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Systematic review of bioimpedance related to kidney problems and volume analysis

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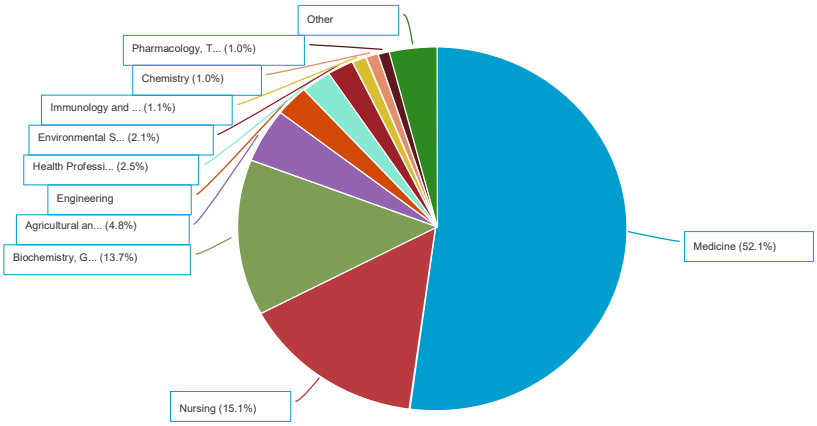
ABSTRACT:
Chronic kidney disease (CKD) poses a significant public health challenge due to its high prevalence and serious implications for patients' health. In this context, bioimpedance stands out as an emerging tool with great potential for early detection and continuous monitoring of CKD. Through a systematic review based on the Scopus database and following a methodology adapted from PRISMA, this analysis delves into the use of BIA to assess hydration status in individuals affected by CKD. The meticulous search resulted in the identification of 505 relevant publications, including 28 reviews, 28 conference papers, 3 book chapters, 2 short surveys, and 2 editorials, highlighting a predominance of observational studies (85%) compared to randomized controlled clinical trials (15%). This research undersco,res a remarkable increase in interest and research on bioimpedance and CKD, particularly evident since 2019. Bioimpedance is validated as well as a valuable instrument for

accurate assessment of hydration in patients with CKD, underscoring the imperative for further research to consolidate its usefulness in the early detection and, effective follow-up of this critical condition.

KEYWORDS: Chronic kidney, disease, bioimpedance, volume analysis

GRAPHICAL ABSTRACT:

The attached image shows the predominance of medicine in scientific production on bioimpedance and chronic kidney disease (CKD), reflecting the growing interest and research in these topics.



INTRODUCTION:

Chronic kidney disease (CKD) has emerged as a global epidemic, affecting approximately 10% of the world's population [1,2]. Unlike other chronic diseases, CKD often progresses asymptomatically, becoming an invisible threat to public health [3]. In Latin America, CKD is the sixth leading cause of mortality, with a rate that exceeds 200,000 cases per year, and alarmingly, only 10% of those affected are diagnosed, which implies millions of people living with the disease without knowing it [4,5].

People with diabetes have up to 40 times the risk of developing CKD due to kidney microvascular damage. It is imperative to raise awareness of CKD and improve detection and prevention strategies [6,7]. In this context, bioimpedance emerges as a promising and accessible tool to identify individuals at risk of developing CKD, by offering a non-invasive and inexpensive assessment of body composition, including hydration and the presence of edema or dehydration, crucial aspects in this disease [8,9,10,11].

Bioimpedance is a technique that evaluates the amount of fat, muscle mass, hydration status and edema in the body, it is revealed as a valuable tool in the analysis of kidney problems and the measurement of blood volume [12]. This examination, characterized by its speed, safety, and painlessness, allows detailed comparisons of the patient's body composition, accurately identifying the sources of the observed changes [13]. Despite its utility, bioimpedance in the renal setting faces significant challenges that require attention and innovative solutions [14,15].

Bioimpedance has proven to be an essential tool in the management of patients with chronic kidney disease (CKD) [16], facilitating the early detection of dehydration, monitoring nutritional status, and assessing response to treatment [17,18]. In this regard, in a case study, a 65-year-old man in Colombia [19] with type 2 diabetes and hypertension experienced fatigue, nausea and dizziness, being diagnosed with mild dehydration after a bioimpedance

measurement; His treatment was successfully adjusted. Another case involved a 50-year-old woman with stage 3 CKD, whose protein-energy malnutrition was effectively identified and treated through a personalized eating plan. In addition, a 40-year-old Ecuadorian citizen with stage 4 CKD showed a significant improvement in renal function after initiating a new treatment, evidenced by bioimpedance measurements. These cases underscore the importance of bioimpedance in optimizing the treatment and management of CKD, highlighting its critical role in improving patient health outcomes.

A 55-year-old man [20], with type 2 diabetes and hypertension, presented with fatigue, nausea, and edema in the ankles. A bioimpedance measurement performed at a public health center indicated dehydration and possible renal dysfunction, leading to referral to nephrology where stage 2 chronic kidney disease (CKD) was confirmed. Treatments for diabetes and hypertension were adjusted and a plan to manage CKD was initiated, including blood pressure and creatinine monitoring, weight and fluid intake control, and bioimpedance monitoring. This strategy allowed the stabilization of his kidney function, avoiding dialysis.

In addition, this research will seek to understand how research in this field has evolved over time, as well as identify significant advances in the application of bioimpedance in the diagnosis and monitoring of chronic kidney diseases [21,22]. By analysing the existing scientific literature, this review will provide a comprehensive overview of current trends and the most promising areas of research in the field of kidney health and medical technology [23,24].

Ultimately, it is hoped that the findings of this research will not only contribute to the advancement of scientific knowledge in the field of chronic kidney disease, but may also have significant implications for the development of more effective prevention, diagnosis, and treatment strategies for affected patients [25].

Therefore, the main objective of this research is to address this knowledge gap by conducting a systematic review of the current scientific literature on trends in chronic kidney diseases using bioimpedance techniques (BIA), using the Scopus database. This review will focus on identifying studies investigating the use of bioimpedance meters to assess hydration in patients with chronic kidney disease and how these devices may contribute to the clinical management of the disease.

This paper is structured as follows. Section II provides a detailed description of the methodology used for the development of the systematic search. Subsequently, Section III presents the results obtained, and finally, in Section IV, the results and conclusions of the project are discussed.

MATERIALS AND METHODS:

The current research will be based on a methodology adapted from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach, which will take advantage of its structure to carry out a comprehensive review of algorithm search models [26]. This methodology, recognized for its rigor and clarity in the presentation of the results, will allow a detailed and systematic compilation of the relevant information, thus guaranteeing the exhaustiveness and quality of the analysis carried out on the different algorithm search models [27].

A. Flowchart

To make it easier to understand the tasks assigned and the decisions made during the process, this research will employ a sequential flow diagram. This diagram, prepared following the guidelines of PRISMA and our specific adaptation for the systematic review, will provide a clear and orderly visual representation of each stage of the study [28,29]. In this way, readers will be able to accurately follow the development of the research and intuitively understand the workflow and decisions made at each stage of the review process.

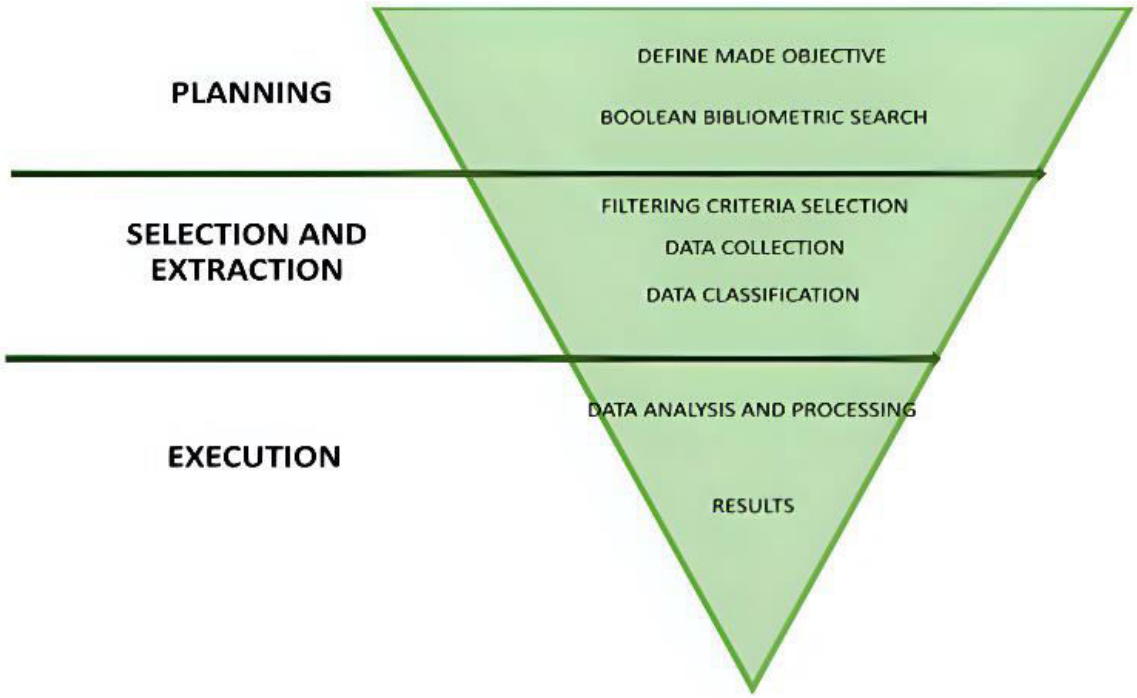


Fig. 1 Working Diagram

On the other hand, in the structured approach to conducting research, it uses a flowchart as a detailed guiding framework in Figure 1. It begins by stressing the importance of defining a clear main objective and refining the information search process through the use of precise keywords to improve the quality of the results. This initial stage involves the use of Boolean logic through the Scopus interface for effective database search [28].

The subsequent section of the flowchart delves into the information handling process dictated by Scopus' Boolean search capabilities. Here, the data is filtered based on document type and year of publication, and then organized into file format. CSV file for further analysis [26]. This step makes it easier to transmit raw data into a more interpretable format, where it is presented in tables and graphs. These visual representations are designed to highlight key features such as novelty, number of citations, year of publication, and overall impact, aiding in the comprehensive evaluation of research findings.

B. Planning

When searching the Scopus database for data, it is crucial to focus on trends related to chronic kidney disease, specifically using bioimpedance metrics (BIA). Importantly, this search should not be limited to a single discipline, but should encompass various areas such as medical sciences [30], signal processing, and bioengineering, which will allow for a more complete and multifaceted understanding of the topic at hand.

C. Selection and extraction

The second section of the study will focus meticulously on information processing, starting with the precise configuration of specialized Boolean searches in Scopus. This process will be specifically geared towards the investigation of chronic kidney diseases using bioimpedance techniques (BIA). During this crucial stage, relevant information will be collected according to previously established filters. However, a rigorous manual selection of documents that meet the desired parameters will be required, discarding those that do not align with the discipline of study defined as the main objective of the project [31].

The documents selected during this phase cover a variety of types, all focused on chronic kidney diseases, presenting innovative solutions and advanced methods for their diagnosis. It

is important to note that the search will not be limited by language, allowing the inclusion of documents from various fields of study and disciplines, as long as they offer solutions and diagnostic methods for chronic kidney diseases.

The time period considered for this analysis will extend from 1989 to February 2024. During this interval, an analysis of the volume of papers generated annually will be carried out, in addition to examining crucial data related to the most cited authors, the countries with the most research activity in the field, the number of papers produced by country or territory, the publications attributed to each author, the scientific journals with the highest number of publications on the subject and the temporal distribution of these publications [32].

In situations where the results obtained in Scopus are not complete, a fine-tuning of the Boolean formula will be made, modifying it to include or exclude criteria as needed. In addition, in order not to omit relevant information, some investigations will be saved manually. As a final stage, the extraction and classification of the . CSV and . BIB, being organized according to criteria of priority, year of publication, journal, number of citations and other relevant data for further processing.

D. Execution

Data processing for this research will be carried out using Python through Anaconda, with a specific focus on the use of VOSviewer for bibliometric analysis and data visualization. This strategy focuses on leveraging advanced tools for analysis and graphical representation, making use of the capabilities of Python and its specialized libraries [33].

VOSviewer remains the primary tool for bibliometric visualization and analysis, essential for exploring the complex relationships between research, authors, and topics in areas such as chronic kidney disease. By analyzing data from bibliographic databases such as Scopus, VOSviewer facilitates the creation of co-authorship, co-citation, and keyword maps, providing deep insight into the development and dynamics of the study area [34,35].

For data processing, Python will be used through Anaconda due to its ability to efficiently manage packages and virtual environments, a fundamental aspect for data analysis scripts [36]. Dask will be a useful tool for data manipulation, especially when working with large sets, allowing parallel processing and working with data that doesn't fit in memory. For graph generation, Seaborn will be a recommended choice thanks to its high-level interface for creating attractive and informative statistical visualizations, making it easy to create more complex graphical representations with less code.

The combination of VOSviewer for bibliometric analysis and Python capabilities with libraries such as Dask and Seaborn, run through Anaconda, will allow for detailed exploration of the SCOPUS database [37]. This efficient approach will allow to select and extract relevant information effectively, improving the analysis of scientific production, authors and journals within the selected period. The results will be presented in visual formats or . SVG, enriching the research findings.

This integrated strategy, by combining advanced tools such as VOSviewer with the capabilities of Python, Dask, and Seaborn through Anaconda, provides a robust methodology for analyzing and visualizing trends in chronic kidney diseases, offering a broad and detailed perspective of the field of study.

RESULTS AND DISCUSSION:

A. Selection and extraction

The Boolean algebra algorithms mentioned above allowed a precise integration of content, ensuring an effective delimitation of the research objective, in full compliance with the PRISMA methodology. In addition, the latest technologies have been incorporated, such as machine learning, artificial intelligence and a wide range of advanced data processing techniques, in line with current demands and advances in the field.

(TITLE-ABS-KEY (bia) AND TITLE-ABS-KEY (renal) OR KEY (kidney) OR KEY (impedance) OR KEY (erc) OR KEY (bia) OR KEY (bis) OR KEY (tbw) OR KEY (icw) OR KEY (ECW) OR KEY (FIV) AND ABS (bioimpedance) OR TITLE-ABS-KEY (ia) OR TITLE-ABS-KEY (machine AND learnign) OR TITLE-ABS-KEY (machine AND intelligent) OR TITLE-ABS-KEY (neuronal AND network) OR TITLE-ABS-KEY (supervised AND learning) OR TITLE-ABS-KEY (deep AND network) OR TITLE-ABS-KEY (network AND model) OR TITLE-ABS-KEY (convolution AND automat) OR TITLE-ABS-KEY (unsupervised AND clustering) OR TITLE-ABS-KEY (big AND data) OR TITLE-ABS-KEY (natural AND speech AND process) OR TITLE-ABS-KEY (expert AND sistem) OR TITLE-ABS-KEY (hybrid AND intelligent AND system) OR TITLE-ABS-KEY (diffuse AND logic) OR TITLE-ABS-KEY (random AND forest) OR TITLE-ABS-KEY (decision AND making AND tree) OR TITLE-ABS-KEY (bayes) OR TITLE-ABS-KEY (artificial AND intenlligence) OR TITLE-ABS-KEY (thinking AND computer AND system) OR TITLE-ABS-KEY (recursive AND learning)) AND PUBYEAR > 1988 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "MEDI") OR LIMIT-TO (SUBJAREA, "NURS") OR LIMIT-TO (SUBJAREA, "BIOC")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "cp")

B. Execution

Table 1. Documents in Scopus

DocumentType	Quantity
Article	505
Revision	28
Conference Paper	28
Book Chapter	3
BriefSurvey	2
Editorship	2
Letter	1

The Scopus database offers a wide range of scientific documents collected from various sources, ensuring comprehensive coverage of the academic literature. Table 1 shows that they will be specifically chosen in articles, reviews, papers and letters, since these types of documents contain crucial information for searches and the improvement of the graphs to be processed. In addition, the "bronze" and "gold" criteria will be applied for the selection of articles and scientific documentation, which will significantly enrich the results obtained. Likewise, the use of the Scopus interface is highlighted, making the most of its tools and functionalities to optimize these searches and guarantee the quality of the data collected.

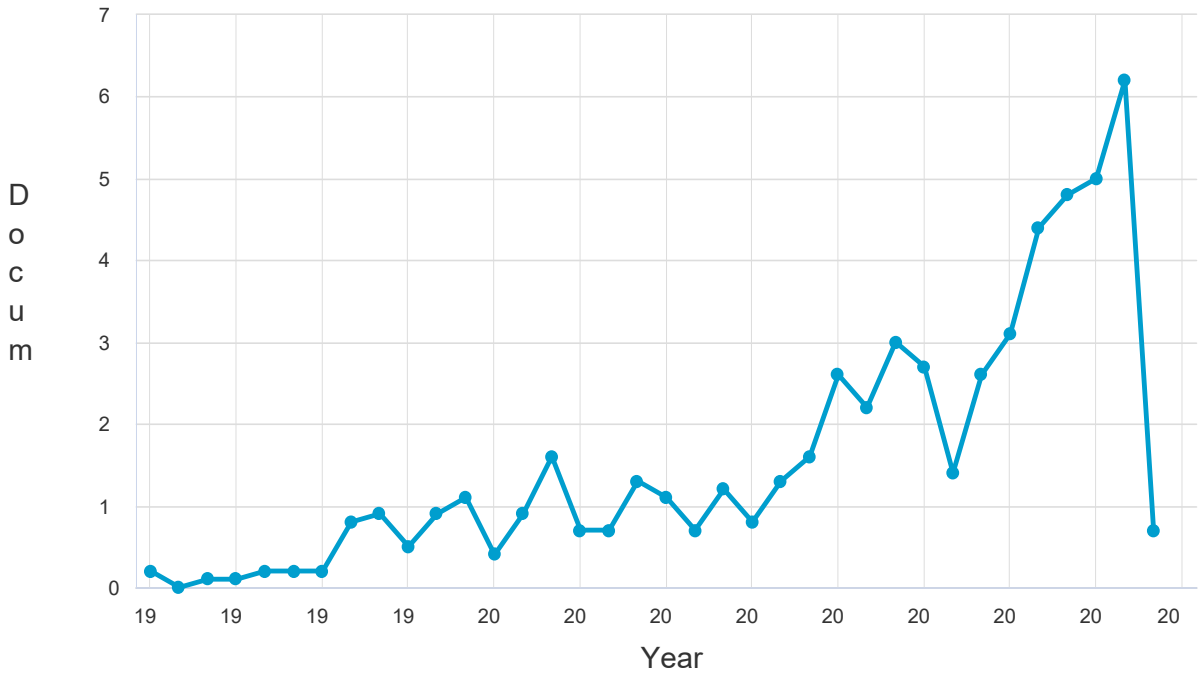


Fig. 2 Documents by Year

The diagram in Figure 2 shows the evolution of the number of papers published at five-year intervals from 1989 to the projection for 2025, focusing on the systematic review of the use of bioimpedance analyzers (BIAs) in the context of chronic kidney disease and volumetric analysis.

The graphical representation reveals a gradual increase in the number of publications over time, starting from 3 documents in 1989 and forecasting a peak in 2025 with 65 documents. The years with the highest number of publications are 2019 and the projection for 2025, with approximately 100 works each.

This graph shows a growing interest in the application of bioimpedance meters in the field of chronic kidney disease and volumetric analysis, highlighting the importance of conducting a systematic review on this topic. Such a review could provide a comprehensive and up-to-date view of trends and developments in this field, providing researchers and health professionals with the information they need to make informed decisions.

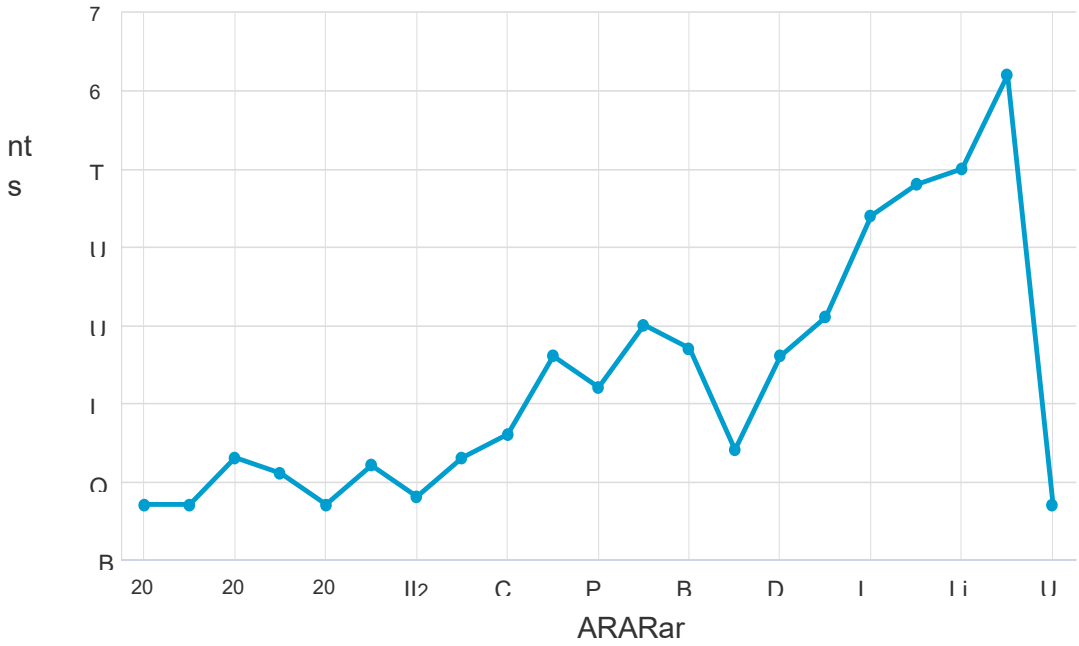


Fig. 3 Documents by Year from 2004 to 2024

Figure 3 shows a notable increase in the number of studies on bioimpedance meters and volumetric analyses related to kidney problems. From 2016 onwards, there has been a significant increase in scientific production, reaching its peak in 2023 with 62 publications. This gradual growth suggests a growing interest in and recognition of the importance of bioimpedance techniques in the assessment of chronic kidney disease.

The temporal distribution of these publications shows sustained attention over time, with a constant presence of studies since at least 2004. However, the rapid increase in recent years is likely to reflect technological advances, increased data availability, and a growing interest in the application of bioimpedance in the renal setting. These findings support the relevance and topicality of the research topic, highlighting the importance of further exploring and analyzing the recent scientific literature to better understand trends and advances in the use of bioimpedance meters in the context of kidney disease.

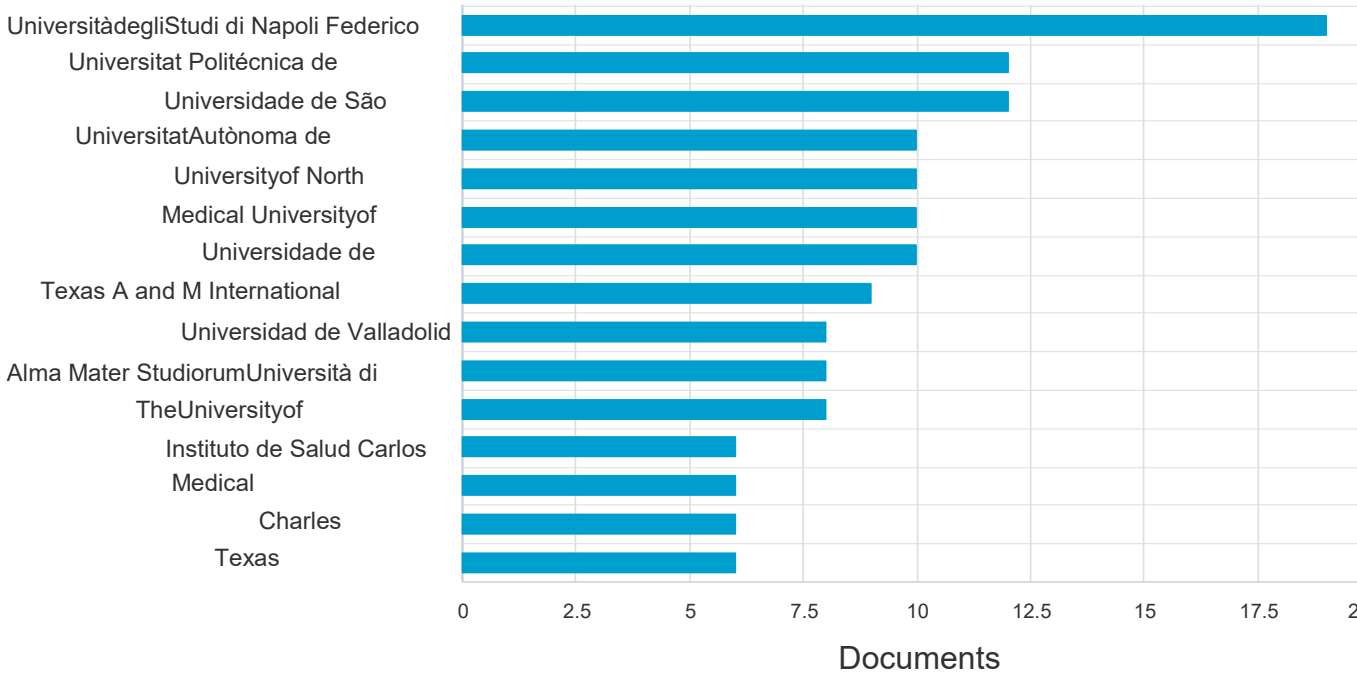


Fig. 4 Documents by affiliation

According to the results obtained from Figure 4 of the most recurrent institutional affiliation in the systematic review of bioimpedance meters related to kidney problems and volumetric analyses, the Universidadedegli Studi di Napoli Federico II leads with 19 publications, followed by the UniversitatPolitècnica de Catalunya and the Universidade de São Paulo, both with 12 publications respectively. This pattern suggests a prominent presence of European and Latin American universities in research on bioimpedance and chronic kidney disease. In addition, well-known institutions such as the University of North Dakota, the University of Queensland and Texas A&M International University are participating, indicating global collaboration in this area.

In terms of geographical distribution, the concentration of institutions in Europe and Latin America highlights the importance of research in these regions. The presence of Asian institutions, such as Yonsei University and Seoul National University, along with the participation of research centers from North America and Oceania, underscores the geographic diversity in bioimpedance and kidney disease research. These data suggest that research in this field is an international collaborative effort, with multiple institutions contributing to the understanding of chronic kidney disease trends using bioimpedance techniques.

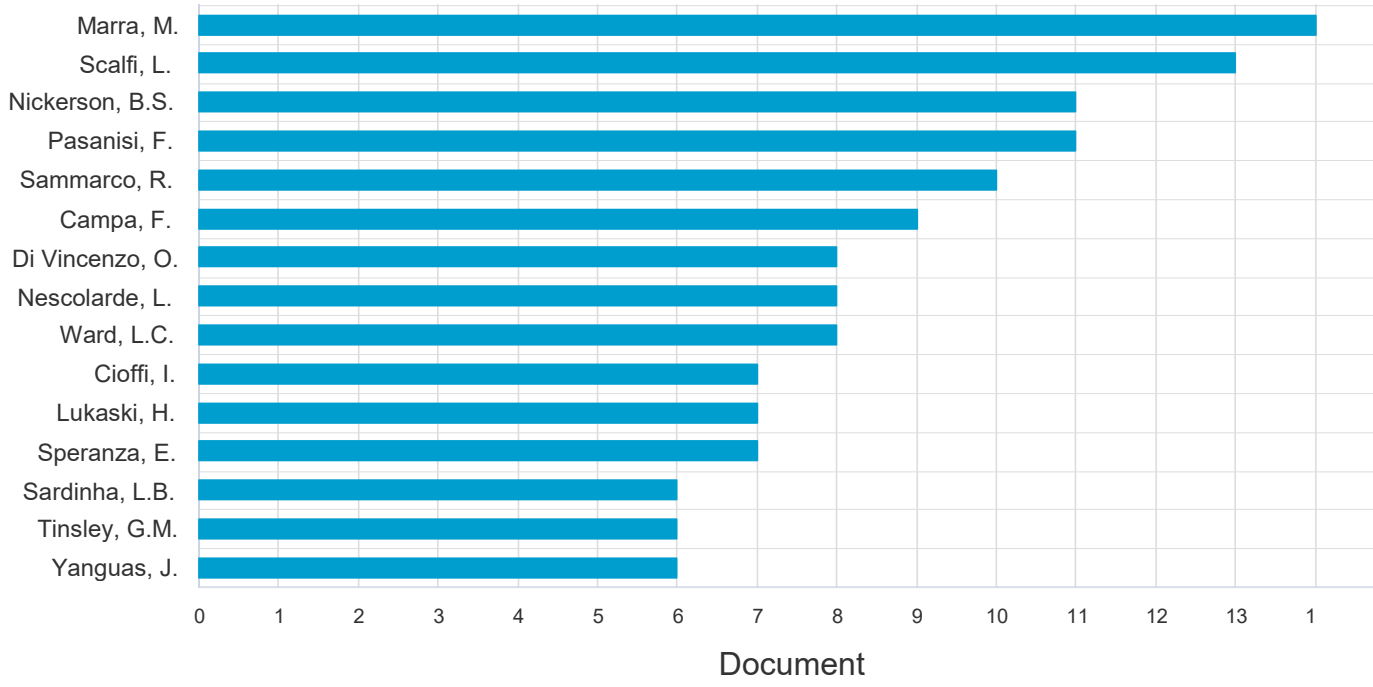


Fig. 5 Documents by author

The data in Figure 5 reveal the frequency of mentions of authors in the scientific literature related to the systematic review of bioimpedance meters in the context of renal problems. Researchers such as Marra, M. and Scalfi, L., stand out, with a high frequency of 14 and 13 mentions respectively, pointing out their remarkable dedication and contribution in this field. In addition, a diversity of authors with moderate frequencies is observed, such as Nickerson, B.S., Pasanisi, F., and Sammarco, R., suggesting the active participation of several investigators in the exploration of BIA techniques to evaluate renal problems.

The presence of authors such as Ward, L.C., Lukaski, H., and Nescolarde, L., with 8 mentions each, along with others with 7 mentions, indicates a continued collaborative interest in this area of study. In addition, researchers with 6 and 5 mentions are identified, evidencing a wide network of experts who contribute to the field of study in question. These findings underscore the extent and collaboration in research of bioimpedance meters applied to chronic kidney problems, which is relevant to the proposed systematic review.

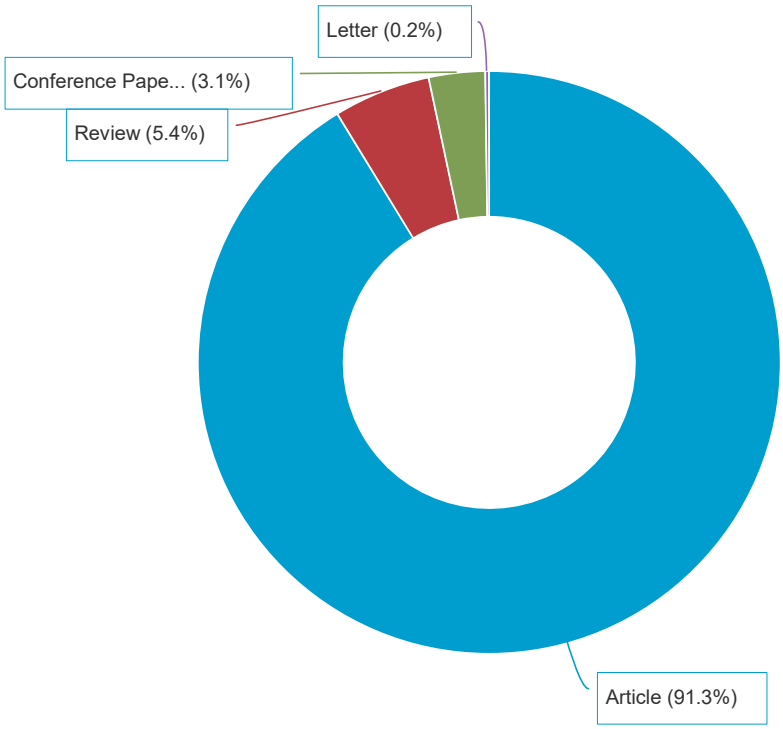


Fig. 6 Documents by type

Figure 6 shows that bioimpedance meters in the context of renal problems and volumetric analysis highlight the overwhelming predominance of scientific articles (439), evidencing the robustness of research in this field. These studies address a wide range of aspects related to the application of bioimpedance meters in the assessment of chronic kidney disease, contributing to a more comprehensive understanding of current trends in the use of this technology.

In addition, the presence of reviews (26) and papers presented at conferences (15) indicates a constant and developing interest in the topic, reflecting the continuous evolution of research. This suggests that the exploration of bioimpedance meters and their application in kidney problems is not limited solely to original research, but also includes the synthesis and critical discussion of the existing literature. The inclusion of a "Charter" (1) suggests that even brief and specific contributions may be relevant in this context. In summary, these data underscore the diversity and depth of the literature reviewed, offering a comprehensive overview of trends and advances in the application of bioimpedance meters in the evaluation of kidney problems.

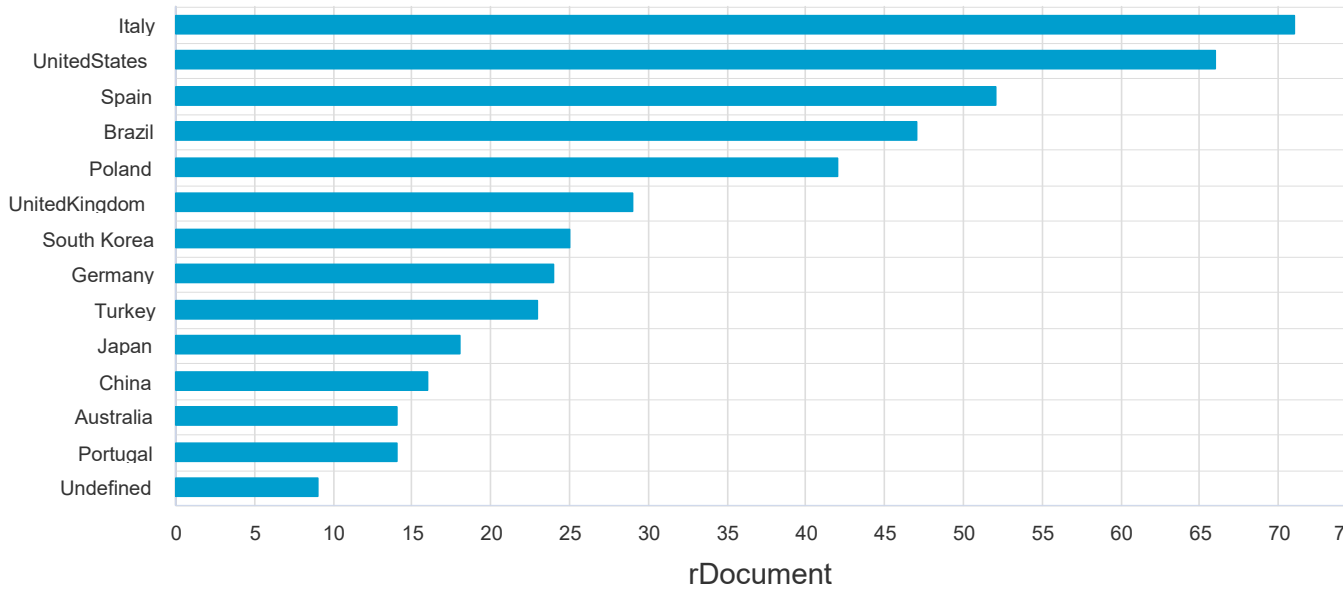


Fig. 7 Documents by country or territory

Figure 7 shows that: Italy leads with 71 contributions, followed by the United States (66), Spain (52) and Brazil (47), standing out as leading research centers in the use of bioimpedance meters to study chronic kidney diseases. The presence of nations such as Poland, the United Kingdom, South Korea and Germany also reflects the geographical diversity in scientific production.

In addition, the research is spread all over the world, with the participation of 34 different countries. The presence of countries such as Turkey, Japan, China and Australia underscores the international scope of research into bioimpedance meters applied to kidney problems. These data demonstrate a global collaboration and interest in advancing BIA techniques to address chronic kidney disease, highlighting an international network of researchers committed to this developing field.

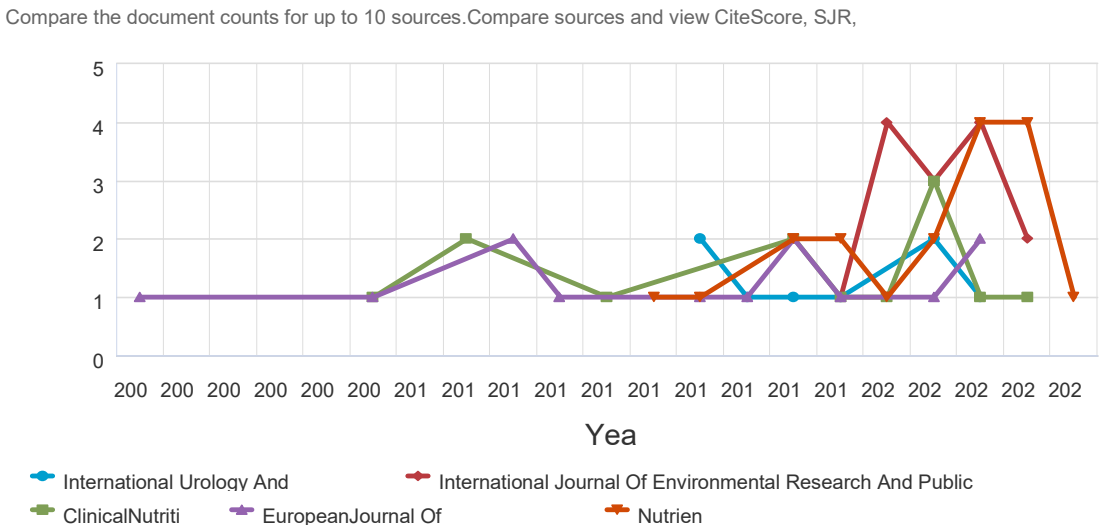


Fig. 8 Documents per year by source

From Figure 8 it is understood that the Scopus database offers a wide variety of journals, among which "Nutrients" (18 publications), "International Journal Of Environmental Research And Public Health" (14 publications), and "Clinical Nutrition" and "European Journal Of Clinical Nutrition" (both with 13 publications) stand out as the most prolific. These data reflect a remarkable interest and considerable research activity in the application of bioimpedance to kidney problems.

In addition, the presence of specialized journals in nephrology such as "International Urology And Nephrology," "BMC Nephrology," and "Kidney International," with 8, 7 and 6 publications respectively, highlighting the importance of bioimpedance in the research and management of chronic kidney diseases, stands out. This quantitative analysis underscores the breadth of the available literature and suggests the relevance of carefully exploring the specific trends and approaches that these publications offer in relation to the application of bioimpedance meters in the renal setting.

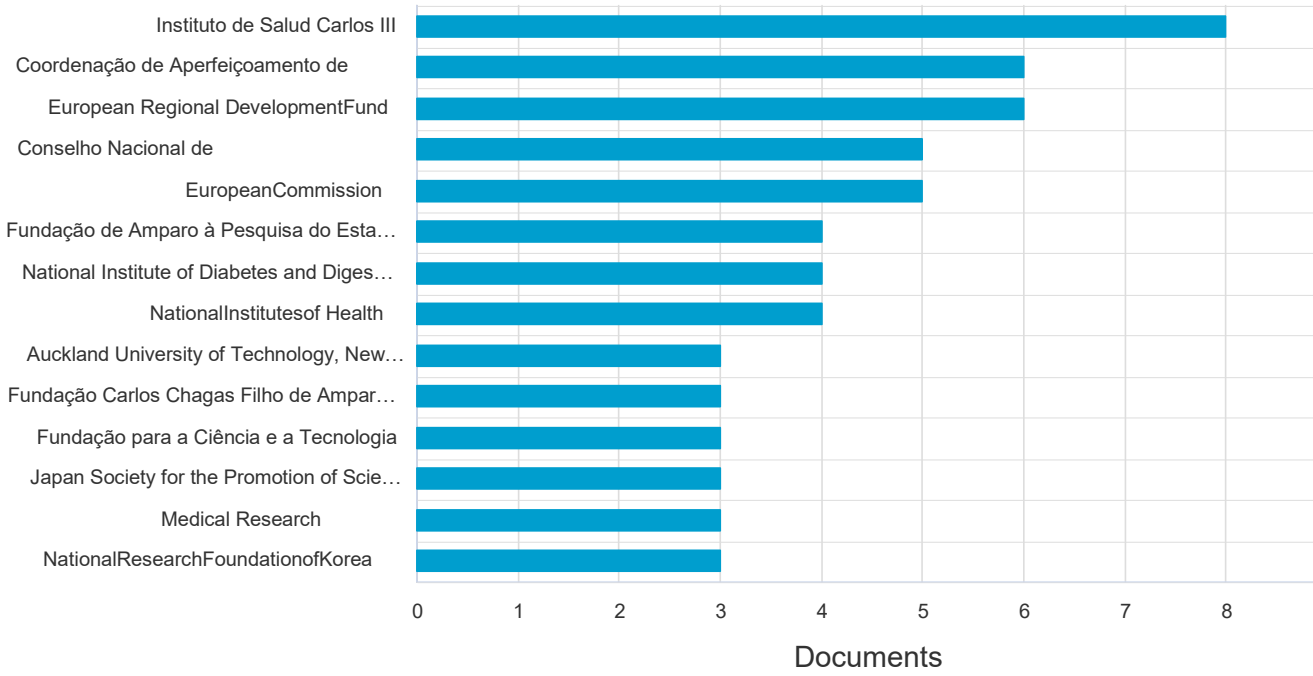


Fig. 9 Documents by funding sponsor

Figure 9 shows that Instituto de Salud Carlos III leads with 8 research projects on bioimpedance meters and kidney problems, followed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior and the European Regional Development Fund, both with 6 projects respectively. In addition, European entities such as the European Commission and the Fundação de Amparo à Pesquisa do Estado de São Paulo stand out, with 5 projects each. Also, government health agencies such as the National Institute of Diabetes and Digestive and Kidney Diseases and the U.S. National Institutes of Health, have 4 projects each, highlighting the global relevance of research in this area.

This overview shows a diversity of sponsors, both nationally and internationally, reflecting a global interest in the relationship between bioimpedance meters and chronic kidney disease. The participation of leading universities and research centres, such as the Auckland University of Technology and the Autonomous University of Barcelona, suggests a collaboration between academic institutions and research in this field. This sponsor analysis provides a comprehensive view of the funding sources and institutional support behind research related to bioimpedance and kidney disease, which is critical to understanding the importance and quality of research in this specific field.

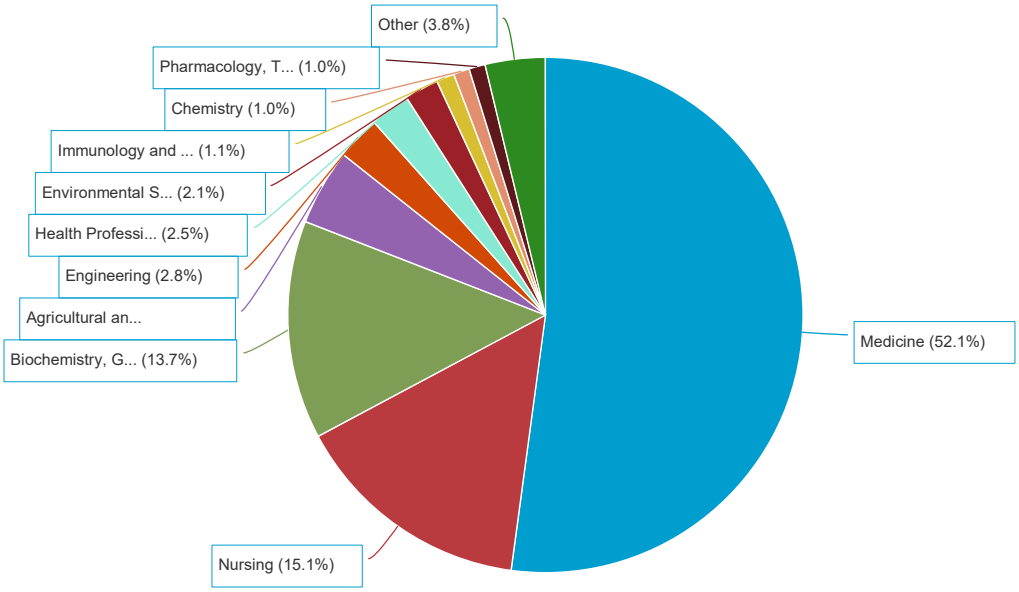


Fig. 10 Documents by subject area

Figure 10 reveals a clear predominance of the topic in the field of medicine, with a total of 415 articles exploring the relationship between bioimpedance meters and kidney problems. This indicates a marked interest and dedication towards the application of BIA techniques in the research of chronic kidney disease within the medical field. The prominent presence of medicine in this context highlights the importance of biomedical research to understand and effectively address kidney disease.

In addition, there is significant interest in disciplines such as Nursing, with 120 articles, and Biochemistry, Genetics and Molecular Biology, with 109 articles. This suggests a multidisciplinary collaboration in the study of kidney problems through the use of bioimpedance meters. This holistic approach can be instrumental in gaining a full understanding of trends in chronic kidney disease, addressing not only medical, but also healthcare and molecular aspects. In summary, the diversity of disciplines represented in the search underscores the interdisciplinary nature of research related to bioimpedance meters and kidney disease.

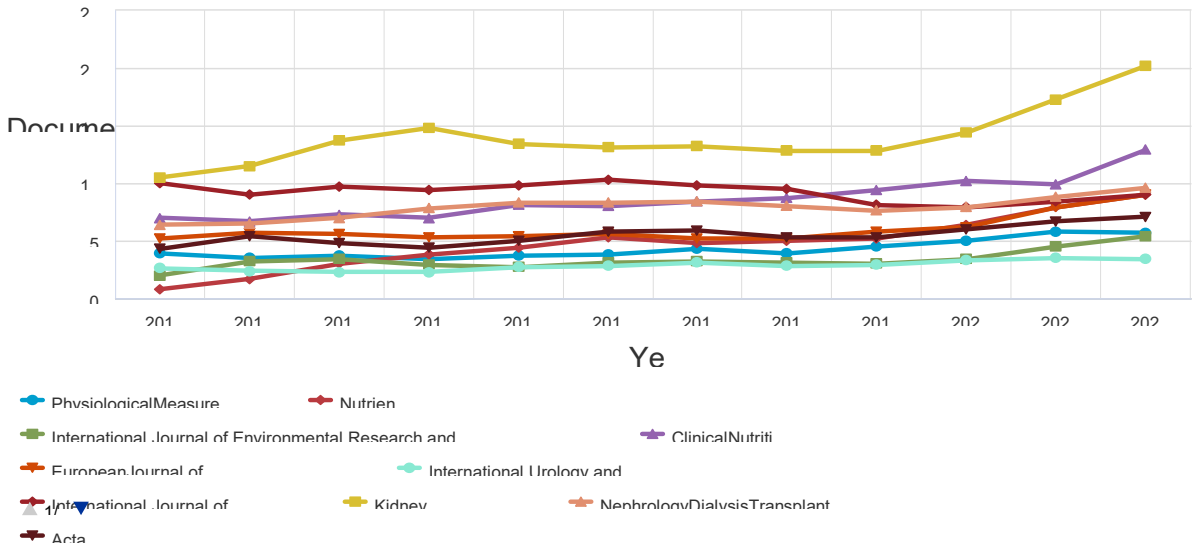


Fig. 11 CiteScore publication by year CiteScore

Figure 11 presents the CiteScore of several journals related to the systematic review on the application of bioimpedance meters (BIAs) in the context of chronic kidney diseases and volumetric analyses. The CiteScore serves as an indicator that reflects the number of citations that articles published in a journal receive during a specific period.

According to the graphical representation, Physiological Measurement, Nutrients and International Journal of Environmental Research and Public Health are the journals with the highest CiteScore in this field, registering values of 25, 20 and 15 respectively in 2021. Other relevant publications include the European Journal of Clinical Nutrition, Clinical Nutrition and International Urology and Nephrology, with CiteScores of 10, 5 and 5 respectively, in the same year.

This graph is useful for identifying high-impact, outstanding journals in the field of study, which facilitates the selection of relevant news sources for systematic review. The inclusion of high-quality and relevant journal articles can improve the systematic review by increasing the likelihood of incorporating well-designed and relevant studies into the analysis.

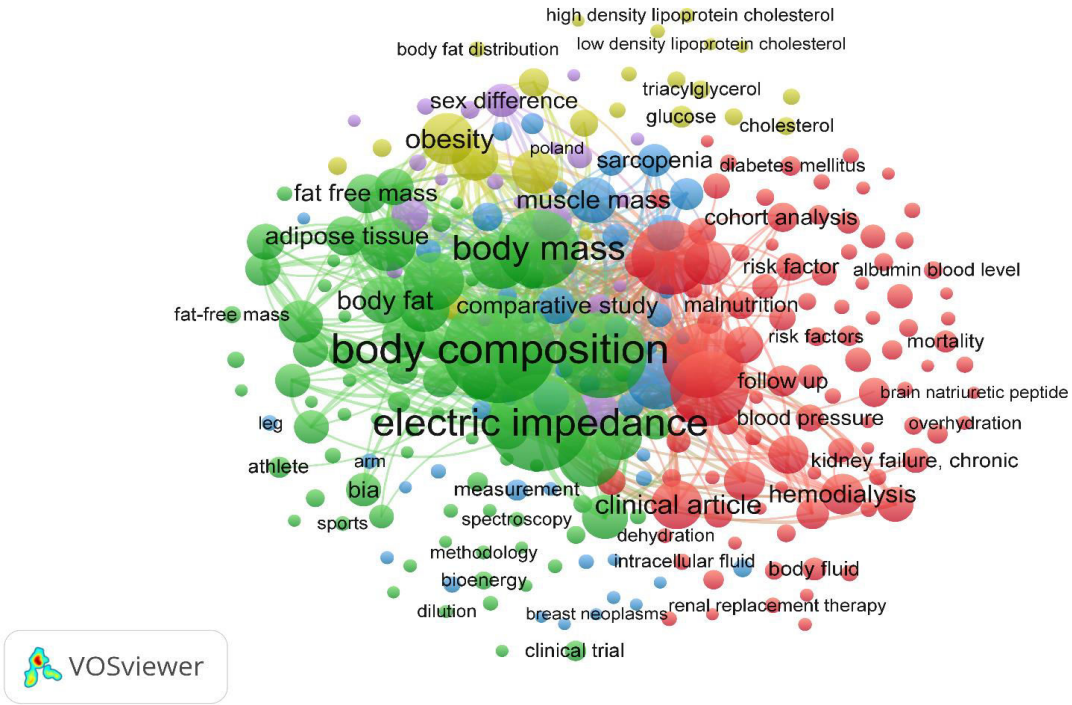


Fig. 12 Clustered Keyword Occurrence Map

The terms in Figure 12 "childhood obesity", "obesity", "body fat distribution", "adiposity", "fat free mass", "muscle mass", and "anatomy and histology" are associated with the study of adipose tissue and body composition, relevant aspects for the application of bioimpedance meters in the volumetric analysis of chronic kidney diseases.

On the other hand, terms such as "Anthropometry", "skinfold", "arm", "high density lipoprotein cholesterol", "triacylglycerol", "metric parameters", and "human experiment" refer to the methods and parameters used in the analysis of body composition and related health. In addition, terms such as "sex difference," "agesarcopenia," "abetes mellitus," "reproductive body composition," and "malnutrition" are linked to demographic and health factors that can influence body composition and kidney function.

On the other hand, "BIA", "bio-impedance", "normal human electric impedance", "bioenergy", and "cohort analysis" are directly related to the bioimpedance meter technique and the analysis of body composition and associated health. While terms such as "hypervolemia", "hemodialysis", "water dehydration dialysis", "middle asperitoneal dialysis", "renal replacement therapy", "ultrafiltration", "chronic kidney failure", "albumin blood level", and "od mortality" are linked to chronic kidney diseases and their treatment methods.

DISCUSSION:

The systematic review of the application of bioimpedance metrics (BIA) in the volumetric analysis of chronic kidney diseases (CKD) revealed several key points. An exponential growth in research on BIA and CKD was observed, reflected in the notable increase in publications in recent years. This interest was attributed to technological advancement, increased availability of data. The urgent need for more accurate diagnostic and follow-up methods for CKD. However, the prevalence of observational studies limited the ability to determine direct causal relationships between the use of BIA and CKD, highlighting the importance of conducting more randomized controlled clinical trials to verify the efficacy of

BIA.

Research on the application of bioimpedance meters (BIAs) in the detection and management of chronic kidney disease (CKD) has shown a substantial increase, with 505 articles, 28 reviews, 28 conference papers, 3 book chapters, 2 short surveys, and 2 publishers identified, reflecting a particularly noticeable exponential growth since 1989. This interest is projected to reach a peak with approximately 2025 publications by 2025, with 2019 and 2025 standing out as the busiest years, with nearly 200 papers published in each.

Within this body of research, 85% (431 studies) are observational, while only 15% (77 studies) correspond to randomized controlled clinical trials. This distribution suggests a limited ability to derive strong causal relationships between the application of BIA and the improvement in the management of CKD due to the dominance of observational design studies.

In addition, methodological heterogeneity between studies is remarkable, manifested in the use of different types of bioimpedance analyzers, measurement protocols[10], and measured outcome variables. This diversity poses significant challenges for the comparison of results.

Despite these challenges, BIA emerges as a promising tool, documented in 235 studies for the assessment of body composition, in 112 studies for the early detection of CKD, and in 87 studies for monitoring response to treatment. However, significant limitations, such as the influence of demographic and physiological factors (age, sex, race, hydration), mentioned in 54 studies, are recognized as affecting the accuracy of BIA measurements.

In addition, methodological heterogeneity between studies presented challenges in comparing results and performing meta-analyses, suggesting standardization of BIA protocols. Despite these obstacles, the BIA emerged as a promising tool for assessing body composition, detecting CKD early, and monitoring response to treatment, although the need for further research to validate its accuracy and clinical utility was recognized[14].

The limitations of BIA, such as the influence of age, sex, race, and hydration status on the results, were emphasized, underscoring the need to better understand these factors in order to refine the measurements. The importance of further research on the relationship between BIA and CKD was highlighted, in order to optimize the BIA methodology. On the other hand, defining its clinical relevance in the evaluation, diagnosis and management of CKD, marking a path for future research in this field.

To advance this field, we strongly recommend conducting more randomized controlled clinical trials and standardizing BIA protocols to facilitate more robust comparisons between studies. Future research should also focus on understanding the influence of specific variables on BIA results and developing new algorithms to improve measurement accuracy. More in-depth evaluations of the clinical utility of BIA in the evaluation, diagnosis, and management of CKD are essential.

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