number of authors per article was 3.69, which indicates the

Table 4
The most productive journals in fitness app research.

Journals	Articles	Number of Citations	2018 Journal Impact Factor	2018 SJR	Quartile
JMIR mHealth and uHealth	48	1022	4.301	–	–
Journal of Medical Internet Research	28	857	4.945	1.74	Q1
BMC Public Health	6	251	2.567	1.38	Q2
Digital Health	6	38	–	–	–
Telemedicine and e-Health	4	152	1.996	0.86	Q1
American Journal of Health Education	4	68	1.200	0.36	Q3
British Journal of Sports Medicine	4	30	11.645	4.14	Q1
International Journal of Behavioral Nutrition and Physical Activity	3	483	6.037	2.97	Q1
PeerJ	3	29	2.353	1.04	Q1
Computers in Human Behavior	3	20	4.306	1.71	Q1
International Journal of Medical Informatics	3	19	2.731	0.96	Q1
Journal of Sports Medicine and Physical Fitness	3	17	1.302	0.54	Q2
Medicine and Science in Sports and Exercise	3	11	4.478	2.07	Q1
Telematics and Informatics	3	10	3.714	1.21	Q1
JMIR Research Protocols	3	9	–	–	–
Trials	3	5	1.975	1.29	Q1
Communications in Computer and Information Science	3	2	0.490	0.17	Q3
Annals of Behavioral Medicine	3	0	3.575	1.58	Q1

Table 5
The most productive conference proceedings.

Conference	Papers	Number of Citation	Frequency
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	13	39	2.69%
ACM International Conference Proceeding Series	6	16	1.24%
Conference on Human Factors in Computing Systems – Proceedings	6	14	1.24%
Studies in Health Technology and Informatics	6	35	1.24%
CEUR Workshop Proceedings	3	0	0.62%
International Conference on Information Systems 2018, ICIS 2018	3	0	0.62%
Annual Hawaii International Conference on System Sciences – Proceedings	3	29	0.62%
ACM UMAP 2019 Adjunct – Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization	2	4	0.41%
ACM Conference on Computer Supported Cooperative Work – Proceedings	2	19	0.41%

trend towards multi-author contributions in the field and a wide dispersion of research. Table 8 summarizes the first 30 authors in the list, with more than two contributions (Table 8).

The most productive authors in terms of the number of articles published are Oyibo K. and Vassileva J., both from the University of Saskatchewan (Canada), with 8 contributions. Third and fourth-ranked Gay V. and Leijdekkers P. are co-authors. In the scope of the subject of our study, they co-authored a total of six articles.

The work of the most productive authors does not attract the highest number of citations. The author, with the highest number of citations in the fitness apps field, is West J.H. His six articles have garnered a total of 655 citations. Three of them are ranked in the top ten most influential papers in Table 8. They were all published in the journal with the most contributions in the field, *Journal of Medical Internet Research*.

The author with the highest h-index (78) is Salmon J., from Deakin University, whose research pertains to the fields of medicine, health professions, and nursing. However, the total number of citations for his three articles was only 35. No other author had an h-

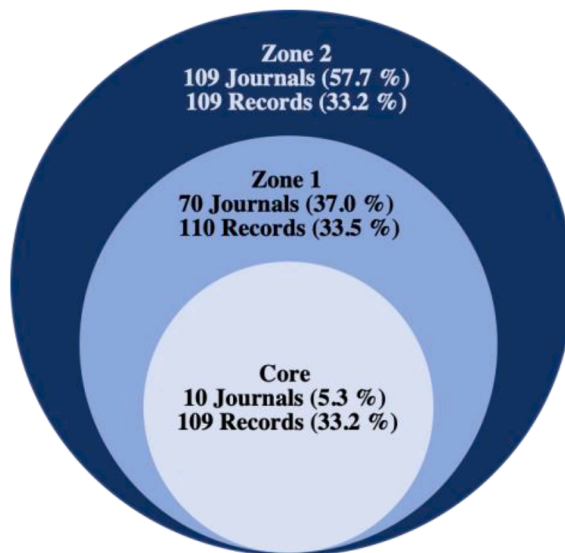


Fig. 4. Dispersion in Bradford rings of scientific production related to fitness apps.

Table 6
Publication dispersion zones under Bradford's Law.

	Journals	Articles	Ratio (Number of Journal)	Theoretical Ratio (1:n:n ²)	Theoretical Number of Journals
CORE	10	109	1	1	10
Zone 1	70	110	n = 7	n = 7	70
Zone 2	109	109	n2 = 10.9	n2 = 49	490
TOTAL	189	325			570

Table 7
Most Cited Articles.

Cited by	Authors	Title	Year	Source title	Citations per year
598	Boulos M.N.K., Wheeler S., Tavares C., Jones R.	How smartphones are changing the face of mobile and participatory healthcare: An overview, with an example from eCAALYX	2011	BioMedical Engineering Online	74.75
316	Krebs P., Duncan D.T.	Health app use among US mobile phone owners: A national survey	2015	JMIR mHEALTH and uHEALTH	79.00
206	Middelweerd A., Mollee J.S., van der Wal C. N., Brug J., te Velde S.J.	Apps to promote physical activity among adults: A review and content analysis	2014	International Journal of Behavioral Nutrition and Physical Activity	41.20
200	Young J., Angevaren M., Rusted J., Tabet N.	Aerobic exercise to improve cognitive function in older people without known cognitive impairment	2015	Cochrane Database of Systematic Reviews	50.00
183	Dimitrov D.V.	Medical internet of things and big data in healthcare	2016	Healthcare Informatics Research	61.00
175	Schoeppe S., Alley S., Van Lippevelde W., Bray N.A., Williams S.L., Duncan M.J., Vandelandotte C.	Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: A systematic review	2016	International Journal of Behavioral Nutrition and Physical Activity	58.33
175	Azar K.M.J., Lesser L.I., Laing B.Y., Stephens J., Aurora M.S., Burke L.E., Palaniappan L.P.	Mobile applications for weight management: Theory-based content analysis	2013	American Journal of Preventive Medicine	29.17
167	Payne H.E., Lister C., West J.H., Bernhardt J. M	Behavioral Functionality of Mobile Apps in Health Interventions: A Systematic Review of the Literature	2015	Journal of Medical Internet Research	41.75
161	West J.H., Hall P.C., Hanson C.L., Barnes M. D., Giraud-Carrier C., Barrett J.	There's an app for that: Content analysis of paid health and fitness apps	2012	Journal of Medical Internet Research	23.00
156	Lister C., West J.H., Cannon B., Sax T., Brodegard D.	Just a fad? Gamification in health and fitness apps	2014	Journal of Medical Internet Research	31.20
153	Haghi M., Thurow K., Stoll R.	Wearable devices in medical internet of things: Scientific research and commercially available devices	2017	Healthcare Informatics Research	76.50
145	Direito A., Pfaeffli Dale L., Shields E., Dobson R., Whittaker R., Maddison R.	Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques?	2014	BMC Public Health	29.00
130	Cowan L.T., van Wagenen S.A., Brown B.A., Hedin R.J., Seino-Stephan Y., Hall P.C., West J.H.	Apps of Steel: Are Exercise Apps Providing Consumers With Realistic Expectations? A Content Analysis of Exercise Apps for Presence of Behavior Change Theory	2013	Health Education and Behavior	21.67
107	Higgins J.P.	Smartphone Applications for Patients' Health and Fitness	2016	American Journal of Medicine	35.67
102	Bardus M., van Beurden S.B., Smith J.R., Abraham C.	A review and content analysis of engagement, functionality, aesthetics, information quality, and change techniques in the most popular commercial apps for weight management	2016	International Journal of Behavioral Nutrition and Physical Activity	34.00
92	Anderson K., Burford O., Emmerton L.	Mobile health apps to facilitate self-care: A qualitative study of user experiences	2016	PLoS ONE	30.67
85	Edwards E.A., Lumsden J., Rivas C., Steed L., Edwards L.A., Thyagarajan A., Sohanpal R., Caton H., Griffiths C.J., Munafò M.R., Taylor S., Walton R.T.	Gamification for health promotion: systematic review of behaviour change techniques in smartphone apps	2016	BMJ open	28.33
82	Balsalobre-Fernández C., Glaister M., Lockey R.A.	The validity and reliability of an iPhone app for measuring vertical jump performance	2015	Journal of Sports Sciences	20.50
78	Sullivan A.N., Lachman M.E.	Behavior change with fitness technology in sedentary adults: A review of the evidence for increasing physical activity	2017	Frontiers in Public Health	39.00
73	Rabin C., Bock B.	Desired Features of Smartphone Applications Promoting Physical Activity	2011	Telemedicine and e-Health	9.13
72	McConnell M.V., Shcherbina A., Pavlovic A., Homburger J.R., Goldfeder R.L., Waggot D., Cho M.K., Rosenberger M.E., Haskell W.L., Myers J., Champagne M.A., Mignot E., Landray M., Tarassenko L., Harrington R.A., Yeung A.C., Ashley E.A.	Feasibility of obtaining measures of lifestyle from a smartphone app: The MyHeart Counts cardiovascular health study	2017	JAMA Cardiology	36.00
72	Ancker J.S., Witteman H.O., Hafeez B., Provencher T., Van De Graaf M., Wei E.	"You get reminded you're a sick person": Personal data tracking and patients with multiple chronic conditions	2015	Journal of Medical Internet Research	18.00
69	McKay F.H., Cheng C., Wright A., Shill J., Stephens H., Uccellini M.	Evaluating mobile phone applications for health behaviour change: A systematic review	2018	Journal of Telemedicine and Telecare	69.00
68	Dehling T., Gao F.J., Schneider S., Sunyaev A.		2015	JMIR MHEALTH AND UHEALTH	17.00

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Table 7 (continued)

Cited by	Authors	Title	Year	Source title	Citations per year
66	Mackert M., Mabry-Flynn A., Champlin S., Donovan E.E., Pounders K.	Exploring the Far Side of Mobile Health: Information Security and Privacy of Mobile Health Apps on iOS and Android	2016	Journal of Medical Internet Research	22.00
64	Wartella E., Rideout V., Montague H., Beaudoin-Ryan L., Lauricella A.	Health literacy and health information technology adoption: The potential for a new digital divide	2016	Media and Communication	21.33
64	Ancker J.S., Witteman HO., Hafeez B., Provencher T., Van de Graaf M., Wei E.	Teens, health and technology: A national survey	2015	Journal of Medical Internet Research	16.00
60	Direito A., Jiang Y., Whittaker R., Maddison R.	“You Get Reminded You’re a Sick Person”: Personal Data Tracking and Patients with Multiple Chronic Conditions	2015	Journal of Medical Internet Research	15.00
		Apps for IMproving FITness and increasing physical activity among young people: The AIMFIT pragmatic randomized controlled trial			

index above 20.

The high inconsistency in the number of citations, the number of author contributions, and the h-index show that no scholar or team of scholars has yet had a decisive influence on the field, which is also related to the fact that the field is still in the precursor stage of research.

Additionally, the authors in Table 8 are not widely dispersed in terms of institutional affiliation, with several authors (and close rankings) being from the same institution. This suggests that a high proportion of the top 30 productive authors are co-authors, as evidenced in Fig. 5. It highlights that only four authors did not co-author papers with others. The remaining 26 authors make up the remaining nine clusters. Moreover, members in each group usually come from the same institutions or countries, with less cross-national/interregional cooperation.

The authors' productivity data are much lower than the values suggested by Lotka's Law (Lotka, 1926). This law states that the number of authors making n contributions in a given period is approximately equal to the number of authors who make $1/n^2$ contributions. Generally, the application of Lotka's Law gives the theoretical result that about 60% of authors make only one contribution in their field of study. In the field of research on fitness applications, the value of Lotka's Law is 92.62% (Table 9). This confirms the huge dispersion of the field, which can be explained either by the novelty of the phenomenon or by a multidisciplinary approach.

Additionally, the analysis of co-citation of authors shows the structure and connections of the co-cited authors, i.e., “which authors are cited together more frequently” (Gaviria-Marin et al., 2019, p. 213). Fig. 6 shows the results of the analysis conducted using VOSviewer, and the number of citations for each author is indicated by the size of the colored dot (Fig. 6).

Authors with more than 35 citations were clustered in five groups. Some of these authors did not contribute directly to our field. However, their articles are frequently cited by other authors in the fitness app research field.

Authors in Cluster 1 mainly tend to focus on research in the areas of social sciences, business, management and accounting, and mathematics. Sub-topics of interest to them include behavior change, physical activities, etc.

Authors in Cluster 2 primarily devote their research to the field of biochemistry, genetics and molecular biology, and health professions. Physical and health education is also one of the sub-topics they are interested in.

In Cluster 3, the main research interests include psychology, and besides, the authors have contributed to the areas of computer science, nursing, and decision making.

The main research interests of the authors of Cluster 4 lie in the arts and humanities, social sciences, computer science, and psychology. They have also undertaken certain interpretative explorations of technological acceptance.

Cluster 5 consisted of only two authors, Richard M Ryan and Edward L. Deci. They are also co-authors of articles with fairly high citations, and both of them have an h-index of no less than 150. Their main areas of research are psychology, in which self-determination theory and motivation are also a point of interest.

4.5. Most productive countries/regions

6 out of the 481 records did not specify the country/region of origin. Of the remaining 475 records, the countries that contributed the most were the United States (29.3%), the United Kingdom (11.2%), and Australia (10%). It should be noted that almost half of the studies were carried out in English-speaking countries. Among the Asian countries, China, India, and South Korea stood out. National/regional contributions are double counted when authors of the same article are affiliated with institutions from different countries (Table 10) (Fig. 7).

4.6. Most productive fields of research

Our results show that the main research areas of study are medicine (23.95%), computer sciences (17.88%), behavioral sciences (6.7%), computer medicine (6.5%), and psychology (6.2%). Most articles contribute to more than one field (Table 11).

It seems that research in fitness apps has flourished through its study in the medical area, followed by its computational features.

Table 8
The most productive and influential authors in fitness app research.

	Authors	Institution	Number of Contributions in Fitness App	Number of Citation in Fitness App	Contributions in all Fields	Number of Citations in all Fields	H-index
1	Oyibo K.	University of Saskatchewan	8	17	51	169	7
2	Vassileva J.	University of Saskatchewan	8	17	235	3307	27
3	Gay V.	University of Technology Sydney	7	73	62	542	12
4	Leijdekkers P.	University of Technology Sydney	6	73	29	541	13
5	West J.H.	Brigham Young University	6	655	52	1537	17
6	Adaji I.	University of Saskatchewan	5	11	43	119	6
7	Lubans D.R.	University of Newcastle, Australia	5	46	241	7810	46
8	Plotnikoff R. C.	University of Newcastle, Australia	5	46	336	9546	53
9	Smith J.J.	University of Newcastle, Australia	5	46	42	1155	16
10	Cho J.	Sogang University	4	30	22	300	8
11	Kajanan S.	National University of Singapore	4	28	14	83	6
12	Kankanhalli A.	National University of Singapore	4	8	129	6461	32
13	Maddison R.	University of Auckland	4	270	173	3939	37
14	Yoganathan D.	National University of Singapore	4	28	7	39	4
15	Albrecht U.-V.	Medizinische Hochschule Hannover (MHH)	3	12	80	601	13
16	Aswani A.	Department of Industrial Engineering & Operations Research	3	8	51	796	12
17	Benson A.C.	Swinburne University of Technology	3	7	50	775	13
18	Direito A.	National University of Singapore	3	232	20	492	9
19	Fukuoka Y.	University of California, San Francisco	3	8	58	879	19
20	Hall P.C.	Brigham Young University	3	321	21	490	9
21	Jiang Y.	University of Auckland	3	89	119	2706	26
22	Lee H.E.	Hankuk University of Foreign Studies	3	30	8	97	4
23	Lyons E.J.	University of Texas Medical Branch Galveston	3	52	63	1193	18
24	Olabenjo B.	University of Saskatchewan	3	8	5	12	2
25	Ortega F.B.	Universidad de Granada	3	47	343	12146	56
26	Payne HE.	George Washington University	3	202	53	784	17
27	Salmon J.	Deakin University	3	35	372	22151	78
28	Vickey T.A.	National University of Ireland Galway	3	14	7	22	2
29	Von Jan U.	Medizinische Hochschule Hannover	3	12	55	329	10
30	Whittaker R.	University of Auckland	3	232	110	3834	20

The data source was Scopus.

In those cases where the information was not available at Scopus, we used the information provided by WoS.

However, the study from the point of view of consumer behavior, integrated into the field of social sciences, seems not to have taken off yet. We predict significant growth in this domain as fitness apps become more popular, and communication through social networking sites goes viral, particularly among young people.

4.7. Most used research methods

The applied research methods allow the collection of empirical data to contribute to scientific knowledge. It is an important variable to understand the empirical orientations of research in this field of knowledge.

As shown in [Table 12](#), the most frequently used research method was the experiment. The experimental design was used in 24.5% of all research. Most of them were “in the wild” experiments, implemented on a small group of participants ($n < 50$) who were asked to use a fitness app, developed expressly for the research, for a short period. The second most used research method was the survey (18.5% of the articles), which allowed the evaluation of the user perspective and behavior with self-reported data.

The third-ranked research method was content analysis. The articles that used this method analyzed and evaluated the total or

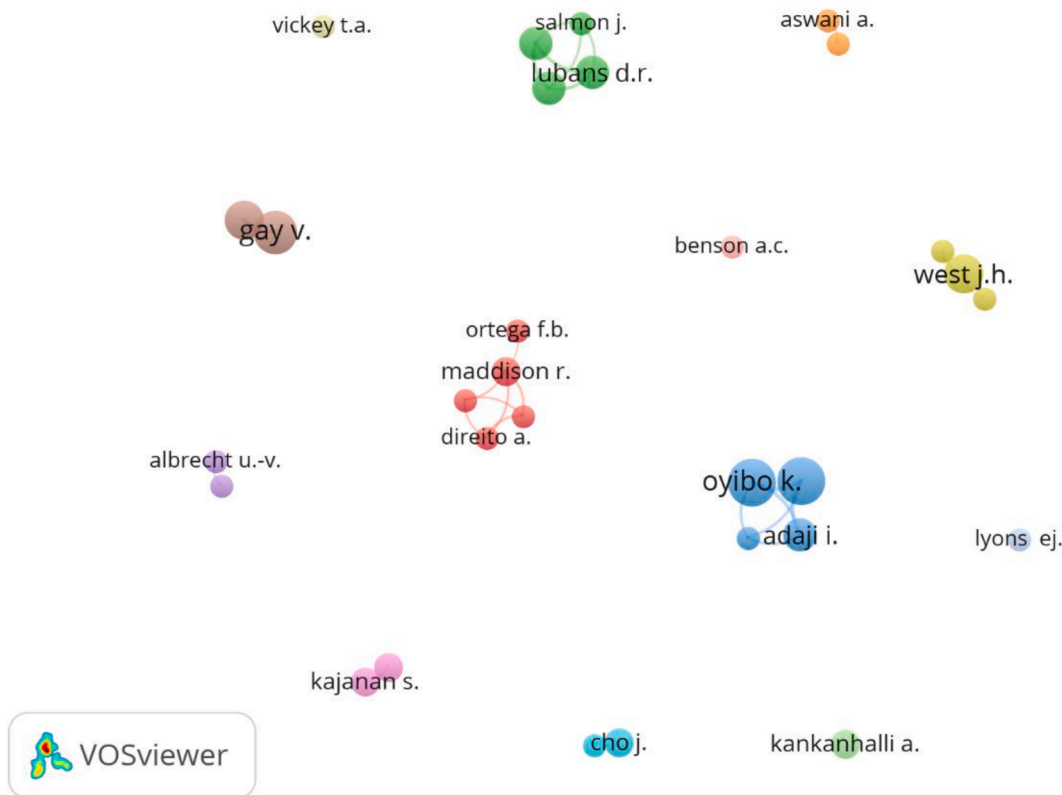


Fig. 5. Correlation in co-authorship (for top 30 authors with more than two contributions).

Table 9
Productivity of authors.

Number of Articles Published	Number of Authors	% of Total Authors
8	2	0.11%
7	1	0.06%
6	2	0.11%
5	4	0.23%
4	5	0.28%
3	16	0.90%
2	101	5.69%
1	1645	92.62%

partial functionality of a range of fitness-related apps, their technical characteristics and the attributes that make them more valued by users, more effective in changing consumer behavior, etc. For example, Cowan et al. (2013) calculated a theoretical score for each of the 127 health and fitness applications to determine whether the applications included relevant aspects of the behavioral change theory.

The content analysis articles allow us to understand how fitness-related apps have evolved over the years and how researchers' focus has changed over that same period. By reviewing relevant articles, we found that behavior change techniques, gamification features, and consumer engagement strategies have been attracting attention, as shown in Fig. 8. Fig. 8 summarizes articles on content analytics from 2012 to 2019 from West et al. (2012), Cowan et al. (2013), Direito et al. (2014), Lister et al. (2014), Edwards et al. (2016), Rose et al. (2017), Moral-Munoz et al. (2018), Priesterroth et al. (2019) and Cotton and Patel (2019).

5. Main topics analyzed and lines of research

5.1. Keywords

The analysis of the frequency of appearance of the keywords allows the reader to approach the main topics analyzed in the articles in this field. The analysis of the keywords selected by the authors allows the determination of which relationships are established between a field of research and others close to it (Duran-Sanchez et al., 2016).

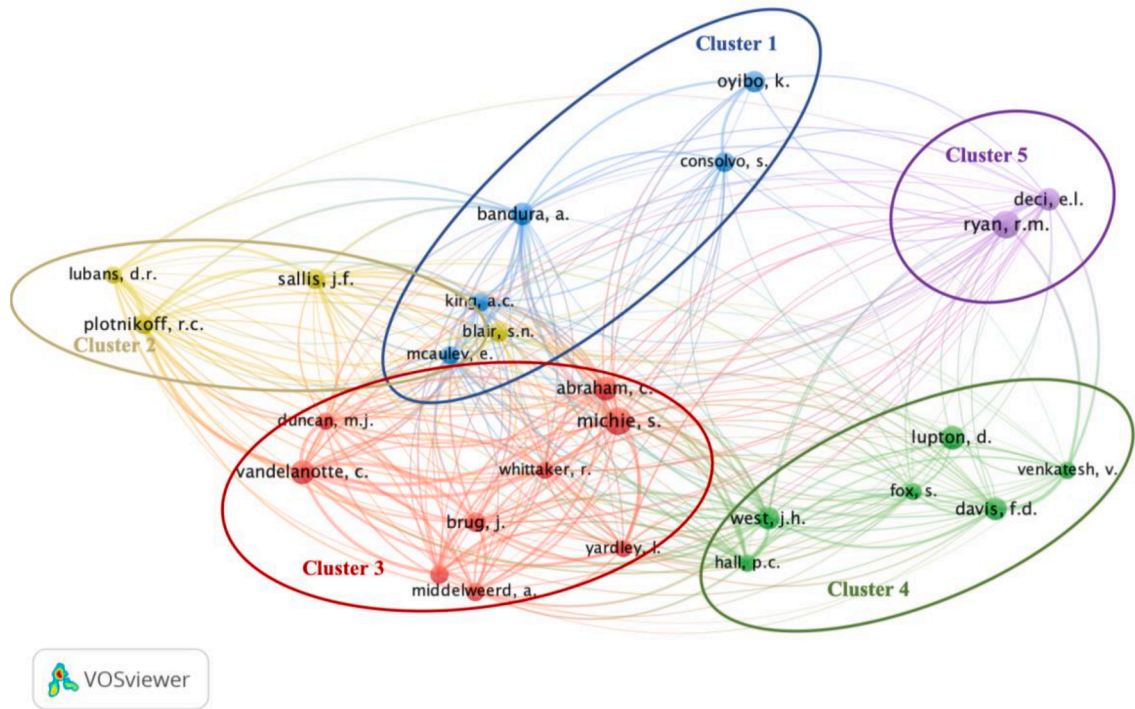


Fig. 6. Co-citation of authors.

Table 10
Most cited countries/regions.

Countries/Regions	Number of Contributions	Percentage
United States	141	29.3%
United Kingdom	54	11.2%
Australia	48	10.0%
Germany	45	9.4%
China	29	6.0%
Canada	29	6.0%
Netherlands	19	4.0%
India	18	3.7%
Italy	17	3.5%
South Korea	15	3.1%
Spain	14	2.9%
Singapore	13	2.7%
Sweden	9	1.9%
Taiwan	9	1.9%
Belgium	9	1.9%
Austria	8	1.7%
Portugal	8	1.7%
Greece	8	1.7%
France	7	1.5%
Denmark	7	1.5%
New Zealand	7	1.5%
Switzerland	7	1.5%
Brazil	7	1.5%
Norway	6	1.2%

As shown in Table 13, the terms “physical activity” and “mHealth” appear in 28.1% of all the contributions. Both keywords are the conceptual core of fitness app research. Physical activity is also related to the terms “exercise” (6.9%), “obesity” (1.7%), and “weight loss” (2.3%).

Portability is a concept associated with new devices for self-monitoring of activity: the terms “wearables” and “fitness tracker(s)” appeared in 3.1% and 4.8% of articles, respectively.

The principle of playful functions is reflected in the term “gamification,” with 3.33% of the articles, which is a factor that can

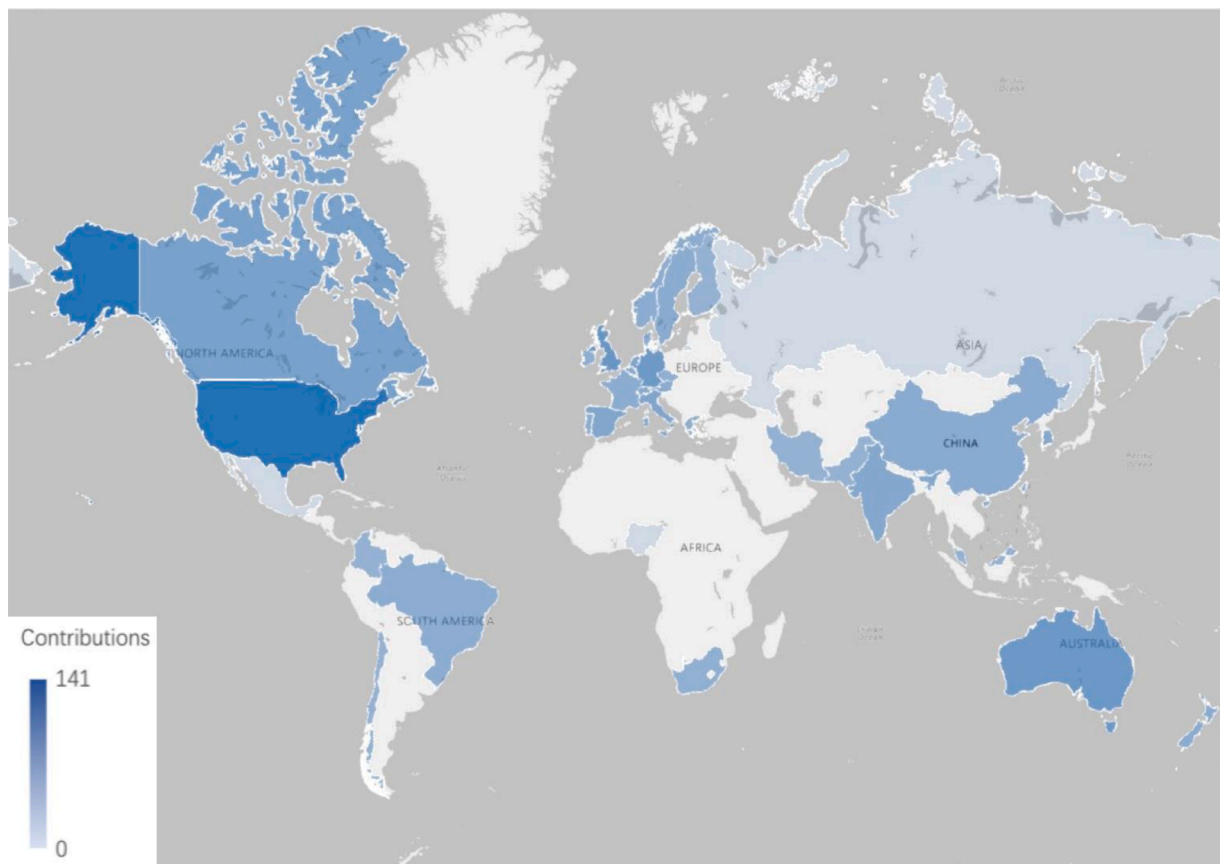


Fig. 7. Map of contributions by countries/regions.

Table 11
Frequency of published articles by research field.

Investigation Field	Frequency	Percentage
Medicine	189	39.13%
Computer Science	170	35.20%
Health Professions, Health Care Sciences & Service	78	16.15%
Social Sciences	68	14.08%
Engineering	68	14.08%
Medical Informatics	28	5.80%
Mathematics	27	5.59%
Decision Science	24	4.97%
Business, Management, Economics and Accounting	19	3.93%
Psychology and Psychiatry	16	3.31%
Nursing	13	2.69%
Biochemistry, Genetics, Cell Biology, and Molecular Biology	12	2.48%
Sport Sciences	10	2.07%
Arts and Humanities	9	1.86%
Environmental Sciences & Ecology	7	1.45%
Physics and Astronomy	7	1.45%
Education & Educational Research	6	1.24%
Public, Environmental & Occupational Health	5	1.04%
Materials Science	5	1.04%
Energy	5	1.04%
Communication and Telecommunications	4	0.83%
Neuroscience	4	0.83%
Economics, Econometrics, and Finance	4	0.83%
Cardiovascular System Cardiology	4	0.83%

Table 12
Main research methods used.

Methodology	Frequency	% of the total
Experiment	118	24.5%
Survey	89	18.5%
Content analysis	54	11.2%
Literature Review	37	7.7%
Interview	27	5.6%
Focus group	16	3.3%
Other methods	166	34.5%
Total*	507	105.4%

*Out of the total 481 articles, 25 articles (5.2%) used multiple methods. Of these, 24 articles used two methods and one article used three methods.

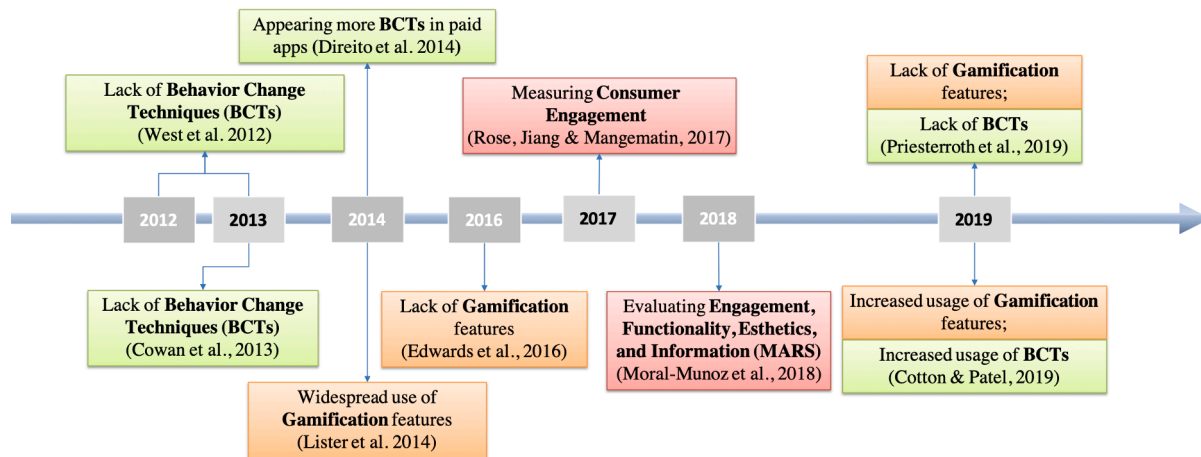


Fig. 8. Timeline of hot topics of content analysis articles.

Table 13
Frequency of occurrence of keywords (>6 times).

Keywords	Occurrence	Percentage
Physical activity	73	15.2%
mHealth	62	12.9%
Exercise	33	6.9%
Smartphone	32	6.7%
Apps	29	6.0%
Mobile applications	28	5.8%
Fitness	27	5.6%
Mobile health	25	5.2%
Health	23	4.8%
Mobile phone	17	3.5%
Fitness trackers	17	3.5%
Telemedicine	16	3.3%
Gamification	16	3.3%
Physical fitness	16	3.3%
Fitness apps	15	3.1%
Fitness app	15	3.1%
Wearables	15	3.1%
Technology	12	2.5%
Behavior change	11	2.3%
App	11	2.3%
Weight loss	11	2.3%
EHealth	10	2.1%
Mobile app	9	1.9%
Persuasive technology	8	1.7%
Obesity	8	1.7%
Motivation	8	1.7%
Health promotion	8	1.7%

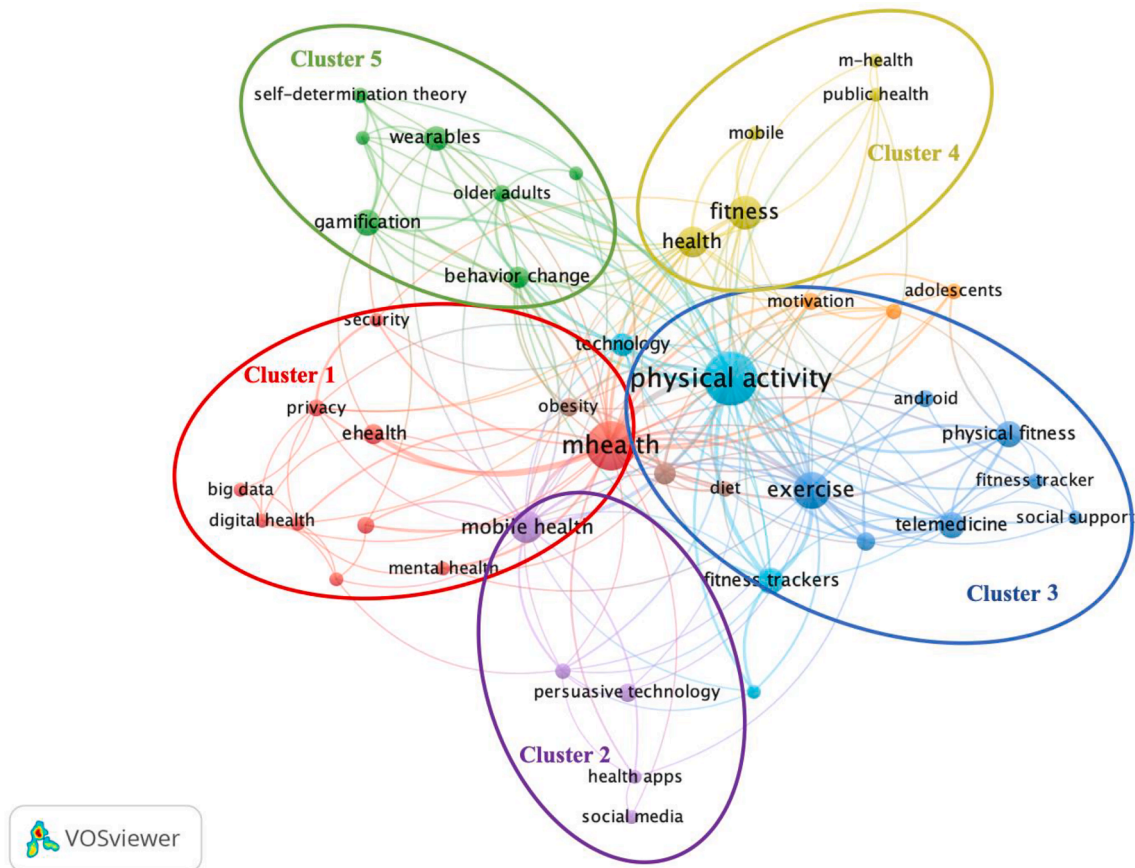


Fig. 9. Correlation map between keywords.

increase user adherence to the programs.

Fig. 9 maps the correlation between the keywords. To make the map clearer, with more focus on the core of the field of study, we removed the keyword “app” and its various related forms from the mapping analysis.

The most frequent keywords were located in five differentiated clusters.

Cluster 1, which we named “Digital mHealth” is mainly related to mHealth and eHealth (electronic health). They are platforms for fitness apps. Also included in this group are keywords such as privacy and security, which are all related to the technology and device issues of fitness applications.

Cluster 2, which we named “mHealth and fitness trackers,” is pretty similar to Cluster 1, with only an emphasis on fitness trackers and persuasive technology as well as health apps and wearable electronic devices.

Cluster 3, which we named “Physical activity, motivation, and social support,” comprises keywords such as physical activity, exercise, physical fitness, etc. Social support and motivation are also included in this group, which may be since these two are also important factors that support people to stick to physical activity (Tang et al., 2015).

Cluster 4, which we named “Generalistic keywords,” is more macro in nature and contains a wide range of topics such as fitness, mobile, and public health.

Cluster 5, which we named “Behavior change and gamification,” includes keywords such as behavior change, gamification, wearables, and self-determination theory.

5.2. Main topics of research

Finally, based on all the information obtained as well as our thorough review of the contributions that are part of this bibliometric study, we now describe the main topics of research on the subject of fitness apps:

- 1) Descriptive studies of the possibilities of the applications and the quality of their functions. Most of the research is related exclusively to physical activity, alongside some studies on diet. For example, Li et al. (2019) analyzed the quality of nutritional recommendations of applications available in China for a healthy lifestyle, nutrition, and disease prevention.

- 2) Analysis of the quality and performance of the use of the apps concerning the objectives of the users. The performance is measured through an evaluation of different indicators, such as the level of physical activity or weight loss. In this criterion of research, the use of innovative features is particularly important. For example, [Mata et al. \(2018\)](#) tested the performance of the training planning function of the relevant apps and confirmed the high performance of these app-generated training and nutrition plans through expert validation.
- 3) Analysis of the benefit of the use of fitness apps for the chronically ill. Patients affected by severe chronic diseases can undergo improvement in their general condition through lifestyle improvements. For example, [Bonato et al. \(2019\)](#) analyzed the possibility of using an app for monitoring physical exercise routines for people affected by HIV. The apps are used to encourage patients to exercise to improve their general condition.
- 4) Examination of the use of fitness applications to encourage people with a specific need due to their socio-demographic profile to follow the minimum physical activity requirements established by the WHO. This includes the specific physical exercise needs that can be implemented through apps for the elderly ([Mas et al., 2016](#)), children ([Tripicchio et al. 2017](#)), or people with disabilities ([Pérez-Cruzado and Cuesta-Vargas, 2013](#)).
- 5) Study of factors affecting user motivation to continue using Fitness Apps. Increasing user motivation is an integral part of a significant number of articles. Very high abandonment rates are observed in the use of these applications, and there is a lack of user engagement ([Bardus et al., 2016](#)). Among the factors that may influence the use of the apps, some researchers are interested in the aesthetics of the user interface ([Bardus et al., 2016](#)), social relations ([Lewis et al., 2019](#)) and the personalization ([Zhou et al., 2018](#)).
- 6) Exploration of the social problems associated with fitness apps. Some articles focus on the problems related to fitness apps and the adherence to hegemonic beauty canons. In this line of research, [Honary et al. \(2019\)](#) concluded that the use of these apps might increase social pressure to achieve unrealistic beauty ideals and could thus increase the incidence of eating problems, such as anorexia or excessive physical exercise. Another issue of concern relates to the privacy of and the large amount of personal data collected by these apps ([Adhikari et al., 2014](#)).
- 7) Examination of fitness apps as complementary products to wearable devices. Wearable devices provide more accurate and convenient data for measuring people's daily activity levels. However, they are usually associated with relevant mobile apps for health data visualization and analysis. For example, [Lee et al. \(2019\)](#) concluded that children who use wearable devices with mobile app interventions increase their physical activity over time. The emergence of the Internet of Things (IoT) has provided more help to improve people's health behaviors. However, this then brings up the issue of information security and privacy. Thus, [Bohé et al. \(2019\)](#) offer complementary approaches for building a better IoT ecosystem.

6. Conclusions and limitations

This study aimed to present in detail the current state of research on fitness applications through an exhaustive bibliometric analysis and bibliometric mapping. The social function and health potential of fitness apps represent a recent and growing phenomenon, which justifies an increase in the intensity of scientific research in recent years. 89.4% of the contributions were published 2014 onwards when the usage of these apps had already been an important trend in the commercial market for several years. Several bibliometric indicators (e.g., distribution of years of publication, Price's index, author productivity, Bradford's Law, h-index, number of citations, source of publication, research areas, research methods, etc.) were analyzed to understand the main features and patterns of research on fitness apps. Moreover, the scientific mapping analysis of the co-occurring keywords, co-authors, and co-citing authors provided an additional analysis from a time-depth perspective.

In general, it is important to note the great dispersion of research, with a very high number of authors who have only made one contribution being a characteristic of a field of research that has not yet reached maturity. Research in this field is still in its precursor stage. Moreover, many of the studies have a relatively high number of co-authors. This situation is reflected in the indicator of author productivity, which is relatively low (Oyibo, K. and Vassileva, J. being the most active author with eight published articles). However, the most productive authors are not the most influential authors. West. J.H. has gained 655 citations for his four articles, ranking first for this field of study.

This dispersion of research is also reflected in the source of the publications. Although there is a specialized journal in mHealth (JMIR mHealth and uHealth), it can be found that submissions on fitness apps are distributed across a large number of academic journals and conference proceedings.

With this data and support from the analysis of scientific mapping, it can be concluded that authors or prestigious journals have not been integrated and the research references in this field are relatively fragmented, partly due to their novelty and multidisciplinary requirements but also due to the technical orientation of the developers to circumvent the basic health, social, and behavioral aspects of health, society, and behavior.

As in many other areas, the United States remains a prominent contributor in this area. China and India are the most productive in developing countries. These two countries are increasing their productivity and expanding their influence in various fields of scientific research at present.

The most common research method used in this field is the experimental procedure that measures behavioral changes or changes in health indicators after a period of use. The second most used method is the survey, followed by the analysis of content.

A considerable amount of literature is related to medicine, computer science, and healthcare. Many authors have also focused on this main area of research.

Additionally, physical activity was the most frequently occurring keyword. "Behavior change" linked to "physical activity" is also an important keyword. Specifically, it refers to concepts such as behavior change theory, behavior change techniques (e.g., goal

setting, self-regulation), etc. However, relatively few studies on consumer behavior from a social science perspective have been found. It seems that consumer-related research has mainly focused on analyzing the optimization of the functionalities of mobile applications from a medical or computer science point of view and neglected the aspects intrinsic to consumer behavior such as the motivations for using fitness apps, the attitude towards them, or how social networks influence the choice of the app to be used. The fact that the keyword “motivation” appears only 8 times and all after 2018 is a clear indication of this finding.

Based on the generalization of all the information obtained and the review of the abstract and some of the full text, we found that the performance and function of fitness apps, the benefits for chronic disease treatment, the influence of using fitness app for public health, and factors of motivations of using fitness apps are currently popular research topics in this field. Future research could build on these directions and incorporate relevant issues from a social science perspective (e.g., consumer motivations, consumer engagement, consumer behavior, etc.) to further investigate on fitness applications.

This article is useful in understanding the early state of research in the fitness app field. However, it is necessary to consider several limitations. One of the limitations of this study is the delimitation of the sample search criteria. In essence, the concept of fitness serves as a central reference for the applications that users utilize to perform self-monitoring of health-related factors, particularly the level of physical activity. The control of “diet” is another health factor that overshadows and is superimposed on the concept of fitness, but one that could also be considered as a separate field in future studies, or add it to the keyword search scope for getting more comprehensive results.

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CRediT authorship contribution statement

Yali Liu: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing - original draft, Visualization. **Maria Avello:** Supervision, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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