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Medical informatics and biophysics in medical universities of European countries: A systematic review and meta-analysis

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ABSTRACT

Aims: This systematic review aims to assess the prominence of medical informatics and biophysics in European medical schools, recognizing the growing importance of technology in healthcare.

Methodology: A comprehensive search of Medline and PubMed databases was conducted by employing MeSH terms and relevant keywords following PRISMA guidelines.

Results: The review reveals limited body of research on this topic, with 41 relevant studies identified. These studies underscore the value of medical informatics and biophysics in medical education. They emphasize the necessity of certification and reveal variations in curricula and training across European nations.

Scientific novelty: This study contributes to existing literature by highlighting the scarcity of research on subject.

Conclusions: The findings emphasize the significance of incorporating medical informatics and biophysics into medical education across European nations. Standardization, international guidelines, and accreditation procedures are imperative to ensure the competence of healthcare professionals in utilizing technology and information systems effectively.

Keywords: medical informatics, biophysics, medical education, curriculum

INTRODUCTION

Research Problem

Nowadays healthcare industry depends more and more on auxiliary information systems. It has moved its attention to technical applications and evolved into an information-intensive environment. As a result of this change in emphasis, efforts should be taken to ensure that upcoming healthcare professionals are ready for it. Whereas the science of collecting, storing, and utilizing medical information in healthcare is the subject of the newly growing field of medical informatics [1, 2]. The goal of medical informatics is to provide access to vital patient medical data at the exact moment and location needed to make medical decisions. The administration of medical data for research and teaching is a key component of medical informatics. The field of clinical informatics centers around data innovation that empowers proficient information gathering using mechanical apparatuses to propel clinical comprehension and smooth out persistent treatment [3-5].

The progress of natural sciences, particularly biology, physics, and chemistry, is directly linked to the advancement of contemporary healthcare. One of the interbranch sciences, biophysics, emerged at the intersection of the physical and biological sciences. An interdisciplinary field of science called biophysics examines the energetics, structures, and functions of biological things using physical methodologies and techniques [6]. The study of the basic processes by which diverse physical elements affect human health is a component of biophysics; it focuses on the physiological and pathological symptoms of the organism and the corresponding concepts of diagnosis and therapy [7-10]. Therefore, understanding that is essential for aspiring healthcare professionals.

To help future doctors develop a scientific perspective of a living organism and the activities taking place inside it, medical universities must teach biophysics. Also, it shows physical and chemical basis of biological events and aids students in understanding the fundamentals of contemporary physical and biophysical approaches. The domains of bioenergetics, biomechanics, bioacoustics, and bio electrodynamics, which are crucial for medical diagnosis and treatment, are connected to biophysics. In order for future doctors to comprehend the physical and chemical nature of biological events and to use this knowledge in medical practice, integrative teaching of biophysics in medical school is essential [11-14].

There is a need for a comprehensive understanding and integration of medical informatics and biophysics in the curriculum to better prepare future healthcare professionals for evolving information-intensive healthcare environment. The research seeks to identify the extent of coverage, potential deficiencies, and areas for improvement in the education of these critical domains in European medical schools.

Research Focus

It was reviewed the history of medical informatics in Europe from the 1960s to the present and emphasized the key turning points in this field's growth [15]. The review is broken down into three main sections: the history of medical informatics from its inception to its most recent development. Pioneering work in signal analysis, laboratory applications, decision assistance, databases, modelling and simulation of biological processes, and biostatistics characterized the early years. During the time of expansion and consolidation, numerous national and international organizations, conferences, and efforts to organize the field were founded. Electronic health records, telemedicine, and mobile health apps are being used more often than ever, and new problems with data privacy, security, and interoperability are starting to develop.

Similar to this, it was emphasized the significance of medical informatics in tackling significant issues facing healthcare systems and propelling advancements in healthcare [16]. His research focuses on the function of medical informatics in e-health, one of the most active fields in terms of both scientific and commercial activity. In contrast, medical informatics as a distinct scientific field started to take off at academic institutions at the end of the 1970s as a result of the presentation of real successes in this field in undergraduate and graduate programs at biomedical schools [17].

International Medical Informatics Association's (IMIA) advice on education in biomedical and health informatics was emphasized by [18]. The report gives a more exhaustive rundown of suggestions, which incorporates rules for program certification, a structure for creating biomedical and wellbeing informatics instruction educational programs, and proposals for instructive course parts and student responsibility rates for every information space.

In addition, "medical and biological physics" is studied in the first year of study in medical universities. It helps future doctors develop a scientific understanding of living things and the processes that take place inside them, explores the fundamentals of contemporary physical and biophysical approaches, and demonstrates the physical and chemical basis of biological phenomena. However, the outcomes of theoretical and empirical study on the issues of continuity and interaction are underutilized in the practice of teaching medical and biological physics. It was suggested that in order to promote interactive learning when studying biophysics, the teacher and students should engage in active conversation during the course [19].

Research Aims & Research Questions

The objective of the current study is to compile recent data on the status of medical informatics and biophysics education in European medical universities. The research aims to investigate the role of biophysics in modern medical diagnosis and therapy, emphasizing the application of physical and biophysical techniques. Additionally, the study intends to explore the potential connection between biophysics and medical informatics and how integrating these subjects in medical education could enhance the overall learning experience. In summary, the research seeks to shed light on the importance of medical informatics and biophysics in European medical colleges and their relevance to contemporary medical practice.

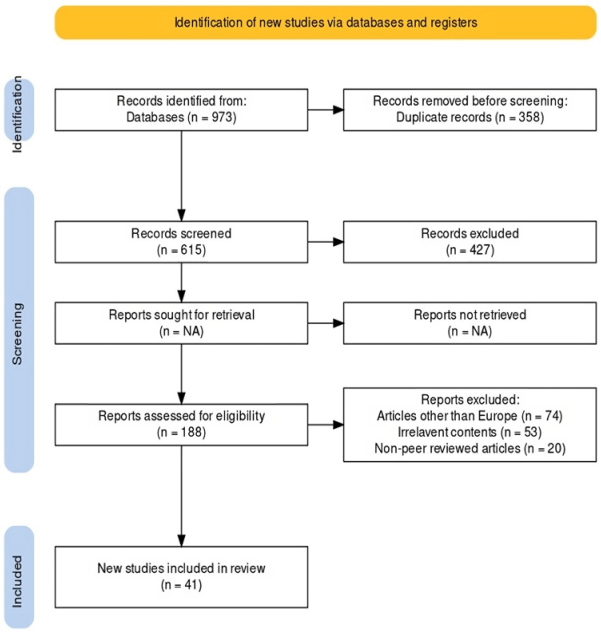

Figure 1. PRISMA flowchart for choosing appropriate literature for systematic review (Source: Author's own elaboration)

METHODS

Search Strategy

Online literature databases such as Medline and PubMed were searched for pertinent English-language full-text papers published after September 2023. A search strategy that considers all relevant publications was developed by incorporating terms from the MeSH and keywords from relevant literature. The search criteria were "Europe OR European counties" and "Medical Informatics OR Health Informatics" and "biophysics" and "Medical University or Health education." The reference lists of the articles that were incorporated were cross-referred to track down other appropriate examination. This examination was done as per PRISMA guidelines (**Figure 1**) [20].

Criteria for Inclusion & Exclusion of Studies

Studies could only be included if they met the inclusion requirements. The distributions' titles and modified works were independently evaluated by the creators to view as any that would be reasonable for a full-text survey. The entire text evaluation was conducted using the same procedure. Lastly, personally reviewing reference lists from included publications to locate other, potentially relevant research (**Table 1**).

Data Extraction & Analysis

The data extraction process involved the independent collection of information by the authors, encompassing details such as the author's name, publication year, study population, research design, and conclusions. In instances, where discrepancies arose between the two reviewers during data collection, attempts were made to reconcile differences using the original articles as a guide. If a consensus could not be reached, a third reviewer was brought in to adjudicate. The data was extracted in Microsoft Excell and analyzed by the authors.

Table 1. Criteria for inclusion & exclusion of studies in systematic review

Inclusion criteria	Exclusion criteria
Studies on medical informatics & biophysics in medical universities of European countries	Anything excluding recorded subjects on medical informatics & biophysics in medical universities of European countries
Peer-explored research with a wide range of study plans (for example, quantitative, subjective, & blended strategies)	Something besides peer-evaluated articles & writing, for example, reviews, web pages, books, etc.
Research conducted in English	Publications in other languages

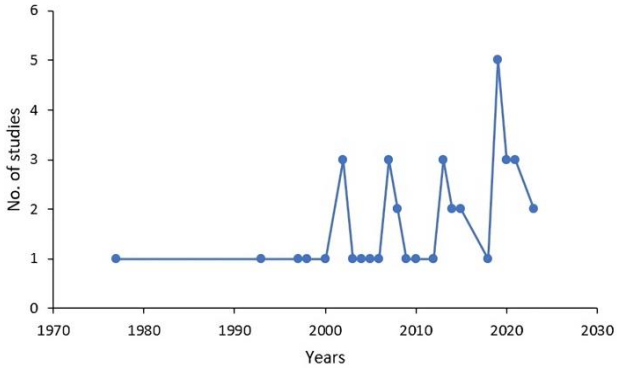

Figure 2. Year-wise distribution of selected studies (Source: Author's own elaboration)

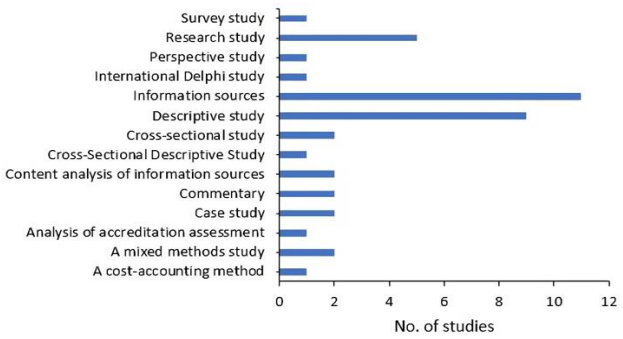

Figure 3. Distribution of selected studies on study design (Source: Author's own elaboration)

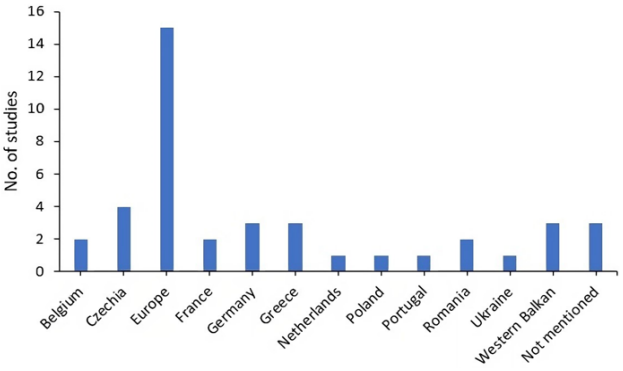

Figure 4. Country-wise distribution of selected studies (Source: Author's own elaboration)

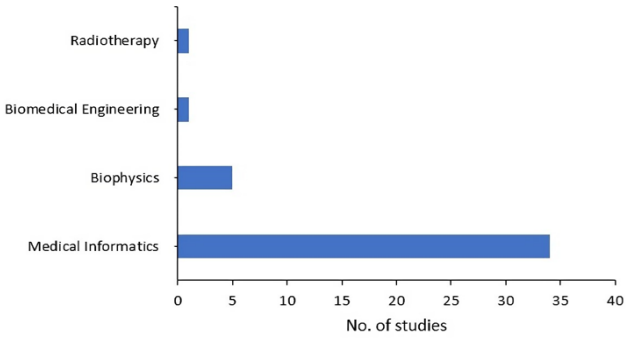

Figure 5. Distribution of selected studies on field of study (Source: Author's own elaboration)

RESULTS

A total of 973 articles were found after the initial search, which resulted in the deletion of 358 duplicate items. After looking at their titles and abstracts, 427 publications were removed from the study. 188 articles that were still in were carefully reviewed and then put through extra screening based on research.

41 publications containing research on medical informatics and biophysics in medical universities in European nations were included in the study and were determined to be appropriate (**Figure 1**).

The selected studies were from 1977 to 2023. Most of the studies were published in after 2000 as presented in **Figure 2**.

The selected studies used various study designs. The most of the studies used information sources as study design followed by descriptive study design and research studies as presented in **Figure 3**.

Further, the country-wise or area wise distribution of selected studies showed that all studies were from various countries as presented in **Figure 4**.

Further, distribution of selected studies based on studied subject has been as presented in **Figure 5**.

The data from selected studies were extracted and presented in **Table 2**.

Table 2. Characteristics & findings of selected studies

R	Year	SD	SAP	Key findings/implications
[18]	2023	International Delphi study	European Union Horizon	In area of biomedical & health informatics, it makes Suggestions for targeted undergraduate & graduate studies. IMIA can certify reputable biomedical & health informatics education curricula. It also encourages information sharing on courses and programs in biomedical and health informatics through its Working Group on Health and Medical Informatics Education.
[21]	2014	Information sources	France	Francois Gremy made notable contributions to medical informatics. He established IMIA in 1967 & helped found EFMI. Gremy's impact spanned from hard sciences to clinical medicine, earning him recognition as a philosopher in field of medical informatics.
[22]	2014	Information sources	France	Francois Gremy was a pivotal figure in evolution of medical informatics. It delves into his life & achievements, highlighting his instrumental role in founding IMIA. Gremy was also a pioneer in establishing a curriculum centered on medical uses of computing. Also, he was a driving force behind formation of EFMI.

Table 2 (Continued). Characteristics & findings of selected studies

R	Year	SD	SAP	Key findings/implications
[23]	2015	A cost-accounting method	Belgium	HERO project aims to create a costing model that offers precise cost data for radiotherapy resources. This model considers resources available, cancer epidemiology, & specific radiotherapy practices within various European countries. To achieve this, project employs time-driven activity-based costing, a specialized cost-accounting approach designed to accurately capture complexity & variability of radiotherapy services.
[24]	2008	Cross-sectional study	Poland	It provides an overview of history and current status of medical physics and biomedical engineering education in Poland. In the academic year 2007/2008, there were 14 universities offering medical physics as a specialized program, and 6 universities of technology offering biomedical engineering studies as a distinct discipline in Poland. This information highlights the availability and distribution of educational programs in these fields within the country during that period.
[25]	2003	Research study	NA	This paper discusses the relationship between biophysical stimuli and cellular responses in the context of bone fracture healing. It also explores the potential and limitations of various experimental models for assessing and improving non-invasive interventions in this area. The paper emphasizes the importance of technological advancements, including the ability to deliver focused stimuli with adjustable signal characteristics and intensity. Additionally, non-invasive monitoring of healing callus mechanical properties and the development of a comprehensive knowledge base for creating effective and dependable treatment protocols are identified as crucial prerequisites to establish biophysical stimulation as a widely accepted approach in healthcare.
[26]	2002	Information sources	NA	Biomedical informatics encounters significant challenges related to its infrastructure. These challenges encompass the creation of data models and databases for storing biomedical data, the integration of this data with external databases, the extraction of valuable information from unstructured natural language text, and the critical task of safeguarding databases containing sensitive information. These infrastructure-related hurdles are central to the effective management and utilization of biomedical data for research, healthcare, and privacy protection.
[27]	1977	Descriptive study	Germany	The author estimates that in the future, there will be an average of around 50 positions annually for medical computer scientists in Germany, including Berlin (West). Additionally, the text emphasizes the need for the development and organization of curricula for further qualifications and refresher courses for individuals already involved in the field of medical informatics.
[28]	2009	Research study	Ukraine	The National Medical University in Kiev is proactively enhancing its curriculum to equip its students with the skills and knowledge needed to navigate the evolving medical landscape. This involves incorporating the modern technology and interdisciplinary approaches into their education. The university's efforts aim to not only benefit its students but also to bolster the healthcare in Ukraine. By producing the well-trained professionals and fostering the creation of the medical equipment meeting the international standards, these initiatives the promise to contribute significantly to the advancement of healthcare within the country.
[29]	2007	Information sources	Belgium	Telemedicine, a product of modern changes in our world, represents a convergence of traditional healthcare and information technology. It encompasses a wide array of services. This approach offers a practical means to deliver both regular and specialized healthcare services, with the capacity to enhance access to care and elevate the quality of healthcare provided.
[30]	2021	Survey study	Netherlands	European Federation of Organizations for Medical Physics (EFOMP) has actively worked to enhance and synchronize the education and training of medical physicists throughout its member countries in Europe. The study's findings indicate a generally well-aligned structure in these programs, consisting of a bachelor's phase, a master's phase, and a clinical phase following the completion of the master's degree. However, there are variations in the specific topics covered within these education and training programs.
[31]	2023	Cross-sectional study	Portugal	The field of Biomedical and Health Informatics (BMHI) operates at the intersection of various disciplines, making it challenging to define and characterize the workforce and training needs in this domain. A study in Portugal identified 23 programs offering relevant BMHI education. Among these, eight (35%) were specifically designed as dedicated educational programs in BMHI, primarily at the master's level (63%) and often located in the northern part of the country (7). There are currently four programs with potential for accreditation, but they may require some additional work in specific areas to meet eligibility criteria.
[32]	2004	Case study	European states	The role of a Biomedical Physics-Engineering (BMPE) educator in faculties of health science has historically lacked a clear definition, leading to occasional doubts about its status within such faculties. To address this issue, it is essential to conduct thorough research and identify best practices that can justify the presence of this role within health science faculties. This paper briefly presents the findings of preliminary exploratory case studies conducted at universities in three European countries: The Czech Republic, the Republic of Ireland, and the Netherlands. The data for these studies were gathered from university websites, published documents, curricular materials, and textbooks. In some cases, semi-structured interviews and on-site observations were also used to supplement the information.
[33]	2007	Commentary	European states	Study discusses historical development of Medical and Biological Engineering and Science (MBES) in Europe, highlighting its significant contributions to economic growth and competitiveness. It emphasizes that excellence in MBES research and education can be a driving force for the knowledge society and economy, attracting international talents and acting as a bridge between biology, nanotechnology, and information technology (bio-nano-info). The text underscores the importance of "engineering for health" in fostering future frontier research and enhancing innovation and knowledge production.

Table 2 (Continued). Characteristics & findings of selected studies

R	Year	SD	SAP	Key findings/implications
[34]	2015	Information sources	Western Balkan Region	Bioengineering & medical informatics (BE&MI) is identified as one of rapidly growing engineering disciplines globally, gaining prominence in leading regions & countries. Western Balkan countries have embarked on an initiative to introduce new educational programs in BE&MI across all three levels of higher education. This effort is being facilitated through funding from European Commission, particularly Tempus project titled "studies in bioengineering and medical informatics–BioEMIS."
[35]	2007	Case study	Greece	Health informatics is a significant and established field that bridges multiple disciplines, including medicine, nursing, engineering, biology, and others. The University of Athens has offered a postgraduate course in health informatics for over fifteen years, making it one of the pioneering and enduring programs in Europe. Given the dynamic nature of biomedical and health informatics, continuous evaluation and adaptation of the course are essential to keep pace with the evolving landscape of this field.
[36]	2002	Descriptive study	Europe	This study focuses on Nursing Informatics Education in Europe and highlights the diversity in educational systems across the continent. To address these differences, IMIA has developed international recommendations for health and medical informatics education. The study specifically examines these IMIA recommendations in the context of nursing informatics education.
[37]	2005	Research study	Greece	Health informatics is a well-established and interdisciplinary field involving informatics, medicine, nursing, engineering, biology, and related subjects. In Europe, the coordination of health informatics education at the postgraduate level has become crucial, especially in light of European Community programs like Telematics for Health Care under the Fifth and Sixth Framework Programs (2000-2006). A European M.Sc. course has been developed to address these needs, drawing from previous program experiences. The curriculum has evolved into an Inter-University program involving five Greek Universities. The paper's objective is to provide an up-to-date description of the academic program and a brief evaluation of its implementation phase.
[38]	2013	Research study	Western Balkan countries	The fields of bioengineering (BE) and medical informatics (MI) are rapidly advancing and highly significant in the realm of scientific research and innovation globally. Recognized as pivotal challenges, they are integral to research and innovation strategies worldwide. The Education, Audiovisual and Culture Executive Agency (EACEA) has awarded a regional Tempus project titled "Studies in Bioengineering and Medical Informatics - BioEMIS." This project aims to introduce specialized study programs in Western Balkan countries, including Serbia, Montenegro, and Bosnia and Herzegovina. The study provides an overview of the key principles and guidelines for the development of Bioengineering and Medical Informatics study programs, adhering to European best practices.
[39]	2012	Information sources	Germany	Education forms foundation for the efficient operation of a healthcare system. It is an integral part of the curriculum for medical students and is further reinforced through training. To achieve success and continued progress, international collaboration in both concept and practice is essential. Cooperation between institutions allows for exchange of valuable experiences and recommendations. Ultimately, such partnerships may pave way for modernization at a European level in field of healthcare education.
[40]	1993	Commentary	European countries	Teaching medical informatics in the medical curriculum can be challenging due to expanding course requirements. A practical approach is to integrate it horizontally with current topics. Medical informatics is crucial as it equips health professionals to manage vast medical information efficiently. In some European countries, it's federally mandated in medical education, recognizing its importance as clinics and offices become more computerized. This is especially critical for nurses dealing with patient-monitoring equipment. Despite efforts by the National Library of Medicine to train professionals, a shortage of teaching staff hampers its adoption. Expanding specialization in medical informatics within public health curricula may help address this issue.
[41]	2013	Descriptive study	Western Balkan countries	The study discusses the significance of bioengineering (BE) and medical informatics (MI) in scientific and engineering fields, highlighting their importance in research and innovation strategies in the European Union (EU) and other leading regions globally. Many universities are either redesigning existing programs or creating new ones to educate future biomedical engineers, physicians, and researchers. To address the growing demand for education in these fields, the European Commission has initiated various scientific and educational programs, such as Framework Program and Horizon 2020. Additionally, the Education, Audiovisual and Culture Executive Agency (EACEA) has granted the regional Tempus project "Studies in Bioengineering and Medical Informatics - BioEMIS." This project aims to introduce specialized study programs in BE and MI in Western Balkan countries like Serbia, Montenegro, and Bosnia and Herzegovina. The study provides a state-of-the-art analysis of European study programs in BE and MI, offering essential guidelines for developing new curricula in these fields.
[42]	2000	Information sources	Europe	Health informatics is an emerging and significant field that spans multiple disciplines, including informatics, medicine, nursing, engineering, and biology. As European Community programs like Telematics for Health Care increasingly require skilled professionals, there's a growing need for postgraduate education in this field. In response, a European M.Sc. course has been established, aligning with these requirements. The curriculum draws from previous program experiences and has evolved into an Inter-University initiative involving five Greek universities. This study described the new academic program and offer a brief evaluation of its implementation phase.

Table 2 (Continued). Characteristics & findings of selected studies

R	Year	SD	SAP	Key findings/implications
[43]	2002	Descriptive report	Czech Republic	This paper discusses the establishment of a new program in Biomedical Informatics with a doctoral degree in the Czech Republic. The program is the result of cooperation between Charles University in Prague and the Academy of Sciences of the Czech Republic, with an agreement signed in 1997. The primary objective of this agreement was to collaborate on the development and implementation of joint education and training for young researchers. Currently, there are 19 scientific disciplines in postgraduate doctoral studies in biomedicine, including a scientific board on Biomedical Informatics, established in 2001. The paper outlines the involvement of university teachers and researchers from the EuroMISE center–Cardio in the board of biomedical informatics and describes the initial activities of the board in the context of postgraduate doctoral studies in biomedicine.
[44]	1998	Information sources	Greece	Health informatics is an emerging and vital interdisciplinary field encompassing informatics, medicine, nursing, engineering, biology, and related subjects. In Europe, there's a growing need for coordinated postgraduate education in this field, especially with European Community programs like "Telematics for Health Care" in the Fourth Framework Program (94-99) requiring well-trained professionals. A European M.Sc. course has been developed to meet these needs. The curriculum was created based on outcomes from the ERASMUS Workshop held in Athens in 1990. The course's implementation continues under a specific contract, and a 6-year evaluation, including input from both staff and students, has demonstrated its success.
[45]	1997	Information sources	Europe	Health Informatics is a rapidly growing and significant interdisciplinary field that encompasses various disciplines, including Informatics, Medicine, Nursing, Engineering, and Biology. In Europe, there is a pressing need to coordinate postgraduate education in this field, primarily due to the requirements of European Community programs like "Telematics for Health Care" in the 4th Framework Program (94-99). These programs demand a supply of well-trained professionals with advanced skills and knowledge. The European M. Sc. course in Health Informatics has been designed to meet these objectives and address the growing demand for expertise in this field.
[46]	2010	Descriptive study	Czechia	In Czechia, eight medical faculties provide medical biophysics courses that encompass various topics, including X-ray imaging, MRI, and physical therapy. The curriculum places a strong emphasis on maintaining high-quality standards, employing a combination of written tests and oral exams. It underscores the significance of (bio)physical knowledge in ensuring the safe and effective use of biomedical devices in healthcare.
[47]	2020	Information sources	Europe	In this article, the authors offer a brief preview of how analyzing the disciplinary characteristics within individual histories can help illuminate the process of interdisciplinary evolution in the field of medical informatics in Europe.
[48]	2019	Descriptive & historical analysis	NA	This study explores the interdisciplinary nature of medical informatics by examining the themes addressed by its pioneers. The data for this analysis is primarily derived from personal accounts and stories of European scientists collected by IMIA WG History, along with some biographical notes. Many of these researchers had backgrounds in technical and scientific fields, and it was common for them to have dual specializations. The study discusses the proportions of the main topics approached by these pioneers and highlights that the interdisciplinary roots of medical informatics were established during its pioneering period when the foundational concepts and chapters of the field began to take shape.
[49]	2018	Descriptive study	Romania	The history of Romanian Medical Informatics has a long and substantial history, characterized by a dedicated and capable professional community. The Romanian Society of Medical Informatics has been established through the collective efforts of this community. Their goal is to carry forward the tradition of excellence, set new objectives, and actively participate as a valued member of the international biomedical and health informatics community.
[50]	2008	Information sources	Europe	On March 21, 2008, the Medical Informatics community mourned the loss of an individual who was known for their innovative thinking, unwavering optimism, and dedication to humanitarian causes. This individual had been a driving force in advancing the concept of eHealth not only in Europe but also on a global scale.
[51]	2013	Descriptive study	Czechia	This study discusses the use of information technologies in enhancing the teaching methods for preclinical medical studies, particularly in the field of Medical Biophysics at Charles University's Medical Faculty in Hradec Kralove. The approach involves the use of a Medical Information System (MIS) for online medical data processing and storage during practical exercises and a Learning Management System (LMS) called Moodle for interactive online presentation of study materials. Students play dual roles as patients and physicians and engage in five practical exercises covering various medical imaging and examination techniques. These exercises simulate basic noninvasive medical examinations and imaging procedures, helping students transition from theoretical to clinical aspects of their studies. The approach has been found to improve performance in medical physics, informatics, and soft skills like interviewing and communication, contributing to their learning outcomes and skill development.
[52]	2006	Descriptive study	Romania	Development of medical informatics education in Romania, particularly in Timisoara, was significantly shaped by generous support provided by Professor Jan H. van Bemmel. This collaboration took place during a period when political conditions limited contacts between Western and Eastern countries. The text highlights several important actions and events that characterize this long-lasting collaboration. Professor Jan H. van Bemmel's support evolved over time, adapting to the historical context. It began with the provision of books, journals, and software. Subsequently, it expanded to include support for Romanian colleagues to attend conferences. Finally, collaboration evolved into more active and direct partnerships in the field of medical informatics education.

Table 2 (Continued). Characteristics & findings of selected studies

R	Year	SD	SAP	Key findings/implications
[53]	2021	Analysis of accreditation assessment	European institutes	An accreditation process in biomedical and health informatics that is based on current educational recommendations from international organizations in the field must consider the needs and requirements of every healthcare profession in clinical, nursing, and public health institutions, universities, and health organizations.
[54]	2021	Research study	German interdisciplinary teachers	In the current study, medical doctors and members of the medical informatics industry developed multidisciplinary teaching teams. This teaching team collaborated to create and deploy new seminars to teach digital capabilities over the course of several academic years. The courses address assisted health care, telemedicine, and technological adoption in relation to the medical specialty. Therefore, the viability and utility of multidisciplinary teaching teams to impart digital capabilities could be demonstrated in the DigiWissMed project. Medical informatics is a crucial component of the medical industry's digitization. Experts in this area should be involved in teaching digital capabilities to provide future-proof medical education.
[55]	2020	Mixed methods survey	European medical students	According to a study that assessed the needs of medical students regarding digital health literacy and digital skills in medical education, the majority of European medical students have a positive attitude towards the digitalization of health care and are willing to take an active role and accept responsibility, especially as mediators of digital health literacy to patients. However, this study also discovered a lack of expertise in using and assessing digital health technologies, which was linked to the absence of pertinent topics in the medical curriculum. Education providers and decision-makers should acknowledge the significant contribution that future health professionals make to health innovation, develop interprofessional concepts that ensure continuous learning, and evaluate them in a continuous exchange with their students while also staying abreast of the most recent scientific and technological developments.
[56]	2020	Content analysis of information sources	European institutes offering education in BMHI	This research proposed that the certification process be used to evaluate and apply worldwide guidelines, therefore assuring the caliber of training in health informatics.
[57]	2019	Cross-sectional descriptive study	European Union medical schools	According to this survey, barely one-third of all medical schools in the European Union provide any courses on these subjects, making it difficult for medical students to get familiar with health information technology. The disparity in training possibilities for medical students on topics related to health information technology among the various nations emphasizes the need for further effort to improve the medical curricula.
[58]	2019	A mixed methods study	Postgraduate medical students	According to his analysis, worldwide requirements for health informatics capabilities are ignored in postgraduate medical education in the UK. To educate doctors for employment in increasingly digital healthcare contexts, it is vitally necessary to incorporate key health informatics capabilities into training curricula.
[59]	2019	Perspective study	European institutes offering education in BMHI	The current educational programs are available at the undergraduate and graduate levels and include a number of specializations, including bioinformatics and health informatics, among others. However, not all nations have had the same development in educational programs.
[60]	2019	Content analysis of information sources	Institutions in Slovak Republic and the Czech Republic	According to this study, there are significant differences in the titles of the disciplines, the standards for passing them, the curricula, and the suggested reading lists. This research suggested combining curricula with a focus on using biophysical knowledge practically to provide complete patient care.

Note. R: Reference; SD: Study design; & SAP: Study area or population

The result of this review reveals a diverse landscape of educational programs and challenges across European nations. Francois Gremy's pioneering contributions to Medical Informatics, including founding of IMIA and European Federation for Medical Informatics (EFMI), underscore the significant role he played in shaping field. Health Economics in Radiation Oncology (HERO) project's focus on cost data for radiotherapy resources shows practical applications of informatics in healthcare resource management.

The study highlights disparities in the availability of courses related to health information technology and informatics in European medical schools. Only around one-third of medical schools in the European Union offer such courses, indicating a need for greater emphasis on these topics in medical curricula. Furthermore, the study emphasizes the importance of incorporating key health informatics capabilities into postgraduate medical education to prepare doctors for an increasingly digital healthcare landscape.

The analysis also points to the necessity of standardizing and integrating biophysical knowledge into medical education to enhance patient care. It reveals that there are significant variations in discipline titles, curricula, and standards across the field of informatics in Europe, necessitating efforts to standardize and align educational programs. Additionally, the research underscores the importance of interdisciplinary collaboration and continuous learning in the digital healthcare era, with medical students playing a pivotal role in advancing health innovation and digital health literacy (**Table 2**).

Our results showed that the incorporation of medical informatics and biophysics into medical education in European nations is a critical step to ensure that healthcare professionals are prepared to meet the challenges of a rapidly evolving healthcare landscape. It helps to improve patient care, efficiency, and innovation while maintaining high standards of competence and safety.

DISCUSSION

In European nations, medical informatics and biophysics are fundamental parts of medical school. Their importance stems from their capacity to enhance patient care, spur innovation, and tackle challenging healthcare issues in a world that is becoming more data-driven and technologically advanced. IMIA's advice on education in biomedical and health informatics was emphasized by [18]. In addition, a structure for creating biomedical and health informatics instruction educational plans, the report offers exhortation on program license, proposals for the components of instructive courses, and student responsibility rates for every information space.

The international guidelines for instructing biomedical and health informatics were first made public in 2000 and then modified in 2010. Due to recent developments in research, technology, healthcare systems, and the biomedical and health informatics workforce, it is now crucial to update the recommendations. The updated recommendations aim to help educators develop biomedical and health informatics curricula at different educational levels, identify critical knowledge, abilities, and skills for certification of healthcare professionals and those working in the field, provide evaluators of academic biomedical and health informatics programs with a tool to compare and accredit the quality of delivered programs, and encourage universities, organizations, and other educational institutions. As a result, the area of medical informatics education has changed to reflect developments in the healthcare sector and the demand for healthcare workers to have up-to-date skills and competences [18].

In the current paper, we systematically review nine studies that show the value of biophysics and medical informatics at medical schools across Europe. It was observed that IMIA gives accreditation of top-notch biomedical and health informatics education programs in one of the studies they chose [18]. Similar to our findings, it was reported that the clinical, nursing, and public health institutions, universities, and health organizations must base their clinical, nursing, and public health institutions' accreditation processes for biomedical and health informatics on the most recent educational recommendations made by international organizations in the field [53]. Our results are consistent with a prior research by [61]. The healthcare system's scheduling, which is a very time-consuming operation, can benefit from their research. A recommended heuristic algorithm is included in the decision support system. Multifunctional software tool with an intuitive user interface. A simulated comparison of the schedule created utilizing the method given in the article and other relevant methodologies is presented and examined in this study. Investigated in one hospital setting is the impact of the software tool on efficiency and standard of surgical services.

Additionally, in another chosen research, medical experts in informatics and physicians developed multidisciplinary teaching teams. This teaching team collaborated to create and deploy new seminars to teach digital capabilities over the course of several academic years. The courses address assisted health care, telemedicine, and technological adoption in relation to the medical specialty. Therefore, the viability and utility of multidisciplinary teaching teams to impart digital capabilities could be demonstrated in the DigiWissMed project. Medical informatics is a crucial component of the medical industry's digitization. Experts in this sector should also be involved in teaching digital capabilities to ensure that medical education is prepared for the future [54].

It was found that in his analysis of the needs of medical students regarding digital health literacy and digital skills in medical education that the majority of European medical students have a positive attitude towards the digitalization of health care and are willing to play an active role and accept responsibility, especially as mediators of digital health literacy to patients Machleid [55]. The lack of knowledge in utilizing and evaluating digital health technologies was also found in this study, and it was determined that this was due to the medical curriculum's exclusion of relevant subjects.

According to [56], the certification procedure can enable the evaluation and implementation of worldwide guidelines while guaranteeing the caliber of health informatics education. Furthermore, according to a chosen research by [57], only one-third of the medical schools in the European Union provide any courses at all on the issue of health information technology, making it difficult for medical students to get familiar with it. The need for additional effort on enhancing the medical curriculum is highlighted by the unequal distribution of training opportunities for medical students on health information technology topics amongst the various nations.

Our chosen studies revealed significant variations in subject names, passing standards, curricula, and suggested readings [58-60, 62] highlighting the need to primarily unite curriculum with an emphasis on practical application of knowledge in medical informatics and biophysics to prepare doctors for thorough patient care.

CONCLUSIONS

The current systematic evaluation emphasizes the critical place that biophysics and medical informatics play in medical education throughout European nations. The study emphasizes how crucial it is to incorporate biophysics and medical informatics into the curricula of medical education at European institutions. Future healthcare workers need to be well-versed in these fields to be able to manage the changing healthcare environment, which is becoming more and more dependent on information technology and scientific developments. However, as advised by international organizations, accreditation procedures are crucial to guaranteeing the caliber of instruction in medical informatics and biophysics. These procedures give curriculum development and program assessment a structure, fostering quality and consistency in healthcare education. This research also emphasizes the differences in training opportunities and curricula among European nations. To guarantee that medical students obtain thorough and consistent instruction in these crucial fields, there has to be more standardization in the nomenclature of subjects, the standards for passing courses, and the recommended material.

Implications for Practice & Policy

The emphasis on the crucial roles of biophysics and medical informatics suggests a need for immediate integration of these subjects into the medical education curriculum. This integration is vital to adequately prepare future healthcare professionals for the evolving healthcare landscape. Further, recommendation for accreditation procedures aligns with ensuring quality and consistency of education.

Implementing or strengthening accreditation processes can be a practical step for institutions and policymakers to guarantee the effectiveness of medical informatics and biophysics instruction.

Additionally, policymakers may consider developing or reinforcing regulatory frameworks that mandate the inclusion of medical informatics and biophysics in medical education programs. This can provide a structured approach to curriculum development and ensure compliance with international standards. Policymakers could further explore avenues for harmonizing educational standards and sharing best practices to enhance the overall quality of medical education across borders.

Limitations of the Study

The study may be subject to publication bias, as it relies on available literature. Published studies are more likely to report positive results, potentially leading to an overestimation of the positive aspects of the integration of biophysics and medical informatics in European medical education. The study may encounter challenges due to the diverse nature of educational systems across European nations. Differences in curriculum structures, teaching methodologies, and institutional policies could impact the comparability of findings.

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