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Types of technology for teaching respiratory sounds: Scoping Review.

Tipos de tecnologias para o ensino dos sons respiratórios: Scoping Review.

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ABSTRACT

Objective: To synthesize available evidence regarding the technologies used to teach auscultation of breath sounds. Method: A scoping review of the literature following the Joanna Briggs Institute-JBI guidelines. The conduct of a protocol registered with the Open Science Framework was reported using the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P). The Preferred Reporting Items for Systematic Reviews and Meta-analyses for Scoping Reviews (PRISMA-ScR) checklist was used when reporting the scoping review. Results: Of the 1,956 studies identified in the databases, 20 dealt with the research topic. The types of technology were 8 (40%) High Fidelity Simulation Training, 7 (35%) Software, 3 (15%) Web Archives, and 2 (10%) Multimedia, where 10 (50%) were developed for Medical Students and 8 (40%) had Comparative Studies as their method. Conclusion: The studies demonstrated the need to consider new types of technologies for teaching respiratory sounds with improved teaching methods that incorporate emerging technologies and address different learning styles, especially in recent years, where technologies are widely used for the automatic diagnosis of respiratory diseases.

Keywords: Auscultation; Teaching; Software; Respiratory sounds; Technology.

RESUMO

Objetivo: Sintetizar evidências disponíveis em relação aos tipos de tecnologias utilizadas para o ensino da auscultação dos sons respiratórios. Método: Revisão de escopo da literatura seguindo as diretrizes do Joanna Briggs Institute-JBI. A condução de um protocolo registrado no Open Science Framework foi relatada usan-do os Itens Preferenciais de Relatórios para Revisão Sistemática e Protocolos de Meta-Análise (PRISMA-P). Ao relatar a revisão de escopo, foi utilizada a lista de verificação de Itens de Relatório Preferidos para Revisões Sistemáticas e Meta-análises para Revisões de Escopo (PRISMA-ScR). Resultados: Dos 1.956 estudos identificados nas bases de dados, 20 versavam sobre a temá-tica da pesquisa. Os tipos de tecnologias foram 8 (40%) Treinamento com Simulação de Alta Fidelidade, 7 (35%) Software, 3 (15%) Arquivo da Web, e 2 (10%) Multimídia, onde 10 (50%) foram desenvolvidos para Estudantes de Medicina e 8 (40%) tiveram como método, Estudos Comparativos. Conclusão: Os estudos demonstraram a necessidade de considerar novos tipos de tecnologi-as para o ensino dos sons respiratórios com métodos de ensino aprimorados que incorporam tecnologias emergentes e abordam diferentes estilos de aprendizagem, especialmente nos últimos anos, onde as tecnologias são amplamente utilizadas para o diagnóstico automático de doenças respiratórias.

Palavras-chave: Auscultação; Ensino; Software; Sons Respiratórios; Tecnologia.

INTRODUCTION

The COVID-19 pandemic resulted in many people experiencing lung complications. The auscultation of respiratory sounds is one of the main techniques for detecting pathologies and respiratory complications, common in patients admitted to Intensive Care Units (ICUs), especially in the postoperative period, such as patients on mechanical ventilation and with certain movement limitations. Investigating the types of technologies for teaching the auscultation of respiratory sounds has become essential. (OLIVEIRA; LEON; SARAC, 2022).

The teaching of auscultation of respiratory sounds plays an important role as a basic pillar in the diagnostic process, as it allows for the evaluation of the noises generated in the airways by the airflow, which manifest with a certain frequency and amplitude that integrates with other clinical elements of the physical examination. The main advantages of this technique are its simplicity, portability, non-invasiveness, and the fact that it provides instant and dynamic information. Its disadvantage is that it is a subjective technique, influenced by the cooperation of the patient and environmental noise. (BINIAKOWSKI, 2019; BERTRAND et al., 2020).

Furthermore, more recent studies suggest automated methods for detecting respiratory phases and adventitious sounds in recordings of lung sounds, as the interpretation of lung sounds auscultated with a traditional stethoscope involves inherent subjectivity and relies on auscultation skills. However, during the COVID-19 pandemic, there were radical changes in people's lives, and among these changes, the methods of teaching and learning stand out, with the prominent use of Information and Communication Technologies (ICT) by students in the health field. (HSU et al., 2022; VERAS et al., 2022).

There are few review articles on the teaching of auscultation of respiratory sounds available in the literature. Ward & Wattier et al., 2011, demonstrated technologies to enhance thoracic auscultation in clinical simulation. On the other hand, HSU et al. 2022 revealed the evolution of the stethoscope: advancements with the adoption of machine learning and the development of wearable devices. (WARD; WATTIER, 2011; HSU et al., 2022).

Although there is a substantial amount of research on the learning of respiratory sounds, a preliminary search was conducted in the PubMed, Open Science Framework, Cochrane Database of Systematic Reviews, and JBI Evidence Synthesis databases, and no current or ongoing systematic or scoping review on the topic was identified. Scope reviews can be used to identify knowledge gaps or to describe the methodological approaches used in a specific topic or field. (PETERS et al., 2020).

For this, the study had the guiding question: what types of technologies are being used to teach the auscultation of respiratory sounds? The aim was to synthesize the types of technologies used for teaching the auscultation of respiratory sounds.

METHODS

This is a Scoping Review with a research protocol registered on the Open Science Framework (https://osf.io/3wrd5/), under DOI identification: 10.17605/OSF.IO/3WRD5, developed and structured based on the recommendations of the international guidelines PRISMA-ScR and the Joanna Briggs Institute, Reviewers Manual, following the theoretical framework established by Arksey and O'Malley. (AROMATARIS et al., 2024).

The conduct of the protocol was reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. (PRISMA-P). This happens because the guidelines for scope review protocols do not yet exist. (POLLOCK et al., 2022). The preferred reporting items checklist for systematic reviews and meta-analyses for scoping reviews (PRISMA-ScR) were used to report the scoping review. (MUNN et al., 2018).

The eligibility criteria for scope review were developed considering the mnemonic **PCC**: **Population** - Students and professionals in Health Sciences. It is not always necessary to define the participants. A scoping review aimed at describing the details of research projects used in a specific area of study may not need to detail the types of participants involved in that research (POLLOCK et al., 2022);

Concept - Technologies (methods, techniques, and instrumentation) for respiratory sounds (human);

Context - Teaching-Learning (Training at academic, professional, improvement, and specialization levels).

As exclusion criteria, due to the researchers' limitations, studies on veterinary medicine (animals) and social media materials were excluded.

The types of sources of evidence published and not peer-reviewed were considered, about consolidated products or research projects, with open access to research, regardless of the methodological approach, period, and languages.

The search strategy and the initial and secondary searches were conducted in collaboration with a research librarian.

In the first stage, a limited initial search was conducted in the MEDLINE database (PubMed) to identify articles on the topic using the MeSH terms from the research title and boolean operators, as follows: ((Technology) AND (Teaching)) AND ("Respiratory Sounds"). This step was carried out on October 13, 2023, and a total of 56 results were found.

In the second stage, the keywords in the titles and abstracts of relevant articles and the MeSH terms that describe the articles were used to develop a comprehensive search strategy. An initial search was conducted on October 14, 2023, using the following search strategy: ((((Technology) OR (Software) OR (Artificial Intelligence) OR (Deep learning) OR (Digital stethoscope) OR (Neural network) OR (Computer Simulation) OR (Manikins) OR (Patient simulation) OR (Algorithms) OR (Electronic stethoscope)) AND ((Teaching) OR (Educational Technology) OR (Learning) OR (Medical Education) OR (Clinical education) OR (Education, Nursing))) AND ((Respiratory sounds) OR (Lung sounds))) NOT (Animal). A total of 461 results were found.

This search strategy was adapted for the databases COCHRANE, LILACS, MEDLINE, SCOPUS, and Web of Science and was conducted through institutional remote access on the CAPES Journal Portal, based on the identification of the Federated Academic Community (CAFe), to standardize data collection across the databases and ensure an expanded search for articles.

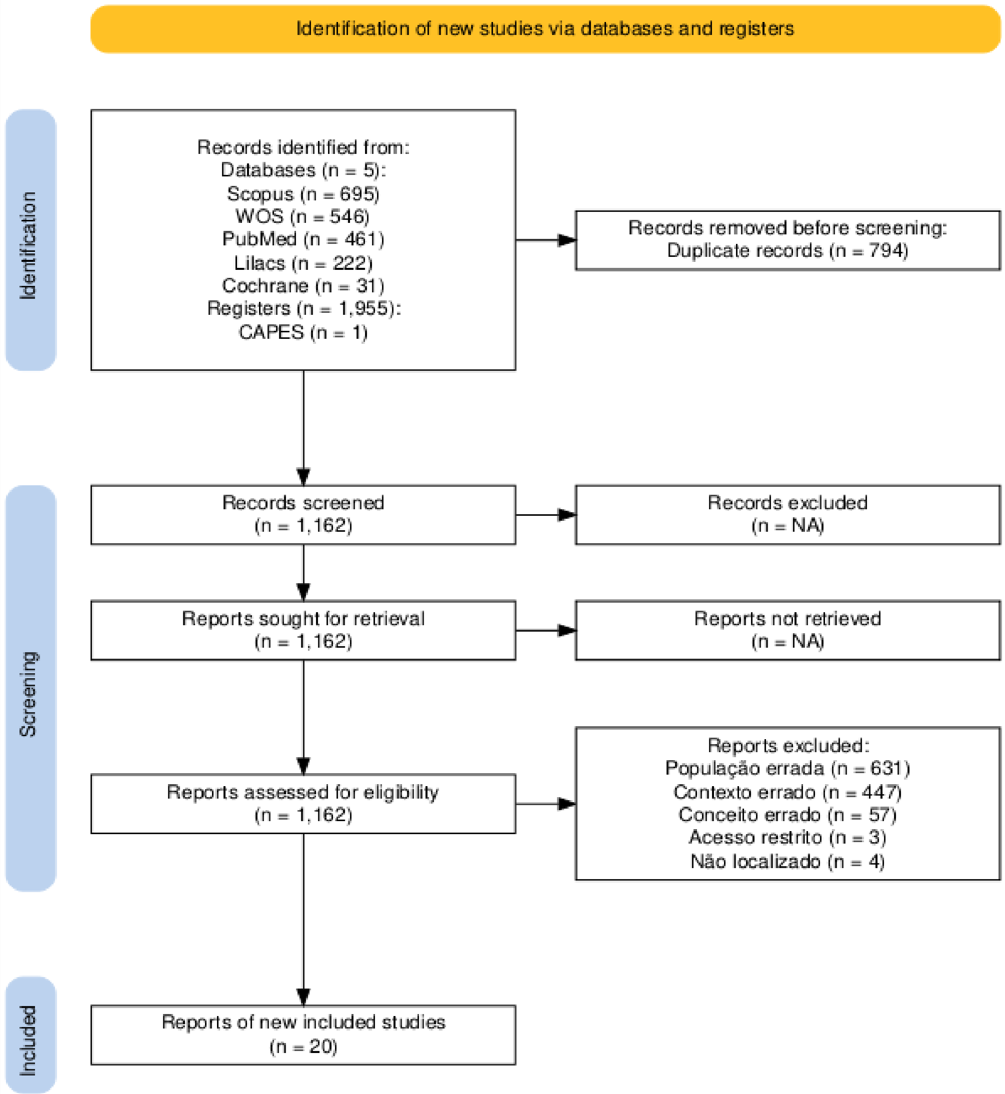
For the third stage and gray literature, the catalogs of theses and dissertations from the open access repositories of the Coordination for the Improvement of Higher Education Personnel (CAPES), Theses and Dissertations of South Africa (ETD Portal), Online Academic Archive (DIVA), Online Electronic Theses Service (EThOS), European Thesis Portal (DART), Open Access Theses and Dissertations (OATD), Open Access Scientific Repository of Portugal (RECAAP), and the National Library of Australia, Trobe, were used. (TROVE). A search was conducted on Google Scholar for unpublished literature.

After the searches, all identified citations were exported from their respective databases in RIS (Research Information Systems) format and grouped in the Rayyan Systems Inc. application. (Cambridge, MA, USA) and the duplicates have been removed. Subsequently, two independent reviewers analyzed titles and abstracts according to the inclusion criteria for the citations in the scoping review. Following a similar process, the reviewers read the full text of the selected citations in detail concerning the inclusion criteria.

The discrepancies among the evaluators were resolved by including an additional evaluator.

The process of including studies is reported and presented in Figure 1, following the JBI recommendations for the PRISMA 2020 flowchart. For this, we used the Shiny application (https://estech.shinyapps.io/prisma_flowdiagram). (PAGE et al., 2021; HADDAWAY et al., 2022).

Figure 1. PRISMA 2020 Flow Diagram



Data extraction was carried out using an instrument adapted from the JBI form, with the results entered into electronic spreadsheets available in Microsoft Excel 2016®, created by the researchers themselves and analyzed through descriptive statistics. (POLLOCK et al., 2023).

After data extraction, due to the limitations caused by the lack of data from the selected studies, the reviewers decided not to include the Qualis of the scientific journals of the selected studies in the study results, as stated in the review protocol.

RESULTS

Based on the analysis of the 1,956 studies identified in the selected databases, thesis repositories, and search engines, only 20 addressed the topic and constituted the final sample of the research.

Table 1 below presents the titles and authors of the research, including links to search for the types of technologies used in the studies.

Table 1 – Author, titles, country, and year of publication of the studies. Manaus-AM, 2024.

Title	Authors	Link
CompuLung: a multimedia CBL on pulmonary auscultation	Mangione, S.; Oliveira, A.	https://pubmed.ncbi.nlm.nih.gov/1482999/
Multimedia presentation of lung sounds as a learning aid for medical students	Sestini P; Renzoni E; M; Beltrami V; Vagliasindi M	https://pubmed.ncbi.nlm.nih.gov/7544742/
Computer-based lung sound simulation	Kompis M; Russi EW	https://pubmed.ncbi.nlm.nih.gov/9246857/
Effect of multimedia on the self-learning of lung sound in medical students	Park, MJ; Ribeiro, MG; Ribeiro, D.C.; Mo, EK; Ribeiro, IG; Ribeiro, J.	https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01046291/full
[A new medical education using a lung sound auscultation simulator called "Mr. Lung"]	Yoshii C; Anzai T; Yatera K; Kawajiri T; Nakashima Y; Kido M	https://pubmed.ncbi.nlm.nih.gov/12235955/
Organização e avaliação de um software para ensino de ausculta respiratória.	Fátima A. Caromanoa; Adelson Corigliano; Maria Sílvia Pardo	https://www.revistas.usp.br/fpusp/article/view/78248/0
A construção de um software educativo sobre ausculta dos sons respiratórios.	Melo, Francisca Nellie de Paula; Damasceno, Marta Maria Coelho	https://doi.org/10.1590/S0080-62342006000400016
A French national research project to the creation of an auscultation school: The ASAP project	Andrès, Emmanuel; Ribeiro, Sandra; Gass, Raimundo; Brandt, Christian	https://dx.doi.org/10.1016/j.ejim.2008.08.013

Improved auscultation skills in paramedic students using a modified stethoscope	Simon EL; Lecat PJ; Haller NA; Williams CJ; Martinho SW; Carney JA; Pakiela JA	https://pubmed.ncbi.nlm.nih.gov/22633756/
Evaluating the impact of high- and low-fidelity instruction in the development of auscultation skills	Chen, R; Ribeiro, LE; Ribeiro, GR	https://doi.org/10.1111/medu.12653
OMARC: An online multimedia application for training healthcare providers in the assessment of respiratory conditions	Meruvia-Pastor O; Patra P; Andrés K; Twomey C; Peña-Castillo L	https://pubmed.ncbi.nlm.nih.gov/26980355/
Usability of Computerized Lung Auscultation–Sound Software (CLASS) for learning pulmonary auscultation	Ana Machado; Ana Oliveira; Cristina Jácome; Marco Pereira; José Moreira; João Rodrigues; José Aparício; Luis M. T. Jesus; Alda Marques	https://dx.doi.org/10.1007/s11517-017-1697-8
A prospective study on the efficacy of patient simulation in heart and lung auscultation	Bernardi S; Giudici F; Leone MF; Zuolo G; Furlotti S; Carretta R; Fabris B	https://pubmed.ncbi.nlm.nih.gov/31337361/
The effect of high- and low-fidelity simulators in learning heart and lung sounds by undergraduate nurses: a randomized controlled trial	Mutlu B, Yılmaz OE, Dur S	https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01988870/full
[Evaluation of the use of a simulation software in the learning of cardiopulmonary auscultation in undergraduate medical students]	Malmartel A; Ecollan M; Bories MC; Jablon E; Planquete B; Ranque B	https://pubmed.ncbi.nlm.nih.gov/32660857/
Examining Knowledge, Skill, Stress, Satisfaction, and Self-Confidence Levels of Nursing Students in Three Different Simulation Modalities	Üzen Cura, Sengül; Kocatepe, Vildan; Yildirim, Dilek; Küçükakgün, Hilalnur; Atay, Selma; Ünver, Vesile	https://dx.doi.org/10.1016/j.anr.2020.07.001
The use of spectrograms improves the classification of wheezes and crackles in an educational setting	J. C. Aviles-Solis; I. Storvoll; Sophie Vanbelle e H. Melbye	https://pubmed.ncbi.nlm.nih.gov/32440001/
Do basic auscultation skills need to be resuscitated? A new strategy for improving competency among nursing students	Goldsworthy, S; Gomes, P; Oliveira, M; Oliveira, J D; Oliveira, J; Pereira, G; Oliveira, L	https://pubmed.ncbi.nlm.nih.gov/33341062/
Respiratory Auscultation Lab Using a Cardiopulmonary	Kaminsky J; Bianchi R; Eisner S; Ovitsh	https://pubmed.ncbi.nlm.nih.gov/33768144/

Auscultation Simulation Manikin	R; Lopez AM; Soares L; Talukder N; Quinzinho A	
The Effect of a Child Model on Breath-Sounds Examination Skills and Satisfaction on Nursing Students	Thamruangrit S; Santati S; Granger J; Buadong D; J Thongsri	https://pubmed.ncbi.nlm.nih.gov/35885692/

The predominant language in the publication of the studies was English, with 70% (n = 14) of the included studies, followed by Portuguese with 15% (n = 03), Korean with 5% (n = 01), French with 5% (n = 01), and Japanese with 5% (n = 01) of the included studies.

Regarding the countries, the United States of America had the highest number of studies conducted, representing 15% (n = 3) of the research, followed by Brazil with 10% (n = 2), Canada with 10% (n = 2), France with 10% (n = 2), Italy with 10% (n = 2), Turkey with 10% (n = 2), South Korea with 5% (n = 1), Scotland with 5% (n = 1), Japan with 5% (n = 1), Norway with 5% (n = 1), Portugal with 5% (n = 1), Switzerland with 5% (n = 1), and Thailand with 5% (n = 1).

Table 2 presents a summary of the main findings regarding the types of technologies for teaching the auscultation of respiratory sounds, along with the target audiences and study methods.

Table 2 – Types of technologies, target audiences, and methods. Manaus-AM, 2024.

Collection indicators	Main findings
Types of technologies	High-Fidelity Simulation Training – 8 (40%) Software – 7 (35%) Web Archive – 3 (15%) Multimedia – 2 (10%)
Target audience	Medical Students – 10 (50%) Nursing Students - 6 (30%) Physiotherapy Students – 2 (10%) Health professionals – 2 (10%)
Study methods	Comparative Study – 8 (40%) Controlled and Randomized Clinical Trial – 5 (25%) Pilot Study – 2 (10%) Controlled Clinical Trial – 1 (5%) Intervention Study – 1 (5%) Validation Study – 1 (5%) Prospective Study – 1 (5%) Experience Report – 1 (5%)

DISCUSSION

The research resulting from the analysis of the results revealed that high-fidelity simulation training is a new methodology for health education aimed at skill training and includes sophisticated and realistic mannequins. Therefore, the mannequin is a vital tool for encouraging training, leading to proficient target skills. (THAMRUANGRIT et al., 2022).

Most of the studies were conducted for medical students. This happens because this technique originally belonged to the domain of doctors; however, although no data has been found regarding nurses' competence in auscultation, this technique is an integral part of nurses' clinical assessment. (GOLDSWORTHY et al., 2021).

The methods used by researchers in the studies were predominantly comparative. This also relates to the need to teach students to distinguish between normal and pathological breath sounds. The performance of the technique of pulmonary auscultation is evaluated in two ways: by comparing findings among professionals and by assessing the performance of a specific sound with a specific diagnosis. (BERTRAND et al., 2020; KAMINSKY et al., 2021).

During professional health training, it is essential to encourage the technique of conventional auscultation through the use of audiovisual technology and simulation. However, modernity has also brought a dangerous reality composed of a large amount of misinformation. A survey conducted on the "YouTube" platform regarding respiratory sounds in supposed educational sites revealed the presence of many misleading and confusing pieces of information. (BERTRAND et al., 2020).

On the other hand, currently, most universities use e-learning platforms to offer courses. Distance education is a modern complement and, at times, even an alternative to traditional education. However, teachers face difficulties in keeping students' attention, which ultimately leads to the abandonment of online education systems. To solve this problem, game technologies or gamification techniques were proposed (KHALDI; BOUZIDI; NADER, 2023), a technology that was not found in our research for teaching the auscultation of respiratory sounds.

Scope revisions do not take into account feasibility, suitability, importance, or effectiveness; therefore, advanced analytical methods were not used. The JBI scope review guidance suggests the use of basic qualitative content analysis. (POLLOCK et al., 2023).

In our searches, we did not gain access to CINAHL via CAFe. This could result in the loss of valuable studies. We also do not aim to verify the automatic learning of respiratory sounds, but we observed a significant number of studies focused on this theme. However, our findings reveal positive varieties for the types of technologies for teaching the auscultation of respiratory sounds.

Multimedia – Multimedia (materials, often computer applications, that integrate some or all of the combined packages of text, sound, graphics, animation, and video) are often used in conjunction with other technologies or on their own. SESTINI et al., 1995 and KOMPIS; EW, 1997, used multimedia programming, associating lung sounds with computer-generated graphics as a teaching resource for medical students. The objective was to investigate whether a multimedia presentation of the acoustic and graphic characteristics of lung sounds could enhance the learning of lung auscultation by medical students, compared to conventional teaching methods. (SESTINI et al., 1995; KOMPIS; EW, 1997).

Software - The use of software (programs and operational data that instruct the functioning of a digital computer) was the second most used and versatile technology as well. MANGIONE; and DENNIS, 1992, developed a Multimedia Computer-Based Learning (CBL) program called "CompLung," which incorporates graphics and images with sound and motion. However, this software did not allow students to record respiratory sounds or test the knowledge they had acquired. (MANGIONE; DENNIS, 1992).

On the other hand, MARQUES et al., 2018, developed the Computerized Pulmonary Auscultation Software (CLASS) and evaluated physiotherapy students using three different usability testing methods: computer screen videos (CSVs), think-aloud reports (TA), and facial expression videos. (FEVs). The combination of the three usability methods identified the advantages/disadvantages of the CLASS and guided future developments. (MARQUES et al., 2018).

CAROMANOA; CORIGLIANO; and PRADO, 2002, developed software with a "multimedia kit" for physiotherapy students, divided into three stages: the first stage focused on the anatomical-functional review of the cardiorespiratory system; the second stage aimed to teach the fundamentals of respiratory auscultation; and the third was directed towards the technique of pulmonary auscultation, concluding with the simulation of clinical cases, which resulted in satisfactory learning outcomes for the students. (CAROMANOA; CORIGLIANO; PARDO, 2002).

MELO; and DAMASCENO, 2006, added to their study with nursing students the use of 3D technology, including avatars (virtual representations of the patient, nurse, and objects) and a virtual environment for auscultation, employing simulation procedures. However, the research results were not presented. (MELO; DAMASCENO, 2006).

Web archives - Web archives (a collection of saved/preserved web pages) require greater collaboration, and we are investing in that. E. Andrès et al., 2009, developed an ambitious study called the ASAP project or "Analysis of Auscultatory and Pathological Sounds." Its goal was to provide the patient and the medical team with non-invasive, mobile, and communicative measurement tools that would allow for the secure transmission of vital information, objectively qualified by signal processing tools (ANDRÈS et al., 2009).

A fundamental characteristic of this type of technology is the use of an online platform to facilitate access for users in remote locations, such as OMARC, an online multimedia application designed to train health students in the assessment of respiratory diseases. Its interface consists of two distinct components: a sound glossary and a rich multimedia interface that presents clinical case studies and provides access to lung sounds placed within a model of the human torso. (MERUVIA-PASTOR et al., 2016).

High-fidelity simulation training – Finally, high-fidelity simulation training (a controlled learning environment that accurately represents reality) is the most widely used technology today. CHEN; GRIERSON; and NORMAN, 2015, in their studies with nursing students, assessed the impact of high-fidelity simulation or "mannequin" learning compared to low-fidelity simulation or "computers," and demonstrated that there was no significant difference in performance between the mannequin instruction groups and the computer simulation groups. (CHEN; GRIERSON; NORMAN, 2015).

On the other hand, MUTLU; YILMAZ; and DUR, 2019, revealed in their studies that the use of high-fidelity simulators is more effective in teaching heart and lung sounds to nursing students than low-fidelity simulators. (MUTLU; YILMAZ; DUR, 2019).

In turn, ÜZEN CURA et al. 2020 examined the levels of knowledge, skill, stress, satisfaction, and self-confidence of undergraduate students in three nursing schools and observed an increase in knowledge levels after practice in the three groups that had similar knowledge levels before practice.

The stress levels on the Virtual Analog Scale of the students in the standardized patient group were higher than those of the others. The average satisfaction scores regarding student learning were higher in the standardized patient group. The students in the part-time instructor's group showed lower self-confidence scores regarding their learning. The student's skill scores were lower in practice with standardized patients than in other areas (ÜZEN CURA et al., 2020).

CONCLUSION

The types of technologies currently used for teaching the auscultation of respiratory sounds are 8 (40%) High-Fidelity Simulation Training, 7 (35%) Software, 3 (15%) Web Archive, 2 (10%) Multimedia, where 10 (50%) were developed for Medical Students and 8 (40%) were Comparative Studies. The limitations in accessing paid domains may result in the exclusion of important studies on respiratory sound technologies.

There is an urgent need to consider new types of technologies for teaching respiratory sounds, especially in the technical skills of auscultation for healthcare professionals, where, in recent years, technologies have been widely used for the automatic diagnosis of respiratory diseases. (HONKOOP; USMANI; BONINI, 2022). We consider it necessary to conduct new studies on the subject with different approaches as important.

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