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Bibliometric study on scientific productivity in the use of smart bracelets

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Abstract

In recent years, wearable sensors and mHealth applications are becoming an important part for recording and monitoring health parameters. The aim is to characterize bibli-ometric indicators on scientific productivity in the use of smart bracelets according to scientific journal, study topic and publication trend. A bibliometric study was per-formed. The data extracted from the articles were: year of publication, name of the journal, language of publication, country, type of study and subject matter. A total of 45 studies were identified (21 cross-sectional and 24 experimental), of which 43 were published in English, one in Spanish and one in German. A total of 32 scientific journals published eight research topics related to smartwatch use [active living with 17 studies (37.8%), followed by stress and anxiety with 7 studies (15.6%), nanogenerators (batteries) with 6 studies (13.3%), computing with 5 studies (11.1%), chronic diseases 4 studies (8.9%), COVID propagation 3 studies (6.7%), energy expenditure 2 studies (4.4%) and occupational health 1 study (2.2%)]. The journal Sensors (Basel) published the most articles in the last 6 years (n=7, 16%). The scientific productivity of both study types reflects a positive trend (cross-sectional studies R2= 0.82 and in experimental studies R2= 0.76). A total of 45 cross-sectional and experimental studies using smart-watches were verified in eight different study topics. The most investigated category was active living and the journal that published the highest number of articles was the journal Sensors (Basel).

Key Words: bibliometrics; smart bracelets; wearable technologies; trends.

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Wearable devices represented by smart wristbands can objectively and continuously monitor and record real-time data, such as physical activity, energy consumption, and sleep quality.[1] A mobile health device (mHealth) is a small communication device that works with a smartphone or tablet to help people monitor their health at any time, reducing the use of medical resources and improving quality of life.[2] Generally, mobile health devices (e.g., smartphones, wristbands, and watches) use mobile technology, wireless devices, and sensors.[3] Smartwatches enable users to more conveniently understand their own health status, adjust their lifestyle in a timely manner, and prevent or reduce the potential risk of disease occurrence.[1] In fact, in recent years wearable sensors and mHealth applications are becoming an important part of healthcare practice by enabling continuous and longitudinal recording and monitoring of health parameters outside of consultations.[4] Smart wristbands are commonly used to monitor physiological data generated by body movement, where users can have a better understanding of their physical condition during the exercise process.[5] Even, studies in recent years have used for the management of patients with chronic diseases such as diabetes, cardiovascular diseases, stroke and early functional recovery after surgery,[1] as well as to monitor, sleep patterns, heart rate and also to calculate running speed.[6] Even, it can be used to track and monitor individual behavior to know the energy expenditure, brain activity, muscle activity,[7] to know the physiological, psychological, emotional and environmental state,[8] among other topics. Consequently, with the advancement of science and technology, mobile devices (smart watches) have become equipment that play a relevant role in the control and monitoring of health in general. So studying the scientific productivity

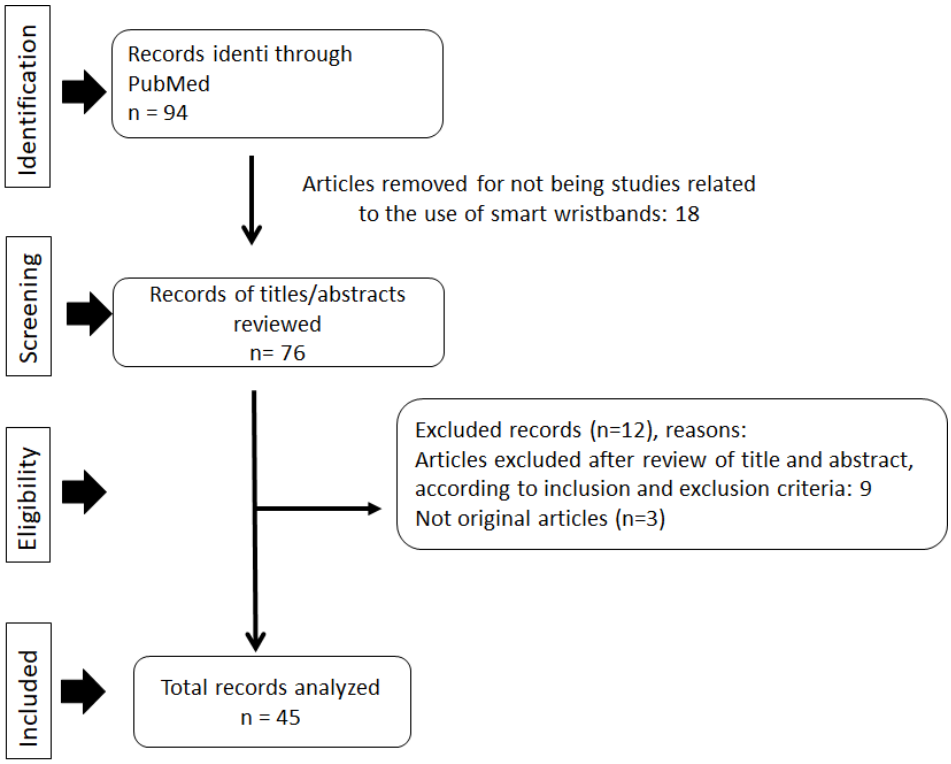

Fig 1. Screening process and selection of records according to the PRISMA (Preferred Reporting Items for Reviews and meta-analysis) flowchart.

Table 1. *Bibliometric indicators used in the study.*

Indicators	**f**	**%**
Language of publication		
English	43	95.6
Spanish	1	2.2
German	1	2.2
Total	45	100
Continent		
Asia	16	35.6
Europe	17	37.8
Latin America	3	6.8
North America	3	6.8
Central America	0	0
Africa	1	2.2
Oceania	1	2.2
Multicenter	4	8.9
Total	**45**	**100**

of this technology is highly relevant, because, these portable devices will play an important role in the field of health care and are better integrated into people's daily lives.[9]

Therefore, the aim of this study was to characterize the bibliometric indicators on scientific productivity in the use of smart wristbands according to scientific journal, subject of study and trend of publications from 2017 to 2022.

Materials and Methods

A bibliometric documentary study was carried out on the scientific productivity of the use of smart bracelets. The research data were extracted from the Pubmed database of the National Library of Medicine of the United States (https://pubmed.ncbi.nlm.nih.gov/). This database was used because it has a high coverage of English-language journals, in addition to containing citations and abstracts of biomedical literature and is the closest to our object of study (use of smart wristbands). The search strategy was applied during the period from 2017 to 2022. Studies published in English, Spanish, and German were considered. To achieve the relevance of this bibliometric review, the articles included the following keywords: i) Smartwatch, smart bracelet, device, sensor, wearable technology; ii) Monitoring, digital health, mobile health, Patient, human activity; iii) Uses, utilization, application, practice.

Table 2. *Number of scientific journals that have published original articles on the use of smart bracelets y.*

N°	Journals	f	%
1	ACS Nano	1	2.2
2	Annu Int Conf IEEE Eng Med Biol Soc	2	4.4
3	Behav Sci (Basel) (Behavioral Sciences)	1	2.2
4	BMC Health Serv Res (BMC Health Services Research)	1	2.2
5	BMC Public Health	1	2.2
6	Comput Intell Neurosci (Computational Intelligence and Neuroscience)	4	9
7	Comput Methods Programs Biomed	1	2.2
8	Electrophoresis	2	4.4
9	Geriatr Gerontol Int (Geriatrics & Gerontology International)	1	2.2
10	Healthcare (Basel)	1	2.2
11	HERD	1	2.2
12	IEEE J Biomed Health Inform	1	2.2
13	IEEE Trans Haptics (IEEE Transactions Haptics)	1	2.2
14	Integr Cancer Ther (Integrative Cancer Therapies)	1	2.2
15	Int J Clin Pract (International Journal of Clinical Practice)	1	2.2
16	Int J Environ Res Public Health	1	2.2
17	J Healthc Eng (Journal of Healthcare engineering)	1	2.2
18	J Med Internet Res (Journal of Medical Internet Research)	1	2.2
19	J Supercomput (The Journal of supercomputing)	1	2.2
20	JMIR Form Res (JMIR formative research)	1	2.2
21	JMIR Mhealth Uhealth	2	4.4
22	JMIR Res Protoc	1	2.2
23	Math Biosci Eng (Mathematical biosciences and engineering)	1	2.2
24	Medicina (Kaunas)	1	2.2
25	PLoS One	1	2.2
26	Psychiatr Hung (Psychiatria Hungarica)	1	2.2
27	Public Health	1	2.2
28	Qual Life Res (Quality of Life Research)	1	2.2
29	Sensors (Basel)	7	16
30	Sleep Disord	1	2.2
31	Small	2	4.4
32	Vnitr Lek (Vnitrni Lekarstvi)	1	2.2
	Total	45	100

Initially, all keywords were used together, using the Booleans "and" and "or" to order them. Subsequently, these words were grouped into two or three and a new search was performed, such as, for example, smartwatch and monitoring and patient. As indicators of scientific productivity, the year of publication, journal name, language and country of publication, type of study and subject matter related to the use of smart bracelets were considered. In addition, the observation technique was used to extract bibliometric indicators. The indicators of the scientific articles were recorded on an observation sheet. The terms indicated were searched for in the title, abstract and keywords of the manuscripts. Inclusion criteria were: i) peer-reviewed articles; ii) articles providing all required bibliometric indicators listed; iii) published in English, Spanish and German. In the case of studies that included systematic reviews and meta-analyses, these were excluded from the analysis. The

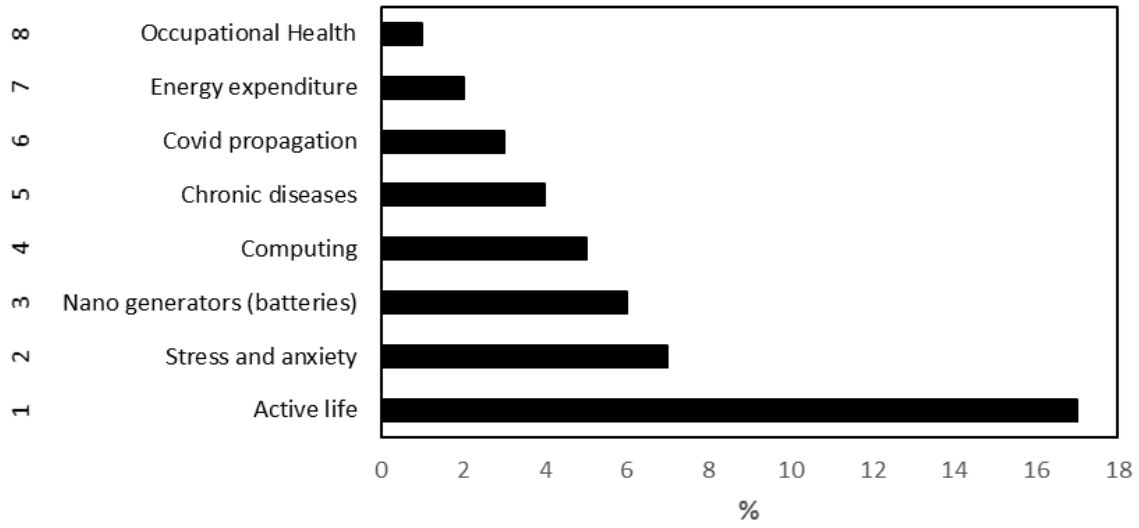

Fig 2. *Use of smart bracelets according to study topics.*

procedure for extracting the bibliometric indicators was performed by two of the investigators in this study (JST and CAL). Each of the observers recorded the information separately. A third observer collated the records of the first two observers. In this way, the information extraction process was certified. In cases where there was no coincidence, this third observer verified each of the indicators and made the pertinent corrections. A general matrix of the studies was then generated, which allowed the analysis of the bibliometric indicators.

The PRISMA guidelines were used to identify and extract the data for the bibliometric review (Figure 1).[10] Initially, a total of 94 scientific articles related to the use of smart wristbands were identified. Subsequently, 18 studies were eliminated for not being related to the object of study. In the next stage, the titles and abstracts were read, evaluating whether they corresponded to the objective of this research, taking into account the inclusion criteria, and 12 articles were eliminated. In the third stage, of the 64 eligible studies. Literature reviews, systematic reviews and meta-analyses were excluded. In the end, 45 studies were considered and used for bibliometric research. The data collected in the bibliometric matrix were used to organize the results. These were performed in Microsoft Excel spreadsheets. Tables and graphs were prepared. Descriptive statistical analysis, such as frequency, range and percentage (%), was considered to quantify the studies.

Results

The bibliometric indicators organized by language of publication and continent are shown in Table 1. A total of 45 studies were identified, where 43 were published in English, one in Spanish and one in German. Overall, Europe published the highest number of articles related

Table 3. **Types of studies that have been published from 2017 to 2022 on the use of smart wristbands**.

Years	All studies		Transversals		Experimental	
	f	%	f	%	f	%
2017	3	6.7	0	0	3	12.5
2018	3	6.7	2	9.5	1	4.2
2019	2	4.4	1	4.8	1	4.2
2020	11	24.4	6	28.6	6	25
2021	11	24.4	5	23.8	4	16.7
2022	15	33.3	7	33.3	9	37.5
Total	**45**	**100**	**21**	**100**	**24**	**100**

to the use of smart wristbands (n= 17, 37.8%), followed by Asia (n=16, 35.6%), multicenter study (Brazil, USA and Mexico) (n=4, 8.9%), Latin America and North America (n=3, 6.8%) and Africa and Oceania with one study each (2.2%).

Table 2 shows the list of journals that have published original studies on the use of smart wristbands from 2017 to 2022 in the Pubmed database. It was possible to identify 32 journals worldwide. For example, the journal Sensors (Basel) published the most articles in the last six years (n=7, 16%), followed by the journal Comput Intell Neurosci (n=4, 9%). The other journals published 1 and 2 articles, respectively.

In relation to the study topics, Figure 2 shows eight categories, which were extracted from the 45 studies. In general, active life was the most published topic with 17 studies (37.8%), followed by stress and anxiety with 7 studies (15.6%), nanogenerators (batteries) with 6 studies (13.3%), computing with 5 studies (11.1%), chronic diseases with 4 studies (8.9%), COVID propagation with 3 studies (6.7%), energy expenditure with 2 studies (4.4%) and occupational health with 1 study (2.2%).

Table 3 and Figure 3 show the trend in scientific productivity in relation to cross-sectional and experimental studies. Twenty-one cross-sectional studies were identified in the last six years. However, 24 experimental studies were identified. In general, as the years go by, the productivity of both types of studies reflects a positive trend. The explanatory power (R^2= 0.82) is greater in cross-sectional studies than in experimental studies (R^2= 0.76).

Discussion

This study aimed to characterize the bibliometric indicators on scientific productivity on the use of smart wristbands according to scientific journal, subject of study and trend of publications from 2008 to 2022. The results of the study in the last six years have shown a vast scientific productivity on the use of smart bracelets. A total of 45 original researches have been identified, corresponding to ±7.5 articles per year, whose scientific journals that have published in greater proportion are the Sensor BAsel journal (seven articles) and Comput Intell Neurosci (four articles). In fact, these results are consistent with studies with similar characteristics, where a significant increase in productivity in Information and Communication Technologies (ICT) has been reported.[11,12] And even recently, the World Health Organization (WHO) since 2018 has expanded the range of mHealth coverage to include the use of other digital technologies for public health,[12,13] which evidently demonstrates the relevance of investigating the use of smartwatches. Thus, bibliometric research can offer significant potential for investigating scientific activity, as well as for analyzing current topics of interest for research in the field of science and technology.[11] In this context, original studies published in scientific journals play a key role among researchers. Not only because they make it possible to disseminate and share data and materials generally accepted in the scientific community, which are fundamental for the development and scientific progress of a given area.[14] They also guide decision-

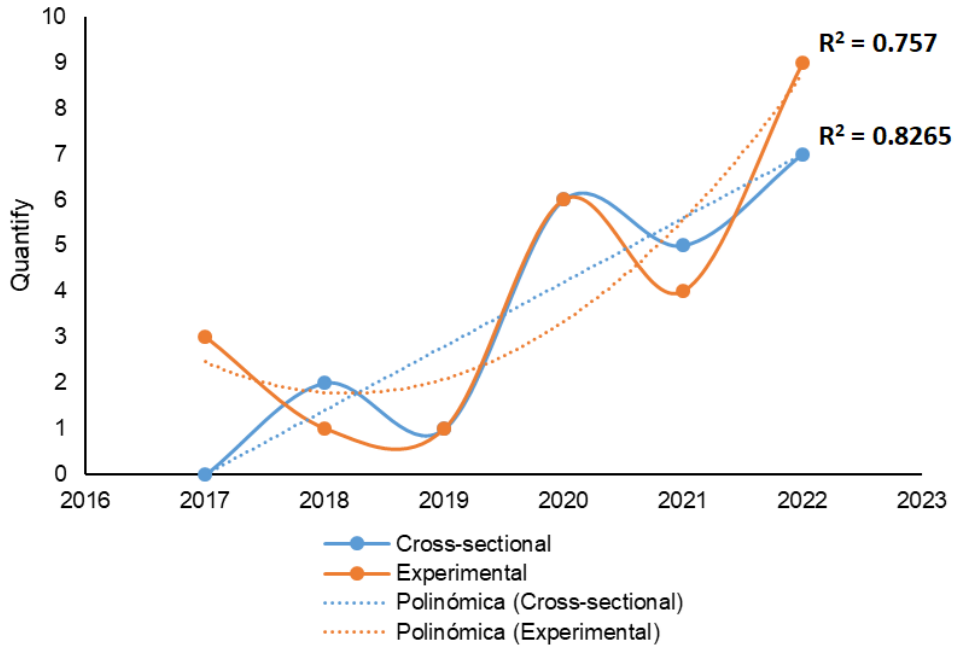

Fig 3. *Trend values of cross-sectional and experimental studies on the use of smart wristbands.*

making in the development of research policies and priorities. Also, we verified eight categories of topics that correspond to the use of smartwatches, i.e., active living, stress and anxiety, nano generator (batteries), computing, chronic diseases, COVID propagation, energy expenditure, and occupational health. These categories are mostly health oriented, where the active living category was the most addressed by the studies, followed by stress and anxiety. This evidence demonstrates that studies use smartwatches for prevention, diagnosis, treatment, monitoring and health management, leading to cost savings in healthcare systems and improving effectiveness and efficiency among patients.[15] In addition, the topics investigated allow to identify new lines and areas of research, as well as the obsolescence of certain topics and performance of scientific activity,[12] and promotion of positive changes in health behavior and disease control in the general population.[16]

In relation to the types of study and the trend in publications in the last six years, the results have shown 21 cross-sectional studies and 24 experimental studies, in both cases the trend was positive. The pattern in both types of studies showed a polynomial relationship, reflecting a greater explanatory power in the cross-sectional studies than in the experimental studies. In both cases, an increase in publications is imminent, as such research is not only important for the advancement of science and for professional development,[17] but also for selecting appropriate methods, communicating relevant results, engaging in reflective critique of the results achieved,[18] and identifying the efficacy of intervention programs with better outcomes.[19] In fact, the use of smartwatches can be fruitful for cross-sectional, experimental and longitudinal studies. For example, when intended to be studied during normal daily activities, accurate information about their physiological, psychological, emotional, and environmental states can be obtained by generating sensor data and additional self-reported data,[8] at a single or multiple points in time, or to verify changes that occurred as a product of intervention programs at certain points in time. Therefore, these smart wearable devices have the function of sensor connectivity, with the ability to detect, collect, display or transmit information over time, and the ability to transmit data over the Internet and can be worn for long periods of time without interfering with daily routines among participants or patients.[3]

In essence, not only the use of wearable sensors and mHealth applications are on the rise to measure health parameters outside of consultations,[4] but also, research using new therapeutic technologies, including robotics, virtual reality and motion-based games, is rapidly increasing in recent years,[20] aimed at reducing the deterioration of the health of the world's population. Therefore, an explosion of studies on smartwatches, including those using Apple devices, is expected in the coming years.[21]

This study presents some strengths, for example, it is one of the first bibliometric studies that allowed us to characterize scientific productivity on smartwatch use. These results will serve as a baseline for future comparisons, as well as to verify the most researched topics, trends and strengthen new lines of research. In addition, the information documented in this study can help to identify the most researched journals and types of studies that reveal progress in the use of new wearable technologies.

Notwithstanding the above, the study also presents some weaknesses that deserve to be highlighted. For example, we used a single database, we limited ourselves to searching for information from the last six years (2017-2022), covering original studies. However, future studies should broaden the search spectrum to other databases, range of years and even, consider documentary studies (literature reviews, systematic reviews, letters to the editor, essays, among others).

In conclusion, this bibliometric study identified 45 original studies, both cross-sectional and experimental, which have used smartwatches in eight different study topics, the most researched category being active living and the journal that published the highest number of articles was Sensors (Basel). We also verified that the trend of original article publications in the last six years is increasing. These results can serve as a means of reflection for researchers, as well as for companies and institutions dedicated to the manufacture and commercialization of wearable systems.

List of acronyms

CAL - Christopher Avendaño Llanque
ICT - Information and Communication Technologies
JST – Jose Sulla-Torres
PRISMA - Preferred Reporting Items for Reviews and meta-analysis
WHO - World Health Organization

Contributions of Authors

MCB, RGC, JST: conception, design, drafting of the manuscript, analysis and interpretation of the data, critical review and final approval of the version to be published, agreement to be responsible for all aspects of the work to ensure that issues related to the accuracy or completeness of any part of the work are adequately investigated and resolved; MCB, RGC, JST, RVE: critical review of important intellectual content; RVE, CAL, ACG, MZC: systematization of the studies, critical review and final approval of the version to be published. All authors read and approved the final edited manuscript.

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Conflict of Interest

The authors declare they have no financial, personal, or other conflicts of interest.

Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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