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Simulation-based training in medicine: a scientometric investigation of Scopus-indexed articles

Treinamento por simulação em medicina: uma investigação cienciométrica de artigos indexados na Scopus

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ABSTRACT

Introduction: Simulated training (ST) in healthcare is a method that exposes students to complex clinical scenarios in controlled environments, allowing them to practice and develop skills without risk to the patient. However, few studies have analyzed the scenario of ST in medical education in the university environment for the development of medical skills.

Objective: The study analyzed the use of ST in universities in the field of medical education.

Method: We identified relevant articles on simulated training and medical education using the main search terms. The Scopus database was used. VOSviewer was used to carry out the bibliometric analysis.

Results: The analysis included 3,968 articles. There has been an increase in publications on ST in medical education. Most of the publications came from developed countries, especially the United States, the United Kingdom and Canada. BMC Medical Education was the journal that published the most articles on the subject. The main research hotspots identified were clinical competence, curriculum and computer simulation.

Conclusion: Simulated training in medical education has attracted the attention of researchers over the years, with an increase in scientific production in the area. Bibliometric analysis suggests that this area will continue to grow, with an emphasis on clinical competence, interns and residencies, curriculum, computer simulation, surgical training, resuscitation and artificial intelligence.

Keywords: Simulation training; Medical education; Universities.

RESUMO

Introdução: *O treinamento simulado (TS) na área da saúde é um método que expõe estudantes a cenários clínicos complexos em ambientes controlados, permitindo a prática e o desenvolvimento de habilidades sem risco ao paciente. No entanto, poucos estudos têm analisado o cenário do TS na educação médica no ambiente da universidade para o desenvolvimento de habilidades médicas.*

Objetivo: *O estudo analisou o tema treinamento por simulação em saúde na educação médica, na universidade.*

Método: *Identificamos artigos relevantes sobre TS e educação médica usando os principais termos de busca. A base de dados utilizada foi a Scopus. O VOSviewer foi utilizado para realizar a análise bibliométrica.*

Resultado: *A análise incluiu 3.968 artigos. Houve um aumento de publicações sobre TS em educação médica. A maioria das publicações provém de países desenvolvidos, com destaque para os Estados Unidos, o Reino Unido e o Canadá. O jornal BMC Medical Education foi o que mais publicou artigos sobre o tema. Identificaram-se os principais hotspots de pesquisa, tais como competência clínica, currículo e simulação por computador.*

Conclusão: *O TS na educação médica vem ao longo dos anos chamando a atenção dos pesquisadores, com um aumento da produção científica na área. A análise bibliométrica sugere que essa área continuará a crescer, com ênfase em competência clínica, internos e residências, currículo, simulação por computador, treinamento cirúrgico, ressuscitação e inteligência artificial.*

Palavras-chave: *Treinamento por Simulação; Educação Médica; Universidades.*

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INTRODUCTION

Simulated training (ST) is a method that provides systematic, proactive, and controlled exposure of students to progressively more complex clinical challenges, including those life-threatening situations, which could not be trained otherwise[1]. The objective of the ST is to recreate the real world in a student's practice situation, which must be faced with realism, in a safe environment that allows the student to make mistakes, aiming to preserve patient safety and prevent possible damage.

ST also enables the training of rare situations in daily practice[2]. After the end of the scenario, the debriefing is carried out with the students, providing a new opportunity for training and mitigation of medical errors and the development of medical skills[3]. Therefore, among other learning situations, this type of method has drawn the attention of researchers and teachers in medical education.

Preventable medical errors are the third leading cause of death, and nonfatal iatrogenesis causes disability in more than 3.5 million patients per year in the U.S.[4]. In this scenario, the emergence and the need for training with simulated patients to reduce iatrogenic events and prevent deaths related to health care was evidenced. In addition, ST enables increased learning, knowledge retention, and the development of medical skills[5]. Non-technical skills such as decision-making and communication can also be effectively developed through ST[6]. On the other hand, in the context of universities, understanding and evaluating under which conditions ST is more effective in medical education is a challenge for researchers in the area[7].

The use of ST in the context of medical education in universities requires well-planned and structured criteria, with an appropriate method, trained professionals, and efficient resources to achieve the proposed objectives[8]. The scenarios developed for the simulation practice should be similar to reality and in well-defined scopes regarding the aspects to be developed during the simulation activity[9]. However, there is a variability in teaching practices, i.e., non-compliance with the criteria described above[8], as well as different ST methods used, among other conditions, which affect the quality of training, negatively impacting results and modulating the potential benefit that students could obtain through ST[3].

Although there is a growing interest in ST and medical education, we did not find any bibliometric analysis in the context of universities. General research trends in the field remain unclear. Bibliometric analysis is a widely used method to present the research basis and critical points of a topic or field of research; it evaluates and statistically quantifies large amounts of bibliometric data[10]. It examines the distribution of search components such as countries, journals, keywords, authors, hotspots, and search trending topics[10].

Moreover, we identified some gaps in the scientific literature, such as the majority of studies aimed at professionals and not undergraduate students[11], in health most studies are in the field of nursing[12], simulated training environments are generally carried out in hospitals and not in health universities, thus our interest in understanding how this happens in universities in undergraduate training[13]. Finally, we reinforce that we did not identify any bibliometric analysis in holistic/comprehensive topics only in specific topics, such as Virtual Reality, ST in surgeries, Artificial Intelligence, among others. Therefore, the objective of this article is to analyze the topic of simulation training in health in medical education at the university.

METHOD

Bibliometric methods are an integral part of research evaluation methodology within scientific fields and are increasingly used in the study of various aspects of science[14]. In this study, the database used was Scopus. This database was used due to its wide scope, as it is the largest with citation data from peer-reviewed articles in the literature of various disciplines, and is a product of Elsevier[15]. After screening, 3,968 articles were included for bibliometric analysis. The schematic flowchart for article recruitment was carried out according to the following steps: a) In Scopus, the search was made using "ALL FIELDS, TITLE, ABS, KEY, b) using the search strategy (N=4.625), c) The type of filtered documents were articles and English language (N=3961), d) The data were tabulated in MS-Excel and VOSviewer, e) The results were analyzed with bibliometric parameters and d) Discussion and conclusion of the study.

Search strategy

The data for this article were acquired from the Scopus database, and no analysis period was defined. The search was started on February 20, 2024 and contained all articles with the terms using the combination shown in Chart 1. This strategy enabled a broader analysis of the field of study, simulation training in health, medical education, and university. Therefore, these keywords were used so that as many relevant publications as possible were incorporated into the extracted data. The search strings were: "simulation"[All Fields] OR "simulation training"[All Fields] OR "patient simulation"[All Fields] OR "high fidelity simulation"[All Fields] OR "simulation-based education"[All Fields] OR "simulation-based research"[All Fields] OR "computer simulation"[All Fields] OR "simulation teaching"[All Fields] OR "low fidelity simulation"[All Fields] OR "virtual reality"[All Fields] OR "VR"[All Fields] OR "role

playing"[All Fields] OR"augmented reality"[All Fields] OR"AR"[All Fields] OR "manikins"[All Fields] OR "manikin"[All Fields] OR "mannequin"[All Fields] OR "mannequins"[All Fields] OR "task-trainer"[All Fields] OR "standardized patient"[All Fields]) AND "Health Care"[All Fields] AND medical education "[Article title, Abstract, Keywords] AND NOT " nursing" [Article title, Abstract, Keywords] AND "universities" [Article title, Abstract, Keywords].

Inclusion and Exclusion Criteria

All data from the Scopus database, including article information such as author names, titles, journals, keywords, institutional affiliations, citations, and abstracts were downloaded. All of these data were converted into xls. file (Microsoft Excel) to check data error. Then, the downloaded data were filtered by inclusions, which were: (1) only publications in the form of articles were considered, (2) articles published in English. The corresponding authors of the present study, WL and LSSN, reviewed the titles of all articles for inclusion in the analysis. Any differences between them were discussed and resolved by a third author. Duplicate documents were defined as articles with the same title, authors, and year and were identified using Microsoft Excel software.

Statistical analysis

Scientometrics is involved in the analysis of productivity and measurement of scientific fields. The quantitative evaluation of the productivity of the publication through scientometric parameters is a very reliable technique to understand the impact of any research on a community[16]. This study explores the global publications related to simulation training, using scientific research through quantitative metrics of Scientiometry and Bibliometrics. In this study, Excel version 2019 (16.0) and VOSviewer were used to separately describe the basic characteristics of publications, countries, institutions, keywords, and citations. VOSviewer is a software with text mining and advanced visual analysis functions, which is used to construct co-occurrence analyses[16,17]. Co-occurrence analysis helps to quantify the common information in various data, revealing the association of content and common relationships of the information[18]. The type of co-occurrence analysis research is broad, including co-country analysis, co-institution analysis, and co-keyword analysis and co-citation. After searching the literature, the time of publication, journals, countries, institutions, and keywords from the literature were extracted using Excel. Subsequently, the analysis was separated into three stages: (1) a descriptive statistical analysis of the growth pattern, number, year, institution, country and main journals of the publications; (2) a co-citation analysis to rank the most influential articles in this field, and then (3) a co-occurrence analysis on the keywords and burst using VOSviewer.

The results and the discussion are presented in topics together for better presentation. The topics are: Research Status, Hotspots and Co-Institutions, and Hotspots Research and Top Topics.

RESULTS AND DISCUSSION

With this bibliometric analysis, it was possible to observe the increase in the number of articles between the years 1968-2024. In this study, we searched the Scopus database to analyze the state of the art, development of research trends, contribution of different countries in the field of study on simulation training in medical education at the university. The search hotspots were presented using keyword clustering through the bibliometric map generated in Vosviewer. Co-citation analyses, most cited articles and research trends were performed using the Scopus database and burst analysis to verify trends in hotspot topics. We conducted this review as a way to encourage dialogue among researchers in this field of study.

Survey status, Hotspots, and co-institutions

The 3,961 articles analyzed in the Scopus database, published between 1968 and 2024, confirmed the upward trend in publications on simulated health training at the university. This information can be explained by the changes in the pedagogical perspective that occurred in the curricula of health courses, especially in medicine and nursing in the analyzed period. Changes, such as greater incorporation of active methodologies, learning process built on the exercise of learning by doing, constant relationships between theory and practice, creative thinking, and meaningful learning may partially explain this increase in publications[19]. Another aspect is the concern with medical education based on scientific evidence as a way to reduce errors in professional practice and increase patient safety[20]. The advancement of technology is another factor to be considered for the increase in the number of studies in the field of study, which may have contributed to the development of new instruments, procedures and research methods[3]. We emphasize that from 2010 onwards the number of publications exceeded 100 per year, reaching 411 in 2023, which demonstrates the important growth of the area. This approach is in line with the concept of meaningful learning proposed by David Ausubel, in which new knowledge is substantially integrated into the student's preexisting cognitive structure[45].

The articles were published in 1,225 journals. The three journals with the highest contributions were BMC Medical

Education *(IF = 3.2)* , Journal Of Surgical Education (IF = 2.9) and Education Academic Medicine (IF = 8). The scope of these journals is in medical education, with a more interdisciplinary approach, only the Journal of Surgical Education is specific in the topic of surgical medical education. Academic Medicine is the journal with the highest Impact Factor (IF) and is among the most cited; these data are in accordance with previous studies of the scientometric type in medical education [13,21].

In the scientometric analysis of co-countries the USA (n = 1,545) was the country with the highest number of publications in the field of simulation training in health, followed by Canada (n = 328), the United Kingdom (n = 298), Germany (n = 267) and Australia (n = 196), as shown in the map in Figure 1. This result demonstrates an imbalance of publications between countries/regions of the world; on the other hand, it points out that this topic has attracted the attention of some countries. The economic factor is a determinant of investments in scientific research, the countries with the highest number of publications are considered economically developed. Another aspect is the investment and concern of these countries with patient safety, which is why there is greater investment in studies and research on simulated training in health[22].

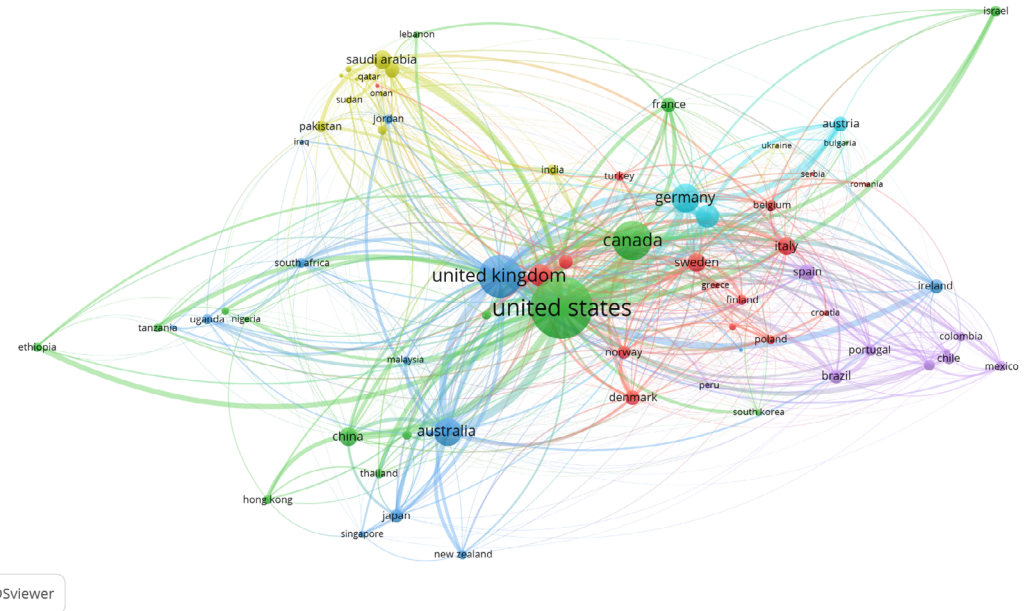
We observed a collaborative network between North America and Europe as well as Australia. The USA was the country with the highest number of publications, which reinforces its dominance in this field of study, in accordance with what has

Table 1. Top-10 Contributions from Journals.

TOP	Journal title	Number of publications	Publications n (%)	Country	IF
1	BMC Medical Education	*197*	*4.9%*	*United Kingdom*	*3.2*
2	Journal Of Surgical Education	*138*	*3.4%*	*USA*	*2.9*
3	Academic Medicine	*117*	*2.9%*	*USA*	*8.0*
4	Medical Teacher	*78*	*1.9%*	*United Kingdom*	*4.2*
5	BMJ Open	*72*	*1.8%*	*United Kingdom*	*3.0*
6	Medical Education	*59*	*1.4%*	*United Kingdom*	*7.6*
7	Journal Of General Internal Medicine	*54*	*1.3%*	*USA*	*6.4*
8	Plos One	*49*	*1.2%*	*USA*	*3.7*
9	GMS Journal for Medical Education	*28*	*0.7%*	*Germany*	*0.3*
10	International Journal of Environmental Research And Public Health	*27*	*0.6%*	Switzerland	4.6

Legend IF=Impact Factor (*Clarivate Science Citation* Index-2022).
Source: Prepared by the authors.

Figure 1. Analysis of co-countries.



Source: Generated by *Vosviewer Software.*

been reported in other scientometric analyses on ST in health[22]. In addition, it was in the USA that the first studies and the first simulators in health emerged[20]. Greater investments are needed for a greater participation of other countries/regions in understanding this field in different contexts.

In the co-citation analysis, the article published in 1993, entitled "Evidence for the effectiveness of CME: a review of 50 randomized controlled trials" was the most cited (n = 1306) (Table 2). This study is an adjuvant in the field of research because it systematizes knowledge about continuing medical education, in addition to proposing new interventions, using strategies to activate or reinforce medical practice, including the simulated patient[22]. According to the metrics of the Scopus database (2024) this article has had more than 935 citations since its publication.

We classified the studies in Table 2 by macro topics, which revealed two topics:: Medical Education (articles #1, #5, #6, and #10) and simulated training (articles #2, #3, #4, #7, #8, #9, and #10).

Although Artificial Intelligence (AI) has appeared as a trend in the most recent publications, its approach in the reviewed studies has proven to be incipient and often superficial. AI has the potential to revolutionize medical education by personalizing teaching, providing real-time feedback, and simulating complex clinical scenarios with high fidelity. However, few studies critically discuss ethical limits, technological dependence, or the risk of dehumanization of medical care. It is therefore necessary to expand research on how AI can contribute to meaningful learning (Ausubel, 1968)[45], integrating students' previous knowledge with new experiences in a contextualized and active way.

Research Hotspot and Key Topics

We analyzed 12,867 keywords. Analysis of the research *hotspots* showed that the top global research topics in simulated training were humans (n = 3366), medical education (n = 2750), education (n = 1620), and medical students (n = 1030). These *hotspots* gradually expanded to include educational and research terms, such as controlled study (n = 993), curriculum (n = 914), questionnaire (n = 884), and clinical competence (n = 869) (Table 3 and Figure 2).

In contrast, the term simulation training, which was highlighted in the studies above, appeared only (n= 457) times as a keyword in the co-occurrence analysis. We attribute this contrary finding to the choice of database and search sequences. On the other hand, terms such as learning (n=520), medical school (n=463), patient care (n=432) and skills (n=408) are considered hot topics in this context of simulated training and university. These terms also appear in bibliometric research on the synthesis of medical education[13].

Table 2. TOP 10 most cited articles.

TOP	Title	Year	Number	Journal
1	Evidence for the effectiveness of CME: a review of 50 randomized controlled trials[23]	1993	1306	*Jama*
2	Simulation-Based Education Improves Quality of Care During Cardiac Arrest Team Responses at an Academic Teaching Hospital: A Case-Control Study[24]	2008	502	*Chest*
3	Second Life: an overview of the potential of 3-D virtual worlds in medical and health education[25]	2007	479	*Health Information an Libraries Journal*
4	The impact of video games on training surgeons in the 21st century[26]	2007	460	*Jama Surgery*
5	Use of e-mail to teach residents pediatric emergency medicine[27]	1998	402	*Jama Pediatrics*
6	Instructional design variations in internet-based learning for health professions education: a systematic review and meta-analysis[28]	2010	389	*Academic Medicine*
7	Improving In-Hospital Cardiac Arrest Process and Outcomes With Performance Debriefing[29]	2008	372	*Jama Network*
8	Effect of communication skills training for residents and nurse practitioners on quality of communication with patients with serious illness[30]	2013	359	*Jama*
9	National medical simulation training program in Denmark[31]	2004	309	*Critical Care Medicine*
10	Improving patient safety by using interprofessional simulation training in health professional education[32]	2006	258	*Journal of Interprofessional Care*

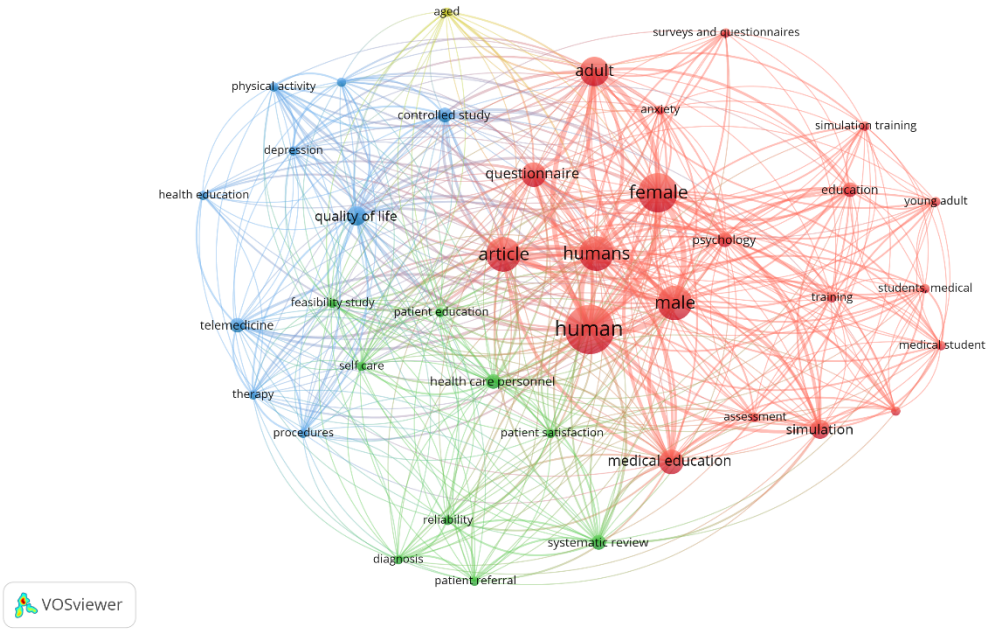
Legend: CME= Continuing Medical Education.
Source: Prepared by the authors.

Table 3. The frequency of the top 20 keywords.

TOP	Keyword	Number	TOP	Keyword	Number
1	Human	3366	11	Interns and Residents	644
2	Medical Education	2750	12	Larger clinical studies	625
3	Education	1620	13	University Teaching	582
4	Medical Student	1030	14		534
5	Controlled study	993	15	Learn	520
6	Curriculum	914	16	Computer simulation	457
7	Questionnaire	884	17	Medical School	463
8	Clinical competence	869	18	Patient care	432
9	University Hospital	720	19	Human Experiments	437
10	Surgical Procedure	647	20	Skills	408

Source: Prepared by the authors.

Figure 2. Keyword co-occurrence analysis.



Source: Generated by Vosviewer Software.

Of interest in the article by these authors mentioned above, the most cited synthesis of knowledge was a systematic review on simulated training[33]. In another scientometric analysis of medical education, the term "Medical simulation and standardized patient" was among the most cited topics, with 7.1% of the total number of articles[21]. In contrast, another scientometric-type study on simulated training, but in nursing, pointed out that simulation using virtual reality (VR) is the main trend for future studies[12]. We believe that in our study, the term VR with the objective of using the concept of computer technology to create and maintain an environment in which the physical presence of a user is projected, allowing the user to interact with this environment, can appear as synonyms, such as computer simulation or simulation.

A burst analysis of the keywords was also performed to verify the trends and the results were; clinical competence related to the development of clinical skills, essential in simulated training[34]. Internships and residencies: stages in which simulated training is used to prepare students for clinical practice[35]. Medical education that includes simulations for practical learning in the curriculum, indicating in the curricular structure that simulations can be integrated as a teaching tool[36,37]. Computer simulation specifically associated with the use of technology and computer simulations in training. Surgical training that benefits from simulations for the practice of procedures without real risks for patients[38,39]. Resuscitation where simulated training is essential to teach cardiopulmonary resuscitation techniques and other emergencies[40,41].

Another topic is Artificial Intelligence (AI); researchers have shown that in medical education it can modify traditional learning methods[22]. AI can offer tools for simulation, diagnosis, and personalized learning. Thus, it is possible to redefine the training of students for the challenges of modern medical education. Some AI tools, such as high-fidelity scenarios with virtual reality (VR)[42], 3D printer[43], and surgical skills training[44] are topics considered as trending.

Limitations and Strengths

First, the data from this study were retrieved only from Scopus without searching other databases such as Web of Science and Pubmed. Second, our study did not include gray and non-English language literature, which can lead to publication bias. Third, the co-word analysis was conducted based on the high-frequency *DECS* terms; some new emerging or low-attention topics may have been missed, affecting the clustering results. Therefore, in the future, it is necessary to search a variety of databases and combine them with other methods of analysis, including a qualitative assessment, to better understand the application of simulated training in medical education at the university. On the other hand, our study has strengths; to the best of our knowledge, studies that use holistic bibliometric analysis to assess critical points and boundaries in the field of simulation training and medical education are scarce. Simulation-based medical education is a widely used method, being considered a priority for countries worldwide, and scientometric analyses can reveal the factors that drive knowledge advancements in the medical education agenda, such as vital academic institutions, individual researchers, and research groups.

FINAL CONSIDERATIONS

The objective of this article is to analyze the topic of simulation training in health in medical education at the university. By analyzing this field of study, we can say that the topic has been drawing the attention of researchers over the years, with an increase in scientific production in the area, especially after the year 2010. The United States has the largest number of publications in this field. BMC MEDICAL EDUCATION is the journal with the most publications. Literature review suggests that this area will continue to grow, with an emphasis on clinical competency, interns and residencies, curriculum, computer simulation, surgical training, resuscitation, and artificial intelligence. The challenge of future research will be to evaluate under which conditions ST is more effective in medical education and how new methodologies, with the use of more effective and intelligent technologies, can promote this greater effectiveness in the teaching and learning of medical students.

AUTHORS' CONTRIBUTIONS

Luiz Sinésio Silva Neto, Wellington Luiz, and Neila Barbosa Osório participated with the conceptualization of the study, data curation and formal analysis of the data, the methodology, and the writing of the manuscript. Itamar Magalhães Gonçalves, Fernando Rodrigues Quaresma, and Erika da Silva Maciel participated in the formal analysis of the supervision data and in the writing, review, and editing of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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DATA AVAILABILITY STATEMENT

Research data are available in the body of the document

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