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Newborn screening and referral for congenital anomalies by lay health workers in Pakistan: a mixed-methods study to evaluate the effectiveness of a co-created educational intervention

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Abstract

Background Globally, 8 million babies are born with a congenital anomaly annually causing 240,000 neonatal deaths, with 95% disease burden in Low- and Middle-Income Countries (LMICs). Early neonatal screening, timely referral and management can lead to reduced disability and mortality. The WHO recommends employing lay health workers (HWs) as agents to promote health due to critical shortage of health service providers worldwide. This study aims to assess the effectiveness of a learner-centered educational intervention to train lay HWs to screen neonates for external congenital anomalies and to refer affected families towards care.

Methods The CARe (Congenital Anomalies Registry) educational intervention was designed for lay HWs, with a two-week classroom component followed by two weeks of hands-on training under guided supervision at a selected hospital in Karachi. A focused curriculum was developed. Fifteen HWs underwent pre-service training. Knowledge was assessed using pre-, post- and delayed post-tests; Sign test was used to determine the effectiveness of the educational intervention by assessing if the difference between the scores was statistically significant (p-value of < 0.05). Association of median test scores with demographic factors was examined using the Kruskal Wallis test. Concordance between HWs and a helpline physician in identifying anomalies was assessed using Gwet's AC. Skills assessment was conducted using a checklist and two focus group discussions (FGDs) were organized to capture HWs' perspectives on the curriculum.

Results A statistically significant increase (p-value < 0.001) in knowledge of HWs was depicted by the post-test scores, not associated with any socio-demographic factors. Skills assessment scores showed that 11 out of 15 HWs were either 'Good' or 'Excellent' in clinical and communication skills. Gwet's AC showed concordance at 0.93 with a

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p-value < 0.001, indicating 'very good' inter-rater agreement. Thematic content analysis of FGDs disclosed positive feedback on overall training, with specific emphasis on the effective strategies used by content trainers.

Conclusions This study provides preliminary evidence that the CARe educational intervention was effective. From our experience, the results could be attributed to effective training, which was reliant on meticulous planning, honest execution of the plan, teaching expertise, attitude of trainers, supportive supervision and an enabling learning environment. HWs could potentially be utilized to deliver public health interventions effectively, especially amid healthcare workforce shortages in LMICs.

Keywords Health worker, Educational intervention, Newborn screening, Congenital anomalies, Supportive supervision, Co-creation, Curriculum

Background

Global health agendas, led by the WHO and the UN, have emphasized the pivotal role of community health workers (CHWs) in advancing universal health coverage by adopting transformative strategies in health worker (HW) education [1]. Globally, the needs-based shortage of HWs, including doctors, nurses and all other HW cadres, is expected to be more than 14.5 million in 2030, with developing countries facing the greatest impact [2]. 'Task-shifting' and 'task-sharing' are key strategies for optimizing healthcare delivery and the WHO recommends 'lay' HWs for improving maternal and newborn health services [3, 4]. A lay HW is one who performs functions related to healthcare delivery and has received some level of training in the context of an intervention, but does not hold a formal professional or paraprofessional certificate or tertiary education degree [5].

Congenital anomalies (CAs) affect 8 million children every year, with a proportionately increasing contribution to neonatal and under-5 mortality as global interventions for addressing the highest burden of neonatal conditions are increasingly successful [6, 7]. Early identification of anomalies, timely referral and cost-effective management can prevent deaths and mitigate disabilities in up to 70% affected children, particularly in low- and middle-income countries (LMICs) [8]. A comprehensive physical examination of all newborns within 24 h of birth is an essential component of the postnatal care model, allowing early detection of anomalies [9, 10].

Pakistan, with a population of more than 240 million, reports dismal health indicators coupled with critical shortage of healthcare providers [11, 12]. CAs are among the top five causes of death, contributing to 10% neonatal and 5% under-5 deaths [13, 14]. Systematic neonatal screening for CAs is not routinely conducted for the vast majority of births at hospitals and birthing centers, nor for home deliveries conducted by midwives or traditional birth assistants [15–17]. As a result, many CAs are often overlooked, leading to mortality and late or complicated clinical presentations [18–21]. With an annual birth cohort of approximately 7 million and limited resources, there is a pressing need for practical solutions to expand health service coverage in Pakistan [22].

Interactive Research & Development (IRD) initiated the Congenital Anomalies Registry (CARe) project in Karachi, Pakistan, in January 2023, to develop an effective screening model for CAs. A learner-centered educational intervention, which included a curriculum with appropriate learning experiences, was designed and utilized to build the knowledge and skills of lay HWs to screen neonates for external CAs and to counsel and refer the affected families for timely management. This study aims to evaluate the effectiveness of the educational intervention, firstly, by assessing changes in the knowledge and skills of HWs after exposure to the intervention and secondly, by measuring the concordance between the identification of CAs by trained HWs and a helpline physician during the first three months of data collection. Perspectives of HWs regarding this innovative educational intervention are also explored through focus group discussions (FGDs) for the purpose of improvement in future.

Methods

The educational intervention consisted of two weeks of classroom training followed by two weeks of clinical onsite training.

Study design and participants

A mixed-methods, sequential, exploratory study design with a bracketed approach (i.e., quantitative → qualitative → quantitative) was employed, with integration at the 'interpretation of results' phase (Fig. 1) [23]. Non-probability, purposive sampling was used to recruit 15 HWs who completed four weeks of the CARe educational intervention. HWs that exited during the training or the first three months of project implementation were excluded. The aim was to hire enough health workers to manage round-the-clock data collection according to patient flow at the selected sites. Subsequently, 13 out of 15 trained HWs were hired who then became eligible for the delayed post-test.

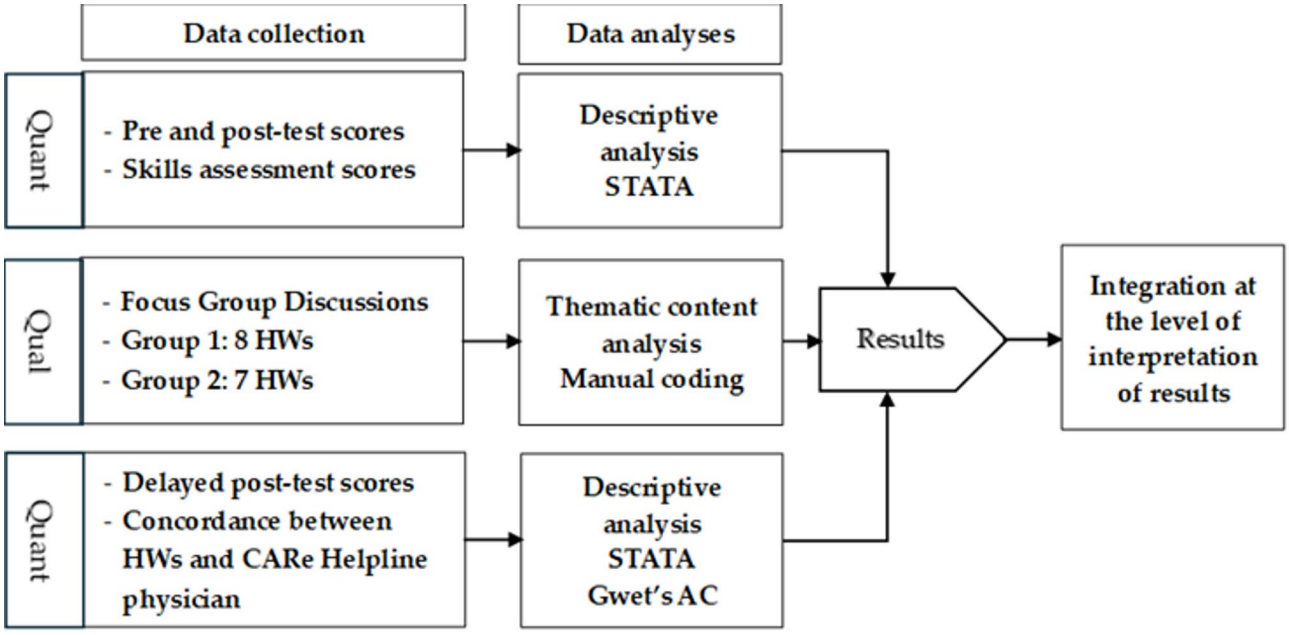

Fig. 1 Mixed-methods, sequential, exploratory study design, with a bracketed approach

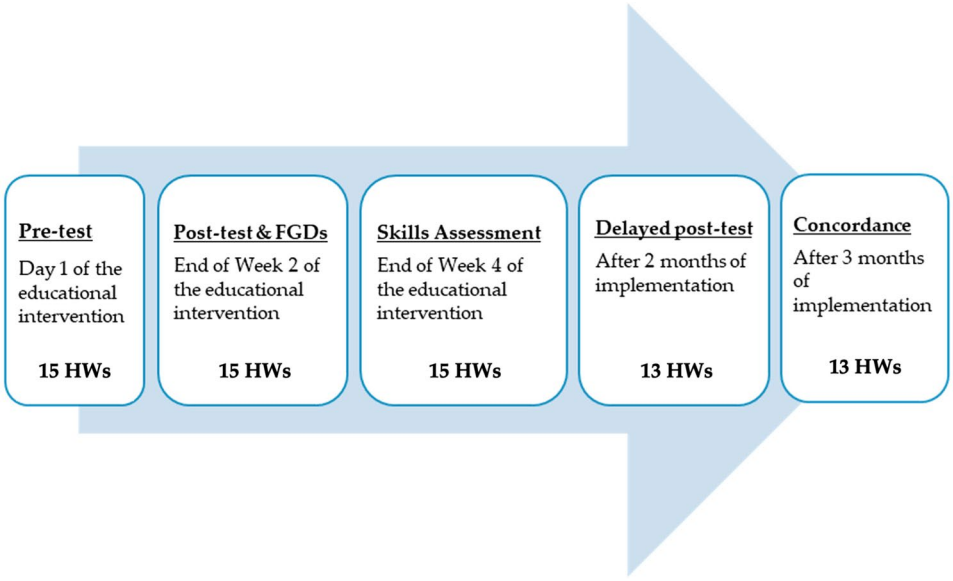

Fig. 2 Timeline for assessments

Clinical trial number

not applicable.

Quantitative study design

A quasi-experimental, interrupted time-series study design was used [24, 25]. *Knowledge assessment* was conducted in the training room at the institutional office, using pre- and post-tests, at the beginning and end of the two weeks of classroom training respectively (Fig. 2). The pre- and post-tests were identical 20-item MCQ assessments, with one mark per question (maximum score: 20), administered in Roman Urdu. This was followed by two weeks of hands-on clinical training at one of the three selected study implementation sites; one secondary (Qatar) and two tertiary hospitals (Civil and Jinnah) with high birth volumes were selected. *Skills Assessment* was conducted to evaluate clinical and communication skills at the end of the on-site clinical training using a 'Task-specific checklist' (Additional file 1)**.** *Retention of knowledge* was assessed at two months by a delayed post-test and at three months by assessing concordance in

identification of CAs by HWs and the confirmation provided by the CARe helpline physician.

Quantitative data analyses

Continuous variables were reported as median with interquartile range, due to the small sample size (n < 30). Frequencies with proportions were used to describe categorical variables. Data were analyzed using STATA version 16. For knowledge assessment, the total scores obtained on the pre-, post- and delayed post-tests were documented for each HW. Sign test was used to determine the effectiveness of the educational intervention by assessing whether the differences in median pre- and post-tests were significant. P-value of < 0.05 was considered significant. The cumulative effect size $r = Z/\sqrt{N}$ was calculated. Association of median pre- and post-test scores with demographic factors was examined using Kruskal Wallis test. For skills assessment, the total scores obtained by each HW were calculated. Scores were categorized into five groups: 'Not assessed', 'Unsatisfactory', 'Satisfactory', 'Good' or 'Excellent'. Descriptive statistics were calculated for the type of anomaly (minor or major) identified. CAs were classified according to the WHO definitions to ensure consistency and comparability with international data. Major anomalies were defined as structural changes that have significant medical, social, or cosmetic consequences for the affected individual and typically require medical or surgical intervention. In contrast, minor anomalies were defined as structural changes that do not pose significant health problems and have only limited social or cosmetic consequences [26]. Agreement among raters was assessed using Gwet's AC with 'Physician agrees' and 'Physician disagrees' for the type of anomaly. Interpretation of Gwet's AC is as follows: <0.4 (poor), 0.4–0.6 (moderate), 0.6–0.8 (good), >0.8 (very good) agreement.

Table 1 Phases of CARe project

Phase 1	Phase 2: Implementation	
Planning & development (5 months)	**2a: Hiring, training, on-site pilot (1 + month)**	**2b: Project implementation by HWs (12 months*)**
■ Institutional Review Board & Ethics Review Council approval ■ Development of the curriculum ■ Development of data collection tools (Questionnaires, consent form) ■ Selection and approval of sites ■ Translation of questionnaires and training material in Roman Urdu ■ Counseling guidelines ■ Referral guidelines	■ Recruitment of health workers ■ 2 weeks classroom education & training of HWs ■ Pre and post-tests, assessment of skills ■ Individual feedback given to HWs by the facilitators ■ FGDs ■ 2 weeks on-site pilot ■ Initiation of data collection	■ Taking informed consent ■ Screening for congenital anomalies by HWs ■ Identification of anomalies ■ Data collection & sharing ■ Liaising with the helpline physician for confirmation of anomalies ■ Counseling affected families ■ Referral of affected babies ■ Daily summaries & reports ■ Follow-up call at Day 29 ■ Ensuring confidentiality and privacy of the patient

*This study focuses on the first three months of screening and data collection by trained HWs

Qualitative study design

An exploratory design was chosen to investigate the learning experiences of HWs and their perspectives on different curricular components [27]. Two FGDs, each of one-hour duration, were conducted at the end of the two-week classroom training with seven and eight participants respectively. A semi-structured FGD guide was used (Additional file 2), and the FGDs were conducted by an independent facilitator to avoid bias. With two FGDs, full thematic saturation was not expected; however, convergence of themes across both groups indicated adequate coverage for the exploratory aims of this study.

Qualitative data analyses

Data from the FGDs were transcribed from the voice recorder onto a Word document by an intern and reviewed by the Project Manager. Transcripts were read multiple times; thematic content analysis was conducted for descriptive presentation of qualitative data, and a codebook was developed [28]. Data was coded manually by two researchers to reduce researcher bias and to enhance inter-rater reliability [29]. Coders met regularly to compare and refine coding. Disagreements were resolved through discussion to achieve a consensus to enhance credibility of the analysis. Responses about specific aspects of training were categorized into themes. Additionally, data were also churned to generate themes through an inductive method. Themes were clustered into 'Basic themes', which were incorporated within 'Organizing themes' which, in turn, were grouped under a 'Global theme', representing first, second and third order abstractions as part of the layered qualitative analysis [30]. To mitigate potential bias arising from their dual roles as trainers and curriculum designers, the coders engaged in reflexive discussions and actively considered any data that contradicted the dominant themes. Content analysis was employed to quantify qualitative data by examining who says what, to whom, and with what effect, in order to make interpretations regarding the data [31, 32].

CARe project

The CARe project was implemented in Karachi, Pakistan, to develop a model newborn screening (NBS) project for CAs (Table 1). In the initial 6-month phase, a contextualized curriculum was developed, and training was conducted, followed by a 12-month screening phase, which

included an iterative process of curriculum refinement and hands-on skills improvement. This study focuses on the first three months of screening and data collection by trained HWs.

Literature review revealed that there is no pre-existing curriculum for this purpose and for this target audience of lay HWs, therefore, an outcomes-based, learner-centered curriculum was developed using Kern's dynamic six-step approach [33]. It included [1] *Problem identification & general needs assessment* with a comparison of current versus ideal approach towards the identified issue (Additional file 3); [2] *Targeted needs assessment* for identification of specific requirements to facilitate effective implementation (Additional file 4), and an informal survey conducted with HWs from different programs, revealing a strong preference for Roman Urdu language for the education and data collection tools; [3] *Outcomes* desired for screening newborns for CAs, counseling families and giving appropriate referrals were documented (Additional file 5); [4] *Educational strategies* included selection of developers, trainers, content resources and learning strategies; [5] *Implementation* of the curriculum which included training; and [6] *Evaluation*. The latter three steps are detailed below.

Table 2 CARe tools

Tool	Description and Purpose
Starter kit for HWs	■ Included a backpack, a water bottle, a stethoscope, torch, measuring tape, stationery, disposable gloves, tongue depressors, hand sanitizer and an Android phone for data collection
CARe Anomalies Manual	■ Pictorial information on basic anatomy, description, types, and International Classification of Disease (ICD-10) codes for 79 commonly seen external anomalies, including 35 major* and 44 minor** anomalies
CARe Checklist	■ List of anomalies detailed in the CARe Anomalies Manual, providing a quick reference to guide HWs during screening
Global Birth Defects App *(Dolk et al., 2021)*	■ The basic version used as a teaching tool to facilitate HWs in individual and group activities to identify and code anomalies
CARe Clinical Examination Booklet	■ Clinical examination teaching guide, including approach, ethics and steps during newborn screening
CARe Counseling Guidelines	■ Detailed information for HWs to counsel families of newborns identified with anomalies ■ Anomaly-specific information about the condition, initial management where relevant, and the importance of timely intervention
CARe Referral Guidelines	■ Information for HWs to advise families on when and where to take newborns with anomalies for management ■ Anomaly-wise information on facilities, specialties and outpatient clinics
Data collection forms:	
■ Consent form	■ Informed consent from HWs before conducting tests and FGDs; informed consent from parent/family prior to newborn screening
■ Enrolment form	■ Demographic data, anomaly details and photographs, and referral details
CARe knowledge assessment tests & key	■ Pre-, post- and delayed post-tests ■ Twenty multiple choice questions (MCQs) in Roman Urdu (Urdu language written in Latin script), each carrying one mark.
Skills assessment checklist	■ Task-specific checklist by content and clinical experts ■ Desired skills for screening identified into 16 small tasks, 1 mark each ■ Taking informed consent, anthropometric measurements, vitals and screening the baby from head to toe ■ Pilot-tested on three HWs
FGD Guide	■ Timing and details of the FGD; the FGD questions
CARe Learning Objectives	■ Provided a daily roadmap for learning during training
Techniques for empathetic counseling	■ Taught by the trainer psychologist to HWs through role-play

Educational strategies

For development of the curriculum, a 'core team' was established, consisting of content and clinical experts (Additional file 6). The curriculum was delivered by two main content trainers, the REDCap application was introduced by two data trainers, empathetic counseling was taught by a psychologist, and clinical examination of neonates was demonstrated by a pediatric surgeon. Existing reference tools (Table 2) were adapted, modified and translated to Roman Urdu. Iterative changes were made based on feedback from the HWs project team and clinical experts. Since HWs had varying educational backgrounds, content was carefully delivered to allow sufficient time for assimilation, while reiteration and revision were employed to increase familiarity. Interactive teaching & learning strategies were used along with a didactic component (Additional file 7). Strategies included small-group learning, individual and paired activities, use of photographs to identify anomalies, brain breaks, demonstration, low-fidelity simulation using locally purchased dolls for experiential learning, data entry using practical case scenarios and standardized patients, role-play and role-modelling by facilitators. Frequent testing and continuous formative assessment were employed to enhance learning.

HW training and implementation of the curriculum

Keeping cultural considerations in mind, female HWs were recruited from local communities since the project required HWs to work in labor rooms and in Gynae wards. They were required to have a minimum of ten years of education, to be able to read and write Roman Urdu and basic English and demonstrate familiarity with the use of mobile phones. Fifteen HWs were selected for pre-service training from a pool of 30 applicants. After classroom training, individual feedback was given

to the trainees, highlighting their strengths and areas of improvement. Clinical training began at Qatar Hospital which also marked the initiation of the on-site implementation with screening of newborns by HWs. Training adopted a non-hierarchical task-sharing approach, with supportive supervision provided by the project team and clinical experts as a safety net [34, 35]. The purpose was to familiarize HWs with the facility staff, programmatic processes and workplace dynamics and to streamline data collection. The importance of effective communication skills, empathy, professionalism and social accountability were reiterated during training through role play and role-modelling. HWs were provided with a training stipend during the four weeks of training. At the conclusion of the clinical on-site training, certificates of completion were awarded to the trainees and thirteen HWs were selected based on their test results, clinical and communication skills, attitude and teamwork. Competitive salary packages were offered with transport allowance and overtime compensation as needed.

Screening was gradually expanded to include all three study sites through staged implementation where newborns were examined from head-to-toe for major and minor external CAs by trained HWs and anomalies were recorded on data collection forms. Telemonitoring was established through encrypted, site-wise WhatsApp groups, where HWs posted photographs of anomalies in real-time. These groups were supervised for the first three months by the Project Manager and the Training Coordinator to streamline the identification of anomalies, data collection, counseling and referral; they also provided helpline support by confirming each identified anomaly, and guiding the HWs on counseling, management and referral advice. After the initial 3-month phase, helpline support was available as and when required to promptly address any issues.

Table 3 Demographic profile of CARe health workers ($n = 15$)

Socio-demographic variables	Categories	Frequency	%
Age in years	19–22	4	26.7
	23–27	4	26.7
	28–35	4	26.7
	36–46	3	20.0
Education level	Intermediate	8	53.3
	Matriculation*	5	33.3
	Graduate/Masters	2	13.3
Ethnicity	Urdu-speaking	5	33.3
	Sindhi	2	13.3
	Memon	2	13.3
	Hazara	2	13.3
	Baloch	1	6.7
	Bihari	1	6.7
	Punjabi	1	6.7
	Sindhi Memon	1	6.7
Marital status	Single/Unmarried	9	60.0
	Married	4	26.7
	Divorced	2	13.3
Habit of taking betel nuts/ smokeless tobacco	No	10	66.7
	Yes	5	33.3
District of Residence	Korangi	10	66.7
	District West	3	20.0
	District Central	1	6.7
	District South	1	6.7
Health-related work experience (in years)	0 (No experience)	4	26.7
	1–2	6	40.0
	> 2	5	33.3
Overall work experience (in years)	1–3	8	53.3
	4–6	4	26.7
	7–14	3	20.0

*Matriculation: Ten years of education in Pakistan

Feedback and evaluation

Feedback was provided to the HWs throughout the training and implementation phases. An expert review was conducted after the first three months of data collection. Photographs of identified anomalies were reviewed by a panel of clinical experts (Additional file 6) who confirmed the HW diagnosis and provided feedback to mitigate overdiagnosis or misdiagnosis. This valuable information, gained through exchanges between HWs, the project team and clinical experts, was reflected in curricular revisions and refresher trainings were conducted for the HWs accordingly.

Results

Demographic information of the fifteen HWs (Table 3) indicates a mean age of 29.1 (± 7.9) years and a median age of 27 years (IQR: 22–35). Sign test was performed for statistical hypothesis testing of the knowledge assessment scores (Table 4). The cumulative effect size between pre- and post-test scores $r = Z/\sqrt{N} = 3.873/\sqrt{15}$ was 1 indicating an extremely strong effect and a significant sign test p-value (< 0.001) between the pre- and post-test scores of participants was observed. Association of socio-demographic variables with test scores was assessed (Table 5). At baseline, no significant difference was seen, indicating that the study population was homogenous. A similar result was observed with the post-test scores. The skills assessment results (Table 6) showed that 11 out of the 15 HWs (73.3%) were 'Good' or 'Excellent' in clinical and communication skills, with a median skills assessment score of 13 (IQR: 9–14).

Of the 5,801 babies delivered at the three sites during the study period, 3,794 babies (65.4%) were screened by CARe HWs. A total of 1,012 CAs were identified in 850 newborns; thus, a prevalence of 22.4% was established.

Table 4 Knowledge assessment of health workers

Test	Number of participants	Median	IQR		Pre-test vs. Post-test (*p*-value*)	Post-test vs. Delayed Post-test (*p*-value*)
Pre-test	15	5.0	2.0	7.0	< 0.001	-
Post-test	15	18.0	14.0	20.0		0.388
Delayed post-test	13**	18.0	13.0	19.0	-	

*Sign test

**13 out of 15 HWs were hired who were eligible for the delayed post-test

Table 5 Association of median pre and post-test scores with demographic factors

Variables	Categories	Pretest			Post-test		
		Median	IQR	*p*-value*	Median	IQR	*p*-value*
Education	Graduate/Masters	9.5	6.0–13.0	0.21	19.5	19.0–20.0	0.20
	Intermediate	5.0	3.0–7.5		17.5	15.0–19.5	
	Matriculation**	5.0	2.0–5.0		12.0	12.0–18.0	
Age	19–22	4.5	2.0–6.5	0.90	18.5	17.5–19.5	0.30
	23–27	5.0	1.5–10.5		14.5	13.0–17.0	
	28–35	5.5	5.0–6.0		15.0	9.5–19.0	
	36–46	5.0	2.0–7.0		20.0	15.0–20.0	
Marital status	Divorced	3.5	2.0–5.0	0.68	19.0	18.0–20.0	0.34
	Married	5.5	3.0–6.5		13.5	9.5–17.5	
	Single/unmarried	5.0	4.0–8.0		18.0	15.0–19.0	
Health-related work experience	0 (No experience)	3.5	2.0–5.0	0.42	16.0	13.0–19.0	0.46
	1–2	5.5	4.0–8.0		16.5	12.0–19.0	
	> 2	6.0	5.0–7.0		19.0	17.0–20.0	

*Kruskal-Wallis test

**Matriculation: Ten years of education in Pakistan

Table 6 Skills assessment of health workers (Total marks = 16)

Scores	Grade categories	No of health workers	% of health workers (95% CI)
-	Not assessed	0	0.0
< 8	Unsatisfactory	2	13.3 (4.0–30.5)
8–10	Satisfactory	2	13.3 (4.0–30.5)
11–13	Good	6	40.0 (15.2–64.8)
14–16	Excellent	5	33.3 (9.4–57.2)

Of the neonates with anomalies, 708 (83.3%) presented with a single anomaly, 126 (14.8%) with two anomalies, 14 with three anomalies (1.6%) and two neonates (0.2%) with four and five anomalies each. Categorization of anomalies showed that 61 were major (6.0%), 946 were minor (93.5%), and for 5 anomalies (0.5%) the diagnosis could not be established. Concordance was assessed between the HWs and helpline physician on the identified anomalies and overall concordance was found to be 93.8% (95% CI: 92.4%–95.2%) (Additional file 8). Gwet's AC showed concordance at 0.93 with a p-value < 0.001, indicating 'very good' inter-rater agreement. Positive percent agreement was 96.8% and negative percent agreement was 98.6%. The individual knowledge test scores of the thirteen hired HWs and concordance observed for screened anomalies is shown in Fig. 3.

To complement the quantitative results, qualitative findings were analyzed using thematic content analysis. Figure 4 shows a thematic network centered around a global theme of 'Feedback of trainees on the CARe educational intervention' with six organizing themes reflecting trainees' perspectives that emerged during analysis. The majority of trainees expressed satisfaction with the overall training structure; this included the training experience, sequence and duration of training. Roman Urdu was preferred by 80% of participants, who stated that it was easy to read, understand and write.

Feedback on the content trainers was provided by all fifteen HWs with an average of four and two responses per participant in the first and second group of FGDs respectively. Positive feedback was provided, with trainees commenting most frequently on the effective teaching style, stress-free learning approach and good attitude of both the content trainers (Table 7). There was no negative or critical feedback given by any trainee for the content trainers. Participants valued the trainers' clear and engaging teaching style, their supportive and empathetic attitude, and the safe learning environment that encouraged questions without fear of criticism. As one trainee noted, *"Dr Trainer 1's style of teaching is very good; things become very clear for us,"* while another emphasized, *"We would never be scared... Whatever query came in*

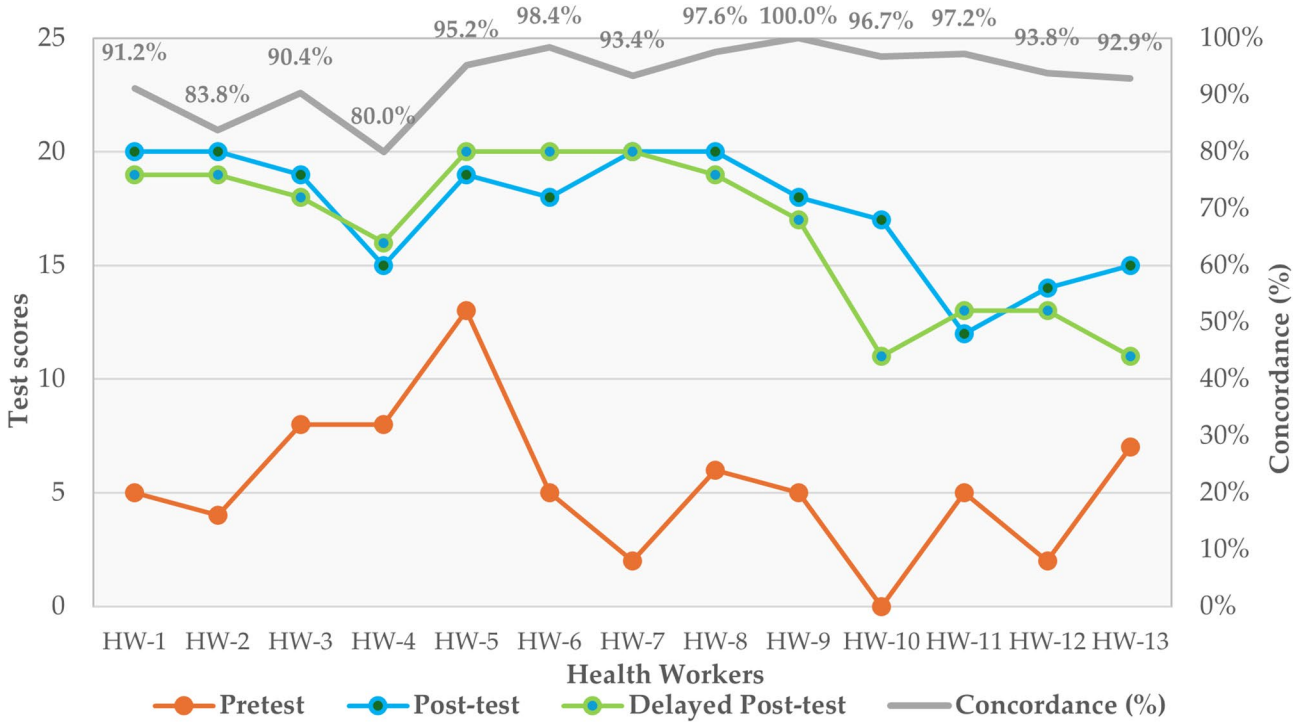

Fig. 3 Comparison of median test scores (primary y-axis) and overall concordance (%) per health worker (secondary y-axis)

our minds, we would just ask the teachers." Twelve HWs provided negative feedback on the teaching style of one of the data trainers, stating that the trainer seemed "*confused*" and "*not prepared*". One trainee said that the trainer "*failed to clear concepts*" whereas another went on to say that she had a "*bad attitude*". One HW stated:

> *"When many people would ask her questions, then she would make faces or show annoyance.... and her tone would suddenly be a little harsh."*

In contrast, six trainees praised the second data trainer. Four of the five HWs who responded commended the psychologist's roleplay-based teaching of counseling skills. Two appreciated the pediatric surgeon for effective hands-on teaching and concept clarification.

Ten HWs gave feedback on the curriculum; four found the content very good and easy to understand, while six initially felt it was daunting and extensive with photos of anomalies making it seem overwhelming. By the end of week two, however, the same HWs felt confident, crediting trainers' effective teaching, simplification and revision of concepts which led to consolidation of learning. One HW who had not previously studied science, described her experience as:

> *"Ma'am, the first day that I came and saw the book, my head spun...and I thought how will I ever be able to articulate these terms...? So, I faced a lot of difficulty in the initial 2 or 3 days but the way the trainers explained and the way they taught us with different activities .... helped us absorb each and every word into our minds...they asked us not to worry about spellings at all. They told us we could write in Urdu or Roman Urdu."*

Eleven trainees appreciated the use of multiple teaching & learning strategies moving from group work to pairs to individual tasks, with daily rotation of learning partners. Five trainees rated the Global Birth Defects App as good and user-friendly. Nine trainees gave similar feedback on the REDCap data collection tool, highlighting its skip logic and multi-select features whereas three of them criticized that the forms were still in the developing phase. Ten HWs found learning objectives helpful for delineating daily content and tracking progress, while twelve noted that daily end-of-session summaries improved retention and clarified concepts. Nine trainees described the brain breaks as enjoyable and relaxing, noting that they boosted their energy levels. Seven HWs gave mixed feedback on the neonatal examination training. They appreciated starting with a mannequin before moving to real babies, but four suggested allocating more time for this session. A trainee said:

> *"If we had transitioned on to examine the real baby directly, then we would not know the way to handle it. Dolls were lifeless on which we practiced. So, with*

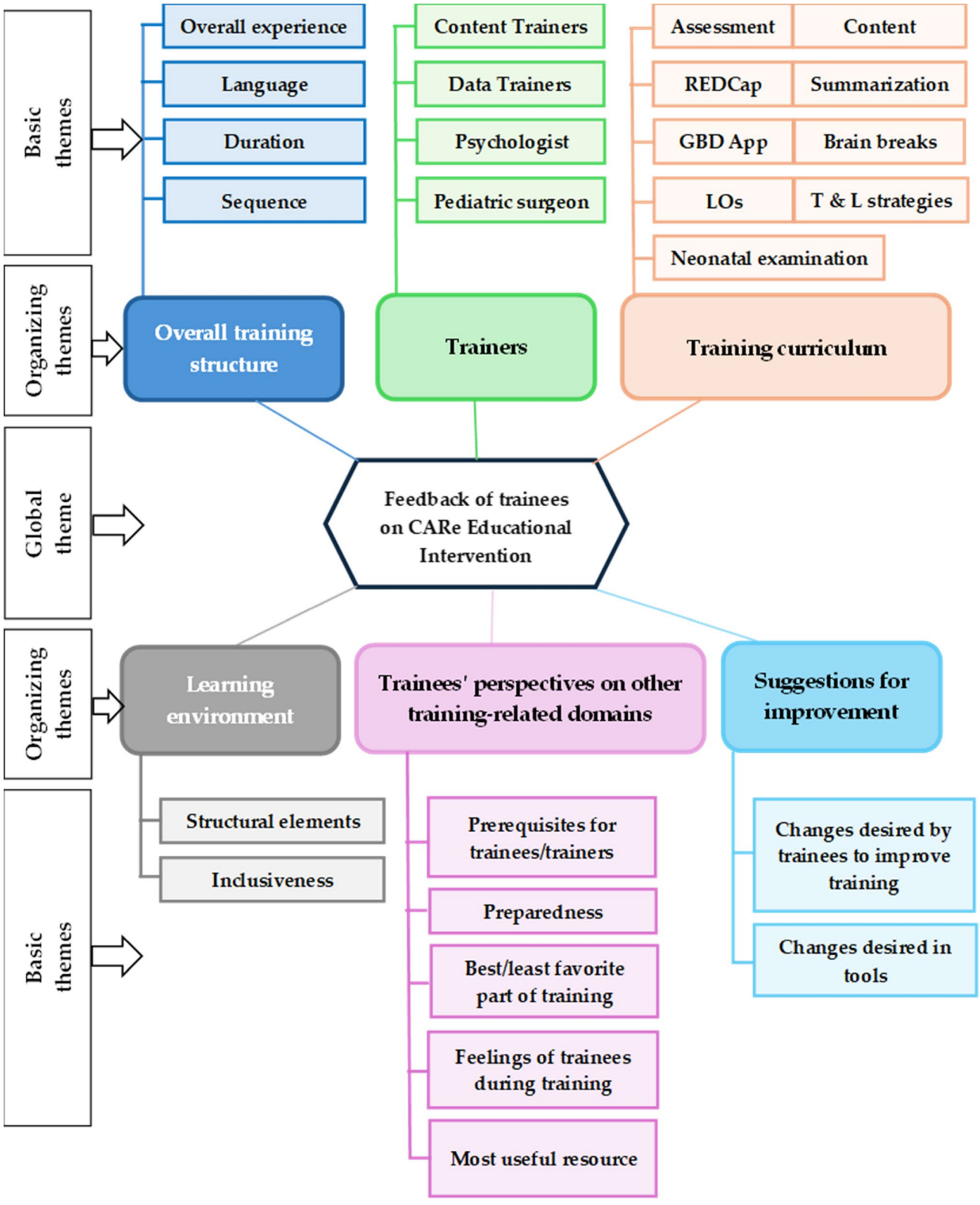

Fig. 4 Thematic network

Table 7 Basic theme - Trainee feedback on content trainers (*N* = 15)

Codes	Sub-codes	No of responses
1. Effective teaching style (28)	Memorization/Rote learning not required	1
	Very good teaching style	3
	Effective way of teaching	5
	Unique teaching style	1
	Gave a roadmap	1
	Provided good guidance	1
	Satisfied the learners	1
	Simplified the content	2
	Clarified concepts	6
	Inclusive	4
	Responsive teachers	3
2. Ensured stress-free learning (11)	Stress-free approach	6
	Stress-free environment	1
	Open, friendly environment	1
	Both trainers are a source of inspiration	1
	Flexible approach	1
	Gave freedom to use preferred language	1
3. Good attitude (8)	Encouraging	4
	Polite	1
	Patient	1
	Concerned about the progress of each student	1
	Worthy of appreciation	1

the dolls, we got to know how to hold babies, where to place the head; they demonstrated everything. So, I preferred this."

Nine trainees acknowledged that the assessment strategies used were good. One commented that the questions asked during assessments were clear and another said that adequate time was given to respond. One HW commented:

"They assessed us in groups, so we developed good understanding with everyone. Then in pairs, which was also good. Individual assessment was also done which helps one gauge about one's own self."

Nine trainees commented on structural aspects of the learning environment; seven found it comfortable and enabling, while two noted distractions like the screen's brightness and wallpaper pattern in the room. All participants, however, described the overall environment as non-threatening, friendly, comfortable, and inclusive. One participant noted:

"The best thing that I liked about this training was that our teachers would make sure to include everyone ..... and she does not single anyone out."

Trainees identified good attitude, secondary education and good communication skills as the most important prerequisites for HWs to benefit from this training. Similarly, effective teaching skills, good attitude and knowledge were identified as favorable attributes for trainers. The CARe Training Manual was identified as the best learning resource by five HWs. Seven trainees commented on preparedness by saying that they felt confident to handle screening of real babies at the hospital sites, with one commenting:

"We also know if any baby has anomalies, then we can also tell parents that your baby has such and such issue and you can take your baby to this place. So, this is really good that now it really feels that we have also become half-doctors."

Four HWs suggested improvements, while six were fully satisfied with the training. Recommendations included more time for counseling, consent-taking, and practical sessions; using a screen and projector for data training; including more photos of real babies with anomalies in the manual; and ensuring trainers tailor time and attention to learners' needs.

Discussion

Trained HWs have played effective roles in health service delivery in many settings [36, 37]. Our findings demonstrate a significant change in the relevant knowledge and skills of HWs engaged in newborn screening for CAs after exposure to a four-week structured educational intervention.

We build upon prior evidence of employing a learner-centered educational intervention as a structured, effective approach to enhance knowledge and skills of HWs [38, 39]. Literature indicates that the following strategies increase the credibility and quality of educational interventions: reporting multiple outcome measures instead of single, longer lengths of educational interventions, effect-size reporting, assessing long-term effects of the intervention rather than only immediate ones and conducting randomized experiments [40]. Apart from randomization, all the above-mentioned strategies were employed to strengthen the CARe educational intervention. The large effect size documented in the results emphasizes the practical significance and the potential applicability of this educational intervention.

No significant association was seen between HWs' demographic factors and baseline pre-test scores and post-test scores; the former result indicated that the study population was homogenous and the latter that socio-demographic factors did not impact learning and the resultant improvement in scores after training could potentially be attributable to the educational

intervention. The fact that the median delayed post-test scores did not change signifies that the HWs retained the knowledge that they had gained. Knowledge retention can be attributed to various factors. Longer instructional duration and interactive group learning have been linked with durable learning [41, 42]. Frequent testing, which has been known to boost retention, was employed in CARe training and formative feedback was provided to promote learning [43, 44]. Literature review also shows that retention of knowledge and skills is better if HWs are placed at high-volume centers where they have ample opportunities for practice, which was the case with CARe HWs who were engaged in screening at the busiest hospitals in Karachi. Lastly, refresher classes with practical sessions help in improving retention and this strategy was also employed by the CARe project team [45].

Since the knowledge post-test scores show a significant improvement after training and the median skills assessment score is also high, it can be suggested that training could have positively influenced both knowledge and skills acquisition. This inference is supported by the CARe HWs' responses during the FGDs and further by a systematic review exploring effectiveness of training [46].

A combination of didactic sessions with interactive learning, experiential and on-site learning, followed by refresher sessions was identified as the most effective training modality for CHW programs by a global systematic review and a similar approach was utilized for the CARe intervention [47]. Results of the qualitative component of this mixed-methods study highlight additional evidence-based approaches employed in the CARe educational intervention that were appreciated by the HWs. Studies show that comprehensibility is better when the text is in the native language and that localized versions of documents enhance accessibility, especially for HWs [48, 49]. Roman Urdu is very popular among the masses in South Asia as a mode for communicating on social media [50]. An overwhelming response from CARe HWs confirmed the preference for Roman text for learning and data collection.

There was consensus amongst trainees for both content trainers, with overwhelmingly positive feedback from all participants. Clarification of concepts, addressing student queries with patience and simplifying the content were acknowledged by all trainees. 'Teacher clarity' is a construct that was investigated in detail in the 1970s. Bush et al. state that teacher clarity involves explaining concepts in a comprehensible manner, at an appropriate pace, using examples and illustrations in the presentations [51, 52]. Student achievement is seen to be strongly associated with meaningful learning which is linked with the way information is presented and how learning tasks are assigned to students to promote clarification of concepts [53]. Meaningful learning, reflected in the CARe HWs' test scores, led to a sense of satisfaction and achievement which was reflected in the responses during the FGDs. The elements of effective teaching and learning strategies reported in literature, such as inclusiveness, were adopted and utilized by the CARe content trainers and recognized by HWs [54, 55]. The deliberate integration of diverse expertise across training components could also have potentially contributed to both participant engagement and the overall quality of the intervention.

Identification of learning gaps, such as weaknesses in the teaching approach of one data trainer, indicates that these were self-aware students who were able to identify obstacles during learning [56]. Use of interactive strategies in education such as small group learning and peer learning are known to promote cognition through discussions [57]. CARe training began with group learning which gave time to the students to gain confidence and experience the advantages of small group learning; this was followed by learning in pairs which encouraged peer learning; and eventually, individual learning acclimatized the learners to increasing responsibility and ownership [58–60]. The learning environment strongly affects student achievement and satisfaction. An enabling, respectful, and non-threatening learning environment was provided for CARe training which was recognized by the HWs.

Financial as well as non-financial incentives like training, appreciation, certification, competitive salaries and streamlined supply of items that aid in the performance of job-related tasks were provided to CARe HWs; in our experience and that of others these incentives increase HW motivation and satisfaction impacting outputs [47]. There is evidence to indicate that supportive supervision enhances learning for CHWs [61]. We ensured supportive supervision through on-site hands-on training, telesupport by a helpline physician, accessible project team, and regular process review.

In comparison to our study, the large-scale Lady Health Worker (LHW) Program, launched in Pakistan in 1993/1994, has been recognized as a fairly successful initiative within a relatively weak health system, in which women are employed and trained to deliver primary healthcare services within their communities. Their training and assessment protocols have some similarities with the CARe educational intervention [47]. However, results were reported to be poor despite extensive academic training, indicating a serious deficiency in knowledge and compromised counseling skills [62]. CARe implementation reflected a more structured training approach in an enabling environment with periodic assessments, supportive supervision and close monitoring of processes and outcomes, a combination of which may have contributed to encouraging results.

Feedback from CARe trainees was a valuable source of information and was used to modify the curricular content and the data collection tools. Co-creation, an emerging concept, has been described to foster shared responsibility and trust, and to promote student-teacher partnership and collaborative learning [63]. However, relevant literature on co-creating curricula in medical education is scarce and warrants additional research to establish feasibility [64, 65].

Philosophical perspectives and learning theories underpinning the CARe educational intervention

Philosophical perspective

The educational philosophical perspective closest and most compatible with the CARe educational intervention is 'Essentialism' where core knowledge is considered an absolute requirement for all students [66]. The passivity of students as mere recipients of knowledge was realized as a drawback of essentialism. Nonetheless, essentialism satisfied the core requirements of CARe training where all learners were exposed to the core curriculum and standardized outcomes were desired from all learners, with adequate time provided to learn at different paces.

Learning theories

Learning theories offer frameworks to help understand how learning takes place. These theoretical lenses could be used to align instructional practices addressing diverse learning needs to ensure educational learning objectives are achieved.

Behaviorism Training programs are governed by *behaviorism*. In the CARe project, training was the stimulus which resulted in learning of the skill by the HW.

Cognitive learning theory This theory emphasizes the importance of prior knowledge and aptitude for learning. In CARe, scaffolding was used to provide individualized support in the form of guided supervision by project trainers, especially when hands-on training was initiated at the hospitals; this support was gradually reduced and then withdrawn as learners became independent [67].

Experiential Learning Theory (ELT) Learners were provided opportunities for hands-on practice, reflection, and application, consistent with ELT's cycle of experience and reflection.

Humanism Professionalism and ethical considerations were included in the curriculum for holistic learning, adding the *humanistic* element to this intervention.

The CARe intervention strategically combined elements from different learning theories, using the strengths of one to offset the limitations of another. Learner passivity of behaviorism was complemented by learner-centeredness proposed by humanism and an enabling environment was ensured to facilitate learning through active interaction with students. A systematic review of meta-analyses also shows that the combination of teacher-centered and student-centered instructional practices gives better results compared to either practice alone [53]. Scaffolding, proposed by cognitivism, was actively employed as 'supportive supervision' in CARe training and implementation; however, it was ensured that the sources of support are multiple and the facilitators offering this support are qualified to do so. ELT is highly relevant in clinical environments where learners are shadowing or working to strengthen their skills [68].

Conclusion

This mixed-methods evaluation study provides preliminary evidence that the CARe educational intervention to train HWs was effective. From our experience, the results could be attributed to effective training, which was reliant on meticulous planning, honest execution of the plan, teaching expertise, attitude of trainers, supportive supervision and an enabling learning environment. HWs could potentially be utilized to deliver public health interventions effectively to promote health, while providing financial benefit to them, especially when developing countries face critical shortage of healthcare workers. Transferable lessons from the implementation of this educational intervention for HWs have a strong potential to be replicated to build capacity of traditional birth attendants, midwives or nurses in similar settings regionally and globally. However, large, multi-site studies will help build this evidence.

Limitations

The study yields promising preliminary findings; however, the lack of a control group limits the ability to attribute the improvements exclusively to the intervention. This was the first curriculum, to our knowledge, that was designed specifically for NBS for CAs by lay HWs. Therefore, a true comparison of assessment scores was not possible. Skills assessment could not be pre-tested since the HWs had not conducted NBS prior to initiation of their training and it was unethical to allow them to handle newborns prior to relevant training. Skills were assessed using a checklist to determine if a task was performed, but this tool was not designed to capture 'how' the task was done. Complementing the checklist with Global Rating Scale will allow better judgement of skills through observation. Pilot-testing of skills assessment checklist with calculation of inter-rater reliability is also recommended to enhance objectivity of the ratings.

The content and construct validity of the educational and assessment tools were reviewed by several experts

without employing a formal methodology as they were custom designed for this intervention; formal validation studies would enhance the methodological strength. While steps were taken to protect data confidentiality, the use of WhatsApp groups for data sharing within the team poses a potential threat to data security and safer, feasible alternatives should be explored for future use.

Although the FGDs were conducted by an independent moderator to minimize bias, the administration of tests and the analysis of both quantitative and qualitative components were conducted by members of the project team, thus introducing risk of bias. A truly independent evaluation may be able to mitigate this risk.

Abbreviations

CARe	Congenital Anomalies Registry
CAs	Congenital Anomalies
CHWs	Community Health Workers
FGD	Focus Group Discussion
HW	Health Worker
LHW	Lady Health Worker
LMICs	Low- and Middle- Income Countries

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-08095-6.

Additional file 1: Task specific checklist for skills assessment. The task-specific checklist that was developed to assess clinical skills of the HWs during the training phase.

Additional file 2: The semi-structured guide for the FGDs that was developed in line with the research objectives.

Additional file 3: Problem identification & general needs assessment. This outlines the current challenges in newborn screening for congenital anomalies (CAs) compared to the ideal scenario.

Additional file 4: Targeted Needs Assessment. Identification of specific requirements for learners, environment and stakeholders to facilitate effective implementation.

Additional file 5: Broad learning outcomes of the CARe educational intervention. Intervention outcomes that were clearly delineated in the planning phase have been listed.

Additional file 6: CARe team roles. Details of the program team, including their credentials and roles, are provided.

Additional file 7: Education & training schedule. The weekly class schedule for the 2-week classroom training is provided.

Additional file 8: Concordance between HWs and physician on identified anomalies. The percentage of concordance for major and minor anomalies is presented.

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None.

Authors' contributions
SJ, MF and LS contributed to the conceptualization of the study and designing the methodology; SJ and MF were responsible for data collection; AAM conducted the data analysis and contributed to the interpretation of analysed data along with SJ. The original draft was prepared by SJ who also contributed to the revisions, refining and editing of the manuscript along with MS, SA, TZ and LS. Supervision and expert review were conducted by SA, TZ and LS.

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Data availability
All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Declarations

Ethics approval and consent to participate
Administrative approvals were sought from the selected sites. Approval from IRD's Institutional Review Board (IRD_IRB_2023_03_001) and Aga Khan University's Ethics Review Committee were secured. Informed consent was taken prior to administration of the pre- and post-tests, and before the FGDs, including consent for recording the discussion. HWs were taught about concepts of patient and data confidentiality, privacy and ethical considerations. Informed consent was also taken from caregivers prior to examining the newborns and photographing any identified anomalies.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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