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A Bibliometric Analysis of the Trends in the Research on Wearable Technologies for Cardiovascular Diseases

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Abstract. In this paper, a bibliometric analysis of research on wearable technologies for cardiovascular diseases was conducted with Bibliometrix and based on 1675 papers collected in Scopus from 2000 to 2022, and interesting results were presented. The US and China stood out for their sustained productivity in the field of cardiovascular diseases. The examination of the authors' keywords revealed that between 2000-01 and 2009-12, "Respiration" and "personalized applications" were the most popular research topics, however from 2010-01 to 2019-12, attention was given to "ECG," "Wearable devices," "Wearable sensors," and "heart rate". This study suggests that in the present decade, researchers should focus on topics related to artificial intelligence, hypertension, ECG, wearable sensors, and African countries must address their technological gap in the coming years.

Keywords. Wearable, Cardiovascular, Bibliometric, Bibliometrix

Introduction

Cardiovascular diseases constitute a great interest among practitioners and scientists in the last years because of the high number of deaths they cause worldwide [1]. In cardiology, traditional wearable devices are limited because they cannot continuously collect physiological parameters during periods of activity but also for monitoring the patient in real-life conditions. These days, advances in nanotechnology, material science, and information technologies allow us to remove these limitations with smart wearable technologies [2]-[6].

This bibliometric study carried out with the Bibliometrix software [7] deals with 1675 documents collected on Scopus. It focuses on wearable technologies for cardiovascular diseases with a particular focus on the thematic orientation of scientific publications in the field from 2000 to 2022. Our development is based on the following research questions:

RQ1: From 2000 to 2022, what are the characteristics of the thematic evolution of research on wearable technologies for cardiovascular diseases?

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RQ2: What are the motor, basic, declining, and emerging topics in wearable technologies for cardiovascular diseases as we enter this new decade (2020-2030)?
RQ3: Who are the leading authors and countries in wearable technologies for cardiovascular diseases research?
RQ4: What are the future directions of research on this topic?

Our work will guide researchers, especially younger ones, in defining their research objectives and critical aspects to explore in the field of wearable technologies for cardiovascular diseases.

1. Methods

As the main objective of this study is to present the thematic dynamics, and research productivity in wearable technologies for cardiovascular diseases, we opted for a bibliometric analysis using the Bibliometrix software, which is very flexible and which allows for an in-depth analysis of scientific mapping on a given topic [7, 8]. Biblioshiny, a graphical interface offered by Bibliometrix, allows performing bibliometric analysis from several databases (Scopus, web of science, Pubmed, etc.). For this work, we leveraged Scopus, a transdisciplinary reference database offering a greater coverage of health sciences than the Web of Science database. Compared to Pubmed, Scopus provides the possibility to perform an analysis of the number of citations [9].

On March 12, 2022, a search on Scopus with the string “wearable” AND “cardiovascular” allowed us to gather a set of 1675 documents from various sources. We used this bibliographic database to conduct performance analysis and scientific mapping to address our research questions.

2. Results

2.1. Performance Analysis

2.1.1. Global Information about Data

From 2000 to the time of writing, 6869 authors have written 1675 papers from 876 different sources with an average of 14.93 citations per paper. The annual production of publications is growing at a rate of 14.04%, with a maximum value of 331 publications for the year 2021.

2.1.2. Leading Authors and Countries

This section presents the most influential authors and countries based on the published literature on wearable technologies for cardiovascular diseases. Tables 1 and 2 show the 5 authors and sources respectively that have had the most significant impact on the scientific world in the last 2 decades on the topic. We considered three bibliometric indicators for a better overview: productivity, local influence, and citation. Inan OT is the most productive author (29 publications) with the highest local impact (H-index:11), while Wang Z is the most locally cited author with a total of 69 citations.

Table 1. Top 5 Leading Authors. AN: Articles Number. H-I: H-Index. LCN: Local Citations Number.

Most Relevant (AN)	Local Impact (H-I)	Most Local Cited (LCN)
Inan Ot (29)	Inan Ot (11)	Wang Z (69)
Na (23)	Wang J (10)	Turakhia Mp (59)
Zhang Y (22)	Martin Ss (8)	Halperin Jl (53)
Poon Ccy (16)	Yang J (8)	Krittanawong C (53)
Wang J (16)	Zhang Y-T (8)	Zhang Y (53)

Statistics from the *Journal of the American College of Cardiology have* shown that in the world in 2019, 17.9 million deaths are recorded each year due to cardiovascular diseaseand 81% of these deaths, of which more than a third are early, occur in low-income African countries [1]. We, therefore, considered it important to present in this section a geographical overview of the scientific production of wearable technologies for cardiovascular disease. Table 2 shows the top 5 most productive countries, with the USA and China leading with 2632 and 1114 publications, respectively. African countries combined have 57 papers, with South Africa, Tunisia, and Nigeria at the top of the list with 11 and 9 articles, respectively. South Africa is the African country with the highest number of citations, with a total of 12.

Table 2. Top 5 Leading countries in the world and in Africa. AN: Articles. LCN: Local Citations Number.

In the world		In Africa	
Most Relevant (AN)	**Most Local Cited (LCN)**	**Most Relevant (AN)**	**Local Impact (H-I)**
USA (2632)	USA (9504)	South Africa (11)	South Africa (11)
China (1114)	China (2279)	Tunisia (9)	Tunisia (9)
Italy (522)	Italy (1334)	Nigeria (9)	Nigeria (9)
Germany (442)	Hong Kong (1134)	Algeria (8)	Algeria (8)
Japan (383)	Korea (1062)	Cameroon (6)	Cameroon (6)

2.2. Science Mapping

2.2.1. Trend Topics

An interesting method for gaining a general overview of the topics of interest in the scientific output in a given field is to observe the occurrence of “authors” keywords. Thus, the trend of topics summarized in Table 3 shows that during the decade 2000- 2009, the topics of interest according to their frequency are: “respiration” and “Personalized applications”. On the other hand, during the decade 2010-2019, we identify: “ECG”, “wearable devices”, “wearables sensors”, and “heart rate” with an occurrence higher than 50%. It is interesting to note that the first 3 topics that have been emerging in research since 2000 at the time of this study are Cardiovascular diseases, Wearables, and Machine learning.

Table 3. Trend Topics from 2000 to 2022.

2000-01 to 2009-12 **Topic (frequency)**	**2010-01 to 2019-12** **Topic (frequency)**	**2020-01 to 2022-03** **Topic (frequency)**
Respiration (5)	ECG (71)	Cardiovascular diseases (68)
Personalized applications (4)	Wearable sensors (67)	Wearables (67)
Embedded systems (3)	Heart rate (64)	Machine learning (59)
Decision support system (3)	Wearable devices (63)	Deep learning (30)
Integration (3)	Heart rate variability (46)	Artificial intelligence (25)
Inductive plethysmography (3)	Wearable sensor (27)	Sensors (21)
	Sudden cardiac death (24)	Biomedical monitoring(6)

2.2.2. Thematic Evolution

To better understand the conceptual structure of the scientific production in a given field, it is interesting to analyze the thematic map of the “authors” keywords.

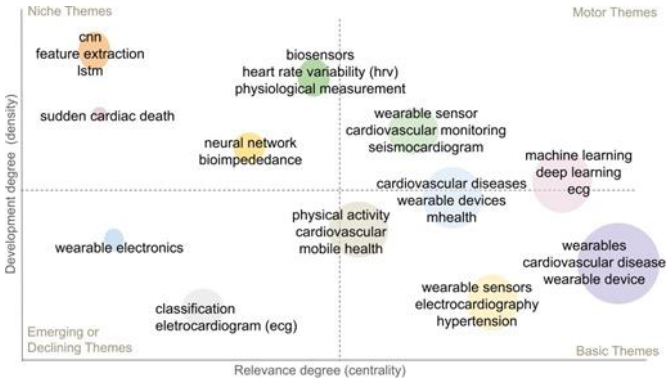

Figure 1. Thematic map of the ’” ’author’s keywords (Time slice 2020-2022).

We can note in **Figure 1** that the different keywords used by researchers between January 2020 and March 2022 are grouped under 12 different clusters, and each cluster belongs to a specific quadrant allowing us to categorize it. In the bottom left quadrant named emerging and declining themes, we find two clusters that include “electrocardiogram” & “classification” on the one hand and the other hand “wearable electronics”. Their position denotes their low density and slightly below average centrality for wearable technologies related to cardiovascular diseases. The top left quadrant contains four clusters: "neural network" & “bioimpedance”, "cnn" & "feature extraction" & “lstm”, “sudden cardiac death” and finally "biosensors" & "heart rate variability" & "physiological measurement". This quadrant presents the themes with a high density despite their non-vital importance to the subject. The themes that are vital to the field but have low development are presented in the lower right quadrant. These are: "physical activity" & "cardiovascular" & "mobile health", "wearable sensors" & "electrocardiography" & "hypertension" and "wearable" & "cardiovascular disease" & "wearable device" . The two clusters“wearable devices” &“cardiovascular diseases” & “mhealth” and “ECG” & “deep learning” & “machine learning” have a slightly above-average degree of development despite their vital importance for the use of wearable

technologies to detect or monitor cardiovascular diseases. They are intermediate between the basic themes and the motor themes, which are the central themes for the field with a high degree of development. The cluster “wearable sensors”&“cardiovascular monitoring”&“seismocardiogram” is the only one that belongs to the quadrant of motor themes.

3. Discussion

We have identified in the literature some similar studies [10], [11] but this one improves the understanding of the conceptual structure of research on wearable technologies for cardiovascular diseases.

The first research question RQ1 concerns the main topics that mark research on wearable technologies for cardiovascular care. Through the analysis of the ” authors’ keywords, the results show “Respiration” and “Personalized applications” as the main topics of interest for researchers between 2000-01 and 2009-12 while in the past decade (2010-2019), researchers focused on: “ECG”, “Wearable sensors”, “Wearables devices” and “Heart rate”. This observation suggests a change in the focus and interest of researchers over the last two decades. Indeed, we can also note notable changes in the field of research over the last three years (2020-2022) with the appearance of evocative themes such as artificial intelligence, machine learning, and deep learning. These themes are undoubtedly linked to challenges such as the management of Big data, their security, and personal data protection. The results of the thematic evolution analysis that we performed between 2020 and 2022 give us important characteristics of the current thematic dynamics of research on the use of wearable technologies for cardiovascular diseases and the topics that deserveparticular interest from researchers in the future. These elements allow us to answer research questions RQ2 concerning motor, basic, dying, and emerging topics in wearable technologies for cardiovascular diseases. Thus, among the basic topics, it is appropriate to put a particular emphasis on these: "physical activity" & "cardiovascular" & "mobile health", "wearable sensors" & "electrocardiography" & "hypertension" and "wearable" & "cardiovascular disease" & "wearable device". Indeed, it will be necessary to orient research to obtain significant results regarding the use of wearable technologies as a tool for early detection or diagnosis (ECG) and prevention (physical activity) of cardiovascular diseases. Because hypertension is one of the most dangerous risk factors for cardiovascular diseases, it is essential to increase the research effort in this area. In addition, some irrelevant terms have been developed over time, such as “sudden cardiac death” and “feature extraction”, while other relevanttopics, such as those mentioned above requiring special attention from researchers, are at a very low-density level.

The performance analysis allowed us to solve research question RQ3 and provided future research guidelines for research question RQ4. Indeed, here we summarized the 5 researchers and countries that influenced the world of research on the use of wearable technologies for cardiovascular disease between 2000 and 2022. Despite the growing burden of cardiovascular disease in Africa, we noted the continent’s poverty regarding scientific production on the subject. Considering the data analysis conducted from the Scopus database, which is not exhaustive, the conclusions of this study could have some limitations.

4. Conclusion

In this paper, a bibliometric analysis of research on wearable technologies for cardiovascular diseases was performed, and interesting results were presented. Through performance analysis, this article identifies the five leading authors and countries. While African countries remain at the bottom of the statistics overall, the US and Chinastood out for their sustained productivity. Analysis of the thematic evolution of the subject has allowed us to identify the main topics that have marked the past two decades. Between 2000-01 and 2009-12, researchers focused on respiration and personalized applications. From 2010-01 to 2019-12, new topics of interest such as ECG, wearable sensors, wearable devices, and heart rate were explored.

To inform the scientific community and incite implications for policy, practice, and research, we have identified highly developed but non-capital topics: feature extraction, physiological measurement, and sudden cardiac death. Our study finds that researchers might focus in the next decade on issues related to prediction and prevention supported by wearables. However, this study has some limitations related to the sample size considered. It will have to be expanded for a complete analysis.

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