Bilge International Journal of Science and Technology Research
ISSN: 2651-401X
e-ISSN: 2651-4028
Research Article
2023, Volume: 7, Issue: 2, 187-197
Received: 10.09.2023; Accepted: 28.09.2023
DOI: 10.30516/bilgesci.1358090

A Bibliometric Analysis of Wearable Health Technology Research

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Abstract: The aim of this provision is to include researchers in scientific publications revealing their research activities in the field of wearable health technologies and conducting research on this subject. In this context, bibliometric analysis of English articles in the Web of Science database between 1996 and 2023 was conducted using the R programming language. The search criteria included keywords such as "health," "technology," "physical activity," "devices," "sensors," "design," "adoption," "information technology," "user acceptance," and "acceptance." This search yielded a comprehensive collection of 5,327 studies related to wearable health technologies published between 1996 and 2023.. The data set obtained from these people was analyzed where the "biblioshiny" in the RStudio program was located. As a result of the research, the most frequently used words, the most relevant institutions in the field, and the stored regional growth amounts and citation records were obtained. This study is an important resource for researchers who want to conduct research and studies in the field of wearable health technologies. Since the calendar year 2023 has not been finalised, some graphs do not show the relevant year.

Keywords: technologies, bibliometric analysis, wearable health technologies.

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Citation: Yılık, P. (2023). A Bibliometric Analysis of Wearable Health Technology Research. Bilge International Journal of Science and Technology Research, 7(2): 187-197.

1. INTRODUCTION

In our rapidly globalizing and technologically advancing world, the realm of technology progresses at an unprecedented pace. The concept of health, which is the most important factor of human life, also has its share of this development. The healthcare sector, like many other fields, harnesses the power of these technological strides, shifting certain services onto virtual platforms. This transition not only enhances the accessibility of healthcare services but also facilitates easier diagnoses and treatments for patients. Furthermore, the integration of information technology into the healthcare sector enhances service efficiency and quality, while concurrently contributing to the reduction of medication errors, data inaccuracies, and medical mistakes (Ülke and Atilla, 2020).

It is necessary to create an effective health system to ensure the general health of the society and make it sustainable. This health system becomes even more effective with the advancement of technology and the correct integration of health information systems into our lives. In today's world, computers, internet and communication technologies have become an integral part of our daily lives. The widespread use of these technologies in many areas facilitates the work and daily lives of both individuals and institutions. Institutions in the health sector also use information technologies and health information systems in the planning and management stages of health services (Peker et al., 2018).

Technological advancements have revolutionized healthcare, making it more accessible to people from anywhere and at any time. Key innovations driving this transformation include health informatics, hearing aids, sensor technologies, and mobile devices, with a particular emphasis on smartphones and wearable technological accessories like smartwatches (Şimşir and Mete, 2021).

Thanks to the use of technological advances in healthcare systems, many benefits can be enjoyed, especially during crisis periods such as pandemics. Wearable health technology products can be used to facilitate the isolation of individuals who have the disease or are at risk of infection, especially as in the recent pandemic crisis we have experienced worldwide. In this way, the physical distance between patients and healthcare professionals can be increased and the density in hospitals can be reduced. However, the problem of controlling individuals and thus spreading the epidemic can be solved more easily. For this reason, many countries have developed different solutions for remote patient monitoring. These countries are diligently

crafting strategies aimed not only at minimizing the impact of past epidemics, which continue to affect us, but also at proactively addressing future infectious outbreaks through the utilization of wearable health technology products (Deringöz et al., 2021).

Wearable technology products are designed as special electronic devices that can track data over long periods, usually wirelessly, and they are synchronized with computers or smartphones. These products are among the cutting-edge wearable computers that can be integrated in different ways into different parts of various objects, such as rings, smart glasses, smart watches, shoes, or bracelets. Although wearable technologies that can synchronize with smartphones have begun to appear more frequently in recent times, this process has a longstanding history. . Hearing aids, glasses, overalls and clothing-like products that balance body temperature, and shoes are the products of this technology that were used in the past and are still being developed and used (Büyükgöze, 2019).

It is a necessity to take advantage of the opportunities of technology in the health sector in order to continuously and regularly monitor diseases, perform immediate interventions and contribute to the improvement of preventive and therapeutic health services by providing rapid digital data transmission to relevant health departments. Technological developments can provide positive benefits not only during medical operations, but also before and during the healing process (Dahil, 2023:1). Therefore, just as in every other field, the healthcare sector experiences inevitable changes and developments due to advancing technology. This ongoing transformation process, expected to accelerate in the coming years, is further facilitated by the opportunities offered by wearable technology.

Wearable Health Technologıes

The healthcare industry tends to benefit from the assistances of this advancement along with developing technology in order to increase the quality of patient care, reduce costs, improve patients' living standards and increase the efficiency of healthcare services. The ongoing need for technology in healthcare continues to grow, driven by the emergence of new imaging capabilities and the effective utilization of big data for data transmission. This synergy has led to an increased adoption of wearable medical devices, which hold significant promise in disease treatment. Innovative products, born out of the rapid evolution of wearable technology, are swiftly integrating into everyday life (Aydın, 2019).

Wearable technologies refer to electronic devices that can be attached to the skin, can be easily carried, and can be integrated into clothes or accessories and carried along with us. These wearable technologies can perform many functions, especially by having a combined working system with products such as computers and smartphones. However, in some cases, wearable technologies can be more functional than traditional technological devices. Wearable technologies offer the ability to track and monitor features that cannot be detected by mobile phones and computers, such as biofeedback and psychological state monitoring, as well as the ability to collect data on this feedback. Wearable devices used today include smart watches, smart bracelets, glasses, lenses, smart implants used in dental treatment, e-textile products, smart fabrics, headbands, rings and jewelry such as hearing aids. The most commonly used wearable devices include smart bracelets, hearing aids and smart watches. The history of wearable technologies actually goes back a long way. The first wearable device was produced in 1955 for cheating in games. Since then, wearable technologies have seen remarkable advancements, particularly in the gaming and entertainment sectors, but more notably in the fields of health and fitness (Demirci, 2018; Sağbaş et al., 2016).

Wearable products that can be used in health, sports, jewelry, clothing and many other areas are very common today. These devices make it easier to keep track of daily tasks, such as frequently used mobile phones and computers, and help carry out tasks more efficiently. Swift task completion not only saves time for users but also benefits service providers (Çakır et al., 2018).

Wearable technology products, which provide great benefits in remote treatment processes of individuals and monitoring the data generated during treatment processes, especially in the healthcare sector, will undoubtedly begin to take more part in our lives in the near future. Aging population and increasing population growth rate will further increase the need to benefit from health systems, which will shape new types of current services in health systems. With developing technology, wearable technology products that can provide remote patient control will play an active role in this change, among the methods that will change in parallel with this progress in healthcare systems.

2. MATERIAL AND METHOD

2.1.Material

The research dataset comprises articles sourced from the Web of Science Core Collection database. AND and OR conjunctions were used when searching; Keywords specific to wearable health technologies were selected, focusing on article titles to ensure alignment with the research topic.. Words representing health technologies were searched in the article title and the subject was clarified by searching for the concept of wearable health technologies in the results obtained. At the article level, we employed search terms such as "health," "technology," "physical activity," "devices," "sensors," "design," "adoption," "information technology," "user acceptance," and "acceptance" using the "OR" conjunction . In this way, we tried to access all the studies in the field of wearable health technologies in the database. Another limitation of the search is the time period and indexes. In this context, articles published between 1996 and 2023 were included in the data set.

2.2.Method

The significance of open-source programming languages, known for their cost-free access and abundant resources, continues to grow in the global landscape of data science.. mong these languages, the R programming language holds a

prominent position. For bibliometric analyses in this study, we employed the Biblioshiny algorithm (Cuccurullo et al., 2016), a tool written in the R language, known for its open-source nature. At the same time, the software used is a free web-based interface (R Team, 2014).. The R programming language is an open source programming language designed specifically for statistical calculations and provides an environment used in this field. This language was developed in 1996 by Ross Ihaka and Robert Gentleman at the University of Auckland in New Zealand. However, the foundations of this programming language are based on the S programming language developed by John Chambers and his team at Bell Laboratories in the 1960s. The R programming language is well developed and includes features that make it easy to visually present data with graphs, a simple to use and effective programming language (Arslan, 2015). This study includes bibliometric analysis methods analyzed with the R programming language.

As a result of the limitations, 5827 articles were identified and these articles were downloaded in plain text format. For the subsequent bibliometric analysis, a total of 5,327 articles (excluding early access articles) were utilized, and this analysis was conducted using the R package program. Elements of the downloaded articles such as data set, sources, authors and documents were examined in bibliometric analysis. The specific findings and details of these investigations are expounded upon in greater depth within the results section of the study . The bibliometric study was performed using R using the following commands: install.packages ("devtools") and devtools::install_github (massimoaria/bibliometrix). Next, the package's library was activated with the command library (bibliometrix). Finally, the database was accessed using biblioshiny (maxUploadSize=500). Here, the parameter "maxUploadSize=500" means that 5327 documents from the WOSCC database were downloaded as WOSCC text files in eleven groups.

3. RESULTS AND DISCUSSION

3.1. Research Results

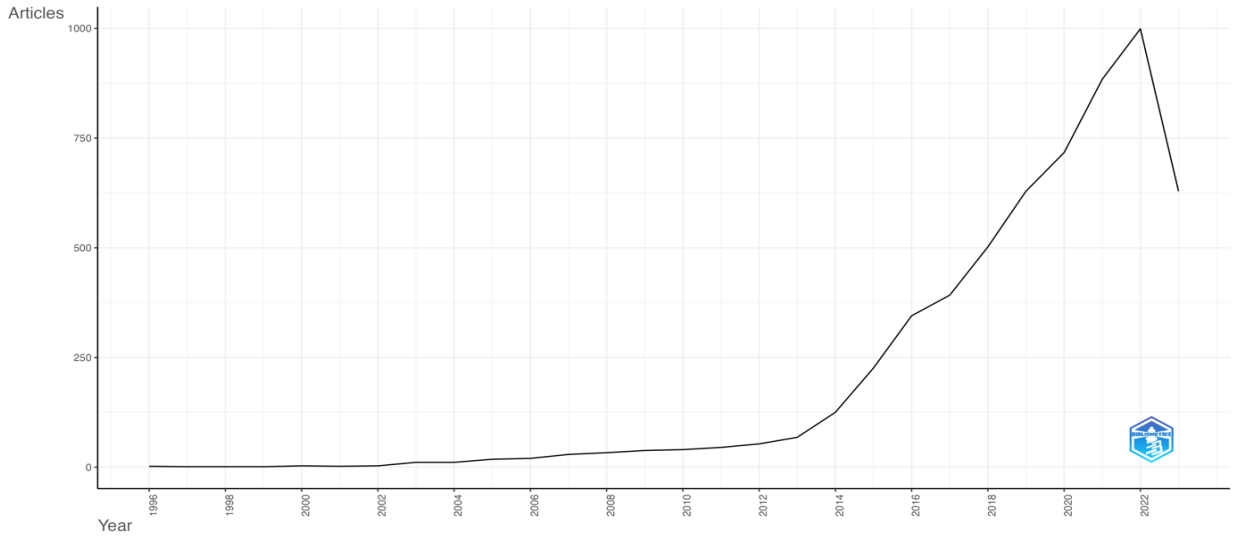
The 5327 articles analyzed in our study cover research between 2002 and 2023. Numerical information of the articles is shown in Table 1. When Table 1 is examined, there are 2645 sources in which the mentioned articles are published. The annual citation rate per article is 2,426. Additionally, the annual growth rate of the studies is 23,74. In our study, the number of single-author articles appears to be 333,corresponding to 062% of the average studies done. Another important value of the study is the international co-authorship percentage of 2,282, which indicates that our study is a suitable area for different research to work together.

Table 1: Basic Information About the Data Set

DEFINITION	RESULTS
Basic Information About the Data Set	
Time Range	1996:2023
Sources (Journals, Books, etc)	2645
Documents	5327
Document Average Age	3.92
Annual Growth Rate %	23.74
Average Citations Per Doc	2.426
Document Contents	
Keywords Plus (ID)	946
Author's Keywords (DE)	1300
Authors	
Authors	22072
Authors of Single-Authored Docs	296
Authors Collaboration	
Single-Authored Docs	333
Co-Authors Per Doc	5.14
International Co-Authorships %	2.282

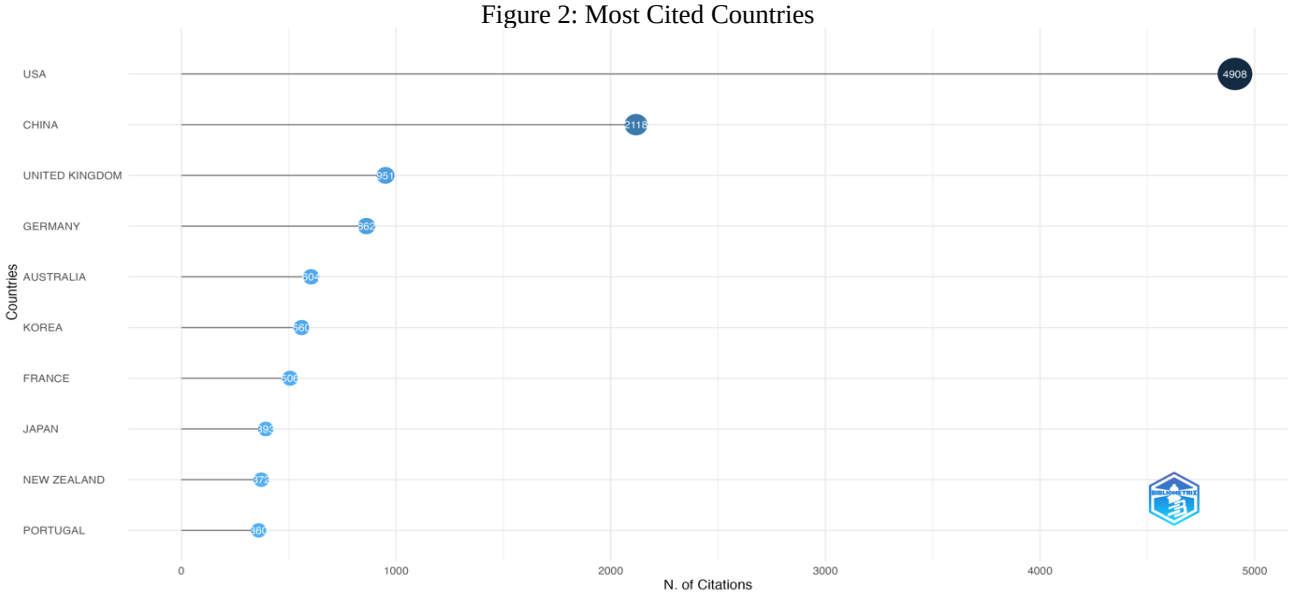
Upon examining Figure 1, it becomes evident that there were no studies recorded between 1996 and 2002. However, a gradual increase in research output is discernible over the subsequent decade, spanning from 2002 to 2012. Following this period, a substantial surge in the number of articles is notable until the year 2022. While the number of studies post-2022 does not exhibit a significant decrease, there is a discernible deceleration compared to the preceding yearsAdditionally, as we mentioned before, the annual growth rate of the study area is calculated as 23,74. Considering the increasing rate of studies, especially in the last 10 years, it is obvious that the subject matter is a current issue and that it will be the subject of much more research in the coming years.

Figure 1: Change in the Number of Articles by Years



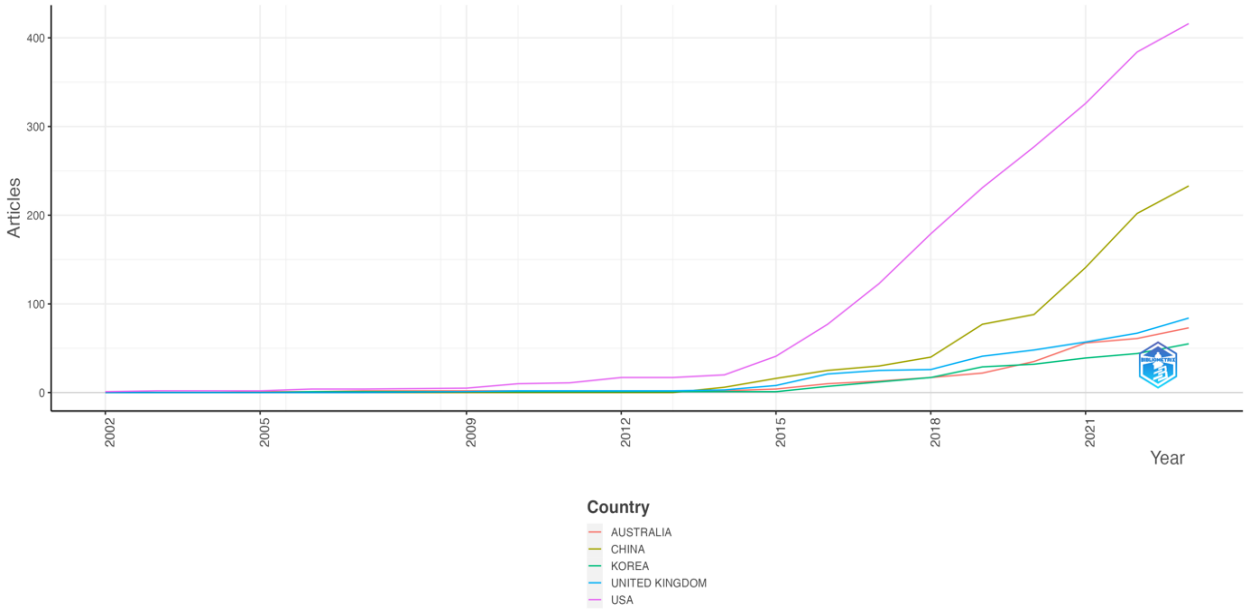
The countries where the most cited studies on the subject were conducted are shown in Figure 2. The USA, China and the United Kingdom are in the top 3 ranks of the most cited studies.

Figure 2: Most Cited Countries



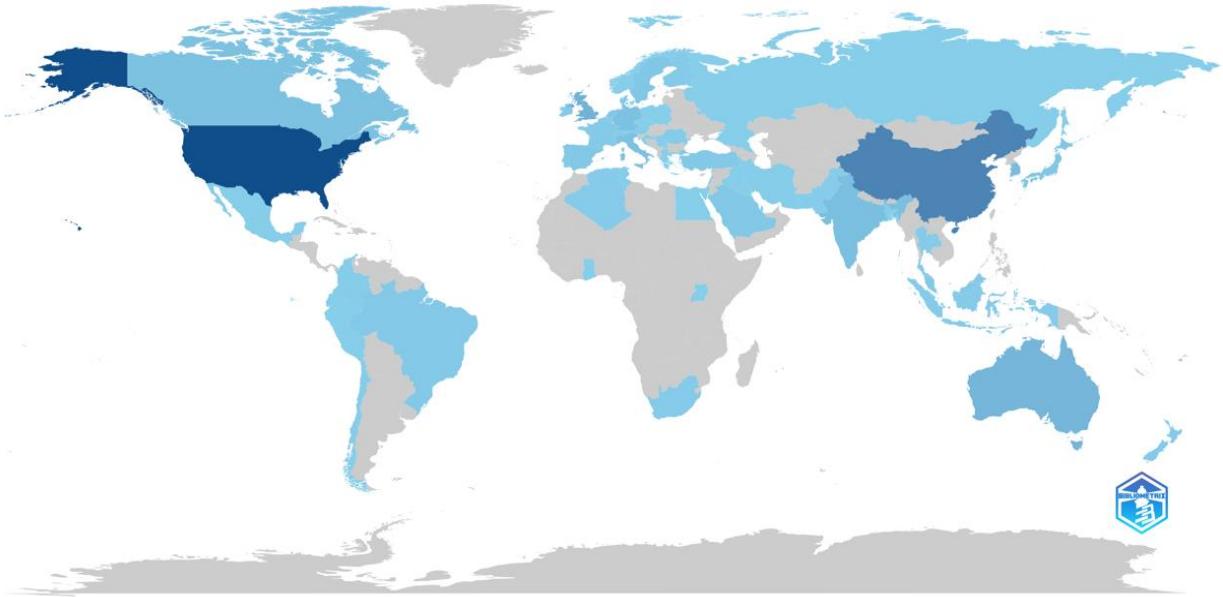
Countries' production over time is shown in the graph in Figure 3. As can be seen in the graph, the increase rate of studies in the last 10 years is remarkable. Especially considering the production numbers of the USA and China, they differ from other countries in terms of production numbers.

Figure 3: Production of Countries Over Time



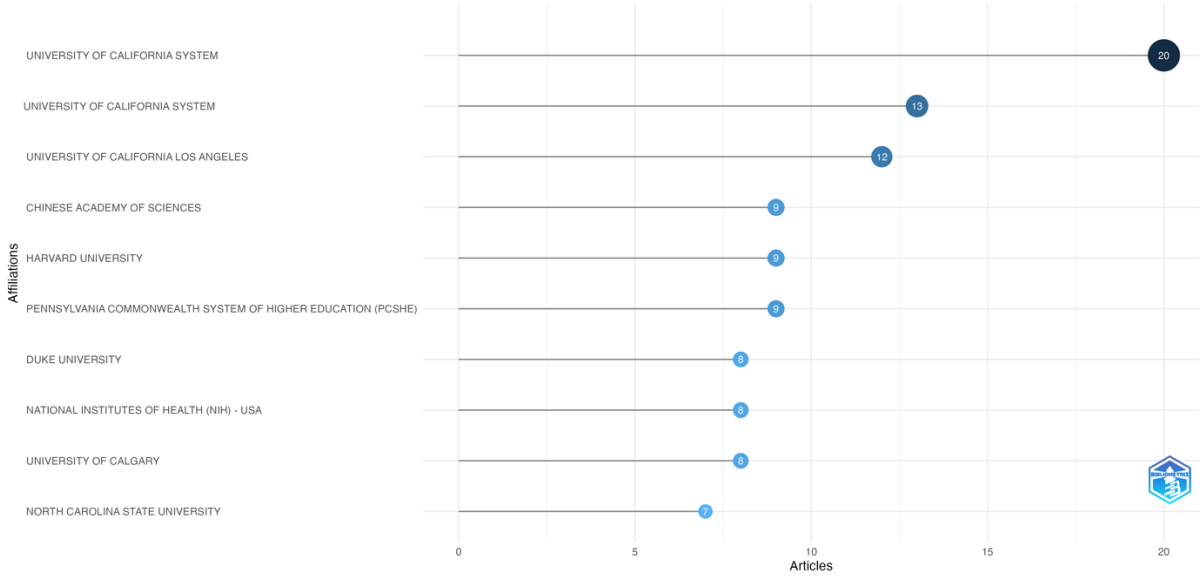
The scientific productions of the countries are shown on the colored World Map as in Figure 4. As can be seen in the figure, it is stated that studies are more intense in the USA and China, Australia, India, Russia, and Central and Western European countries.

Figure 4: Scientific Production of Countries



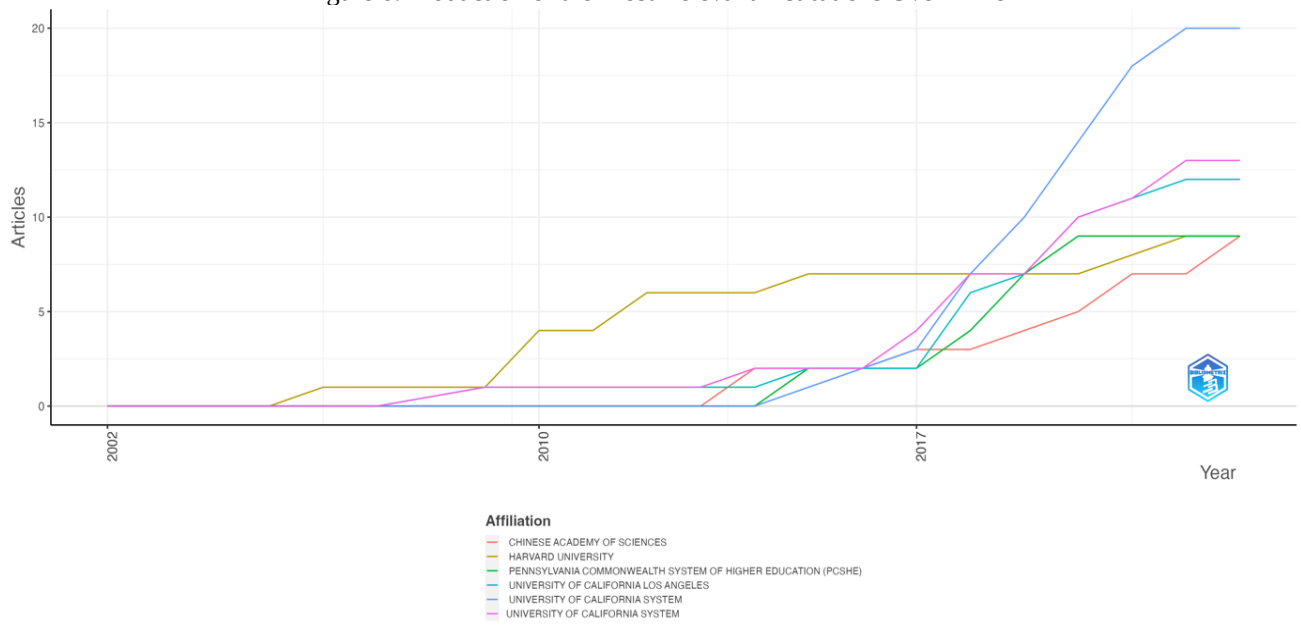
When the institutions working on the subject are examined, it can be seen in Figure 5 that universities in the USA and China are predominant.

Figure 5: Most Relevant Institutions



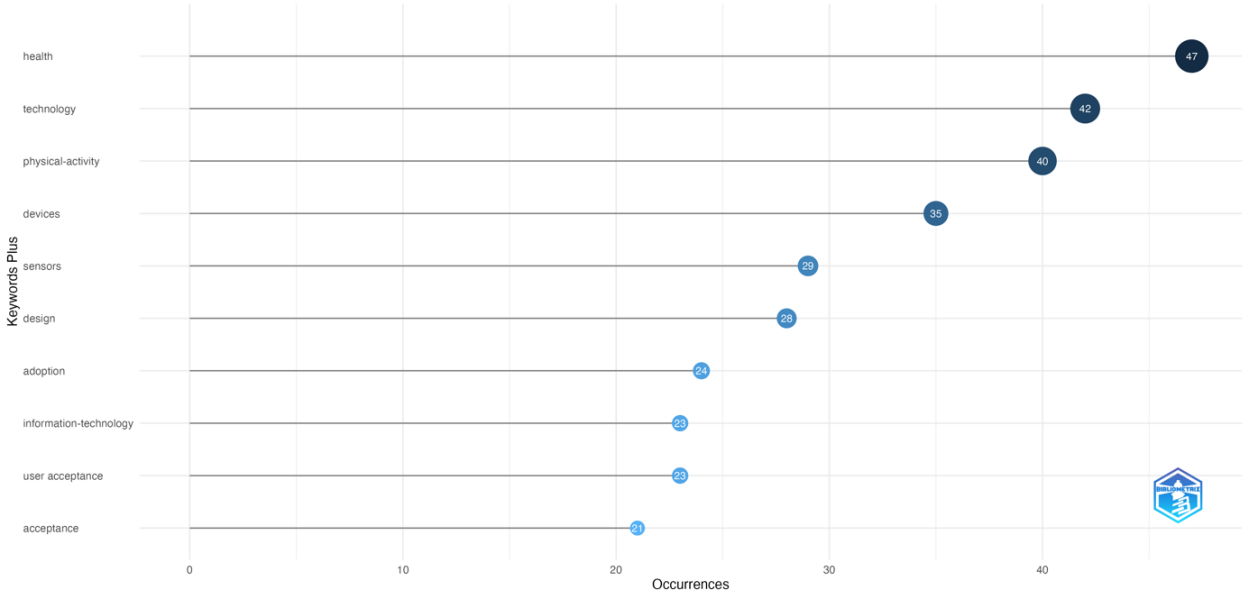
When the production of universities on the subject is examined by years, it is seen that the most relevant institution on the subject is Harvard University. However, in the following years, it was observed that other US Universities carried out more studies on the subject, surpassing Harvard University in terms of the number of studies. We can examine the production numbers of the most relevant institutions related to the subject of the study by year in Figure 6 graphically.

Figure 6: Production of the Most Relevant Institutions Over Time



Upon analyzing the most pertinent words within the scope of our study, we observe that the most frequently used terms include "health," "technology," "physical-activity," "devices," "sensors," "design," "adoption," "information-technology," "user acceptance," and "acceptance," as illustrated in Figure 6.. As a result of the analysis, it can be concluded that the words mostly used are from the field of health and technology. The analysis of the most relevant words within the research field is seen in Figure 7.

Figure 7: Most Relevant Words



The most frequently used words in the studies are shown in Figure 8 through word cloud graphics. The size of each word within the image corresponds to its frequency of use, with larger fonts indicating higher usage. (Köse and Kurutkan, 2021: 421). As seen in the word cloud analysis, the field of study is closely related to the fields of health and technology.

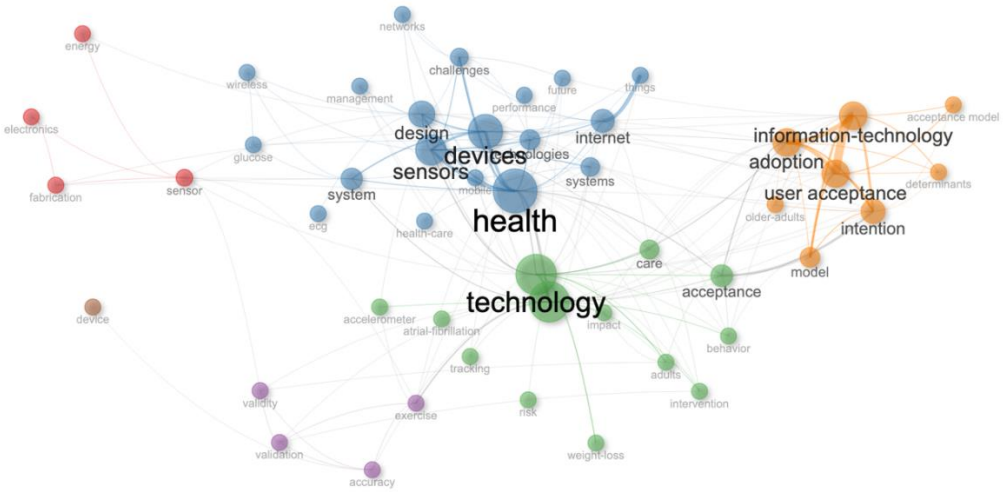
Figure 8: Word Analysis of Studies

In Figure 9, the proportions of words used in the studies are analyzed. Our analysis, which is parallel to the analyzes in Figure 6 and Figure 7, supports the concepts we have stated before. As seen in our analysis, the word with the highest usage rate is the word "health", followed by the second most frequently used word, "technology". The main reason for this is that the studies are mainly associated with the fields of health and technology and are carried out within this framework.

Figure 9: Ratio of Words Used in Studies

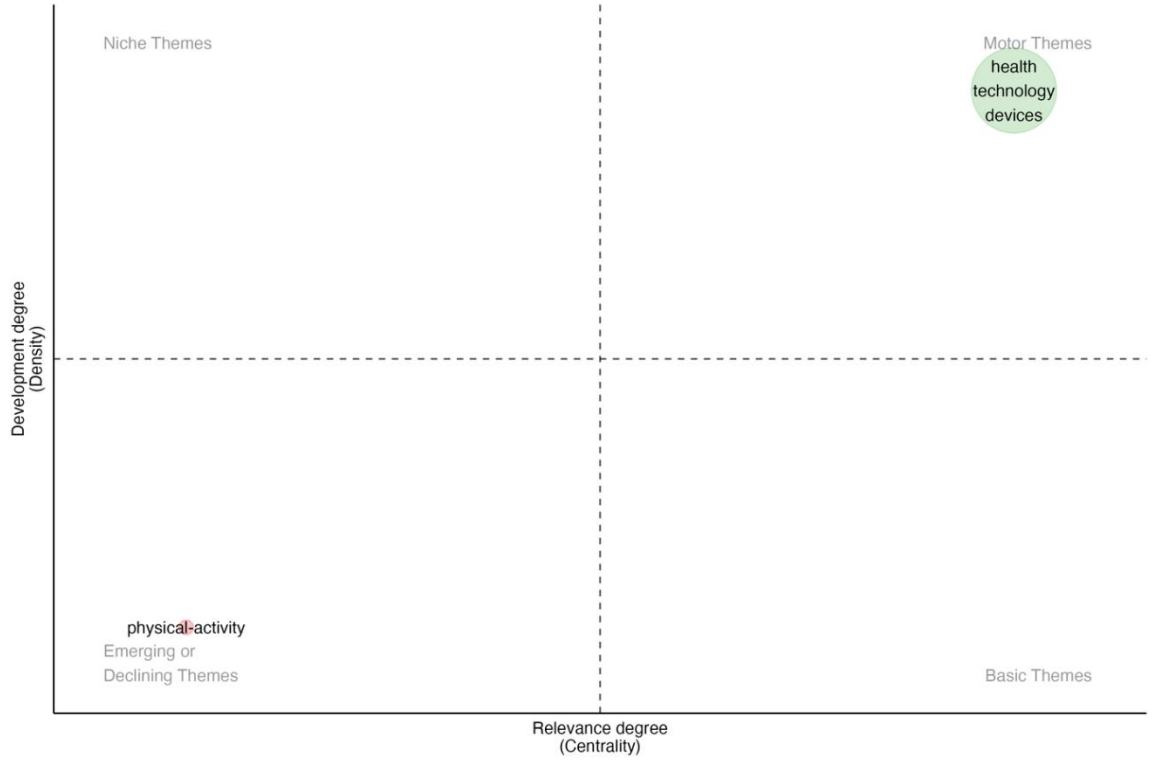
Examining keywords for co-occurrence is an extremely critical analysis for a clear understanding of the study's content. The keywords carefully chosen by the authors reflect the basic message of the study and the center of the research. The network also shows us the connection and flow between words. The thickness of the connection lines between the results also illustrates the relationship between words and the strength of interusability (Oraee et al., 2017). Upon examining the co-occurrence of words used in the studies, Figure 10 reveals the formation of six distinct clusters. Clusters are formed according to the words in the content of the studies and their combined use. In contrast to previously provided graphs such as "Most Relevant Words," "Word Analysis of Studies," and "Ratio of Words Used in Studies," Figure 10 offers insights into the interconnected use of the most frequently employed words in the studies Moreover, our analysis vividly depicts the interrelationships between disciplinary and interdisciplinary fields.

Figure 10: Co-occurrence of Words Used in Studies



The thematic map resembles a 4-section plane, where x and y graphs on the analytical plane show the centrality and density of the results by assigning an impact value to the results. It is expressed with a two-dimensional and four-category diagram based on the centrality and density of the themes. In this diagram, the X-axis denotes a theme's degree of interaction with other networks, referred to as its centrality. The degree of centrality can be considered a measure of importance for a theme in the research field. On the other hand, density represents the strength within a network and can be interpreted as an indicator of theme development (Cobo et al., 2015; Aria et al., 2021:). In the thematic map diagram, the upper right corner is defined by engine themes that are dense and central, indicating that there is intense research in this area. The upper left corner represents highly developed but isolated themes. The lower left corner contains rising or falling themes. The concepts formed in this section are new themes or exist outside the field. The lower right corner contains foundational and transformational themes. Themes that emerge in this section are generally well-studied concepts with strong internal ties (Cahlik, 2000; Turner and Rojouan, 1991; Flórez-Martínez et al., 2021). As can be seen in Figure 11, two different themes emerged in our analysis. The first theme, centered on the overarching title of "Health," combines the terms "technology" and "devices," suggesting a concentration of research activities in these areas. Studies in this domain are well-documented in the literature, indicative of their extensive exploration. Conversely, the second theme is situated within the context of "physical-activity.". Themes in this section suggest a gradual decline in the topic's prominence. Notably, our thematic analysis reveals that while wearable health technologies initially gained traction in the realm of physical activities, they are progressively expanding and evolving within the broader field of healthcare.

Figure 11: Thematic Map



4. CONCLUSION

The field of wearable health technologies predominantly consists of recent and current studies, characterized by a wide-reaching and interdisciplinary literature.. This broad and interdisciplinary feature of the literature has allowed it to be included in many studies. Our analysis underscores a noteworthy surge in research activities, particularly post-2012, a trend largely driven by the rapid pace of technological advancement.. The abundance of studies conducted in the last 10 years in the literature and the relationship of the subject with different literatures pose difficulties for researchers. At this point, it will be beneficial for researchers to review this study in order to benefit from it in terms of time saving and energy consumption. Our analysis clearly states which literatures researchers will study, through which institutions they can access productive resources, and which concepts and words they will focus on. Our study identifies the United States and China as the most influential countries in this domain, with the most relevant institutions situated in these nations.. As a result of the study, the most frequently used words in research were listed through figures and it was concluded that especially the fields of health and technology were the two main themes of the subject. It is clearly seen in our study that technological developments, especially in the last decade, have had a positive impact on health technologies. R Programming Language was used as the visualization program of our study, and the visuals created by the program and provided by the system were used within the scope of the study.

In a similar study, Köse and Kurutkan (2021), in their study titled "Bibliometric Analysis of Internet of Things Applications in Health Services", stated that China and the USA stand out as the countries that produce the most in terms of literature contribution. In this study, it is similarly stated that the USA and China are the countries that contribute the most to the field of wearable technology in healthcare services. Furthermore, Köse and Kurutkan (2021) noted that the most frequently used words in their study included "data," "health," "healthcare," "thing," "internet," and "system." Consistently, our study reveals that the most commonly used words align with these findings and include "health," "technology," "physical-activity," "devices," "sensors," "design," "adoption," and "information-technology," mirroring previous research outcomes.

In another similar study, Sikandar et al. (2022) "Digital Technologies in Healthcare: A Systematic Review and Bibliometric Analysis", Sikandar et al. (2022) examined the studies on the use of digital technologies in healthcare organisations. The researchers who analysed the studies in the literature stated that the studies continue to increase. In this study, similarly, it is stated that the researches and studies in the literature are increasing and the importance of the subject is being realised more and more day by day. Sikandar et al. (2022) analysed the studies conducted between 2017 and 2022 and stated that researchers working in the UK, USA and Australia contributed the most to the literature. In this study, the countries that contributed the most to the field were the USA, China, the United Kingdom, Germany and Australia. Although it seems to be in parallel with the other study, there are some minor differences in this section. Sikandar et al. (2022) analysed the studies conducted since 2017 in their study, which resulted in minor differences in the analysis of contributing countries. Again, Sikandar et al. stated the most commonly used words as “digital health”, “mhealth”, “telemedicine”, “covid-19”, “ehealth”, “digital technologies”, “technology” and“mobile apps” in their study. When this study is compared with this section, parallels and minor differences are observed, as in the case of contributing countries. These discrepancies can be attributed to the variation in the starting point of the examination, which Sikandar et al. (2022) based on the year 2017.

Ethics Committee Approval
N/A

Peer-review
Externally peer-reviewed.

Conflict of Interest
The author have no conflicts of interest to declare.

Funding
The author declared that this study has received no financial support.

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