Biomedical Engineering Research in Chilean Universities - A Bibliometric Analysis

Javiera Vásquez-Salgado, Rosa L. Figueroa, Julio Sotelo, and Manuel Villalobos-Cid

***Abstract*—Biomedical engineering (BME) combines engineering, biology, and medicine to develop innovative healthcare solutions. There is an increasing demand for BME professionals following technological and scientific advances. In Chile, only three universities offer undergraduate BME programs: Universidad de Valparaíso, Universidad de Concepción, and Universidad de Santiago de Chile. Each institution has defined its curriculum, professional profile, and research focus based on its perspective of the needs of the country. However, the scope of their research contribution has not been studied. In this work, we perform a comprehensive bibliometric analysis using data from the SCOPUS database to evaluate publications by researchers affiliated with Chilean undergraduate BME programs from 2000 to 2022. The objective is to identify the research areas of BME in Chile, understand the similarities and differences between universities, analyse their research areas, explore collaboration relationships, and characterise the evolution of this discipline. The main contributions of this work are (1) a quantitative and qualitative analysis of BME research in Chile, (2) the identification of BME research areas and their development over time, (3) the creation of a dashboard-style web tool, and (4) proposing a robust methodology for bibliometric analysis applicable to BME literature in Chile and similar contexts. This work represents the first collaboration involving authors from all universities with undergraduate Chilean BME programs.**

Link to graphical and video abstracts, and to code: https://latamt.ieeer9.org/index.php/transactions/article/view/8343

***Index Terms*—Biomedical engineering, educational programs, bibliometrics, knowledge discovery, Chile.**

I. Introduction

Biomedical engineering (BME) is a multidisciplinary field that combines engineering, medicine, and biology principles by developing innovative solutions addressing healthcare challenges [1]. Over the past decade, there has been a continuous increase in demand for undergraduates and graduates from BME programs due to advancements in technology and science, an ageing population, and growing healthcare needs [2]–[4]. BME programs offer different levels of specialisation, depending on the requirements of each region or country [5], [6].

The first BME undergraduate programs in Latin America were founded in Mexico and Colombia during the mid-1970s, primarily focusing on biomedical instrumentation and systems physiology [7]. Over time, BME programs have grown significantly, with more than 90 available programs. These programs offer a broad range of areas of specialisations, such as bioinformatics, bioinstrumentation, biomaterials, biomechanics, clinical engineering, medical imaging, informatics, and systems physiology, among others [4], [8], [9]. Biomedical engineers have become crucial in public and private healthcare, the electromedical industry, medical devices and health-biomedical research centres [10].

The first Chilean BME undergraduate program was established in 2000 at the Universidad de Valparaíso (UV) [7]. Subsequently, two other universities released BME programs: Universidad de Concepción (UdeC) in 2005 and Universidad de Santiago de Chile (USACH) in 2020. The curricular design of these programs places significant emphasis on integrating theory and practice to ensure that graduates are well-prepared for their future careers [8], [10]. These universities have explicitly implemented different measures to achieve this goal, such as promoting applied research involving BME professionals [8], [11].

Research on biomedical science has been extensively studied in Chile [12]–[17], but there is a lack of focus on BME, particularly in recent years. Chilean universities have established their graduate profiles, specialisation levels, and research areas, adjusting them over time, which may contain bias. Hence, there is a need for quantitative studies to characterise the state of BME research in the country.

Bibliometric analysis is a highly utilised methodology that allows the exploration and analysis of large volumes of scientific data [18]. It provides insight into the dynamics of scientific knowledge, trends, challenges, and research impact by identifying patterns and relationships between different features such as authors, publications, citations, and keywords [19]. Bibliometric analysis has contributed to several disciplines, such as business, electronics, energy, education, biology, and medicine, among others [18], [20], including BME [21]–[25].

In this work, we conduct a comprehensive bibliometric analysis using data from journal documents, conference proceedings and book chapters recorded in the SCOPUS database, published by researchers with affiliation and participation in Chilean undergraduate BME programs from

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2000 to 2022. The goal is characterising BME research through quantitative and qualitative analysis, (1) to identify similarities and differences across universities, (2) to analyse their research areas, contrasting them with the professional profile at the country level, (3) to explore collaboration relationships between researchers and institutions, and (4) understanding the evolution of the discipline. The main contributions of this work are:

1) A bibliometric analysis to quantitatively examine scientific research in the field of BME in Chile, aiming to characterise the research products of each university.
2) Identifying the research areas in BME in Chile and their evolution over time using a mixed qualitative and quantitative approach.
3) The development of a dashboard-type web tool to allow easy verification of the results obtained in this study and the analysis of data from new publications.
4) The proposal of a robust methodology for bibliometric analysis that can be applied to BME literature in Chile and similar contexts.

The manuscript is organised as follows: Section II contextualises BME in Chile, emphasising the undergraduate programs, Section III describes details of the material and methods used, and Section IV shows the experimental results. The last section presents a discussion regarding this work.

Understanding that students often start their biomedical engineering studies with limited knowledge about the field and the research conducted by their professors is essential. By doing so, we hope to help students gain a better understanding of the field in Chile and the different career paths it offers. This work represents the first collaboration involving authors from all universities with undergraduate BME programs in Chile.

II. BME Undergraduate Programs in Chile

Chile has a rich history in BME. In the 1960s, the Instituto de Fisiología at the Universidad de Chile in Valparaiso took the first steps by performing several research theses in the field. In the 1970s, the national BME achieved two significant milestones in bioinstrumentation by creating the first Chilean artificial kidney and a cardiac pacemaker. Subsequently, the Sociedad Chilena de Ingeniería Biomédica (SOCHIB) was established in 1983, integrating researchers nationwide. At the same time, the first postgraduate programs in BME were introduced at the Universidad de Chile and the Pontificia Universidad Católica de Chile [26]. However, it was not until 2000 that the *Universidad de Valparaíso* implemented the first Chilean undergraduate program in BME[1].

Later, three other programs were added: Universidad Iberoamericana de Ciencias y Tecnología (2005), *Universidad de Concepción*[2] (2005) and *Universidad de Santiago de Chile*[3] (2020). However, the former closed after a few years. The Pontificia Universidad Católica de Chile also developed complementary BME minors and majors.

Although universities share similar goals in producing graduates experts in solving complex engineering and medical problems, the BME specialisations differ across institutions. According to their own description, the UV program emphasises bioinstrumentation, medical informatics, clinical engineering, medical informatics, organisation management and healthcare technologies. The UdeC program focuses on medical equipment, clinical bioengineering, and medical informatics, while the Universidad de Santiago de Chile is centred on clinical engineering, biomechanics, medical informatics, and bioinformatics.

Other complementary undergraduate programs have been established in Chile to address the growing need for specialised healthcare professionals derived from BME. The Bioinformatics engineering program at Universidad de Talca (UTalca) was founded in 2003[4], the Bioengineering program at Universidad Adolfo Ibáñez (UAI) was introduced in 2008[5], and the newly proposed Medical bioengineering program at Universidad Católica del Maule (UCM) in 2021[6]. All these programs have an extension from 10 to 12 semesters. The DuocUC Professional Institute has also developed an eight-semester training program for Medical informatics technicians[7].

The previous graduate profiles are characterized in **??**, considering an updated classification of courses regarding previous works [5], [7], [9]. The classification of courses and data regarding the number of students are detailed in **??**, Supplemental material.

UV and USACH share similar graduate profiles, primarily focusing on BME courses. However, USACH offers more *Computing/informatics* courses, while UV includes more *Electrical engineering* and *Social sciences and humanities* courses. The second program may have influenced the curriculum of UV. UCM has a curriculum profile similar to UV and USACH but with more non-disciplinary and *Elective/other courses*. In contrast, the other universities have a more diverse range of course areas with less emphasis on BME. For instance, UTalca offers more computer science, engineering, biology, and bioinformatics courses but lacks electrical engineering courses. UAI provides many fundamental and elective courses, and UdeC maintains a balance across all areas with less emphasis on BME courses. A unique program is the BME program at DuocUC, which lacks a background in basic sciences and fundamental courses.

It is important to note that based on their website and official information, only UV and USACH have researcher experts who have completed formal undergraduate or graduate studies in BME programs.

[1] https://biomedica.uv.cl/
[2] https://admision.udec.cl/ingenieria-civil-biomedica/
[3] https://admision.usach.cl/ingenieria/ingenieria-civil-biomedica
[4] https://icb.utalca.cl/
[5] https://admision.uai.cl/carreras/ingenieria-civil-en-bioingenieria/
[6] https://portal.ucm.cl/carreras/bioingenieria-medica
[7] https://www.duoc.cl/carreras/informatica-biomedica/

III. Material and Methods

To perform the bibliometric analysis, we followed the standard methodology proposed by the literature [18], [27], which involves four steps: (1) aims and scope definition, (2) techniques selection, (3) data preparation, and (4) analysis and report of findings (see Fig. 1). In the context of this study, we describe each step as follows:

A. Aims and Scope Definition

As mentioned, this study aims to characterise BME research in Chile by analysing the output of researchers affiliated with undergraduate BME university programs. Our goals include (1) identifying similarities and differences among universities, (2) analysing the BME research field and comparing it with the professional profile of the country, (3) investigating collaboration relationships between researchers and institutions, and (4) understanding the evolution of the discipline. Our study specifically targets three universities in Chile -UV, UdeC, and USACH- that offer undergraduate programs in BME. Consequently, institutions offering postgraduate and related programs, such as UAI, UTalca, UCM, and Duoc, were excluded from our analysis.

B. Techniques Selection

Although there are numerous tools available for conducting bibliometric analysis, such as HistCite, VOSviewer, GEphy, BibExcel, Citespace, PAJAK, CitnetXplorar, and UCINET [18], [28]–[30], we utilised R v4.2.1 and its integrated development environment RStudio v1.2.5033 due to its applicability and versatility, complemented by their advanced data processing and dashboard desing features [31], [32]. It includes libraries such as ggplot2 [33], dplyr [34], DT [35], tidyr [36], quanteda [37] and Bibliometrix [38], which facilitate the preparation of the data, processing and subsequent analysis. Also, the shiny R package [39] allows the creation of interactive dashboards, which is one of the complementary products of this work.

C. Data Preparation

A comprehensive search was performed using the SCOPUS database, including Web of Science-indexed publications (An overview of this step is provided in **??**, Supplemental material). We cover all the scientific products (i.e. journal documents, conference proceedings and book chapters) authored by researchers affiliated with Chilean universities offering undergraduate degrees in BME that were published between 2000 and 2022 and recorded in SCOPUS until February 2023.

We collected different attributes for each document, such as the names of the authors, ID, affiliations, title, year of publication, journal or conference, abstract, keywords, language, number of citations, and publication type. Regarding documents written in a language other than English, their title and abstracts were translated using the Google Translate API. We used the list of researchers formally presented on the websites of each program. Additionally, we complemented the list by searching SCOPUS by affiliation to include researchers no longer affiliated with these universities. In the case of USACH, we also considered researchers who participate in its BME program design. The list of all researchers considered in our study can be found in **??**, Supplemental material.

We considered a total of 1,545 publications[8]. Specifically, we examined 22 researchers and 229 publications for UV, of which two had no publication records. For UdeC, we reviewed 26 researchers and 1,262 publications. Lastly, for USACH, we studied seven researchers and 54 publications, with one having no publications using this affiliation. The study range considered the date of creation of the programs; for UV and UdeC, it was from 2002 to 2022 and 2005 to 2022, respectively. For USACH, we include data from 2020 to 2022.

To standardise the use of technical terms in characterising publications, we utilised the 2023 IEEE Taxonomy v1.01 (for frequency analysis, term comparison, and clustering) with three levels of granularity[9]. Furthermore, we created a fourth level with all the SCOPUS keywords recorded for each publication studied. As part of the qualitative analysis, we classified these keywords based on their affinity with the BME areas defined in [40]. This allows for studying each university research area and country level. More details on the classification can be found in **??**, Supplemental Material.

D. Step 4. Analysis and Report of Findings

As part of the bibliometric analysis, we conducted two types of evaluations: (1) performance analysis and (2) science mapping [18], which can be defined as:

1) Performance Analysis: This analysis involved applying a range of metrics used to assess the performance of authors and universities [18], [41], [42]. Two types of metrics were utilised, one that focused exclusively on *performance* (e.g. total publications, average publications per year, productivity per active year of publication, and average citations, among others), and another that concentrated on *collaboration* (e.g. contributing authors, co-authored publications, and the percentage of co-authored publications, among others). **??** in Supplementary material describes these metrics.

2) Science Mapping: This analysis examined the scientific context of publications, intellectual interactions, and structural connections among research components [18]. We applied different approaches, including:

1) Evaluating the frequency of technical terms in publication abstracts to characterise research areas.
2) Using statistical tests such as chi-squares to identify technical terms with statistically significant frequency differences, contrasting universities, authors, or periods.
3) Identifying technical terms by studying the universities and periods in which they were researched.
4) Analysing the journals and conferences in which the research products were published.

[8]Codes and database regarding this work can be found in this github link
[9]https://www.ieee.org/publications/services/thesaurus-thank-you.html?

5) Studying collaborations using frequency and cluster analysis.

Depending on the interest of the reader, different levels of analysis can be applied, including (1) the use of journal documents, proceedings, or both; (2) the four levels of terms based on the 2023 IEEE Taxonomy (see Section III-C); and (3) year ranges. The research outcomes can be comprehensively examined using the dashboard that we have implemented[10]. Furthermore, we qualitatively analysed the publication abstracts using SCOPUS keywords to associate the works classified in different research areas.

IV. Results

A. Performance Analysis

Figs. 2a and 2b show the number of researcher authors and publications per year for each university from 2000 to 2022. The university with the highest number of publications was UdeC, with 26 authors and 1,262 publications (from 2005 to 2022), followed by UV, with 20 authors and 229 publications (from 2000 to 2022), and USACH, with seven authors and 54 publications (from 2020 to 2022).

The performance analysis of the three universities during 2020-2022 (as shown in Table I) reveals exciting findings. The average number of publications per author was 7.2, 9.8, and 7.7 for the UV, UdeC, and USACH, respectively. Notably, UdeC had the highest productivity per active year of publication (68.3), twice that of the other universities. Furthermore, UdeC had the highest percentage of publications in conference proceedings, accounting for 36.1% of their publications, while 56.1% were published in journals. USACH, on the contrary, had the highest percentage of publications in journals, accounting for 72.2% of their publications, while 25.9% were conference proceedings. The small gap in the sum completing 100% corresponds to book chapters.

All three universities have a similar proportion of cited publications per published work, ranging between 0.5 and 0.6. However, regarding the number of citations per publication, USACH has an average of 3.1, followed by UdeC with 3.4 and UV with the highest number of citations per publication, at an average of 4.8.

Concerning the collaboration metrics (see Table II), most of the publications included more than one author (> 95.5%), with an average of 6.3 to 7.6 authors per publication. In the case of USACH, there are no publications with a single author. As expected, given the more significant number of publications, the UdeC tripled and quadrupled the average number of contributing authors (1,561) compared to UV (588) and USACH (340), respectively.

TABLE I
PERFORMANCE METRICS CALCULATED USING DOCUMENTS PUBLISHED FROM 2020 TO 2022. (*ave*: AVERAGE; *conf*: CONFERENCE; *proc*: PROCEEDINGS)

Performance metrics	UV	UdeC	USACH
Number of authors	12	21	7
Total publications	87	205	54
Total journal publications	59	115	39
Total conf. proc. publications	15	74	14
Percentage of journal publications	67.8	56.1	72.2
Percentage of conf. proc. publications	17.2	36.1	25.9
Ave. publications by author	7.2	9.8	7.7
Ave. journal publications by author	4.9	5.5	5.6
Ave. conf. proc. publications by author	1.2	3.5	2
Ave. publications by year	29	68.3	18
Ave. journal publications by year	19.7	38.3	13
Ave. conf. proc. publications by year	5	24.7	4.7
Number of active years of publications	3	3	3
Productivity per active year of publication	29	68.3	18
Total number of citations	255	324	91
Ave. citations by publication	2.9	1.6	1.7
Number of cited publications	53	94	29
Proportion of cited publications	0.6	0.5	0.5
Citations per cited publication	4.8	3.4	3.1

TABLE II
COLLABORATION METRICS CALCULATED USING DOCUMENTS PUBLISHED FROM 2020 TO 2022 (*ave*: AVERAGE)

Collaboration metrics	UV	UdeC	USACH
Number of researchers	12	21	7
Number of contributing authors	588	1561	340
Ave. contributing authors	6.8	7.6	6.3
Co-authored publications	86	196	54
Percentage of co-authored publications	98.9	95.6	100

B. Science Mapping

1) Research Areas: Using the chi-square test in analysing and comparing technical term frequencies showed unexpected results. The study of SCOPUS keywords associated with BME publications in Chile revealed a lack of technical terms directly related to the discipline. Instead, we found terms related to strategies and applications exclusively from electrical, electronic, and electricity domains (see **??**, Supplemental material).

It was found that most researchers from the BME program at UdeC, which has the highest production of publications, do not publish in the BME field (see **??**, Supplemental material). It can also be verified by reviewing the journals in which documents were published focused on the electric industry, electronics and electricity (see **??**, Supplemental material). The wordclouds illustrating the frequency of terms can also be found in Supplemental material, **??**.

After reviewing the publications from this university, we found that only six out of 26 researchers have primarily published in BME (SCOPUS IDs 14036817700, 7102732243, 14631693800, 22950573600, 24766261300, and 23028926500). Other authors, including 35599816000, 8700108300, 7401636823, 7003572137, 7101834722, and 7003287200, have made sporadic contributions to this area. More information about the SCOPUS IDs is in Section **??**, Supplemental Material. Between 2005 and 2022, these authors published approximately 213 documents related to BME, about 17% of the total BME-related publications at the university. However, if we consider the period from 2020 to 2022 (see Tables I and II), We observed a reduction in the total BME publications of UdeC from 205 to 45, the number

[10]https://biodiinf.shinyapps.io/BiomedicEngBA/

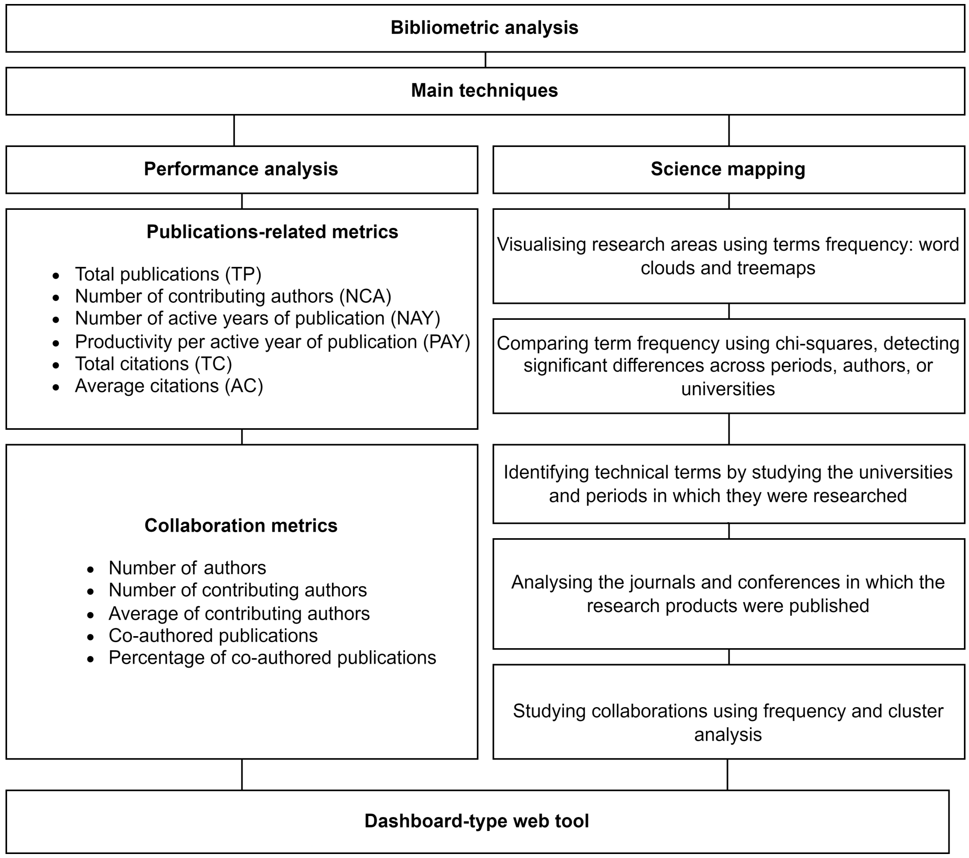
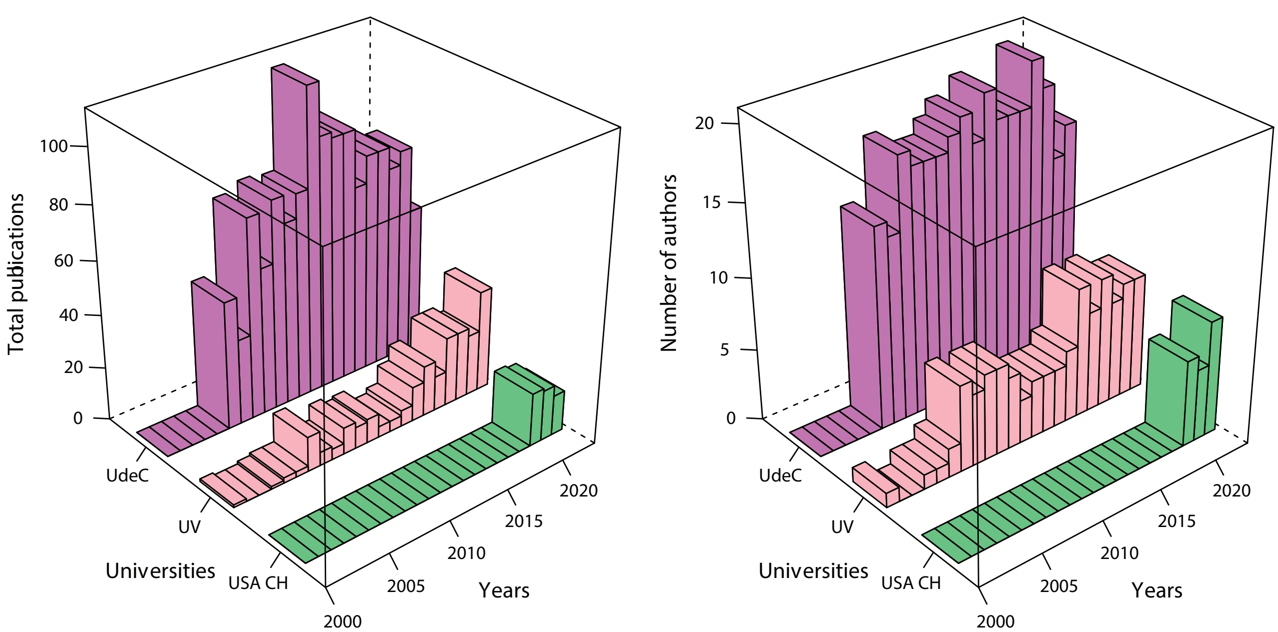


Fig. 1. Scheme that describes the methodology used for the bibliometric analysis, based on [18].



(a) Total publications (b) Number of authors (researchers)

Fig. 2. Total publications and authors (researchers) from BME undergraduate programs: UV, UdeC and USACH (2000 - 2022).

of authors from 21 to 8, and the average number of publications from 9.8 to 5.6. In contrast, authors from other universities have primarily focused on BME research, as demonstrated by their characteristic keywords and the journals in which they published.

The UV has played a significant role in defining the research areas of BME in the country, as indicated by the frequency analysis of keywords in Fig. 3. Initial works in BME from 2000 to 2006 mainly focused on systems physiology, studying neurological responses and glial cells. Later, there was a shift towards medical imaging, proposing various segmentation techniques for detecting diseases using magnetic resonance images. Subsequently, bioinstrumentation and biomedical electronics research led to the development of medical equipment and simulators. The emergence of BME programs from other universities expanded and diversified application areas, such as biofluids, bioinformatics, biomechanics, and clinical engineering.

Fig. 5 shows the research profile of each university based on the keywords used in their publications. The analysis reveals UV strongly emphasises medical imaging while contributing to systems physiology, bioinstrumentation, and biomedical electronics. On the other hand, UdeC researchers have a well-balanced focus on the same research areas. In contrast, USACH has mainly concentrated on systems physiology, biofluids, and bioinformatics, with no work related to medical imaging. Keywords describing the research areas of each university can be found in Section **??**, Supplemental material. The review of the abstracts of manuscripts guided by the keywords and their categorisation allowed us to characterise the following areas:

1) *Biofluids*. The first works in the area were published in 2009. UV has focused on hemodynamic studies using medical images, mainly in the cardiovascular area. UdeC has tested different non-invasive sensors to measure cardiac activity based on haemodynamic parameters. USACH has studied cerebral autoregulation by identifying the relationships with different hemodynamic parameters, diseases and physiological conditions.
2) *Bioinformatics / Genetic Engineering*. Its first manuscripts were published in 2008, and it continues to be a growing area. UV has concentrated its research on gene expression and detecting biological markers dealing with bacterial pathogens. UdeC has designed algorithms addressing molecular sequence analysis, while USACH has centred on phylogeny and structural bioinformatics, including docking and protein structure prediction.
3) *Bioinstrumentation / Biomedical Electronics*. This is an area that has been continuously worked on since 2008. UV and UdeC have extensively researched multiple bioinstrumentation and biomedical electronics applications. UV has published several studies on signal processing, designing, developing, and evaluating medical devices and healthcare instruments, including electroencephalographs, electromyographs, monitoring devices, plethysmographs, polysomnographs, servo-ventilators, spirometers, and simulators. On the other hand, UdeC has realised numerous studies on sensors, patient monitoring, wireless communication, and home-care devices with applications in the mining industry. USACH has the smallest group of researchers studying nausea in chemotherapy patients through electrogastrography signals and developing two devices: a neuromuscular blockade monitoring device and a breathing monitor.
4) *Biomaterials*. All universities have conducted research in the area since 2013. UV has investigated systems for disinfecting with ozonated water, developed algorithms for cancer prevention through microcalcification detection and studied biomimetics, contributing to regenerative and preventive medicine. UdeC has focused on synthesising nanoparticles for biosensors, imaging devices, and therapeutic agents. USACH has worked on biopolymers for sustainable packaging, materials engineering, and heavy metal removal technologies.
5) *Biomechanics*. The first works were published in 2008. UV has studied knee joint modelling, prosthetic design, and muscle mechanics to prevent injuries, enhance athletic performance, and aid patient rehabilitation. UdeC has created algorithms, sensors, and devices for non-invasive gait assessment, minimising expenses. USACH has researched movement mechanics for running to prevent injuries, analysed balance in sports disciplines, and evaluated the functional anatomy of the cardiovascular and pulmonary systems. The first two universities have included 3D printing in their work.
6) *Biomechatronics*. This area began in 2006 and has been worked on sporadically. UdeC has developed driving assistance systems involving interaction between the driver, the vehicle, and the environment. They also designed a 3D-printed myoelectric hand prosthesis that utilises muscle electrical signals for prosthesis movement control. Meanwhile, UV has designed a magnetic bearing system for suspended rotors with potential applications in the medical industry to minimise the risk of lubricant fluid contamination in sterile environments. USACH does not have publications in this area.
7) *Bioionics*. In this area, only UdeC published a manuscript in 2016. The authors proposed a DC/DC conversion strategy to improve bionic device longevity and effectiveness of electrical stimulators, leading to better patient outcomes and quality of life.
8) *Cellular and Tissue Engineering*. It appeared in 2012, and the three universities had worked sporadically. UV has researched disinfection, microfluidic plates, 3D cardiovascular tissue engineering, and white blood cell classification. UdeC has used thermal imaging for non-invasive skin cancer detection and white matter fibre segmentation. USACH has designed a hydrogel film with pH-responsiveness and micro-wrinkle surface patterns that showed excellent antibacterial properties.

Another study analysed the impact of cinaciguat on arterial wall mechanics in neonatal lambs under chronic hypoxia.

9) *Clinical Engineering*. Although it may seem like one of the oldest research areas, its first publications are from 2010. UV and UdeC have emphasised health safety, radiation protection, preventive maintenance, and public health management. USACH, on the other hand, has concentrated on optimising healthcare outcomes through technical efficiency evaluation and promoting healthcare systems and organisations.
10) *Medical Imaging*. This area, which appeared in 2007, has been the largest research focus at a country level and is constantly growing. UV and UdeC have significantly contributed to this area, advancing diagnostic and therapeutic techniques using various imaging modalities such as magnetic resonance images, radiography, computed tomography, and positron emission tomography. The applications of these techniques range from neuroimaging to breast and cardiovascular imaging and medical image segmentation. USACH has only one publication in this area, where authors created a 3D reconstruction model to evaluate respiratory function using computed tomography. This document has no keywords in the SCOPUS database.
11) *Medical Informatics*. Its first publications are from 2011. UV and UdeC have prioritised the development of hospital information systems, medical computing, and telemedicine. UV has also researched standard protocols for hospital data processing, such as HL7 (Health Level Seven). However, USACH has not yet contributed to this area, except for analysing large volumes of data for hospital technical efficiency assessments.
12) *Neural Engineering*. Although it is an area that appeared in 2004, few works have been published. It has received limited but growing research attention at the national level, with each university only a single publication. UV has worked on computational neuroscience, deep learning, and convolutional neural networks to develop stable classification models and address the stability-plasticity dilemma in connection models. UdeC has contributed by studying neuroimaging, neuroanatomy, and neuropathology in disorders such as bipolar and schizophrenia. USACH has also researched neuromuscular blocking agents in designing a low-cost monitoring device.
13) *Rehabilitation / Orthopaedic Bioengineering*. This is a post-2010 area which is growing in recent years. UV and UdeC have focused on research in physical and rehabilitation medicine, regenerative medicine and technology, including robotic rehabilitation devices. In contrast, USACH has not explored this area.
14) *Systems Physiology*. It is the oldest research area in the country, dating back to 2002 and continues to be one of the main research focus. UV has investigated physiological and electrophysiological processes using various methods such as biological models, signal processing, and nerve stimulation. The research has addressed diverse topics, including pathophysiology, blood analysis, psychophysiology, and physiological interactions. UdeC has also studied physiological processes using biological models and signal processing techniques, including nerve and electrical stimulation, for treating different diseases. USACH has focused on cerebral hemodynamics and autoregulation, aiming to understand dynamic cerebral autoregulation and pathophysiology associated with disorders such as Alzheimer's, Parkinson's, and stroke, among others, through developing biological models and signal processing techniques.

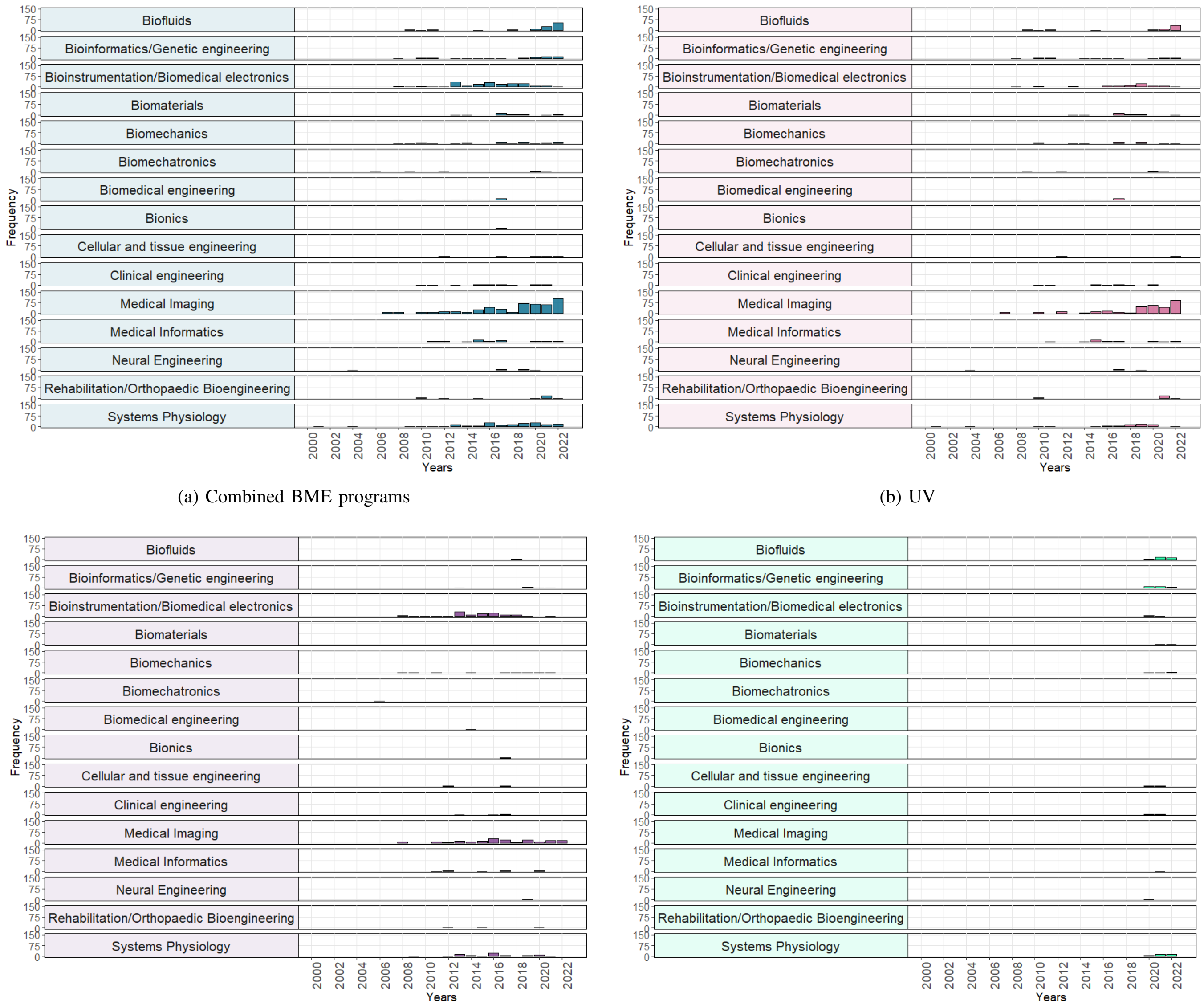
A group of relevant publications were not categorised in any area. They have covered education, curricular design and professional profile definition [7], [8], [10], [11], [43]–[46], contributing to undergraduate programs, including BME.

2) Collaboration Relationships: Fig. 5 shows the different relationships among universities and researchers based on the documents published between 2020 and 2022. We used two distance metrics to compare the sparse document-term matrix with the frequency of SCOPUS keywords of each document, Euclidean and Pearson correlation. The former measures the absolute difference between the production of the universities regarding keyword frequency, depending on the number of publications. In contrast, the latter measures the similarity between the research profiles of the universities based on the type of keywords used, and it is not affected by the number of publications. According to Figs. 5a and 5b, UV and USACH have a similar research profile regarding UdeC independent of the applied distance.

The dendrogram in Fig. 5c shows the relationships among researchers considering the three universities. Notably, UdeC is divided into two significant groups. The first includes researchers who frequently publish in BME (7101834722, 22950573600, 14631693800, 23028926500, 14036817700, and 7102732243), while the second one considers researchers whose research is not centred on this field. One author stands out from the other UdeC researchers (24766261300), having a research profile similar to UV focusing on medical imaging, closely with 6603616278.

UV is also divided into two groups. The former considers the majority of researchers who work on bioinstrumentation and medical imaging (57204948489, 13609644600, 55331777400, 23049450200, 8875435300,23476128900, 6603616278, and 57218456896). The second one comprises two researchers with a profile distant from all other researchers (57189046300 and 57545616900). This group also includes two USACH researchers (6506286421 and 57208341365).

The remaining USACH researchers, whose primary focus is systems physiology, biomaterials and biofluids, conform to a single group. The only author with a separate research profile is 55114462200, whose main BME research area is bioinformatics and clinical engineering. Since this researcher also has publications associated with sustainable energy is close to UdeC researchers.



(a) Combined BME programs

(b) UV

(c) UdeC

(d) USACH

Fig. 3. Frequency of SCOPUS keywords published by researchers representative from areas of BME between 2000 and 2022.

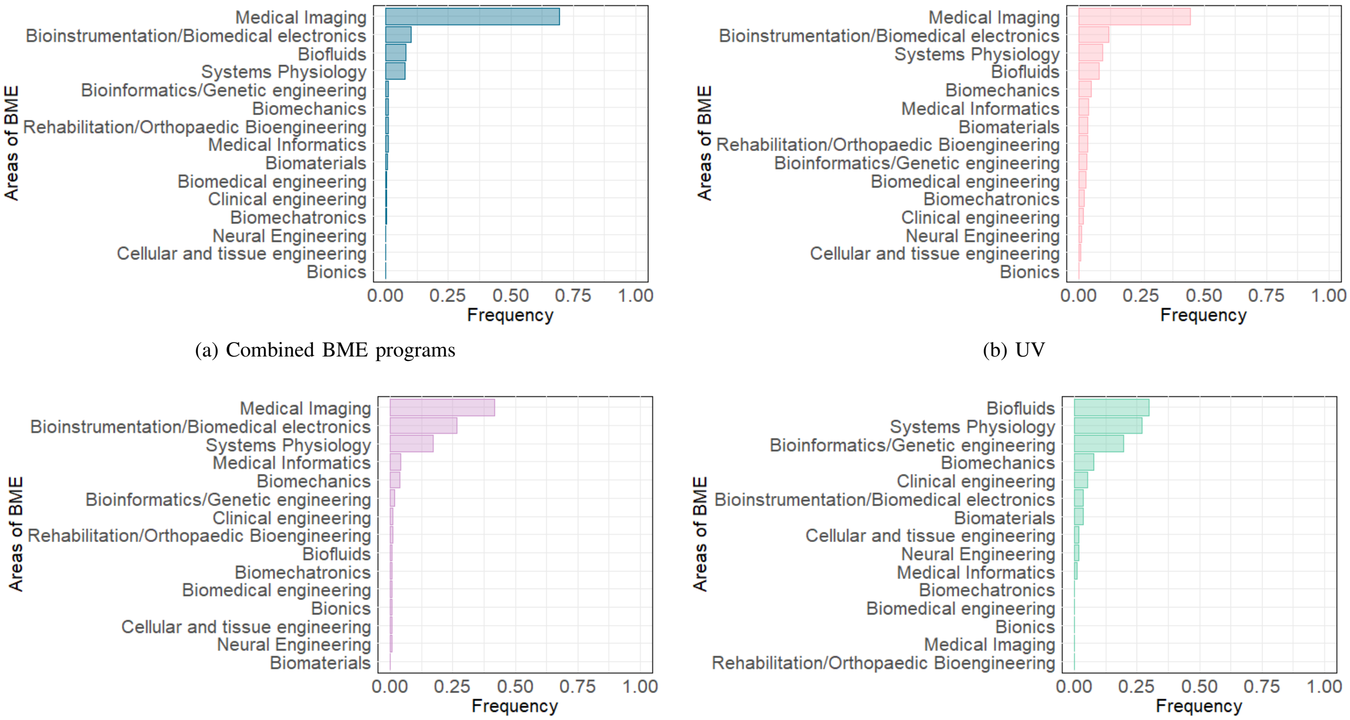
Fig. 6 shows a graph with the collaborative relationships between researchers from the three universities based on their publications from 2000 to 2022. The edges of the graph represent joint publications, with their thickness reflecting their frequency. Despite many collaborations between authors within universities, only two inter-university collaborations associated with nodes 53 (55114462200) and 22 (57208341365) have been performed. Researchers whose nodes present dotted lines do not have publications.

Concerning intra-collaboration relationships (IR), it is important to note that they have consistently grown over time ($IR = 2.0340 \times year - 4062.08$). At the same time, publications in this area show a strong correlation, with a Pearson coefficient of 0.71 ($p < 0.05$ for all coefficients).

V. Discussion

Based on performance metrics, UdeC is leading the BME research in Chile, with high total publications, average publications per author, and contributing authors (see Tables I and II). However, it is essential to consider that many UdeC BME researchers also research other fields, such as sustainable energy, electrical engineering, and electronics, since most participate in other undergraduate programs related to these areas, conforming to the Departamento de Ingeniería Eléctrica. When we consider BME research specifically, the production drops to around 17% for UdeC researchers. Interestingly, the advisory committee members of the program mentioned on the UdeC website are among the top contributors to BME research.

The analysis of keywords, publication abstracts, and research areas suggests UV has significantly impacted BME research in Chile. While initially, research concentrated on



(a) Combined BME programs

(b) UV

(c) UdeC

(d) USACH

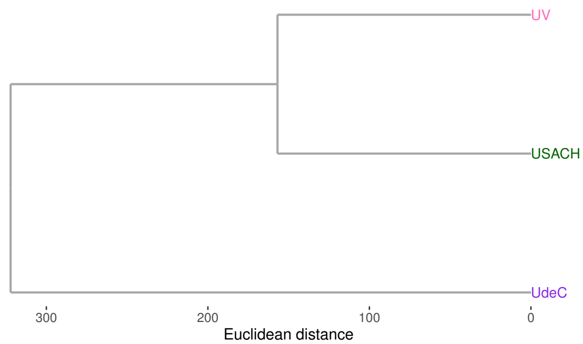
Fig. 4. Frequency of SCOPUS keywords published by researchers representative from areas of BME.

systems physiology, bioinstrumentation, and medical imaging, the UdeC BME program establishment in 2006 helped advance these areas (see Figs. 3 and 4). Subsequently, new research areas have emerged, such as biofluids, bioinformatics/genetic engineering, biomaterials, biomechanics, biomechatronics, clinical engineering, medical informatics, and rehabilitation/orthopaedic bioengineering. USACH researchers have been essential in advancing systems physiology, bioinformatics/genetic engineering, and biomechanics. While bioinstrumentation, medical imaging, and systems physiology remain primary focus areas nationally, other areas, including biofluids, bioinformatics/genetic engineering, biomechanics, neural engineering, and rehabilitation/orthopaedic bioengineering, have shown significant growth potential and promise for future research and development.

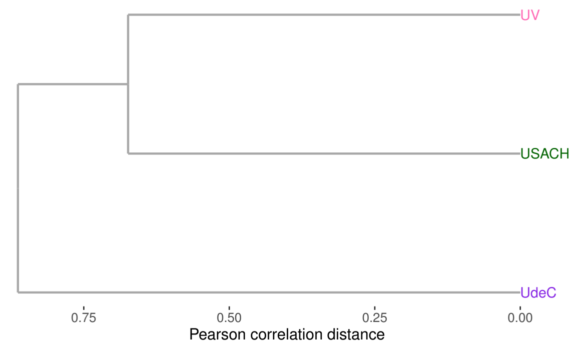
Interestingly, current Chilean BME research is aligned with worldwide Biomedical Engineering 2.0 initiatives [47], which are focused on interdisciplinary advancements, and emphasise the role of global and local networks in terms of research and innovation. Future BME research in Chile could prioritise emerging technologies like artificial intelligence and biotechnology to address the healthcare needs of the country. For instance, this could involve implementing telemedicine for remote areas, exploring personalised medicine for specific populations, and investigating environmental health issues related to industrial areas or pollution. Additionally, it is crucial to address disruptive challenges like earthquakes, fires, social changes, and emerging diseases. Despite the particular context of Chile, BME research in these areas remains limited.

The review of research profiles reveals a discrepancy between the research areas of university researchers and their professional specialisations. While UV researches medical informatics and bioinstrumentation, its primary focus is medical imaging, with little emphasis on clinical engineering and healthcare administration. Similarly, research areas from UdeC include bioengineering and medical equipment, but clinical engineering and medical informatics research is limited. In contrast, USACH has minimal research in bioinstrumentation/biomedical electronics, clinical engineering, and medical informatics, a crucial part of its curriculum. This may be because USACH has a relatively new program, and other areas will be developed in the future. To address these non-covered areas, the universities could benefit from employing faculty members from other departments or recruiting specialised instructors to complement their program of study.

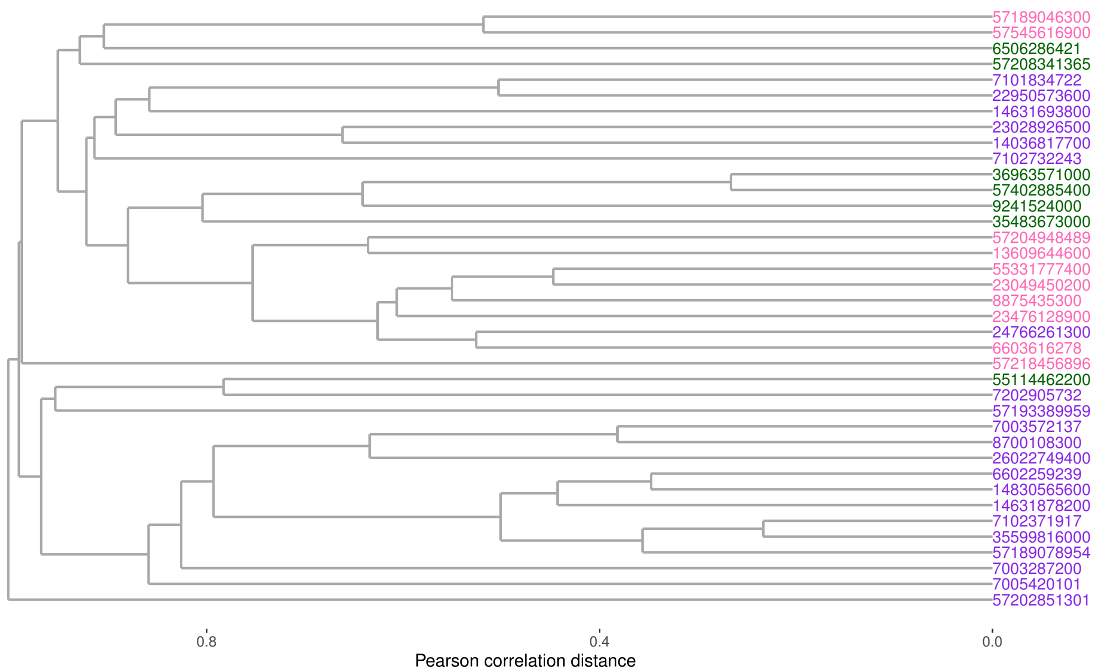
The analysis of research profiles also shows that UV is very similar to UdeC concerning USACH when only researchers who publish in BME are considered (see Fig. 5). However, UdeC distances itself from the rest of the universities, regardless of the distance measure used when all the publications are considered. Regarding the evaluation of similarity between researchers, it is interesting to note the existence of clearly defined groups mainly composed of researchers from the same university. Although some researchers are grouped with others from different universities, there is no interaction between them through publications (see Fig. 6). Only two inter-university



(a) Hierarchical clustering among universities considering the Euclidean distance.



(b) Hierarchical clustering among universities considering the correlation distance.



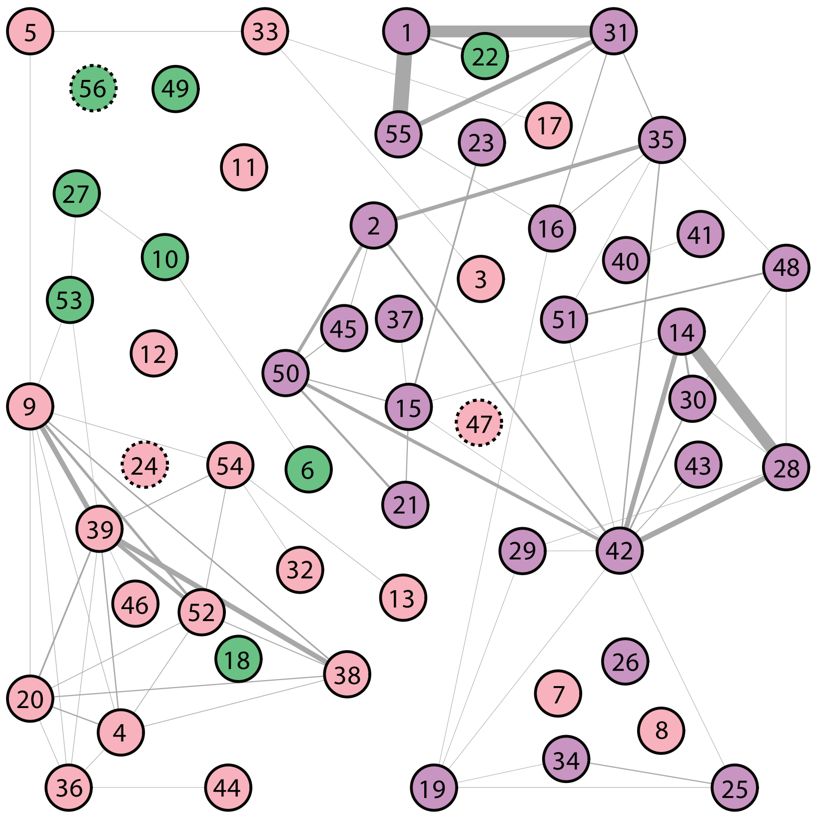
(c) Hierarchical clustering among authors considering correlation distance. Colours represent affiliation to each university.

Fig. 5. Dendrograms for universities and researchers based on Euclidean distances and correlation among keywords from their publications (2020-2022).

collaborations have been performed with nodes 53 (55114462200) and 22 (57208341365). However, these USACH researchers contributed to these works while still students at other universities instead of researchers, so these collaborations do not count towards their research output. Hence, despite the common BME research areas among universities in a small country, there is no inter-university work but growing intra-collaboration relationships.

Although we used a standard methodology, several aspects still require further refinement for future bibliometric analyses. Our study was limited to researchers affiliated with undergraduate BME programmes. We did not consider other universities with similar programmes, including UAI, UTalca, UCM and DUOC, postgraduate, or numerous other groups and researchers who contributed to BME from different fields and could have enhanced our analysis. Although some groups, such as the Biomedical Imaging Center at the Pontificia Universidad Católica de Chile, the Biomedical Engineering Laboratory at the Universidad de Chile, or the Biomedical Informatics Laboratory at USACH, are well-known, many smaller or independent research groups are challenging to identify and include in this kind of analysis.

Our methodology also considered qualitative aspects, which are not bias-free: defining and assigning keywords to BME areas and evaluating abstracts. For instance, we only considered one area per BME keyword, even though some could have fit into multiple categories. This could be addressed using artificial intelligence tools like ChatGPT over keywords or abstracts. However, in previous experiments, we were unsuccessful in adequately characterising documents into the different BME areas,



1	14036817700	29	14830565600
2	26022749400	30	7102371917
3	57545616900	31	23028926500
4	57203457251	32	18435273600
5	36157731300	33	57189046300
6	55391702400	34	6602259239
7	36717384300	35	8700108300
8	57218456896	36	6506521567
9	23049450200	37	57193389959
10	36963571000	38	13609644600
11	57197180823	39	8875435300
12	25654915600	40	7102692198
13	6603616278	41	7401636823
14	35599816000	42	7003572137
15	7102732243	43	56251299300
16	14631693800	44	57215525212
17	56563022900	45	6504152555
18	35483673000	46	55331777400
19	14631878200	47	1
20	55281257500	48	7005420101
21	22950573600	49	6506286421
22	57208341365	50	7101834722
23	24766261300	51	35563978200
24	2	52	23476128900
25	7202905732	53	55114462200
26	57202851301	54	57204948489
27	9241524000	55	7003287200
28	57189078954	56	57442094800

Fig. 6. Graph with relationships between co-authors according to the number of works published between 2000 and 2022 (Davidson-Harel layout algorithm). The edge width is proportional to the number of publications. Authors with dotted line nodes have no published documents during the period. The colours represent affiliation to each university: UV (pink). UdeC (purple) and USACH (green). The authors are listed based on their SCOPUS IDs, except for 1 and 2, who have not published any works. Details can be found in Section **??**, Supplementary Material.

resulting in many false positives erroneously classified as BME works.

Future research can also consider the scientific products generated by theses and dissertations of these universities as part of the analysis, which can add value to the study and provide a broader perspective on BME research in Chile.

VI. Conclusion

In this work, we conducted a comprehensive bibliometric analysis using data from the SCOPUS database to evaluate research publications associated with Chilean undergraduate BME programs from 2000 to 2022: UV, UdeC and USACH.

The results indicate that BME research areas in Chile initially focused on bioinstrumentation/ biomedical electronics and systems physiology but later expanded to include medical imaging, clinical engineering, and biomechanics. In recent years, new areas such as biofluids, bioinformatics/ genetic engineering, bionics, neural engineering, and rehabilitation/ orthopaedic bioengineering have emerged. While each university has a different research focus, UV has played a significant role in defining the research areas at the country level. UdeC has the most extensive scientific production, but most of this work is not focused on BME. Meanwhile, USACH, which has a newly established program, has contributed to diversifying the research areas.

Interestingly, the results also showed that there is no inter-university collaboration. Hence, this work constitutes the first collaboration between the three universities.

Despite the promising results, the current bibliometric analysis can be improved in future work, incorporating university researchers with complementary programs to BME and research centres or laboratories. Additionally, other types of scientific products can be incorporated, for example, thesis, project or other non-indexed publications. This study could also focus on author relationships identifying new institutions or areas regarding BME. Also, the methodology could be enhanced using natural language processing algorithms based on artificial intelligence to study the abstract and minimise the bias associated with qualitative analysis. This work not only offers crucial insights into BME research in Chile, providing a roadmap for future research collaboration and guiding students in introductory BME courses but also emphasises the importance of expanding BME horizons through advanced technologies and cross-disciplinary collaborations to enhance healthcare innovations.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualisation, M.V.C.; methodology, J.V.S. and M.V.C; software, J.V.S. and M.V.C; validation, J.V.S., J.S., R.F., and M.V.C; formal analysis, J.V.S., J.S., R.F., and M.V.C; investigation, J.V.S. and M.V.C; resources, M.V.C; data curation, J.V.S. and M.V.C; writing—original draft preparation, J.V.S. and M.V.C; writing—review and editing, J.V.S., J.S., R.F., and M.V.C; visualisation, J.V.S. and M.V.C; supervision, M.V.C.; project administration, J.V.S. and M.V.C; funding acquisition, J.V.S. and M.V.C. All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] A. Houssein, A. K. Lefor, A. Veloso, Z. Yang, J. C. Ye, D. I. Zeugolis, and S. Y. Lee, "BMC biomedical engineering: a home for all biomedical engineering research," *BMC Biomedical Engineering*, vol. 1, no. 1, 2019.

[2] L. M. Bui, H. Thi Thu Phung, T.-T. Ho Thi, V. Singh, R. Maurya, K. Khambhati, C.-C. Wu, M. J. Uddin, D. M. Trung, and D. T. Chu, "Recent findings and applications of biomedical engineering for COVID-19 diagnosis: a critical review," *Bioengineered*, vol. 12, no. 1, pp. 8594–8613, 2021.

[3] A. Zbiciak and T. Markiewicz, "A new extraordinary means of appeal in the polish criminal procedure: the basic principles of a fair trial and a complaint against a cassatory judgment," *Access to Justice in Eastern Europe*, vol. 6, no. 2, pp. 1–18, 2023.

[4] M. Javaid, A. Haleem, R. P. Singh, and R. Suman, "Sustaining the healthcare systems through the conceptual of biomedical engineering: A study with recent and future potentials," *Biomedical Technology*, vol. 1, pp. 39–47, 2023.

[5] R. A. Linsenmeier and A. Saterbak, "Fifty years of biomedical engineering undergraduate education," *Annals of Biomedical Engineering*, vol. 48, no. 6, pp. 1590–1615, 2020.

[6] C. D. Maria, A. D. Lantada, T. Jämsä, L. Pecchia, and A. Ahluwalia, "Biomedical engineering in low- and middle-income settings: analysis of the current state, challenges and best practices," *Health and Technology*, vol. 12, no. 3, pp. 643–653, 2022.

[7] R. Allende, D. Morales, G. Avendano, and S. Chabert, "Biomedical engineering undergraduate education in latin america," *Journal of Physics: Conference Series*, vol. 90, p. 012019, 2007.

[8] G. Avendaño and A. Rienzo, "Programs in biomedical engineering education: How to improve it," in *VII Latin American Congress on Biomedical Engineering CLAIB 2016, Bucaramanga, Santander, Colombia, October 26th -28th, 2016*, pp. 741–744, Singapore: Springer Singapore, 2017.

[9] J. Azpiroz-Leehan, F. Martínez-Licona, E. G. Urbina-Medal, M. Cadena M., and E. Sacristán Rock, "Biomedical engineering in latin america: A survey of 90 undergraduate programs," in *VII Latin American Congress on Biomedical Engineering CLAIB 2016, Bucaramanga, Santander, Colombia, October 26th -28th, 2016*, pp. 106–109, Singapore: Springer Singapore, 2017.

[10] G. E. Avendaño, "Análisis crítico sobre la formación en ingeniería biomédica," in *V Latin American Congress on Biomedical Engineering CLAIB 2011 May 16-21, 2011, Habana, Cuba*, pp. 377–380, Berlin, Heidelberg: Springer Berlin Heidelberg, 2013.

[11] G. A. Cervantes and A. R. Renato, "Degree models in biomedical engineering," *Revista Ingeniería Biomédica*, vol. 11, no. 22, 2017.

[12] S. Salas and A. Rigotti, "Médicos-centíficos en chile: ¿una especie en extinción?," *Revista médica de Chile*, vol. 133, no. 1, 2005.

[13] S. Salas and M. Russo, "Transparencia en la investigacón biomédica: A propósito de los riesgos asociados al uso de avandia," *Revista médica de Chile*, vol. 138, no. 9, 2010.

[14] G. Valdés, R. Armas, and H. Reyes, "Principales características de la investigación biomédica actual, en chile," *Revista médica de Chile*, vol. 140, no. 4, pp. 484–492, 2012.

[15] G. Valdés, F. Pérez, and H. Reyes, "Análisis de las publicaciones biomédicas chilenas indizadas en PubMed, en los años 2008 y 2009," *Revista médica de Chile*, vol. 143, no. 8, pp. 979–986, 2015.

[16] Ítalo Bavestrello and Y. Carvajal, "Inversión en tecnología: el rol de la ingeniería biomédica en salud pública - investment in technology: the role of biomedical engineering in public health," *Revista médica de Chile*, vol. 147, no. 12, pp. 1632–1633, 2019.

[17] J. Ríos, E. Alcalde, E. Ramírez, M. Campbell, T. P. Labbé, S. Becerra, S. Santander, and M. E. Cabrera, "Una red de biobancos para chile: investigar hoy, para curar mañana," *Revista médica de Chile*, vol. 147, no. 7, pp. 901–909, 2019.

[18] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," *Journal of Business Research*, vol. 133, pp. 285–296, 2021.

[19] S. K. M. Brika, A. Algamdi, K. Chergui, A. A. Musa, and R. Zouaghi, "Quality of higher education: A bibliometric review study," *Frontiers in Education*, vol. 6, 2021.

[20] J. A. Jończyk, A. M. Olszewska, and K. Jończyk, "Application of bibliometric analysis in the research of scientific publications on the quality management of medical services," *Studies in Logic, Grammar and Rhetoric*, vol. 56, no. 1, pp. 143–159, 2018.

[21] J. Bansard, M. Kerbaol, and J. Coatrieux, "A look at...an analysis of IEEE publications in biomedical engineering," *IEEE Engineering in Medicine and Biology Magazine*, vol. 25, no. 5, pp. 6–12, 2006.

[22] J. A. E. Spaan, "Biomedical engineering and bibliometric indices for scientific quality," *Medical & Biological Engineering & Computing*, vol. 47, no. 12, 2009.

[23] E. Zarrabeitia-Bilbao, I. Alvarez-Meaza, R.-M. Río-Belver, and G. Garechana-Anacabe, "Additive manufacturing technologies for biomedical engineering applications: Research trends and scientific impact," *El Profesional de la Información*, vol. 28, no. 2, 2019.

[24] Y.-S. Ho, "Highly cited publications in WoS, biomedical engineering in science citation index expanded a bibliometric analysis," *Biomedicine and Chemical Sciences*, vol. 1, no. 1, pp. 24–34, 2022.

[25] H. Fu, X. Jing, J. Lin, L. Wang, H. Jiang, B. Yu, and M. Sun, "Knowledge domain and hotspots analysis concerning applications of two-photon polymerization in biomedical field: A bibliometric and visualized study," *Frontiers in Bioengineering and Biotechnology*, vol. 10, 2022.

[26] A. Steiner, J. Barros, G. Henríquez, H. Sandoval, L. Valenzuela, A. Vergara-Fernandez, and C. Villagrán, *Ingeniería Biomédica - Nuevos desarfíos para la ingeniería nacional*. Santiago: Instituto de Ingenieros de Chile, 09 2020.

[27] J. L. Ruiz-Real, J. Uribe-Toril, J. D. P. Valenciano, and J. C. Gázquez-Abad, "Worldwide research on circular economy and environment: A bibliometric analysis," *International Journal of Environmental Research and Public Health*, vol. 15, no. 12, p. 2699, 2018.

[28] W. Malpica-Zapata, M. Gómez-Caicedo, and Álvaro Villa-Martínez, "Estudio sobre la investigación en marketing y su importancia en los procesos de exportación: análisis bibliométrico y temático en scopus," *Revista Perspectiva Empresarial*, vol. 8, no. 2, pp. 91–103, 2021.

[29] M. Kumar, R. George, and P. Anisha, "Bibliometric analysis for medical research," *Indian Journal of Psychological Medicine*, p. 025371762211036, 2022.

[30] A. Kemeç and A. Tarakcıoglu-Altınay, "Sustainable energy research trend: A bibliometric analysis using VOSviewer, RStudio bibliometrix, and CiteSpace software tools," *Sustainability*, vol. 15, no. 4, p. 3618, 2023.

[31] A. Kaya and Z. Hatunoğlu, "Publications on accounting standards in web of science database: A bibliometric analysis," *Muhasebe Bilim Dünyası Dergisi*, 2022.

[32] A. Desai and C. Patel, "Review of global research on e-mobility: A bibliometric analysis," *Communications - Scientific letters of the University of Zilina*, 2022.
[33] H. Wickham, *ggplot2 - Elegant Graphics for Data Analysis*, 2016.
[34] H. Wickham, R. François, L. Henry, and K. Müller, *dplyr: A Grammar of Data Manipulation*, 2018.
[35] Y. Xie, J. Cheng, X. Tan, and A. Pickering, *A Wrapper of the JavaScript Library DataTables*, 2023.
[36] H. Wickham, *Tidy Messy Data*, 2023.
[37] K. Benoit, K. Watanabe, H. Wang, P. Nulty, A. Obeng, S. Müller, and A. Matsuo, "quanteda: An r package for the quantitative analysis of textual data," *Journal of Open Source Software*, vol. 3, no. 30, p. 774, 2018.
[38] M. Aria and C. Cuccurullo, "bibliometrix: An r-tool for comprehensive science mapping analysis," *Journal of Informetrics*, vol. 11, no. 4, pp. 959–975, 2017.
[39] W. Chang, J. Cheng, J. Allaire, C. Sievert, B. Schloerke, Y. Xie, J. Allen, J. McPherson, A. Dipert, and B. Borges, *shiny: Web Application Framework for R*, 2023. R package version 1.7.4.9002.
[40] M. Levin-Epstein, ed., *Careers in Biomedical Engineering*. San Diego, CA: Academic Press, 2019.
[41] C. Bota-Avram, "Bibliometric analysis of sustainable business performance: where are we going? a science map of the field," *Economic Research-Ekonomska Istraživanja*, vol. 36, no. 1, pp. 2137–2176, 2022.
[42] N. O. D. Ellili, "Bibliometric analysis of sustainability papers: Evidence from environment, development and sustainability," *Environment, Development and Sustainability*, 2023.
[43] M. Villalobos-Cid, M. Orellana, O. C. Vásquez, E. Pinto-Sothers, and M. Inostroza-Ponta, "Dealing with the balanced academic curriculum problem considering the chilean academic credit transfer system," in *2019 38th International Conference of the Chilean Computer Science Society (SCCC)*, pp. 1–7, 2019.
[44] L. Huallcca, G. Madrid, J. Mellado, D. Vega-Araya, and M. Villalobos-Cid, "An informatics tool for class-to-class planning and academic-load evaluation," in *2020 39th International Conference of the Chilean Computer Science Society (SCCC)*, pp. 1–5, 2020.
[45] F. A. Bello, J. Kóhler, K. Hinrechsen, V. Araya, L. Hidalgo, and J. L. Jara, "Using machine learning methods to identify significant variables for the prediction of first-year informatics engineering students dropout," in *2020 39th International Conference of the Chilean Computer Science Society (SCCC)*, pp. 1–5, 2020.
[46] D. O. Granados, J. Ugalde, R. Salas, R. Torres, and J. L. López-Gonzales, "Visual-predictive data analysis approach for the academic performance of students from a peruvian university," *Applied Sciences*, vol. 12, no. 21, p. 11251, 2022.
[47] M. I. Miller, A. O. Brightman, F. H. Epstein, K. J. Grande-Allen, J. J. Green, E. Haase, C. T. Laurencin, E. Logsdon, F. Mac Gabhann, B. Ogle, C. Wang, G. R. Wodicka, and R. Winslow, "Bme 2.0: Engineering the future of medicine," *BME Frontiers*, vol. 4, 2023.

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