

A Systematic Review of Ultrasound Education in Developing Countries

By

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Abstract

Background

Amid the increasing use of ultrasound in various health care settings, the evidence on the impacts of targeted ultrasound training and education programs on ultrasound examination uptake in developing countries have not been summarized. This current study presents a systematic review with the aim of describing the current research on targeted ultrasound education and training in low- and middle-income countries, with a focus on the uptake of ultrasound screening and imaging.

Methods

Eight online electronic databases (Medline/PubMed, OVID, EMBASE Science Direct, Scopus, CINAHL, Web of Science, Google Scholar, and the Cochrane Library), were searched from inception to March 2022. The inclusion criteria were any/all type(s) of studies on targeted ultrasound education and training in low- and middle-income countries published in English. Opinion articles, book chapters, commentaries, and non-English articles were excluded.

Results

A total of 916 articles were identified after the initial search. After duplicate removal, title screening and assessment according to the inclusion criteria, 12 articles were included. The interventions included, amongst others, advertisements for sensitization on ultrasound use. Generally, the findings showed a significant positive outcome from education and training programs regarding the improved quality and increased amount of ultrasound services. In accordance, the studies inferred a positive impact of the targeted education programs, which ultimately triggered motivation towards the uptake of ultrasound services in the developing countries, with obstetrics and gynaecological ultrasound being the most utilized.

Conclusions

This systematic review concluded that targeted ultrasound education and training programs had a significant positive impact on ultrasound imaging, as demonstrated through improved quality of imaging and scanning services for informed clinical procedures and growing utilization of the portable imaging technology within rural areas.

Keywords

Systematic Review, Ultrasound, Ultrasonography, Education, Training, LMICs, Developing Countries, Healthcare Workers.

Introduction

Since its invention in the 1950s, the ultrasound (ultrasonography) had grown to become one of the most popular and frequently implemented imaging techniques globally. Ultrasounds first use came in 1956 (CME, 2021) (Castilla-Guerra et al.); since then, its functionality has exponentially risen due to an increase in the quality of images produced, going from producing seemingly distorted one-dimensional pictures to generating clear three-dimensional images, portraying information on tissues, such as density, direction of flow, and more. Currently, the ultrasound is used as an effective tool for a large number of medical conditions and diagnostic procedures, due to its various advantages (DerSarkissian, 2019). Ultrasound examination are generally painless and do not require injections or incisions. The machines are relatively cheap, portable and function without ionizing radiation, making them efficient (Hendrickson et al.) and safe (NHS, 2018). According to proponents, ultrasonography is a clinically accepted imaging modality that characterizes low-powered mobile diagnostic pathways that are easy to be learned by medical personnel to enable rapid assessment and treatment procedures (Wells and Williams, 2015). Unlike other imaging tools like Computed Tomography (CT) or Magnetic Resonance Imaging (MRI), ultrasound devices can be used by a single operator, can be handheld, and can provide diagnostic capabilities at relatively low costs, making it an attractive option for medical use in the developing world.

Even though ultrasound machines are relatively popular, there still remains a lack of education, training, and technical support for physicians and other medical professionals in developing countries, resulting in much lower implementation (Shah, 2015). In 1997, for example, the World Health Organization (WHO) stated that almost 50 percent of the developing countries in the world lacked access to ultrasonography. Wherever it was accessible, the equipment was

often either broken or outdated, accounting for its underutilization in such rural settings (Hans and Krieg). The World Health Organization (WHO) has also reported that most healthcare professionals in developing countries and low-income areas did not receive sufficient ultrasound education or training to reach a level of command that would put them in line with internationally accepted standards (LaGrone, 2012) (WHO, 1998).

However, recent decades have witnessed a spurred growth in ultrasonography uptake, where the use of clinically, hand-performed, bedside ultrasound examinations have attracted much popularity as an imaging tool of choice, globally.

Despite this progress, there have been no publications giving a systematic review/overview of the research literature on this topic in lower- and middle-income countries. One study by Kotlyar et al. disclosed that ultrasound examinations changed patient management in over 62% of its cases, with the greatest impact being in obstetric ultrasound, followed by FAST (Focused Assessment with Sonography in Trauma) cardiac ultrasound. In another investigation of patients in the Amazonian Jungle, Blaivas et al. discovered that ultrasound examination changed treatment in 28% of the patients cases, regarding appropriate referral for more definitive care. In another study in Egypt, Mahram et al. stated that antenatal ultrasound examination could predict 89,7% of neonatal growth retardation cases, a major risk factor for foetal mortality. Thus, suggesting that the uptake of ultrasound services is an ideal approach to diagnosing many clinical complications and assisting treatment procedures, and that increasing its utilization and overall application in developing countries would contribute to more favourable health outcomes, underlining the importance of education programs.

This review thus aimed to summarize the findings from quantitative and qualitative studies investigating education programs in low- and middle-income countries with a focus on the use of ultrasound.

Methods

Eligibility Criteria

To answer the research question, a systematic literature review was conducted in accordance with the guidelines of the Cochrane Collaboration (Higgins et al.), and reported as per the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement guidelines (Shamseer, 2015).

Search Strategy for Identifying Studies

A comprehensive electronic search was done in the following eight databases: Medline/Pubmed, OVID, EMBASE ScienceDirect, Scopus, CINAHL, Web of Science, Google Scholar, and the Cochrane Library for relevant articles published in the English language from their inception to a period no later than March 2022. The low- and middle-income (developing) countries were selected according to the definition given by the World Bank; countries with low-income economic power. The key search terms for the studies included in this review will be as follows:

Subject headings	Search terms
Ultrasound	Ultrasonography Ultrasonic Imaging Sonography Medical sonography Echography Echotomography

	Computer echotomography
Education	Teaching Learning Self-efficacy Training Schooling Instruction Empowerment Medical education Medical residency
Program	Course Class System Lesson Curriculum
Healthcare professional	Healthcare worker Doctor Nurse Specialist Technician Ultrasound specialist Medical graduate Resident Medical resident House staff
Developing country	Third-world country Emerging economies Emergent nations Underdeveloped nations Countries in transition
Table 1.	

Inclusion and Exclusion Criteria

Types of Studies: Studies that investigated healthcare professionals in developing countries, at any level, who received targeted ultrasound training or education were included, regardless of whether they were qualitative or quantitative. Additionally, all articles sources' published in English, within the last 20 years were included. All non-English sources were, however,

excluded, as well as articles that did not discuss relevant content, i.e. were unrelated to developing countries' healthcare professionals being exposed to targeted ultrasound education. Finally, all commentaries, opinion articles and book chapters were also excluded.

Participants: The eligible articles focused on doctors and other medical professionals working in developing states or low-income economies. Even though doctors were preferred, as they possess medical licenses enabling them to freely conduct ultrasound examinations, studies including medical students/undergraduates and other professionals, such as midwives and even random participants (as controls) were included, as long as they possess the ability to contribute to reports on the possible desired review outcomes, i.e. increased, decreased or unchanged ultrasound implementation.

Intervention: The quantitative aspect of this review considered articles that evaluated any targeted ultrasound education or training, while the qualitative aspect considered articles that investigated the participants' experiences.

Study Selection and Data Extraction Process

The study selection and data extraction were independently performed by two researchers (JM and VT), and any discrepancies between the researchers were resolved through consensus or inclusion of the third reviewer (CM). Data extraction was then performed using a standard online excel template. To make the extracted data credible for study feasibility, the two reviewers (JM and VT) independently carried out the title and abstract screening alongside the

keywords identified during the electronic search. The screened articles were then critically appraised on a full-text basis, and only those that met the eligibility criteria were vetted for possible inclusion. In case of disagreements, the third reviewer (CM) was involved. In the event that an article lacked sufficient information to determine whether or not it qualified, the authors were contacted for more information. Any other studies deemed unsuitable, based on the inclusion and exclusion criteria were excluded from the review.

The data extracted from all the ultrasound studies included:

Title	Criteria
General Information	Article Title Author(s) Year of Publication
Study Characteristics	Study Design Duration of Study
Participants' Demographics	Number of Participants Country/Geographical Location
Interventions	Application of Ultrasound Length of Ultrasound Education Type of Ultrasound Machine Number of Examinations Completed
Outcomes	Descriptive Findings of the Study: Changes in Decision-Making Process related to Ultrasound Implementation Altered Perception of Proficiency in Conducting Ultrasound Examinations
Table 2.	

Methodological Quality Assessment

Assessment of biases were based on recommendations given in Chapter 14 and 15 of the 'Cochrane Handbook for Systematic Reviews of Interventions'. The two investigators (JM and VT) assessed the methodological quality of each of the included studies. The risk of bias of the various included studies was determined by evaluating their adherence to the Grading of

Recommendation Assessment, Development, and Evaluation (GRADE) approach. This framework focused on reporting how the studies were designed, analysed, and interpreted. Therefore, the GRADE checklist focused on the study results' relevance, validity, methodological suitability and quality of evidence.

Results

Search Outcome

A total of 903 articles were identified from the initial database search, and an additional 13 articles were identified through other sources (Figure 1). After the removal of duplicates, 309 articles remained for possible inclusion. The studies were subjected to abstract screening and reviewed for possible inclusion; however, 235 articles were excluded for not reporting ultrasound use, describing non-medical applications, or not within any of the developing countries. A further 12 studies were excluded after their full-text was not available for review. The 62 studies that remained after abstract and full-text screening were then scrutinized and evaluated independently by the study investigators. The evaluation eliminated 50 articles due to a lack of relevance towards the specific study purpose. After the whole selection process, 12 articles were accepted for inclusion in the systematic literature review.

Characteristics of Included Studies

A summary of the main characteristics and key findings is included in Table 4.

All the eligible studies included were English articles published between 2009 and 2022, focusing on low- and middle-income countries. The studies included numerous types of participants, since some articles considered the healthcare workers only for training while others considered training both healthcare workers and the participants being assessed on the

uptake, shifting trends and benefits of ultrasound. By regions, most of the studies were from the African developing countries (n = 9). The country with the most included studies was Tanzania, with three studies (Mbuyita et al. 2015; 2016; and Reynolds et al. 2016). Rwanda followed, with two studies (Shah et al. and Henwood et al.). The rest of the other African regions (Kenya, Malawi, Uganda, and Mozambique) were represented by only one study each. Two of the included studies addressed Asian regions, namely the Thai-Burma region (Rijke et al.) and the Nepalese region (Kokuzi et al.). Only one of the included studies focused on a multiregional scope, covering Pakistan, Kenya, Zambia, Guatemala, and the Democratic Republic of Congo (Mc Clure et al.).

The most common ultrasound devices used during the education and training in these regions were handheld, portable devices. Three studies reported using portable Nanomaxx and Sonosite ultrasound devices, while another use Micromax and Sonosite. Two individual studies used the portable V-Scan device. Other ultrasound devices used were point-of-care ultrasound devices for bedside training, as well as the 2-M Turbo portable device. However, some studies did not report on their chosen ultrasound device.

The most relevant specialities and professional fields, which were discussed and focused on in the studies, included obstetrics and gynaecology, which represented 67% of the articles. Other key fields discussed included emergency medicine, radiology, and internal medicine.

Regarding publications, the included studies were spread across different various journals. Two of the included studies were published in the African Journal of Emergency Medicine. The rest of the studies were published one of following journals: BMC International Health and Human Rights, Transactions of the Royal Society of Tropical Medicine and Hygiene, PLoS ONE Journal, International Journal of Gynaecology and Obstetrics, Tropical Medicine & international Health, Obstetrics and Gynaecology, Archive of Public Health, BMC Pregnancy

and Childbirth, The Official Journal of the International Society of Ultrasound in Obstetrics and Gynaecology, and Journal of Biosafety & Health Education.

Applications of ultrasound technology presented in the included studies were primarily in the field of obstetric and gynaecological screening (67%). Other key applications of ultrasound services presented in the included studies included radiology, cardiology, abdominal conditions, critical emergency conditions and infectious diseases. The ultrasound examination providers in the included studies included care-takers/-providers like physicians, midwives, community health workers, and residents, particularly women seeking ANC services.

All of the included studies which were reviewed, contained either educational, training, or instructional components on ultrasound examination. There were various comprehensive didactic and practical training schedules for the formal education and training programs that involved video lessons and presentations through PowerPoint. Some other programs were facilitated through workshops that focused on acquiring a specific set of skills, like the FAST Ultrasound technique, within a certain amount of time (number of weeks).

Details pertaining to the educational programs and training modalities are provided in the summary table of characteristics and key details of included studies, in Table 4 (Appendix C).

Findings

Our study found that there was an increased uptake in ultrasound examinations following education programs/courses taking place in developing countries. Other studies express similar results, including Henwood et al. 2016. They adapted their course to include 1-year of follow-up sessions and concluded that they measured an increase in their participants mean OSCE scores, going from 36.9% at the before the initial introductory course, to 74.3 % after it, and even reaching 84.9% by the end of the 1-year long follow-up sessions. In William

Cherniak et al. 2017, radio advertisements were used to educate the community on the benefits of ultrasound and how one can “see their baby”.

Teaching Methods – The studies had varying approaches, when it came to their teaching methods, some preferred hands-on teaching, like Greg Bell et al., 2016 and Naoko Kozuki et al., 2016 while others seemed to prefer lectures as a schooling method, and some ultrasound education courses had both components, like Shah et al., 2009. On the other hand, Teri A. Reynolds et al., 2016 described their participants preferring more hands-on training.

In Greg Bell et al., it was vitally important to the study creators that participants completed an examination and some studying, prior to joining the practical part, as it improved overall results. Through the four initial training courses, the requirements changed from needing 50% to pass to needed 90%, using as many chances as needed.

Sustainability – One study in particular, Shah et al. 2015 , was critical of sustainability, drawing up cost-analysis, and mentioning issues like replaceability of machine parts, lack of mechanics for machine upkeep, and lack of training, as potential barriers. While others, Shah et al. 2009, and Henwood et al. 2016 concluded that sustainability was in fact, achievable. which investigated the impact of ultrasound introduction in two Rwandan hospitals.

Greg Bell et al. 2017 and Patricia C. Henwood et al. 2016, actively created methods to assist the sustainability by planning shorter follow-up sessions after the initial lengthier training sessions, in the form of refresher training and follow-up training, respectively.

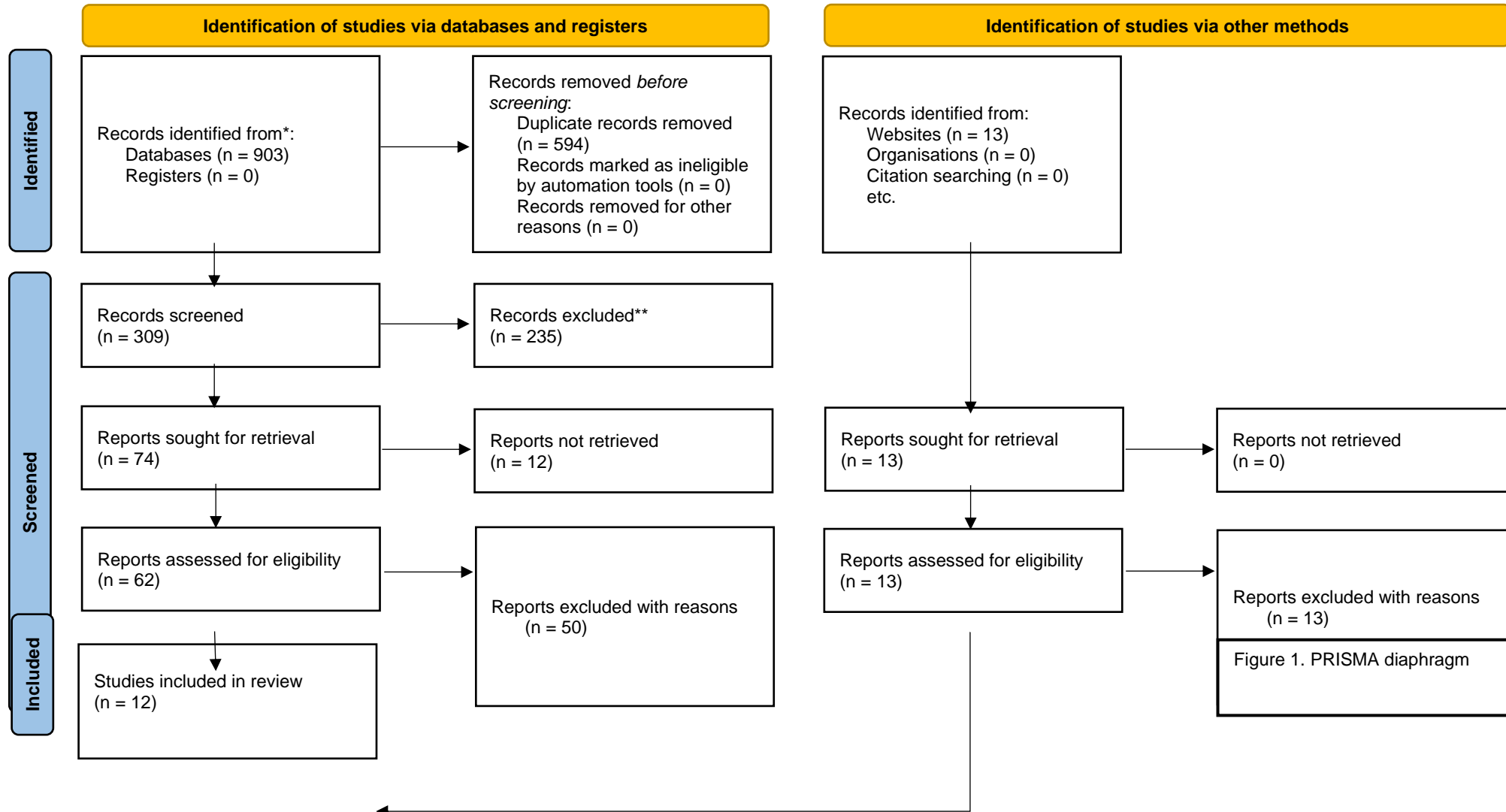
Quality Assessment of Included Studies

The two investigators, JM and VT, also independently assessed the quality of each of the included studies. To ascertain the methodological quality, the risk of bias assessment was done

through the Grading of Recommendation Assessment, Development, and Evaluation (GRADE) approach in the seven key domains: Adequate Sequence Generation, Allocation Concealment, Blinding of Participants and Personnel, Blinding of Outcome Assessment, Incomplete Outcome Data, Selective Outcome Reporting, and Free of Other Bias.

The individual domains and overall risk-of-bias judgement were expressed in 3 levels; low-risk bias, unclear bias, or high risk of bias. Based on these judgement factors, the overall quality of evidence was stated as either low, moderate, or high risk of bias. The above information has been presented Table 3 (Appendix 1) and the risk of bias graph in Figure 2 (Appendix 2).

Identified, Screened and Included Studies



Discussion

The present systematic review investigated the attributive impacts of targeted ultrasound education programs and training towards boosting the uptake of ultrasound examinations in low- and middle-income countries. The review demonstrated growing evidence of utilization of ultrasound imaging, particularly the low-cost portable imaging devices for developing countries. Ten of the included studies were published from 2010 and later; hence, this review demonstrated that there had been an increase of research studies focusing on the use of ultrasound examinations in developing countries. Although the rate of educational studies is constantly growing, most of the studies still focused on task-shifting from the skilled to training for lay providers like the community health workers, midwives, and new medical physicians, including interns and students.

The findings demonstrated that the most common ultrasound examination undertaken in most low- and middle-income countries was for diagnostic purposes in obstetrics and gynaecology, as well as in emergency medical cases. Obstetrical ultrasound imaging could also include determining the foetus' head position, estimating gestational ages, and evaluating placental abnormalities to promote safe deliveries. Similar to the above finding, previous studies in Liberia by Kotlyar et al. found close to 53 of the ultrasound examinations performed in a single-centre study in the Monrovia region were scanning for obstetrical or gynaecological conditions.

Even though obstetrics and gynaecology takes up the majority of examinations, we decided to investigate all available disciplines, including emergency medicine and cardiological ultrasounds.

The most important issue regarding the targeted ultrasound education and training was the patient perception of ultrasound services, which facilitated them to take the examination. In

this review, the patient participants help positive perceptions regarding ultrasound services as witnessed from those who visited the obstetrics scanning. Also, the efforts of the education program creators and trainers highly accounted for an increased uptake since the examiners could offer relevant results to facilitate quality care delivery. In accordance, the finding by Rijken et al. on the Thai-Burmese border demonstrated that ultrasound was viewed as a tool that enhanced safety during pregnancy and delivery. A similar demonstration was observed by Ross et al. in Uganda, where they demonstrated that a low-cost ultrasound program led to increased antenatal clinic visitations alongside attended deliveries at the health clinics. In another relevant study in rural Botswana, Tautz et al. observed that pregnant women showed much trust in the ultrasound examination results, when compared to the bodily sensations in confirming the life of their foetus. Additionally, Kimberly et al. also realized that most patients who attended antenatal clinics expressed that the availability of ultrasound examination was their primary motivation in attending the care meeting. Finally, a study in Tanzania by Firth et al. reported that most women desired the ultrasound examination services despite lacking insight into its benefits.

While the impact of ultrasonography is already established in developing countries, the reviewed studies showed that the targeted ultrasound educational programs and training changed the clinicians patient management by greatly improving it, since the majority had an informed and pre-planned approach for performing surgical or other treatments based on the imaging results. For example, for the surgical procedures planned in caesarean section, the surgery was done as per the norm when it came to imaging results of placenta previa, breeched foetus position, or other possible scan results. Similarly, another published study, one by Spencer and Adler (2008), confirmed that ultrasound examination impacted patient medical care and its planning, in more than 40 percent of the cases investigated.

Conclusion

The current systematic literature review reflected the impacts of targeted sonography (ultrasound) education programs in developing countries. The findings demonstrated that most of the personnel practicing ultrasound actually had little knowledge and lacked formal training, which could have been the uptake of ultrasound examinations was quite low in such regions particularly. With the decreasing costs of ultrasound equipment and increasing availability of less sophisticated ultrasound devices, there is a need and an importance attached to continued education and training on the adoption and effective application of ultrasound technology to facilitate its utilization in developing countries. The review found evidence on the significant role that education and training programs can have in boosting the quality of screening and diagnostic procedures for clinical decision-making. This enhances service delivery standards, which in turn motivate the care-seekers to consider choosing more ultrasound services for their informed treatments and medical procedures. In accordance, this review suggests that the ultrasound is an important diagnostic tool benefitting women's health and obstetrical care and is integral in healthcare delivery for the low- and middle-income countries. Additionally, since ultrasound examination impacts patient management plans, the review suggests that after healthcare providers are educated and trained, the programs should be sustainably kept within the care delivery systems, which would lead to increased accuracy of diagnosis for various patient cases, and thus motivate the patient population.

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Study	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Outcome Reporting	Free of Other Bias	Net Risk
Shah et al.	Low risk	Low risk	Low risk	High risk	Unclear risk	Low risk	Unclear risk	Low
Limani et al.	Low risk	Low risk	Low risk	High risk	Unclear risk	Unclear risk	Low risk	Low
Cherniak et al.	Unclear risk	Low risk	Low risk	High risk	Low risk	Low risk	Unclear risk	Low
Greenwold et al.	Low risk	Low risk	High risk	High risk	Unclear risk	Low risk	Unclear risk	Moderate
Bell et al.	Low risk	Low risk	High risk	Unclear risk	Low risk	Unclear risk	Low risk	Low
Henwood et al.	Low risk	Low risk	High risk	Low risk	Unclear risk	Low risk	Unclear risk	Low
Kozuki et al.	High risk	Unclear risk	High risk	Low risk	Unclear risk	Low risk	Unclear risk	Moderate
Mbuyita et al.	Unclear risk	Low risk	High risk	High risk	Low risk	Unclear risk	High risk	High
McClure et al.	Low risk	Unclear risk	High risk	Low risk	Unclear risk	Low risk	Unclear risk	Moderate
Reynolds et al.	Low risk	Low risk	High risk	Low risk	Unclear risk	Low risk	Unclear risk	Low
Rijken et al.	Unclear risk	Low risk	Low risk	High risk	Low risk	Unclear risk	Low risk	Low
Mbuyita et al.	Low risk	Low risk	High risk	Low risk	Unclear risk	Low risk	Low risk	Low

Table 3. Quality Assessment of Included Studies using Cochrane Handbook

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Bell 2016	+	+	-		+		+
Cherniak 2017		+	+	-	+	+	
Greenwold 2014	+	+	-	-		+	
Henwood 2016	+	+	-	+		+	
Kozuki 2016	-		-	+		+	
Limani 2021	+	+	+	-			+
Mbuyita 2014	+	+	-	+		+	+
Mbuyita 2015		+	-	-	+		-
McClure 2014	+		-	+		+	
Reynolds 2016	+	+	-	+		+	
Rijken 2009		+	+	-	+		+
Shah 2009	+	+	+	-		+	

Appendix B: Figure 2. Risk of Bias Summary

Author, Year	Shah et al., 2009	Outcomes: Besides the focused training times through lectures done thrice per week for the first three weeks and once for the remaining duration, the ultrasound instructor also did ward rounds with trainees during the 9-week duration, encouraging ultrasound utilization in routine clinical practice for immediate feedback for ultrasound exams. Training also included one on one scanning techniques. The conclusion suggested the effectiveness of ultrasound uptake due to training since ultrasound proved helpful in inpatient care. The diagnostic impact is enhanced by choosing the correct applications to implement.
Title	Impact of the introduction of ultrasound services in a limited resource setting: rural Rwanda 2008.	
Journal	BMC international health and human rights.	
Country	Rwanda	
Participants	15 Staff Physicians	
Ultrasound used	SonoSite MicroMaxx Ultrasounds	
Field	Emergency Medicine	
Author, Year	Limani et al., 2021	Prospective record review, College of Medicine, Blantyre, Malawi, GE-Healthcare V-scan Outcomes: After an initial needs assessment, a curriculum for training was developed that covered indications for the diagnostic and interventional ultrasound. Protocols that were included in the training program were focused assessment with ultrasonography for TB in HIV (FASH), chest ultrasound, echocardiography, abdominal ultrasound examinations (ascites, kidneys and bladder), compression ultrasound examinations for deep vein thrombosis, ultrasound guidance for fine-needle aspiration of lymph nodes, ascetic paracentesis, pericardiocentesis and pleurocentesis.
Title	Diagnostic point-of-care ultrasound in medical inpatients at Queen Elizabeth Central Hospital, Malawi: an observational study of practice and evaluation of implementation.	
Journal	Transactions of the Royal Society of Tropical Medicine and Hygiene	
Country	Malawi	

Participants	26 participants (10 were involved in routine clinical care as medical registrars or clinical officers in the Department of Internal Medicine at the QECH)	Based on the results, 250 patients were included and 267 ultrasound was performed, of those, 133 were POCUS (point-of-care ultrasound; defined as performed by a clinician at the bedside), while the rest were RDUS (radiology department ultrasound). The time between request and examination was shorter for the POCUS examinations than radiology department ultrasound ((median 0 days [IQR 0–2, range 0–11] vs. 2 days [IQR 1–4, range 0–15] d, p=0.002). 104/133 (78.2%) POCUS and 90/133 (67.7%) RDUS were deemed to have had an impact on patient management. The study concluded that the training program in POCUS had a positive impact on patient management and was thus significantly effective in influencing the positive uptake of ultrasound in less-well-resourced settings.
Ultrasound used	Not clarified	
Field	Radiology	
Author, Year	Cherniak et al., 2017	Cluster randomized trial, Across eight rural sub-counties, Southwestern Uganda Outcomes: Education was through sensitization or advertisements in three categories; word of mouth adverts, radio sensitization, then word of mouth plus radio advertisements. The main outcome was on attendance to antenatal care, and the rate of attendance was 65.1 (per 1000 pregnant women, 95% CI 38.3–110.4) where sensitization was done compared with the control group that had an attendance rate of 11.1 (95% CI 6.1–20.1). The study concluded that education through advertising significantly improved antenatal ultrasound uptake.
Title	Effectiveness of advertising availability of prenatal ultrasound on uptake of antenatal care in rural Uganda: A cluster-randomized trial.	
Journal	Plos One Journal	
Country	Uganda	
Participants	159 participants (100 intervention group and 59 in control group)	
Ultrasound used	Portable obstetric ultrasound	

Field	Obstetrics and gynaecology	
Author, Year	Greenwold et al., 2014	Outcomes: The ultrasound training was an eight-week program that included a one-week formal lecture with supporting films, followed by practical hands-on training using the machine and biometric charts for seven weeks. The practical training included using the ultrasound machine, first-trimester ultrasound; estimation of gestational age; evaluation of fetal and placental position; and detecting multiple pregnancies and uterine fibroids. The study concluded that ultrasound training in remote areas was feasible, efficient, and sustainable. Thus, it could help local healthcare workers screen their prenatal population for neonatal and obstetrics risks and potentially increase their uptake.
Title	Implementing an obstetric ultrasound training program in rural Africa.	
Journal	International Journal of Gynaecology and Obstetrics	
Country	Mozambique	
Participants	1734	
Ultrasound used	2 M-Turbo portable ultrasound machines	
Field	Obstetrics and gynaecology	
Author, Year	Henwood et al., 2016	
Title	Intensive point-of-care ultrasound training with long-term follow-up in a cohort of Rwandan physicians.	
Journal	Tropical Medicine & International Health	
Country	Rwanda	
Participants	17 physician participants	
Ultrasound used	Not reported	

Field	medicine, radiology, critical care medicine, or obstetrics	(95% CI 78–85.4%). The mean OSCE performance at each subsequent evaluation was at least 75%, and the mean OSCE score at the 58-week follow-up was 84.9% (95% CI 80.9–88.9%). The study reported sustained improvement in ultrasound knowledge and skills from the training program that would enhance patient care to spur high uptake of associated ultrasound services.
Author, Year	Bell et al., 2016	Outcomes: Trainees who attended refresher sessions reported an increase in the proportion passing the knowledge and practical tests at the follow-up compared to the initial session. The mean practical skill score increased over time (2.64 + 0.38, p = 0.02), suggesting a strong correlation between knowledge and practical skill scores, illustrating the importance of pre-workshop training. The study showed promise in promoting knowledge and practical skills among the participants and increasing patient care and utilization.
Title	A pilot training program for point-of-care ultrasound in Kenya.	
Journal	African Journal of Emergency Medicine	
Country	Kenya	
Participants	81 participants	
Ultrasound used	point-of-care ultrasound	
Field	obstetric	
Author, Year	Kozuki et al., 2016	Outcomes: The auxiliary nurses were subjected to two one-week ultrasound training. According to the results, each auxiliary nurse midwife's kappa statistic for diagnosing the non-cephalic presentation was above 0.90 compared with the sonogram reviewers. The authors concluded that with some training, the primary level healthcare workers had the potential of accurately diagnosing obstetric risk factors using ultrasonography, suggesting a potential boost in the uptake of ultrasound in these rural settings.
Title	Accuracy of home-based ultrasonographic diagnosis of obstetric risk factors by primary-level health workers in rural Nepal.	
Journal	Obstetrics and gynecology	

Country	Nepal	
Participants	Three auxiliary nurse midwives, 815 recruited participants	
Ultrasound used	Nano Maxx (Sonosite Inc, Bothell, WA US).	
Field	Obstetrics and gynecology	
Author, Year	Mbuyita et al., 2015	Outcomes: The study group received the interventions three times (during the first, second, and third trimesters of the pregnancy). Healthcare providers who rendered ANC services were trained on using the simple technology of ultrasound (handheld Vscan), where the women consented to receive the scans. Results reported a significant change in the percentage of women attending ANC clinics four times or more (from 27.2 % at baseline to 60.3 %; p = 0001). It was concluded that the training on routine ultrasound scanning using simple technology effectively improved ANC attendance regarding visitation frequencies and motivated facility delivery.
Title	Effects of introducing ultrasound scanning routinely during Ante Natal Care (ANC) clinics on the number of visits of ANC and facility delivery: a cohort study.	
Journal	Archives of Public Health	
Country	Tanzania	
Participants	257 women who attended ANC clinics	
Ultrasound used	portable handheld Vscan	
Field	Obstetrics (ANC)	
Author, Year	McClure et al., 2014	

Title	First, look at a cluster-randomized trial of ultrasound to improve pregnancy outcomes in low-income country settings.	<p>Outcomes: The intervention includes training health workers (e.g., nurses, midwives, clinical officers) to perform ultrasound examinations during antenatal care. In the intervention clusters, an ultrasound examination was offered to pregnant women at ANC visits at 18–22 and 32–36 weeks using trained sonographers. In addition, there was provider training for obstetric emergencies at the referral hospitals and community notification about the project and referral enhancement. No ultrasound examinations will be provided for control clusters, there will be no community notification, and there will not be additional training. The second component of the intervention was the training of referral hospital staff to manage obstetrical conditions. This was performed at each site by a project obstetrician with skills in in-hospital training to provide care for the major obstetric/neonatal conditions such as preeclampsia/eclampsia, obstetric hemorrhage, and newborn resuscitation. The overall evaluation showed the effectiveness of introducing ultrasound during antenatal care and training programs for the ultrasound native providers, which enabled them to screen for pregnancy complications and thus increased uptake of the services.</p>
Journal	BMC Pregnancy Childbirth	
Country	Pakistan, Kenya, Zambia, Democratic Republic of Congo and Guatemala	
Participants	Not specified	
Ultrasound used	Not specified	
Field	Obstetrics and gynaecology	
Author, Year	Reynolds et al., 2016	<p>Outcomes: The course consisted of 16 days of combined didactic and hands-on instruction in bedside ultrasound. A standardized training course was offered distinctively in Tanzania and Mexico, and a report on pre-training and post-training. Overall, the participants were satisfied with the training. The study thus concluded that bedside ultrasound training was feasible and well-received. The trained personnel</p>
Title	Bedside ultrasound training at Muhimbili national hospital in Dar es Salaam, Tanzania, and San Carlos in Chiapas, Mexico.	

Journal	African Journal of Emergency Medicine	demonstrated standardized image acquisition and accurate interpretation of normal and abnormal ultrasound examinations, implying the potential to boost ultrasonography uptake.
Country	Tanzania	
Participants	14 registered doctors	
Ultrasound used	Portable Machine (NanoMaxx, Sonosite, Bothell).	
Field	Internal medicine	
Author, Year	Mbuyita et al., 2014	Outcomes: Learning approaches included didactic and practical sessions; the methods included powerpoint presentations, group discussions, lecture-discussion, and question and answer sessions. In practical sessions, the learning methods included demonstrations through models and samples and hands-on. Results showed that uptake of knowledge by trainees was strongly satisfactory since significant changes were observed in handling radiology, sonology, and pregnancy risk detection. The quality of scanning using the Vscan between the trainees and expert sonologists was 77% compatible. The study concluded that training of health providers had significant outcome results, thus could positively influence the uptake of ultrasound within the local health centers.
Title	Uptake of training on Vscan by midlevel providers working in rural health facilities in Tanzania: implications for reliability.	
Journal	Journal of Biosafety & Health Education	
Country	Tanzania	
Participants	14 health care providers	
Ultrasound used	Vscan	
Field	Obstetrics and gynecology	
Appendix C: Table 4: Characteristics and Summary of key details and findings of included studies.		

