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Use of digital technologies for staff education and training programmes on newborn resuscitation and complication management: a scoping review

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ABSTRACT

Background Poor-quality care is linked to higher rates of neonatal mortality in low-income and middle-income countries (LMICs). Limited educational and upskilling opportunities for healthcare professionals, particularly those who work in remote areas, are key barriers to providing quality neonatal care. Novel digital technologies, including mobile applications and virtual reality, can help bridge this gap. This scoping review aims to identify, analyse and compare available digital technologies for staff education and training to improve newborn care.

Methods We conducted a structured search of seven databases (MEDLINE (Ovid), EMBASE (Ovid), EMCARE (Ovid), Global Health (CABI), CINAHL (EBSCO), Global Index Medicus (WHO) and Cochrane Central Register of Controlled Trials on 1 June 2023. Eligible studies were those that aimed to improve healthcare providers' competency in newborn resuscitation and management of sepsis or respiratory distress during the early postnatal period. Studies published in English from 1 January 2000 onwards were included. Data were extracted using a predefined data extraction format.

Results The review identified 93 eligible studies, of which 35 were conducted in LMICs. E-learning platforms and mobile applications were common technologies used in LMICs for neonatal resuscitation training. Digital technologies were generally well accepted by trainees. Few studies reported on the long-term effects of these tools on healthcare providers' education or on neonatal health outcomes. Limited studies reported on costs and other necessary resources to maintain the educational intervention.

Conclusions Lower-cost digital methods such as mobile applications, simulation games and/or mobile mentoring that engage healthcare providers in continuous skills practice are feasible methods for improving neonatal resuscitation skills in LMICs. To further consider the use of these digital technologies in resource-limited settings, assessments of the resources to sustain the intervention and the effectiveness of the digital technologies on long-term health provider performance and neonatal health outcomes are required.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Novel digital technologies can help provide continual education for healthcare providers, especially for those working in remote areas in low-income and middle-income countries (LMICs).

WHAT THIS STUDY ADDS

⇒ e-Learning platforms or mobile applications were common technologies used for neonatal resuscitation training in LMICs, while high-fidelity mannequins are a more common technology used in high-income countries.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study suggests that the use of lower-cost digital technologies—such as mobile applications, simulation games and/or mobile mentoring—are feasible educational methods that could improve neonatal resuscitation skills in LMICs.

⇒ These digital technologies require further assessment, particularly on what resources are needed to sustain them, and their effectiveness on long-term performance of health providers, and on neonatal health outcomes.

INTRODUCTION

An estimated 2.3 million newborn deaths occurred worldwide in 2021,[1] mainly due to preterm birth complications and intrapartum-related events.[2] These deaths could have been averted by providing high-quality maternal and newborn care.[3] Despite repeated calls for scaling up high-quality care, evidence suggests in low-income and middle-income countries (LMICs), less than half of the recommended maternal and newborn preventative and/or curative clinical actions are routinely provided.[3]

In order to ensure that high-quality newborn care is universally available, healthcare providers need access to initial and continued education and training opportunities. Available evidence has linked limited training opportunities for maternal and newborn health professionals to poor quality intrapartum and postnatal care.[4] Limited

access to in-service training is a particular issue for providers in rural or remote areas, which can also serve to worsen health inequities.[5] Analysis of health facility data from five African countries suggests that the quality of maternity healthcare services is often lowest in primary healthcare facilities with low numbers of births.[6] Similarly, provider newborn resuscitation skills and the ability to manage newborn complications may degrade more quickly in facilities where there are fewer births, and thus fewer opportunities to practice these skills.

In the last two decades, diverse digital technologies for healthcare settings have been developed, aimed at improving front-line clinical practice and healthcare professional education and training.[7] More recently, service disruptions due to COVID-19 have accelerated the use of digital technologies in routine care provision in many countries, including LMICs.[8]

Digital technologies can support continuous professional education and training for providers, including those in limited-resource or remote contexts.[9] Systematic reviews from diverse health topics have found that the use of various digital technologies for education and training—such as online/offline computers, mobile applications, simulation manikins and virtual reality technologies—can increase health providers' knowledge.[10–13] However, no previous review has explored the use of digital technologies for education and training in relation to newborn care. Therefore, the aim of this scoping review was to identify, analyse and compare digital technologies used for staff education and training on newborn care. We also evaluated the acceptability and required resources for digital technologies, and their potential application in the low-resource context.

METHODS

This review was conducted per the Joanna Briggs Institute Methodology for Scoping Reviews and the Preferred Reporting Items for Systematic Reviews[14] and Meta-Analyses extension for Scoping Reviews standards.[15] The protocol for this scoping review was registered in the Open Science Framework.[16] The WHO classification of digital health interventions focuses on the use of digital technologies for healthcare providers.[7 17] As such, our review focused on the use of digital technologies for in-service training and did not include studies

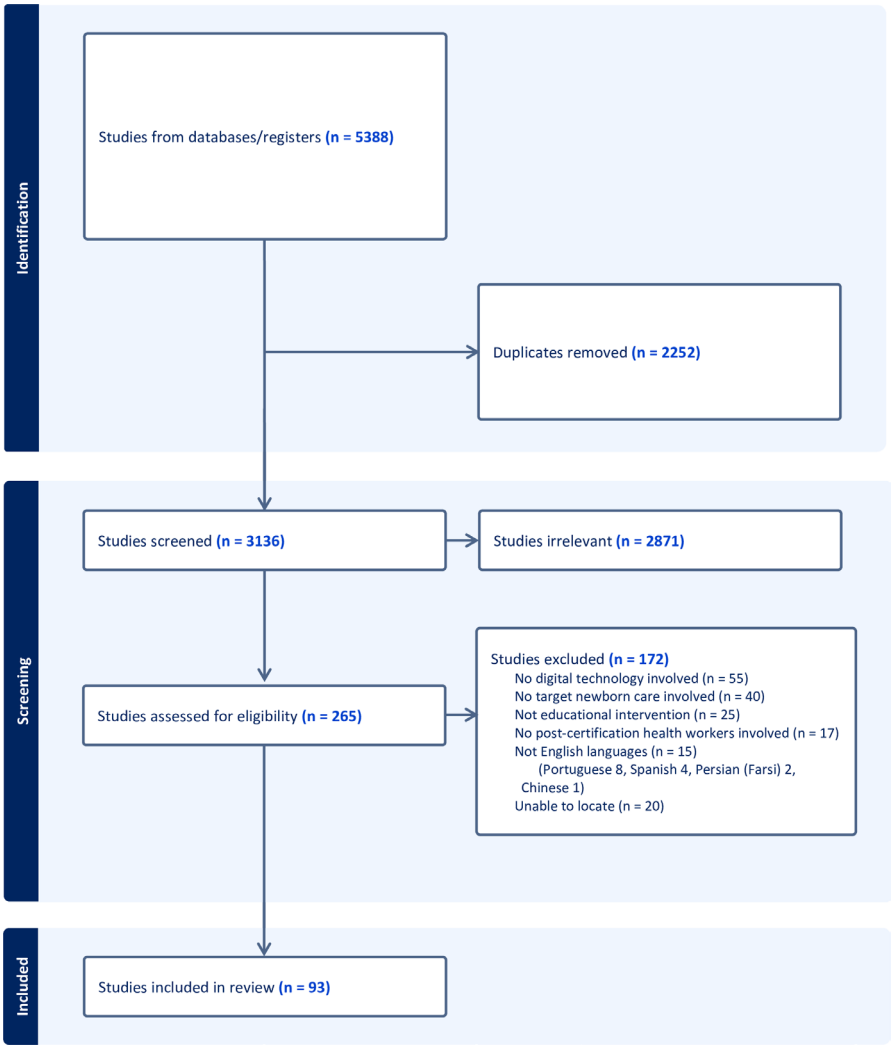

Figure 1 Search result.

Table 1 Characteristics of included studies (n=93)

Characteristic	Number of studies
Study design	
Randomised controlled trial	18
Cluster randomised controlled trial	3
Pre–post study	27
Other interventional study	12
Mixed methods	3
Observational study	6
Qualitative study	4
Case report	9
Pilot study	5
Protocol	3
Other	3
Geographical location	
East Asia and Pacific	2
Europe and Central Asia	15
Latin America and Caribbean	4
Middle East and North Africa	2
North America	41
South Asia	12
Sub-Saharan Africa	14
Multiple regions	3
Income level	
Low-income and middle-income countries	35
High-income countries	58
Topic focus (multiple)	
Neonatal resuscitation	86
Respiratory distress	21
Sepsis	9

that focused on preservice training. Only studies where the main goal of the training programme was to improve healthcare providers clinical competence were included in the review.

Patient and public involvement

This scoping review did not involve direct patient or public involvement.

Selection criteria

Eligible studies were those that described the use of digital technologies for education and training programmes for health professionals providing newborn care. We included studies that focused on newborn resuscitation and complication management for neonatal sepsis and/or respiratory distress. We chose these three clinical practices as they are the major lethal conditions requiring treatment interventions in the early neonatal period, and healthcare providers in facilities with few births have fewer opportunities to practise, therefore, would benefit from regular training. Eligible studies involved use of a digital technology only, or a digital technology used in combination with other education and training activities. We excluded studies that related to interventions aimed only at undergraduate or postgraduate students (ie, preservice training), as our focus was to support in-service education and training. We included primary studies of any design (qualitative, quantitative or mixed methods) as well as study protocols and case reports. We did not include systematic, narrative or literature reviews. Studies from any country were eligible, provided they were published in English from 1 January 2000 onwards, as this was the period during which a rapid increase in the use of digital technologies for health was recognised.[18]

Search strategy and screening for eligibility

We consulted an information specialist and developed a search strategy based on the above criteria (online supplemental material 1). Seven databases were searched on 1 June 2023—MEDLINE (Ovid), EMBASE (Ovid), EMCARE (Ovid), Global Health (CABI), CINAHL (EBSCO), Global Index Medicus (WHO) and Cochrane Central Register of Controlled Trials (CENTRAL). All recovered citations were imported into systematic review software Covidence[19] and duplicates removed. Abstract and full text screening were performed in duplicate on Covidence by four reviewers. Disagreements were resolved through discussion.

Data extraction and synthesis

Data extraction was performed in duplicate using Covidence, according to a predefined data extraction form (online supplemental material 2). The form was pretested by extracting data from five studies and then revised and agreed on the reviewers. Extracted data were summarised descriptively and categorised according to types of digital technologies and how they were used (exclusive or blended), and the mode in which training was delivered (group, individual, mentoring or mixed). We categorised studies as 'exclusive' when they used a digital technology to deliver the entire training, and 'blended' when the digital technology was used in conjunction with other methods to deliver the training.

RESULTS

Characteristics of included studies

The database search yielded 3136 citations after removal of 2252 duplications (figure 1). After title and abstract screening, and full text review, a total of 93 articles were included (online supplemental table 1a,b). Of these, 35 were conducted in LMICs, of which 26 were in South Asian or sub-Saharan African countries (table 1). Neonatal resuscitation was included in 86 studies. There were two studies specific to sepsis[20 21] and five to respiratory distress.[22–26] Six studies described digital devices that were intended to be used for future staff training

Table 2 Use of digital technology and modes of delivery of educational interventions (n=87)

Use of digital technology	Modes of training delivery			
	Group learning (n=40)	Individual learning (n=28)	Mentoring (n=2)	Mixed (n=17)
Exclusive use (n=42)	Teleconference to provide facilitated resuscitation training (8)	eLearning platform (9)/ mobile application (6)/ application for simulated games (4)/computer-based simulation game (8)/virtual reality (1)	Individual feedback via telecommunication (1)	eLearning platform for self-learning with functions for group interactions (3) / social network service (1)/ mobile application and remote facilitation (1)
Blended use (n=45)	Simulation-based learning with high-fidelity mannequins (31)/video laryngoscope (1)	–	Mobile application to assist feedback to daily practice (1)	Mobile phone for remote mentoring after a group simulation training (2) Individual learning via eLearning platform or mobile applications beside a group simulation training (9)/self-guided practice after a group simulation training (1)

in newborn care but did not provide information on the design of educational interventions.[27–32]

What digital technologies were used in education and training, and how they were used

Across the included studies, the following digital technologies were identified: teleconference, eLearning platforms, mobile applications, social network services, high-fidelity mannequins, video laryngoscopy, computer-based simulated games, virtual reality, mobile phone and text messaging services, and motion camera to record skills performance. High-fidelity mannequins are life-like mannequins that can mimic human physiology.

Digital technologies were used exclusively in 42 studies (table 2). Remote education was provided via eLearning platforms (n=12),[20 22 23 33–41] teleconference (n=9),[42–50] mobile applications for self-directed learning (n=7),[51–57] mobile-based simulated games (n=4),[58–61] computer-based simulated games (n=8), of which 5 reported the same intervention,[62–69] mobile virtual reality for simulation (n=1)[70] or social network service (n=1).[71] One computer-based simulated game was implemented onsite as it required a specific device for sensory interface.[69]

Digital technology was blended with other non-digital training activities in the other 45 studies, including onsite simulation-based training for neonatal resuscitation (n=43); multifaceted educational materials on sepsis management (n=1)[21]; applied mobile application to support mentors providing tailored feedback on daily maternal and neonatal care (n=1).[72] In 32 studies providing simulation-based training, high-fidelity mannequins were used to increase fidelity of clinical scenarios.[24–26 73–101] The other 11 simulation-based studies used digital technologies to supplement on-site simulation-based training with digital learning materials,[102–109] video laryngoscopy[110] or provided mobile mentoring following on-site training activities.[111 112]

Digital technologies by income level

A total of 35 studies were conducted in LMICs, of which 22 used digital technology exclusively. The most common methods were eLearning platforms (n=10)[22 33 35–38 40 41 109] and mobile applications (n=9). Mobile applications included the Safe Delivery App (SDA),[51 53–57] Helping Babies Breathe Prompt[58] and the Life-Saving Instruction for Emergencies applications.[59 60] Blended use of digital technology was more common in high-income countries (HICs) (n=34), as was use of high-fidelity mannequins for simulation-based neonatal resuscitation training (n=27).

Educational outcomes of digital technology-based training

There were 29 studies that compared the educational outcomes between intervention and control groups. Of these, 10 studies reported statistically significant better educational outcomes in intervention groups while 1 reported better outcomes in a control group. There were three studies on the SDA, a mobile application providing point-of-care access to clinical protocols. One trial reported improved neonatal resuscitation knowledge at 3 months.[51] Another trial reported improved neonatal resuscitation skills at 12 months, however, there was no significant reduction in perinatal mortality.[53] The third SDA trial was an interventional study that reported significant improvement in knowledge and confidence scores in neonatal care.[57]

There were two trials of 'mobile mentoring' with frequent skill practice: one improved neonatal resuscitation knowledge and skill at 1 year and demonstrated a reduction in neonatal mortality (adjusted relative risk

0.30, 95% CI 0.21 to 0.43)[111]; another study improved skills scores at 1 year.[112]

Four studies evaluated simulation-based training. One study comparing with and without in situ high-fidelity simulation-based training reported greater improvement in scores of neonatal resuscitation skill and team performance at immediate postintervention.[88] Another study compared on-site simulation training with a preceding online classroom and training without an online classroom and reported immediate improvements in knowledge and skills in the intervention group.[105] The other two studies reported improvement in intubation performance during the training intervention.[43 110]

Two studies evaluated coaching via teleconferencing: one showed significant immediate improvements in ventilation performance in the intervention group[50] while another study showed a significant reduction in neonatal resuscitation skill scores in the intervention group.[49]

In pre–post studies, 22 out of 24 studies that assessed trainees' knowledge, skills, performance or confidence scores showed an improvement in the scores at postevaluation. The time points for scoring in the pre–post studies were immediately (n=20), at 1.5 months,[61] at 2 and 5 months (n=2),[65 67] and at 6 months (n=1)[54] postintervention. When measured, there was no reported improvement in team performance.[26] One study showed a reduction in neonatal deaths from 0.8% to 0.6% (as a percentage of all live births).[74] Three studies did not show a significant improvement in neonatal deaths regardless of improvement in neonatal resuscitation performance among healthcare providers.[93 98 109]

Resource requirement for use of digital technologies

Only five studies reported on the cost of using digital technology for educational interventions. Of these, three reported on simulation-based training that involved high-fidelity mannequins. One reported that it cost US$290 000 to develop the simulation programme,[84] another reported a total of US$2985 to run a training workshop,[87] and the third reported that the simulation required an investment of US$3390 to achieve one clinical improvement during the actual clinical care subsequent to the simulation.[94] While the actual cost or cost estimates were not reported in the other two studies, both reported that distance learning was more cost-effective than face-to-face training due to reduced travel expenses for trainers.[42 45]

Participants' perception of digital technologies

32 studies reported participants' perception of the use of digital technologies in training programmes. The digital technologies included high-fidelity mannequins (n=10),[73 75 77 84 86 87 89 90 96 97] teleconferencing (n=6),[42 44 45 47 49 103] e-Learning platforms (n=6),[20 33 40 41 105 106] mobile applications (n=5),[51 55 57 58 104] virtual reality platforms (n=2),[28 108] computer-based gaming (n=1),[62] a social network service (n=1)[71] and a motion camera to record clinical practice (n=1).[31] Trainees reported positive feelings or high satisfaction after using high-fidelity mannequins in all 10 studies. Of these, two studies comparing trainee preference between digital simulators and traditional training found that trainees preferred training with digital simulators.[73 75] Three studies on teleconferencing for neonatal resuscitation training reported negative feedback from participants about logistical issues and the quality of facilitation.[45 47 49] Furthermore, Jones-Bamman *et al* reported that half of the participants felt that simulation training would work better face-to-face than with teleconferencing.[45] The other modalities were positively accepted by trainees with high satisfaction rates and no critical feedback was reported.

DISCUSSION

This scoping review explored the landscape of digital technologies for educational interventions on neonatal resuscitation and management of respiratory distress and sepsis. A majority of the studies used digital technologies to teach neonatal resuscitation and included opportunity for learners to practise or interact. In LMICs, e-Learning platforms or mobile applications were common technologies used for neonatal resuscitation training. In HICs, simulation training that involved high-fidelity mannequins was a more common technology used. Given the use of high-fidelity mannequins is resource intense and requires significant investment in technologies and equipment,[113] it is not surprising that these are more commonly available and applied in high-resource settings. A 2013 literature review reported that interactive strategies such as simulation-based training and hands-on practice would be more effective than passive transfer of information such as lectures and reading.[114] However, the review concluded that both the setting for the training and the digital technologies used should be considered in relation to supporting educational technique and intended learning not merely availability.

Simulation-based training has been proven to be effective to strengthen procedural skills for performing good quality of neonatal resuscitation, however, it has not been conclusively shown whether high fidelity would be more effective than low-fidelity in improving healthcare providers' performance, consequently improving neonatal outcomes.[115] Moreover, the present review found that high-fidelity mannequins were expensive and were mostly implemented in HICs. Simulation-based learning via mobile applications, games or virtual reality could be feasible alternatives to resource-intensive measures such as high-fidelity mannequins to improve neonatal resuscitation skills in LMICs. Low-dose high-frequency (LDHF) practice sessions combined with mobile mentoring were reported to be effective in improving provider performance and neonatal health outcomes in the resource-limited settings.[111] However, LDHF with automated feedback did not reduce neonatal mortality.[93] Application of digital technologies varied between studies, and supporting educational technology and intended

learning were different, making it difficult to compare outcomes and conclude which digital technology is most promising. In addition, it was difficult to compare which digital technology was more cost-effective, as no studies reported economic costs of using digital technologies in relation to health outcomes in low-resource contexts.

Currently, translation and adaptation of digital training programmes are expensive and time-consuming. However, the rapid advancement of technologies, including artificial intelligence (AI) translation programmes, may in the future be another advantage of digital training programmes.[116] Affordable and effective translation could support fast scale-up of effective training programmes. Further research is required to evaluate aspects of ease of expansion and impact on healthcare providers' performance and neonatal health outcomes. The WHO guideline on digital interventions for health systems strengthening states that digital technologies for staff education should be considered as a complement to, but not a substitute for, in-service training.[7] Online provision of information can help scale-up interventions, however, exclusive use of these technologies without a mechanism for interaction may have a limited impact on positive educational outcomes.[114] .

This review identified a lack of research that evaluated long-term outcomes of trainee performance, and whether these digital technologies improve neonatal health outcomes. Additionally, few studies reported on resources required to implement, maintain or scale up digital technology-based training. Future studies should focus on whether a particular digital technology for educational intervention can improve long-term healthcare providers' performance and neonatal health outcomes. Research also needs to examine whether the intervention is cost-effective compared with conventional educational approaches that do not use any digital technologies. Despite the current research gap, the recent increase in the availability of digital technologies has the potential to provide widespread opportunities for continuing education for healthcare providers and improve neonatal care. However, there are also concerns that digital technologies may increase inequalities by providing better access to those in urban areas and those with higher digital skills.[116] Future implementation of digital-based training needs to be carefully designed to be accessible and acceptable to healthcare providers in remote areas and to be easily managed and sustained without intensive resources.

Strengths and limitations

The strength of this review is that it identified studies conducted in countries of all income levels to identify all available digital technologies for educational interventions. In addition, this review included any forms of digital technology to understand how digital technologies can enhance traditional educational interventions. A limitation is that we did not conduct quality appraisal of the included studies, as we included a wide range of evidence sources. However, we consider that the quality of the included studies was assured at a certain level as almost all studies were published in peer-reviewed journals. Another limitation was that we only included articles that were published in English. Therefore, some studies reporting on educational interventions using digital technologies were not included.

CONCLUSION

Digital technologies are increasingly used to provide training in neonatal resuscitation. Lower-cost methods such as mobile mentoring that engage healthcare providers in continuous skills practice are feasible methods to improve neonatal resuscitation skills in LMICs. To further consider the use of these digital technologies in resource-limited settings, an assessment of resources required to sustain the digital technologies is required. Evaluation of the effectiveness of the digital technologies on long-term health provider performance and neonatal health outcomes is also needed.

Contributors SHoriuchi and JPV conceptualised this study. SHoriuchi drafted protocol with input from JPV and RS. SHoriuchi, SHuang, TS and CB performed literature screening and data extraction. JPV and RS provided critical input into advising on the scoping review. SHoriuchi prepared an original draft. All authors contributed to the interpretation and editing the paper. LR advised on the development of the search strategy. SHoriuchi is responsible for the overall content as guarantor.

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Patient consent for publication Not applicable.

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REFERENCES

1 United Nations Inter-agency Group for Child Mortality Estimation (UN IGME). *Levels & trends in child mortality: report 2022, Estimates developed by the United Nations Inter-Agency Group for Child Mortality Estimation, United Nations Children's Fund*. New York, 2023.
2 Perin J, Mulick A, Yeung D, *et al*. Global, regional, and national causes of Under-5 mortality in 2000–19: an updated systematic analysis with implications for the sustainable development goals. *Lancet Child Adolesc Health* 2022;6:106–15.
3 Kruk ME, Gage AD, Arsenault C, *et al*. High-quality health systems in the sustainable development goals era: time for a revolution. *Lancet Glob Health* 2018;6:e1196–252.
4 Munabi-Babigumira S, Glenton C, Lewin S, *et al*. Factors that influence the provision of Intrapartum and postnatal care by skilled birth attendants in low- and middle-income countries: a qualitative evidence synthesis. *Cochrane Database Syst Rev* 2017;11:CD011558.
5 Strasser R, Neusy AJ. Context counts: training health workers in and for rural and remote areas. *Bull World Health Organ* 2010;88:777–82.
6 Kruk ME, Leslie HH, Verguet S, *et al*. Quality of basic maternal care functions in health facilities of five African countries: an analysis of national health system surveys. *Lancet Glob Health* 2016;4:e845–55.
7 World Health Organization. *WHO guideline: recommendations on digital interventions for health system strengthening*. Geneva: World Health Organization, 2019.
8 Mitgang EA, Blaya JA, Chopra M. Digital health in response to COVID-19 in low- and middle-income countries: opportunities and challenges. *Glob Policy* 2021;12:107–9.
9 Hall CS, Fottrell E, Wilkinson S, *et al*. Assessing the impact of mHealth interventions in low- and middle-income countries – what has been shown to work? *Glob Health Action* 2014;7:25606.
10 Huang Z, Semwal M, Lee SY, *et al*. Digital health professions education on diabetes management: systematic review by the digital health education collaboration. *J Med Internet Res* 2019;21:e12997.
11 Brusamento S, Kyaw BM, Whiting P, *et al*. Digital health professions education in the field of pediatrics: systematic review and meta-analysis by the digital health education collaboration. *J Med Internet Res* 2019;21:e14231.
12 Wahabi HA, Esmaeil SA, Bahkali KH, *et al*. Medical doctors' Offline computer-assisted Digital education: systematic review by the digital health education collaboration. *J Med Internet Res* 2019;21:e12998.
13 Martinengo L, Yeo NJY, Markandran KD, *et al*. Digital health professions education on chronic wound management: a systematic review. *Int J Nurs Stud* 2020;104:103512.
14 The Joanna Briggs Institute. *Reviewers' manual 2015: methodology for JBI scoping reviews*. Adelaide, Australia: The Joanna Briggs Institute, 2015.
15 Tricco AC, Lillie E, Zarin W, *et al*. PRISMA extension for scoping reviews (PRISMA-SCR): checklist and explanation. *Ann Intern Med* 2018;169:467–73.
16 Horiuchi S, Vogel PJ. The use of digital technologies for education and training programs for Healthcare providers on newborn resuscitation and complication management: protocol for a scoping review. *Open Science Framework* 2022. Available: https://osf.io/dbgrn/?view_only=dcc4875962804551a817d2854c7a47bb2023
17 World Health Organization. *Classification of digital health interventions*. Geneva: World Health Organization, 2018. Available: https://apps.who.int/iris/bitstream/handle/10665/260480/WHO-RHR-18.06-eng.pdf?sequence=1
18 World Health Organization. Resolutions and decisions Wha58.28 eHealth. The fifty-eight world health assembly. 2005. Available: https://apps.who.int/iris/bitstream/handle/10665/20378/WHA58_28-en.pdf;jsessionid=6CE7ED4A910117B22E81BD1B9D1AFB64?sequence=1
19 Veritas Health Innovation. Covidence Systematic Review Software [Program]. Melbourne, Australia,
20 Andrade E, Quinlan LR, Harte R, *et al*. The development and preliminary evaluation of a clinician E-learning training platform for a neonatal sepsis risk monitor for use in ICU settings. *Appl Ergon* 2023;109:103990.
21 Jefferies A, Shah V. Clinicians prefer simple educational tools for implementing practice change. *Med Teach* 2011;33:e602–6.
22 Fonseca LMM, Dias DMV, Góes FDSN, *et al*. Development of the E-baby serious game with regard to the evaluation of oxygenation in preterm babies: contributions of the emotional design. *Comput Inform Nurs* 2014;32:428–36.
23 LeFlore J, Thomas PE, Zielke MA, *et al*. Educating neonatal nurse practitioners in the 21st century. *J Perinat Neonatal Nurs* 2011;25:200–5.
24 Al-Wassia H, Bamehriz M, Atta G, *et al*. Effect of training using high-versus low-Fdelity simulator mannequins on neonatal intubation skills of pediatric residents: a randomized controlled trial. *BMC Med Educ* 2022;22:497.
25 LeFlore JL, Sansoucie DA, Cason CL, *et al*. Remote-controlled distance simulation assessing neonatal provider competence: a feasibility testing. *Clinical Simulation in Nursing* 2014;10:419–24.
26 Maenhout G, Billiet V, Sijmons M, *et al*. The effect of repeated high-Fidelity in situ simulation-based training on self-efficacy, self-perceived leadership qualities and team performance: a quasi-experimental study in a NICU-setting. *Nurse Educ Today* 2021;100:104849.
27 Baldoli I, Tognarelli S, Vangi F, *et al*. An active simulator for neonatal intubation: design, development and assessment. *Med Eng Phys* 2017;39:57–65.
28 Curran V, Xu X, Simmons K, *et al*. A phenomenological study of the use of 360 degree virtual reality (VR) video in pediatric and neonatal resuscitation training. *Health Technol* 2022;12:151–9.
29 Haynes J, Bjorland P, Gomo Ø, *et al*. Novel neonatal simulator provides high-fidelity ventilation training comparable to real-life newborn ventilation. *Children (Basel)* 2021;8:940.
30 Ricci S, Mobilio GA, Calandrino A, *et al*. RiNeo MR: A mixed-reality tool for newborn life support training. 2021 43rd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC); Mexico, 2021:5043–6.
31 Holm-Hansen CC, Poulsen A, Skytte TB, *et al*. Video recording as an objective assessment tool of health worker performance in neonatal resuscitation at a district hospital in Pemba, Tanzania: a feasibility study. *BMJ Open* 2022;12:e060642.
32 Lengua Hinojosa P, Eifinger F, Wagner M, *et al*. Anatomic accuracy, physiologic characteristics, and fidelity of very low birth weight infant airway Simulators. *Pediatr Res* 2022;92:783–90.
33 Deorari A, Thukral A, Aruna V. Online learning in newborn health: a distance learning model. *Natl Med J India* 2012;25:31–2.
34 Aurora ME, Kopek K, Weiner GM, *et al*. Basics of infant conventional mechanical ventilation: an interactive animated teaching Module. *MedEdPORTAL* 2017;13.
35 Bensman RS, Slusher TM, Butteris SM, *et al*. Creating online training for procedures in global health with PEARLS (procedural education for adaptation to resource-limited settings). *Am J Trop Med Hyg* 2017;97:1285–8.
36 Chandrasekaran A, Thukral A, Deorari AK. E-learning in newborn health - a paradigm shift for continuing professional development for doctors and nurses. *Indian J Pediatr* 2014;81:1376–80.
37 Delgado CA, Gómez Pomar EM, Velásquez P, *et al*. Continuous training and certification in neonatal resuscitation in remote areas using a multi-platform information and communication technology intervention, compared to standard training: a randomized cluster trial study protocol. *F1000Res* 2018;6:1599.
38 Gonçalves GR, Peres HHC, Rodrigues R de C, *et al*. Proposta Educacional virtual Sobre Atendimento DA Ressuscitação Cardiopulmonar no Recém-Nascido. *Rev Esc Enferm USP* 2010;44:413–20.
39 Kadivar M, Seyedfatemi N, Zolfaghari M, *et al*. The impact of virtual-based education on nurses' self-efficacy in the level II neonatal care. *Crit Care Nurs J* 2016;In Press:e9281.
40 Sarin-Gulian L, Espinoza J, Lee TC, *et al*. Development and evaluation of a TELE-education program for neonatal ICU nurses in Armenia. *J Pediatr Nurs* 2021;57:e9–14.
41 Thukral A, Sasi A, Chawla D, *et al*. Online neonatal training and orientation programme in India (ONTOP-IN)-The way forward for distance education in developing countries. *J Trop Pediatr* 2012;58:486–90.
42 Cronin C, Cheang S, Hlynka D, *et al*. Videoconferencing can be used to assess neonatal resuscitation skills. *Med Educ* 2001;35:1013–23.
43 Fang JL, Carey WA, Lang TR, *et al*. Real-time Video communication improves provider performance in a simulated neonatal resuscitation. *Resuscitation* 2014;85:1518–22.
44 Jain A, Agarwal R, Chawla D, *et al*. Tele-education vs classroom training of neonatal resuscitation: a randomized trial. *J Perinatol* 2010;30:773–9.
45 Jones-Bamman C, Niermeyer S, McConnell K, *et al*. Teaching helping babies breathe via telehealth: a new application in rural Guatemala. *Biomed Hub* 2019;4:1–6.
46 Loewen L, Seshia MMK, Fraser Askin D, *et al*. Effective delivery of neonatal stabilization education using videoconferencing in Manitoba. *J Telemed Telecare* 2003;9:334–8.

47 Mileder LP, Bereiter M, Wegscheider T. Telesimulation as a modality for neonatal resuscitation training. *Med Educ Online* 2021;26:1892017.
48 Sobelman C, Richard K, McQuilkin P, *et al*. Adapting helping babies breathe into a virtual curriculum: methods, results, and lessons learned. *Glob Pediatr Health* 2021;8:2333794X211019698.
49 Abou-Zamzam A, McCaw J, Niarison HR, *et al*. Cross-sectional study in Madagascar demonstrates efficacy of virtual mentoring and flipped classroom modifications of neonatal resuscitation programme helping babies breathe. *Acta Paediatr* 2023;112:1783–9.
50 Castera M, Gray MM, Gest C, *et al*. Telecoaching improves positive pressure ventilation performance during simulated neonatal resuscitations. *Telemed Rep* 2022;3:55–61.
51 Bolan NE, Sthreshley L, Ngoy B, *et al*. mLearning in the Democratic Republic of the Congo: a mixed-methods feasibility and pilot cluster randomized trial using the safe delivery App. *Glob Health Sci Pract* 2018;6:693–710.
52 Hawkes CP, Walsh BH, Ryan CA, *et al*. Smartphone technology enhances newborn intubation knowledge and performance amongst Paediatric Trainees. *Resuscitation* 2013;84:223–6.
53 Lund S, Boas IM, Bedesa T, *et al*. Association between the safe delivery App and quality of care and perinatal survival in Ethiopia: a randomized clinical trial. *JAMA Pediatr* 2016;170:765–71.
54 Nishimwe A, Ibisomi L, Nyssen M, *et al*. The effect of an mLearning application on nurses' and midwives' knowledge and skills for the management of postpartum hemorrhage and neonatal resuscitation: pre-post intervention study. *Hum Resour Health* 2021;19:14.
55 Thomsen CF, Barrie AMF, Boas IM, *et al*. Health workers' experiences with the safe delivery App in West Wollega zone, Ethiopia: a qualitative study. *Reprod Health* 2019;16:50.
56 Guitart A, Del Río AF, Periáñez Á, *et al*. Midwifery learning and forecasting: predicting content demand with user-generated logs. *Artif Intell Med* 2023;138:102511.
57 Sarin E, Dastidar S, Bisht N, *et al*. Safe delivery application with facilitation increases knowledge and confidence of obstetric and neonatal care among frontline health workers in India. *J Family Med Prim Care* 2022;11:2695.
58 Chan NH-M, Merali HS, Mistry N, *et al*. Development of a novel mobile application, HBB prompt, with human factors and user-centred design for helping babies breathe skills retention in Uganda. *BMC Med Inform Decis Mak* 2021;21:39.
59 Tuti T, Winters N, Edgcombe H, *et al*. Evaluation of adaptive feedback in a smartphone-based game on health care providers' learning gain: randomized controlled trial. *J Med Internet Res* 2020;22:e17100.
60 Wanyama C, Nagraj S, Muinga N, *et al*. Lessons from the design, development and implementation of a three-dimensional (3d) neonatal resuscitation training smartphone application: life-saving instruction for emergencies. *Adv Simul* 2022;7:2.
61 Billner-Garcia RM, Spilker A. Development and implementation of a game-based neonatal resuscitation refresher training: effect on registered nurse knowledge, skills, motivation, engagement. *J Nurses Prof Dev* 2024;40:24–8.
62 Bardelli S, Del Corso G, Ciantelli M, *et al*. Improving pediatric/neonatology residents' newborn resuscitation skills with a digital serious game: DIANA. *Front Pediatr* 2022;10:842302.
63 Cutumisu M, Brown MRG, Fray C, *et al*. Growth mindset moderates the effect of the neonatal resuscitation program on performance in a computer-based game training simulation. *Front Pediatr* 2018;6:195.
64 Cutumisu M, Ghoman SK, Lu C, *et al*. Health care providers' performance, mindset, and attitudes toward a neonatal resuscitation computer-based simulator: empirical study. *JMIR Serious Games* 2020;8:e21855.
65 Ghoman SK, Cutumisu M, Schmölzer GM. Digital simulation improves, maintains, and helps transfer health-care providers' neonatal resuscitation knowledge. *Front Pediatr* 2020;8:599638.
66 Yeo CL, Ho SKY, Tagamolila VC, *et al*. Use of web-based game in neonatal resuscitation - is it effective *BMC Med Educ* 2020;20:170.
67 Lu C, Ghoman SK, Cutumisu M, *et al*. Mindset moderates healthcare providers' longitudinal performance in a digital neonatal resuscitation simulator. *Front Pediatr* 2020;8:594690.
68 Lu C, Ghoman SK, Cutumisu M, *et al*. Unsupervised machine learning algorithms examine Healthcare providers' perceptions and longitudinal performance in a Digital neonatal resuscitation simulator. *Front Pediatr* 2020;8:544.
69 Agarwal A, Leviter J, Mannarino C, *et al*. Is a Haptic simulation interface more effective than computer mouse-based interface for neonatal intubation skills training? *BMJ Simul Technol Enhanc Learn* 2015;1:5–11.
70 Ezenwa BN, Umoren R, Fajolu IB, *et al*. Using mobile virtual reality simulation to prepare for in-person helping babies breathe training: secondary analysis of a randomized controlled trial (the eHBB/mHBS trial). *JMIR Med Educ* 2022;8:e37297.
71 Anand P, Thukral A, Deorari AK, *et al*. Dissemination of best practices in preterm care through a novel mobile phone-based interactive E-learning platform. *Indian J Pediatr* 2021;88:1068–74.
72 Spindler H, Dyer J, Bagchi K, *et al*. Tracking and Debriefing birth data at scale: a mobile phone application to improve obstetric and neonatal care in Bihar, India. *Nurs Open* 2018;5:267–74.
73 Anderson JM, Boyle KB, Murphy AA, *et al*. Simulating extracorporeal membrane oxygenation emergencies to improve human performance. part I: methodologic and technologic innovations. *SIMUL HEALTHC* 2006;1:220–7.
74 Bhatia M, Stewart AE, Wallace A, *et al*. Evaluation of an in-situ neonatal resuscitation simulation program using the new world Kirkpatrick model. *Clinical Simulation in Nursing* 2021;50:27–37.
75 Campbell DM, Barozzino T, Farrugia M, *et al*. High-Fidelity simulation in neonatal resuscitation. *Paediatr Child Health* 2009;14:19–23.
76 Chang C, Perlman J, Abramson E. Use of a novel manikin for neonatal resuscitation ventilation training. *Children* 2022;9:364.
77 Cooke JM, Larsen J, Hamstra SJ, *et al*. Simulation enhances resident confidence in critical care and procedural skills. *Fam Med* 2008;40:165–7.
78 Cordero L, Hart BJ, Hardin R, *et al*. Pediatrics residents' preparedness for neonatal resuscitation assessed using high-fidelity simulation. *J Grad Med Educ* 2013;5:399–404.
79 Cuttano A, Scaramuzzo RT, Gentile M, *et al*. Education in neonatology by simulation: between reality and declaration of intent. *J Matern Fetal Neonatal Med* 2011;24 Suppl 1:97–8.
80 Faraci MD. The effects of high fidelity simulation on nurses' self-efficacy to perform pediatric advanced life support in the neonatal intensive care unit. *ProQuest Dissertations Publishing* 2013. Available: https://pascal-clemson.primo.exlibrisgroup.com/permalink/01PASCAL_CLEM/1k59mp4/cdi_proquest_journals_1350640767
81 Finan E, Bismilla Z, Whyte HE, *et al*. High-Fidelity simulator technology may not be superior to traditional low-fidelity equipment for neonatal resuscitation training. *J Perinatol* 2012;32:287–92.
82 Gurung R, Gurung A, Basnet O, *et al*. REFINE (rapid feedback for quality improvement in neonatal rEsuscitation): an observational study of neonatal resuscitation training and practice in a tertiary hospital in Nepal. *BMC Pregnancy Childbirth* 2020;20:756.
83 Gurung R, Gurung A, Sunny AK, *et al*. Effect of skill drills on neonatal ventilation performance in a simulated setting-observation study in Nepal. *BMC Pediatr* 2019;19:387.
84 Lindamood KE, Rachwal C, Kappus L, *et al*. Development of a neonatal intensive care multidisciplinary crisis resource training program. *Newborn and Infant Nursing Reviews* 2011;11:17–22.
85 Money N, Kusheleva N, Ruano S, *et al*. Who's counting? Assessing the effects of a simulation-based training intervention on the accuracy of neonatal heart rate auscultation. *J Perinatol* 2019;39:634–9.
86 Pliego JF, Wehbe-Janek H, Rajab MH, *et al*. Ob/GYN boot camp using high-fidelity human Simulators: enhancing residents' perceived competency, confidence in taking a leadership role, and stress hardiness. *Simul Healthc* 2008;3:82–9.
87 Ross J, Rebella G, Westergaard M, *et al*. Simulation training to maintain neonatal resuscitation and pediatric sedation skills for emergency medicine faculty. *WMJ* 2016;115:180–4.
88 Rubio-Gurung S, Putet G, Touzet S, *et al*. In situ simulation training for neonatal resuscitation: an RCT. *Pediatrics* 2014;134:e790–7.
89 Sawyer T, Burke C, McMullan DM, *et al*. Impacts of a pediatric extracorporeal cardiopulmonary resuscitation (ECPR). *Acad Pediatr* 2019;19:566–71.
90 Square ND. *High-fidelity simulation in nursing practice: the impact on nurses' knowledge acquisition, satisfaction, and self-Confidence*. ProQuest Dissertations Publishing, 2012:3523451.Available: http://gateway.proquest.com/openurl?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&res_dat=xri:pqm&rft_dat=xri:pqdiss:3523451
91 Strozzi MM, Varrica A, Colivicchi M, *et al*. High-fidelity simulation-based program improves flow state scale in the perinatal team. *Ital J Pediatr* 2021;47:42.
92 Surcouf JW, Chauvin SW, Ferry J, *et al*. Enhancing residents' neonatal resuscitation competency through unannounced simulation-based training. *Med Educ Online* 2013;18:1–7.

93 Vadla MS, Mdoe P, Moshiro R, *et al*. Neonatal resuscitation skill-training using a new neonatal simulator, facilitated by local Motivators: two-year prospective observational study of 9000 trainings. *Children (Basel)* 2022;9:134.
94 Wetzel EA, Lang TR, Pendergrass TL, *et al*. Identification of latent safety threats using high-fidelity simulation-based training with Multidisciplinary Neonatology teams. *Jt Comm J Qual Patient Saf* 2013;39:268–73.
95 Choi S, Shim H, Lee JH. Efficiency analysis by training sequence of high-fidelity simulation-based neonatal resuscitation program (NRP). *PLoS ONE* 2023;18:e0281515.
96 McGlinn LA, Sundgren NC. Format changes improve learner satisfaction in local neonatal resuscitation program skills education. *Cureus* 2022;14:e30632.
97 Neupane D, Sharma A, Thukral A, *et al*. Simulation based vs conventional training for initial steps in delivery room care of preterm neonates: an open label randomized trial. *Indian Pediatr* 2022;59:847–51.
98 Schwindt EM, Stockenhuber R, Kainz T, *et al*. Neonatal simulation training decreases the incidence of chest compressions in term newborns. *Resuscitation* 2022;178:109–15.
99 Vadla MS, Moshiro R, Mdoe P, *et al*. Newborn resuscitation simulation training and changes in clinical performance and perinatal outcomes: a clinical observational study of 10,481 births. *Adv Simul (Lond)* 2022;7:38.
100 Zanno A, Melendi M, Cutler A, *et al*. Simulation-based outreach program improves rural hospitals' team confidence in neonatal resuscitation. *Cureus* 2022;14:e28670.
101 Zebreski L, Bloodgood K, Wyble K. Preparing neonatal nurses for improved performance, professional development, and national certification through simulation. *Adv Neonatal Care* 2022;22:E131–6.
102 Arul N, Ahmad I, Hamilton J, *et al*. Lessons learned from a collaborative to develop a sustainable simulation-based training program in neonatal resuscitation: Simulating success. *Children (Basel)* 2021;8:39.
103 Gerard JM, Scalzo AJ, Laffey SP, *et al*. Evaluation of a novel web-based pediatric advanced life support course. *Arch Pediatr Adolesc Med* 2006;160:649–55.
104 Prakash V, Thukral A, Sankar MJ, *et al*. “Efficacy and acceptability of an "App on sick newborn care" in physicians from newborn units”. *BMC Med Educ* 2016;16:84.
105 Rose E, Claudius I, Tabatabai R, *et al*. The flipped classroom in emergency medicine using online videos with interpolated questions. *J Emerg Med* 2016;51:284–91.
106 Weiner GM, Menghini K, Zaichkin J, *et al*. Self-directed versus traditional classroom training for neonatal resuscitation. *Pediatrics* 2011;127:713–9.
107 Chan NH, Mistry N, Campbell DM. A simulation-based pilot study of a mobile application (NRP prompt) as a cognitive aid for neonatal resuscitation training. *Sim Healthcare* 2019;14:146–56.
108 Umoren R, Bucher S, Hippe DS, *et al*. EHBB: a randomised controlled trial of virtual reality or Video for neonatal resuscitation refresher training in healthcare workers in resource-scarce settings. *BMJ Open* 2021;11:e048506.
109 Deorari AK, Kumar P, Chawla D, *et al*. Improving the quality of health care in special neonatal care units of India: a before and after intervention study. *Glob Health Sci Pract* 2022;10:e2200085.
110 Moussa A, Luangxay Y, Tremblay S, *et al*. Videolaryngoscope for teaching neonatal Endotracheal intubation: a randomized controlled trial. *Pediatrics* 2016;137:e20152156.
111 Gomez PP, Nelson AR, Asiedu A, *et al*. Accelerating newborn survival in Ghana through a low-dose, high-frequency health worker training approach: a cluster randomized trial. *BMC Pregnancy Childbirth* 2018;18.
112 Ugwa E, Kabue M, Otolorin E, *et al*. Simulation-based low-dose, high-frequency plus mobile mentoring versus traditional group-based trainings among health workers on day of birth care in Nigeria; a cluster randomized controlled trial. *BMC Health Serv Res* 2020;20:586.
113 Bastos RA, Carvalho DRDS, Brandão CFS, *et al*. Solutions, enablers and barriers to online learning in clinical medical education during the first year of the COVID-19 pandemic: a rapid review. *Med Teach* 2022;44:187–95.
114 Bluestone J, Johnson P, Fullerton J, *et al*. Effective in-service training design and delivery: evidence from an integrative literature review. *Hum Resour Health* 2013;11:51.
115 Yousef N, Moreau R, Soghier L. Simulation in neonatal care: towards a change in traditional training? *Eur J Pediatr* 2022;181:1429–36.
116 Organisation for Economic Co-operation and Development. Opportunities and drawbacks of using artificial intelligence for training, OECD social, employment and migration working papers No.266. Available: https://one.oecd.org/document/DELSA/ELSA/WD/SEM(2021)13/En/pdf [Accessed 20 Nov 2023].