Piloting the Children's Automated Respiration Monitor (ChARM) tool in Humanitarian Settings in Chad and Uganda

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INTERNATIONAL RESCUE COMMITTEE

TABLE OF CONTENTS

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ABBREVIATIONS

ARI	Acute Respiratory Infection
CCM	Community Case Management
ChARM	Children's Automated Respiratory Monitor
CHW	Community health worker
FGD	Focus group discussion
iCCM	Integrated community case management
IMCI	Integrated management of childhood illnesses
IRC	International Rescue Committee
MoH	Ministry of Health
PHC	Primary health care
QoC	Quality of care
RMNCAH	Reproductive, maternal, newborn, child, and adolescent health
RR	Respiratory rate
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
WHO	World Health Organization

EXECUTIVE SUMMARY

Pneumonia is the world's leading infectious disease killer of children under five, accounting for more than 800,000 – or around 15% of child deaths annually.[1] Nearly half of all these deaths occur in sub-Saharan Africa. According to WHO's international guidelines for the management of pneumonia, assessment of a child's respiratory rate is a critical component for diagnosing children with pneumonia in low-resource settings. However, counting respiratory rates is challenging, particularly in children as they may breath irregularly and it can be difficult to keep them calm for an entire minute. Miscounting by CHWs and even health providers is common, which can lead to inaccurate diagnosis and treatment.[2]

The Philips Children's Automated Respiration Monitor (ChARM) was developed in response to this challenge. The ChARM device automatically measures the respiratory rate of a child and classifies the breathing rate according to the WHO IMCI guidelines for childhood pneumonia.[3] The International Rescue Committee (IRC) led a mixed-methods research design to evaluate the effectiveness of the ChARM tool among Community Health Workers (CHWs) implementing Integrated Community Case Management (iCCM) in areas hosting refugees in Chad and Uganda. The research aimed to answer three main questions:

1. To what extent are low-literate CHWs able to correctly use the ChARM tool?
2. What is the effect of the use of the ChARM tool by low-literate CHWs in the facilitation of the identification, classification, and treatment of pneumonia in children under five?
3. What is the impact of the ChARM tool on the quality of care provided for children under five with suspected pneumonia?

The results of the study found that low-literate CHWs can correctly use the ChARM tool and those that used the tool were better able to correctly diagnose cough/cold. The introduction of the ChARM tool had no impact on the identification, classification, and treatment of fever or diarrhea, with the CHWs in the intervention and control groups, in both countries, performing similarly in the Quality-of-Care assessment. The main difference in quality of care observed between the two groups, was in the identification of danger signs, with the intervention group in Uganda performing worse than the control group in their systematic identification of danger signs.

The ChARM device was also well accepted by the communities as it provides immediate results and gives caregivers a stronger sense of confidence in the results/diagnostics. However, there is still strong resistance observed when a child is diagnosed with a simple cough and not provided with an antibiotic by the CHW. The red/green light reading on the device somewhat helped to explain the results and subsequent decision-making around the diagnosis and related care to the caregivers.

The ChARM tool offers promising improvements to the correct diagnosis of pneumonia by allowing CHWs to measure respiratory rates more precisely. Correct diagnosis of pneumonia could have a significant impact on decreased deaths from childhood pneumonia and prevent irrational use of antibiotics. The IRC teams from both Chad and Uganda are encouraged by the results of this pilot and both teams plan to present the findings and advocate with their respective Ministries of Health for the inclusion of the ChARM tool into the iCCM guidelines for their country.

INTRODUCTION

Global Situation

Pneumonia is the world's leading infectious disease killer of children under five, accounting for more than 800,000 – or around 15% of child deaths annually. Nearly half of all these deaths occur in sub-Saharan Africa.[1]

Pneumonia is a preventable and treatable disease. Vaccines are available to immunize children against bacterial strains of pneumonia. If children are diagnosed early and correctly, pneumonia can be easily treated with affordable oral antibiotics. Severe cases can be referred to facilities that are better equipped to deliver advanced management of pneumonia, including injectable antibiotics, oxygen therapy and intensive care. However, inaccurate diagnosis, inadequate supplies of medicines and weak referral systems remain a challenge in fighting the disease in low- and middle-income countries and in humanitarian contexts.

Since 2021, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) have recommended integrated community case management (iCCM) of childhood illnesses as a key component of integrated management of childhood illness (IMCI)[4]. iCCM is an equity-based strategy for delivering life-saving interventions of common childhood illnesses (such as diarrhea, malaria, and pneumonia) at the community level, in areas with no access to/limited coverage of facility-based health services. By targeting low-resource settings and vulnerable communities, iCCM can increase access to life-saving treatments for children. iCCM programs involve the training, deployment, and supportive supervision of community health workers (CHWs) and supplies them with the diagnostic skills and tools, and essential medicines to treat children with uncomplicated pneumonia, malaria and diarrhea. Through iCCM, CHWs also play a critical role in referring more severe illnesses to facility-based providers as well as educating families about danger signs, which encourages timely and appropriate care-seeking. Research conducted by the Child Health Epidemiology Reference Group (CHERG) suggests that community case management of pneumonia, if implemented correctly, could reduce the incidence of under-five deaths from pneumonia by 70%.[5]

Guidelines on iCCM provided by WHO and UNICEF outline clear standards for CHWs on the diagnosis and treatment of pneumonia. Despite that, misdiagnosis is common. While low-literate CHWs are able to effectively treat children for pneumonia, malaria and diarrhea, identification of pneumonia continues to be one of the most difficult tasks for low-literate CHWs to manage as it requires not only measuring the respiratory rates (RR) of children under five correctly (currently done by counting the number of breaths and use of a timer), but also being aware of the cut-off points of different age groups that signify that a child has pneumonia and needs antibiotics [6] Studies have shown that this is not only a difficult task for CHWs, but also for health providers with clinical training, many of whom also perform poorly when it comes to correctly classifying children with pneumonia.[7]

Background on Philips Children's Automated Respiration Monitor Device

According to WHO's international guidelines for the management of pneumonia, assessment of a child's respiratory rate (RR) is a critical component for diagnosing children with pneumonia in low-resource settings. This involves CHWs or facility-based health workers manually counting the number of breaths in children with a cough and/or difficulty breathing for the duration of 60 seconds to assess whether the breathing rate is higher than normal (fast breathing). This is typically done using an acute respiratory infection (ARI) timer or wristwatch. Counting RR is challenging, particularly in children as they breathe irregularly and faster than

adults and it can also be difficult to keep them calm for an entire minute. Miscounting is common, which can lead to inaccurate diagnosis and treatment.[8]

The Philips Children's Automated Respiration Monitor (ChARM) was developed in response to this challenge. The ChARM device automatically measures the RR of a child and classifies the breathing rate according to the WHO IMCI guidelines for childhood pneumonia.[9] The device is strapped around the child's torso and counts the number of breaths while he/she is lying down or sitting on the lap of an adult. Field testing on ChARM was initially conducted in East Africa and India from which improvements in the technology and design were incorporated based on the feedback from CHWs and health officers. Randomized Control Trials (RCTs) and additional implementation evaluations to test the usability and accuracy of the device have since taken place in other countries including Ethiopia, Nepal, Mali, Uganda, and India. Results from the study in Ethiopia and Nepal revealed high acceptability of the device. Users found it easy to count respiratory rates and classify pneumonia cases using ChARM and they felt more confident when referring a child to the health facility based on results obtained from the device. Caregivers were also accepting of the use of ChARM on their children. Usability of the device, however, was mixed. In Ethiopia, health workers were able to adhere to the required protocols for ChARM quite well while Nepal saw lower levels of adherence after some time, highlighting the need to consider contextual differences such as training and literacy levels, when introducing automated pneumonia diagnostic tools.[10]

Rationale for assessment

This report is a synthesis of an assessment conducted in 2021 focused on documenting experiences of using the ChARM device to increase CHW capacity to accurately assess and classify children for pneumonia in the intervention areas of Guera region in Chad and Palabek refugee settlement in Uganda, where IRC supports delivery of child health services to vulnerable populations affected by humanitarian crises.

The specific objectives of this assessment include the following:

- Improve CHW capacity to correctly assess and classify children under five for pneumonia using the ChARM device
- Contribute further to the evidence base to illustrate that life-saving treatments for pneumonia can effectively be delivered by low-literate CHWs in low-resource, conflict-affected settings
- Contribute to reducing under-five morbidity and mortality in Uganda and Chad

Country Background

Chad

The humanitarian situation in Chad, one of the poorest countries in the world, remains critical, with more than 4.3 million people in need of humanitarian assistance and one of the highest under-five mortality rates in the world, with 114 out of 1,000 children dying before reaching their fifth birthday.[11,12] Pneumonia is one of the main causes of under-five mortality, killing more than 17,800 children under five in 2018 (24% of overall child deaths).[13] Only 26% of children under five with suspected pneumonia were taken to a health provider for treatment.

In 2015, the Chad MoH launched a 3-year Community Health Strategy which promotes iCCM and mandates CHWs to provide antibiotics to children with pneumonia.[14] A revised national community health strategy is currently under development based on iCCM pilots being conducted throughout the country.

IRC has been supporting implementation of iCCM across three districts in Chad since July 2019 – Liwa, Bitkine and Bol Districts. A total of 193 CHWs have been trained across the three districts and implementation is currently under way in all districts since October 2021 (July 2019 – Liwa; April 2021 – Bitkine; October 2021 – Bol). Malaria, diarrhea and respiratory infectious remain the main causes of admission in IRC's supported health facilities in Chad. In 2018, these three diseases, represented over 50% of admissions.[15]

In Chad, the CHWs were trained through a 9-day training by trainers who received by the national direction of community health care in Chad. It was conducted in two phases including a theoretical phase for seven days and a practical phase for two days. The theoretical phase lasted seven days, the participants were brought together in a training room. The modules were facilitated using a variety of techniques combining illustrated lectures, brainstorming, film screenings, questions and answers and group work.

Uganda

With an estimated 74,000 under-five child deaths a year, Uganda is ranked 14th globally among the countries with the highest burden of under-five deaths.[16] Pneumonia is responsible for approximately 16% of all child deaths.[17]

In 2016, the Government of Uganda developed the Reproductive, Maternal, Newborn, Child and Adolescent Health (RMNCAH) Sharpened Plan, which includes a call for scaling up a prioritized child health intervention package, including scaling up IMNCI and iCCM. The Ministry of Health (MoH) has also recently revitalized and updated their newborn and child health strategy within the Sharpened RMNCAH Plan. This involved updating the national IMNCI guidelines and training materials to include updated policy and clinical guidelines around management of child pneumonia. A Community Health Roadmap was also launched in 2019, outlining key opportunities for strengthening the community health system in Uganda, including plans for drafting a new policy around Community Health Extension Workers (CHEWs) and a broader community health strategy.

Despite these strategic efforts, implementation of child health interventions in Uganda have continued to lag, particularly in low-resource settings like the refugee communities IRC operates within.

According to the Government of Uganda and the UN High Commissioner for Refugees (UNHCR), Uganda hosts 1.29 million refugees.[18] Palabek refugee settlement in Lamwo District, Uganda hosts 41,168 refugees from South Sudan that fled due to intense violence and armed conflicts and includes a host population of 140,000. [19] The 2018 Health Information System (HIS) data revealed that under-fives constituted 32% (30,227) of the overall patient consultations at the health facilities. Lower respiratory tract infections including pneumonia contributed 14% of the total under-five mortality in this area. Lower respiratory tract infection was also the leading cause of morbidity in the under five population (31%), surpassing malaria (27%).[20]

With funding from UNHCR, IRC started implementation of iCCM activities in Palabek refugee settlement in July 2020. At the time, there were already CHWs providing preventative services in the area, however, they were not providing any direct treatment to children under five. A total of 74 CHWs were trained on iCCM across two different groups in July/August 2020, but due to COVID-19 related challenges with the global supply chain management systems, CHWs were only able to begin providing iCCM services in December 2020.

In Uganda, the practical phase on the ChARM tool lasted two days and gathered CHWs in three urban health centers. This phase was preceded by seven days of theoretical training during which practical demonstration sessions on the use of the ChARM tool were given to

CHWs by the trainers. A sample of three primary health care (PHC) facilities (covering eight zones, including intervention and control sites) were randomly selected for Palabek Refugee Settlement, Lamwo District. One of the PHCs included both control and intervention groups.

METHODOLOGY

Study aim and design

The aim of this study is to determine whether the ChARM tool can increase CHW capacity to accurately access and classify children for pneumonia, and whether the tool can facilitate correct identification of children with pneumonia and lead to correct case management, thus improving quality of care by low-literate CHWs, as well as reduce under-five mortality within the intervention groups in areas of Bitkine district, Guera region in Chad and Palabek refugee settlement in Uganda. The research aimed to answer three main questions:

1. To what extent are low-literate CHWs able to correctly use the ChARM tool?
2. What is the effect of the use of the ChARM tool by low-literate CHWs in the facilitation of the identification, classification, and treatment of pneumonia in children under five?
3. What is the impact of the ChARM tool on the quality of care provided to children under five with suspected pneumonia?

A mixed-methods research design was used to evaluate the effectiveness of the ChARM tool. Quantitative methods included direct observations through a Quality of Care (QoC) checklist tool combined with focus group discussions (FGDs) with CHWs, caregivers and community members, to get their perspectives on the ChARM tool. All documents for the Chad assessment were translated from English to French.

Study setting and sampling

The study took place in Palabek Refugee Settlement in Uganda and Bitkine district, Guera Region in Chad. These districts were purposefully selected based on existing IRC iCCM program operations.

A sample of 13 primary health care facilities (seven treatment and six control sites) were purposefully selected in Bitkine District, Guera due to the difficulty in accessing some of the sites during the rainy season. The intervention group included CHWs and communities which benefited from the ChARM tool, whilst the control group were CHWs and communities which did not use the ChARM tool.

After selection, the CHWs in the intervention group were trained on the correct use of the ChARM tool within the catchment health facilities for two days while having practical sessions on real sick children to practice their skills. Each training participant was observed and assessed on the correct use of the device prior to passing them to implement the intervention in their catchment locations (blocks). All the selected participants from Palabek refugee settlement had already received a five days' training in iCCM which was conducted by the national iCCM trainers from the MOH secretariat in a health care setting with real sick patients.

Study participants were randomly selected CHWs supported by IRC programs in Palabek Refugee Settlement and Bitkine district Guera Region. To be considered for inclusion, CHWs were required to be recruited from their local community and working within an IRC-supported iCCM program. CHWs were also required to have been working for a minimum of three months before the assessment took place. A total of 132 CHWs participated in the QoC assessment and the CHWs in the intervention group participated in the FGDs. See Tables 1 and 2 for the breakdown across study site and group.

Caregivers were required to be a minimum of 18 years of age and be the primary caregiver for at least one child under the age of five who had been seen by a CHW within the past four to six months. A total of 64 caregivers/community members participated in the Focus Group Discussions. See Table 2 for the breakdown across study site.

[Table 1: CHWs participating in QoC assessment]

	Uganda	Chad
Intervention group	30	35
Control group	32	35
Sub-total	62	70

[Table 2: CHWs and caregivers participating in FGDs]

		Location	Number of participants
Uganda	**CHW**	Lamwo, Zone 7 Block 3	13 (10 male – 3 female)
		Lamwo, Zone 7 Block 3	9 (3 male – 6 female)
	Community members	Lamwo, Zone 1 Block 4	8 (8 females)
		Lamwo, Zone 1 Block 4	10 (2 male - 8 females)
Chad	**CHW**	Koubo Adougoul	11 (9 male – 2 female)
		Bitkine Sud	9 (7 male – 2 female)
	Community members	Djoroble	21 (5 male – 16 female)
		Kounio	25 (23 male – 2 female)

Data collection

There were two QoC data collection teams in each country (one for control sites and the other for intervention sites). In Uganda, each data collection team consisted of three persons, one data collector, one clinician and one supervisor. In Chad, each team consisted of one data collector and one supervisor, who was a clinician. Each team undertook a standardized training course on the study methodology and use of the data collection tools. The training also included ethics training on how to provide information about the study and obtain informed consent as well as IRC's child safeguarding policy. Data collection took place between August 16-25, 2021, in Uganda and August 30 – September 8, 2021, for the initial assessment in Chad. Data collection was re-completed in Chad between October 19-24, 2021, due to data quality concerns.

Three main data collection activities took place to gather data. QoC assessments were conducted with CHWs involving direct observation of CHWs assessing and treating children. Data was collected using paper-based tools in a quiet space at the selected health facilities with notes taken by the data collectors during enumeration.

Additionally, FGDs were conducted with the intervention groups to get their perceptions on the use of the ChARM tool. in both countries. Two FGDs with CHWs and two FGDs with community members and caregivers were held in each country in groups of eight to 25. The FGDs were held in an undisturbed space at the health facility and notes were taken in paper form. Safety protocols for COVID-19 were observed, including social distancing, masking, and hand hygiene.

Table 3: Data collection activities and tools used

Activity	Methods for data collection

QoC Assessment	QoC checklist: Assessors observed CHWs in primary care hospitals using a structured checklist with 59 questions that gathered information on how CHWs assessed and treated sick children.
Focus Group Discussions with CHWs and caregivers	CHW questionnaire: Assessors visited pre-selected facilities and undertook a semi-structured in-person focus group discussion of 9 questions. Caregiver/community member questionnaire: Assessors visit pre-selected communities and undertook a semi-structured, in-person focus group discussion of 7 questions.

Data analysis

Data from QoC assessments was entered from the paper forms and coded into Excel databases. The study team carried out an analysis of the quantitative data in Excel. FGD transcripts were recorded, transcribed, and translated, as necessary, by the data collectors and then shared with the team. A qualitative analysis was carried out in Excel using a thematic framework to extract key themes emerging from the discussions.

Box 1: Key thematic areas for data analysis

QoC Assessment

1. Whether CHWs piloting the ChARM tool can correctly use and interpret the results from the tool
2. Comparison of the proportion of correct assessments, classifications, and treatments for children with suspected pneumonia by CHWs using the ChARM tool in the intervention group versus CHWs not using the ChARM tool in the control group

Focus Group Discussions

1. Community perception of the ChARM tool and trust in the results6.CHW perception of the ChARM tool
2. Whether CHWs feel the ChARM tool aids in decreasing pressure to provide medication to children that have only simple cough

Ethical Considerations

The study protocol and tools received ethical approval from the Mildmay Uganda Ethics and Research Committee (MUREC) in Uganda and IRC's Institutional Review Board in the United States. Additionally, the protocol was reviewed and approved by the MoH in Chad.

Before the QoC assessments and FGDs, the purpose of the study was explained, and all participants were asked to provide written consent through signed paper forms. The process of consent was obtained in the local language of both CHWs and caregivers.

According to the MoH in Uganda, CHWs must be at least 18 years of age. CHWs in Chad must be at least 25 years of age. Thus, all study subjects were over the age of informed consent. In addition, no data was conducted directly from children, only through their caregivers. No identifiable data was collected about children during the research. For the qualitative data, all potentially identifiable information was removed from the transcripts and excluded from any quotations included in the report. All measures were taken to ensure that

data around the performance of the individual CHWs was not identifiable and only aggregated data was shared with supervisors and MoH officials.

There was no medical risk to children because clinicians re-examined them after they had been initially assessed by the CHWs.

RESULTS

The Quality-of-Care assessment aimed to determine if the CHW was conducting the assessment of the sick child correctly. During the assessment of the sick child, the CHW is supposed to go through the following key steps. First, they should ask and look for danger signs. After they have determined that the child does not have any danger signs that require immediate referral, the CHW should ask the caregiver about the child's symptoms and duration of symptoms. Based on the symptoms that the caregiver has shared, the CHW would then conduct a physical assessment of the child. This would include assessment of respiratory rates, use of a Rapid Diagnostic Test (RDT) for malaria and MUAC assessment. Based on the assessment results, the child would then be classified as having a one or more conditions, or not having any condition. The classification would then determine the treatment or referral options.

USABILITY of ChARM device

Participant characteristics

A total of 62 CHWs in Uganda (30 in the intervention group and 32 in the control group) and 70 CHWs in Chad were included in the QoC assessments. The majority of CHWs in Chad were male (91% - control group; 89% - intervention group), while just over half of the CHWs were male in Uganda (53% - control group; 59% - intervention group).

All caregivers in both arms of the study in Uganda were female and majority were mothers of the child being treated, except for one caregiver in the intervention group. In Chad, most caregivers were female (91% - control group; 97% intervention group), and mothers of the child being treated (83% - control group; 91% intervention group). There were three male caregivers in the control group and one in the intervention group, all were fathers of the child being treated. A small minority of caregivers were not parents of the child (three in the control group and two in the intervention group).

Majority of the children in Uganda were female (57% in the control group and 78% in the intervention group) and above 12 months old (70% in the control group and 59% in the intervention group). The sex of the children treated in Chad was equal – 46% of children were male in the control group as well as 51% in the intervention group. Majority of children treated in Chad were above 12 months old in the control group (69%), while majority of children treated in the intervention group in Chad were under 12 months old (66%).

Correct classification

Overall, the intervention group in Uganda was better at correctly classifying children compared to the control group. In Chad, results were mixed, as there were some areas where the control group did significantly better and some areas where the intervention group did. Correct classification was determined by comparing results from both study arms with the classification results of a re-examination conducted by a re-evaluator immediately following the CHWs assessment. Re-evaluators were the supervisors of the data collection team who were trained iCCM professionals.

Generally, the intervention group was better at referring cases compared to the control group in both countries except for neonatal cases in Uganda and diarrheal cases in Chad. In Uganda,

for cases to be referred with fever, four children (13%) were unnecessarily referred in the control group compared to two cases (in the intervention group (see Table 4). Only one case was unnecessarily referred with fever in the control group in Chad. No cases of chest in-drawing were unnecessarily referred in Uganda, compared to one case in the control group in Chad. For cases to be referred with diarrhea, two children were unnecessarily referred in the control group in Uganda compared to one child in the intervention group. Only one case was unnecessarily referred with diarrhea in the intervention group. For neonatal cases to be referred, no neonates were missed in the control group compared to one neonate in the intervention group. In Chad, no neonatal cases were incorrectly referred in either study arm.

Overall, the difference between correct classification of sick children in Uganda was mixed and not significant when comparing the intervention and control group. For children with malaria, two children were mis-diagnosed in both the control and intervention groups. One case of non-malaria fever was mis-diagnosed in the control group compared to no cases in the intervention group. One case was mis-diagnosed by a CHW for moderate malnutrition in the intervention group compared to no cases in the control group. In Chad, the intervention group generally performed worse than the control group on correctly classifying childhood illness type. For children with malaria, five children in the intervention group were mis-diagnosed compared to two in the control group. The same results were observed for misdiagnosis of non-malarial fever – five in the intervention group and two in the control group were misdiagnosed. Two cases of suspected malaria were misdiagnosed in the intervention group compared to one case in the control group and two cases of diarrhea were misdiagnosed in the intervention group compared to no cases in the control group. Only one case of moderate malnutrition was misdiagnosed in the control group in Chad. There were no cases of severe malnutrition being misdiagnosed across the study arms in either country. In is unclear why the CHWs in the intervention group performed worse with classification.

The largest differences between intervention and control groups in Uganda were seen in the identification of cough/cold and referrals without treatment. A child with a cough/cold was much more likely to be misdiagnosed with pneumonia in the control group (nine children (30%) compared to four children (13%)). A child was also more likely to be unnecessarily referred without treatment in the control group (nine children (30%) compared to one child in the intervention group). It is notable however, that the intervention group did poorer than the control group when diagnosing pneumonia. Two-cases (3%) of pneumonia were mis-diagnosed by CHWs in the intervention group compared to no cases in the control group. It is unclear how this happened and if the CHWs were using the ChARM tool. Similarly, identification of cough/cold in Chad also showed the largest discrepancy between the two study arms. Six cases of cough/cold were wrongly classified in the control group compared to only one case in the intervention group. The control group also performed worse than the intervention group in diagnosis pneumonia – eight children misdiagnosed in the control group (23%) compared to two in the intervention group. No cases were unnecessarily referred in either study arm in Chad.

[Table 4: Correct classification performed by community health workers in Uganda and Chad

CLASSIFICATION	UGANDA				CHAD				CUMULATIVE			
	CONTROL GROUP n=30		INTERVENTION GROUP n=32		CONTROL GROUP n=35		INTERVENTION GROUP n=35		CONTROL GROUP n=65		INTERVENTION GROUP n=67	
	MISCLASSIFIED		MISCLASSIFIED		MISCLASSIFIED		MISCLASSIFIED		MISCLASSIFIED		MISCLASSIFIED	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
7.1 Case to be referred without treatment	9	30%	1	3%	0	0%	0	0%	9	14%	1	1%
7.2 Case to be referred with chest-in drawing	0	0%	0	0%	1	3%	0	0%	1	2%	0	0%
7.3 Case to be referred with fever	4	13%	2	6%	1	3%	0	0%	5	8%	2	3%
7.4 Case to be referred with diarrhea	2	7%	1	3%	0	0%	1	3%	2	3%	2	3%
7.5 Neonatal case to be referred	0	0%	1	3%	0	0%	0	0%	0	0%	1	1%
7.6 Cough/Cold	9	30%	4	13%	6	17%	1	3%	15	23%	5	7%
7.7 Pneumonia	0	0%	2	6%	8	23%	2	6%	8	12%	4	6%
7.8 Malaria	2	7%	2	6%	2	6%	5	14%	4	6%	7	10%
7.9 Non-Malarial Fever	1	3%	0	0%	2	6%	5	14%	3	5%	5	7%
7.10 Suspected malaria case	0	0%	0	0%	1	3%	2	6%	1	2%	2	3%
7.11 Diarrhea	0	0%	0	0%	0	0%	2	6%	0	0%	2	3%
7.12 Moderate Malnutrition	0	0%	1	3%	1	3%	0	0%	1	2%	1	1%
7.13 Severe Malnutrition	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%

Danger signs

Overall, the intervention group in Chad was more systematic in observing danger signs, while in Uganda, the intervention group was less systematic than the control group.

The largest gap in both countries was for inquiring about the child's capability to drink/breastfeed and if they were vomiting everything they consumed. In Chad, the intervention group performed quite well compared to the control group when asking about the child's capability to drink/breastfeed – 97% of CHWs asked the question in the intervention group compared to 69% in the control group (see Table 5). Results from the intervention group were worse in Uganda, however, with (only 25% of CHWs in the intervention group asking this question compared to 67% in the control group. In Uganda, 19% of CHWs in the intervention group asked if a child was vomiting everything, they consumed compared to 53% in the control group. The intervention group again performed much better in Chad with 91% of CHWs asking the questions compared to 63% in the control group.

Both the intervention group and the control group in Uganda generally failed to ask if the child had previously had convulsions (63% in the intervention group and 60% in the control group failing to ask the question) and in checking if the child had edema, though the intervention group performed slightly better (73% in the control group and 66% in the intervention group failing to check). Similarly, both groups in Uganda generally failed to check if the child had chest-in-drawing. Of the 28 cases requiring treatment for pneumonia in the control group, only two CHWs checked for chest in-drawing (7%) and of the 32 cases requiring treatment in the intervention group, only nine CHWs checked (28%). In Chad, the intervention group performed better than the control group in asking if the child had convulsions (89% compared to 34%), whereas the control group more systematically checked if the child had edema than the intervention group (80% compared to 69%). CHWs in Chad were much more systematic in checking if a child had chest in-drawing compared to Uganda. The intervention group performed best, with all CHWs checking for chest in-drawing while in the control group four CHWs (11%) failed to check.

The intervention group in both countries did slightly better than the control group in asking if the child had been sick for more than 14 days or had fever for longer than seven days, however in Chad, CHW performance was much better. Fifty percent of CHWs in the intervention group asked the question in Uganda, compared to 27% in the control group, whilst 77% of CHWs in the intervention group in Chad asked the question compared to 51% in the control group.

All CHWs across both countries did a rapid diagnostic test (RDT) if the child had a fever, except for the intervention group in Chad where four CHWs in the intervention group RDT results were positive in about half of the cases in the control groups in both countries and in the intervention group in Uganda, and approximately two-thirds of the cases in the intervention group in Chad.

Of the 11 cases assessed in the control group in Uganda, the CHWs systematically tried to stimulate a child who was lethargic or unconscious (100% of CHWs in the control group), whereas the intervention group failed to do so for the one case which required treatment. The intervention group was also less thorough than the control group in measuring the middle upper arm circumference (MUAC) (85% in the intervention group compared to 73% in the control group). In Chad, only one child was stimulated in the control group out of five who were unconscious or showing signs of lethargy. No children required stimulation in the intervention group. All CHWs in Chad measured the MUAC of the child.

None of the children in the intervention groups needed to be referred in either country, whilst three CHWs (50%) in the control group in Chad failed to refer. One CHW in the control group in Uganda also failed to refer the one case which presented danger signs.

No neonates were included in the assessment to be checked for the danger signs of pustules or umbilical cord infection.

[Table 5: CHW inquiry/action on child presenting danger signs in Uganda and Chad]

DANGER SIGN QUESTION	UGANDA		CHAD		CUMULATIVE	
	CONTROL GROUP n=30	INTERVENTION GROUP n=32	CONTROL GROUP n=35	INTERVNETION GROUP n=35	CONTROL GROUP n=65	INTERVENTION GROUP n=67
	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
1.1 CHW asks if child capable of drinking/breastfeeding	67% (30)	25% (32)	69% (35)	97% (35)	68% (65)	63% (67)
1.2 CHW asks if child vomits everything they consume	53% (30)	19% (32)	63% (35)	91% (35)	58% (65)	57% (67)
1.3 CHW asks if child has had convulsions	40% (30)	38% (32)	34% (35)	89% (35)	37% (65)	64% (67)
1.4 CHW tries to stimulate a child who is sleeping or appears unresponsive/lethargic	100% (11)	0% (1)	20% (5)	NA (NA)	60% (16)	0% (1)
1.5 CHW asks if child has been sick for more than 14 days or has had fever for longer than 7 days	27% (30)	50% (32)	51% (35)	77% (35)	40% (65)	64% (67)
1.6 CHW checks to see if child has severe chest in-drawing	7% (28)	28% (31)	89% (35)	100% (35)	48% (63)	64% (66)
1.7 CHW checks to see if child has swelling of both feet (edema)	27% (30)	34% (32)	80% (35)	69% (35)	55% (65)	52% (67)
1.10 CHW measures MUAC (if child between 6 months – 5 years)	85% (27)	73% (30)	100% (33)	100% (29)	93% (60)	87% (59)
1.12 If child has danger sign, CHW refers child immediately	0% (1)	NA (NA)	50% (6)	NA (NA)	25% (7)	NA (NA)
1.13a If child has fever, CHW conducts an RDT	100% (26)	100% (27)	100% (33)	88% (28)	100% (59)	94% (55)

* No newborn cases were seen in either country so there was no need for CHWs to check for danger signs of newborn pustules or umbilical cord infection

Assessment:

In Uganda, CHWs were slightly more thorough in their assessment in the intervention group except for asking about a fever and checking the duration of the fever. In Chad, the results were mixed.

Ninety-three percent of CHWs in Uganda asked if the child had a fever in the control group compared to 91% in the intervention group (see Table 6). The results were also quite positive in Chad with all CHWs in the intervention group and 94% of CHWs in the control group asking if the child had a fever. For the cases where a child had a fever, the control group in Uganda was more consistent in asking about the duration of the fever (89% in the control group compared to 69% in the intervention group asked the question), whilst in Chad the control group performed significantly better in asking about fever duration (97% compared to 78%). Majority of children had a fever between 1-2 days in both groups in Uganda and 2-3 days in both groups in Chad.

CHWs in Uganda were equally not systematic about asking if a child had diarrhea (78% in the intervention group and 77% in the control group asking). Most of the CHWs in both groups failed to ask about the duration of the diarrhea, though the intervention group was slightly more systematic in asking the question (47% in the intervention group compared to 40% in the control group). Majority of children had diarrhea between 1-3 days. In Chad, CHWs in the intervention group were much more systematic about asking if a child had diarrhea (94%) compared to the control group (69%), however like Uganda both groups generally failed to ask about the duration of diarrhea (only 42% in the intervention group and 50% in the control group). Majority of the children had diarrhea between 2-3 days across both groups in Chad.

The majority of the CHWs in both countries asked if the child had a cough or difficulty breathing. Only 6% of CHWs in the intervention group and 7% in the control group in Uganda failed to do so. No CHWs failed to ask the question in Chad. CHWs in the intervention group in Uganda were more systematic in asking about the duration of the cough/difficulty breathing (81% in the intervention group compared to 67% in the control group). CHWs in the control group in Chad were slightly more systematic in asking about the duration of the cough/breathing difficulty (100% compared to 94% - 2 cases) Majority of children had a cough for three days in the control group compared to two days in the intervention group in both countries.

[Table 6: Community health worker inquiry of symptoms and duration in Uganda and Chad

DANGER SIGN QUESTION	UGANDA		CHAD		CUMULATIVE	
	CONTROL GROUP n=30	INTERVENTION GROUP n=32	CONTROL GROUP n=35	INTERVENTION GROUP n=35	CONTROL GROUP n=65	INTERVENTION GROUP n=67
	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES	APPLICABLE CASES
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
2.1 CHW asks if the child has a fever	93% (30)	91% (32)	94% (35)	100% (35)	94% (65)	96% (67)
2.2a CHW asks for how long the child has had a fever	89% (28)	69% (29)	97% (32)	78% (32)		
2.2b If yes to 2.2a, average number of days child had a fever	1-3 days	1-2 days	2-3 days	2 days	2-3 days	2 days
2.3 CHW asks if child has diarrhea	77% (30)	78% (32)	69% (35)	94% (35)	72% (65)	87% (67)
2.4a CHW asks for how long the child has had diarrhea	40% (30)	47% (32)	50% (10)	42% (19)		
2.4b If yes to 2.4a, average number of days child has had diarrhea	1-3 days	2 days	3 days	2 days	3 days	2 days
2.5 CHW asks if child has a cough or difficulty breathing	93% (30)	94% (32)	100% (35)	100% (35)	97% (65)	97% (67)
2.6a CHW asks for how long the child has had cough/difficulty breathing	67% (30)	81% (30)	100% (30)	94% (30)	85% (65)	88% (67)
2.6b If yes to 2.6a, average number of days child has had cough/difficulty breathing	3 days	2 days	3 days	2-3 days	3 days	2 days

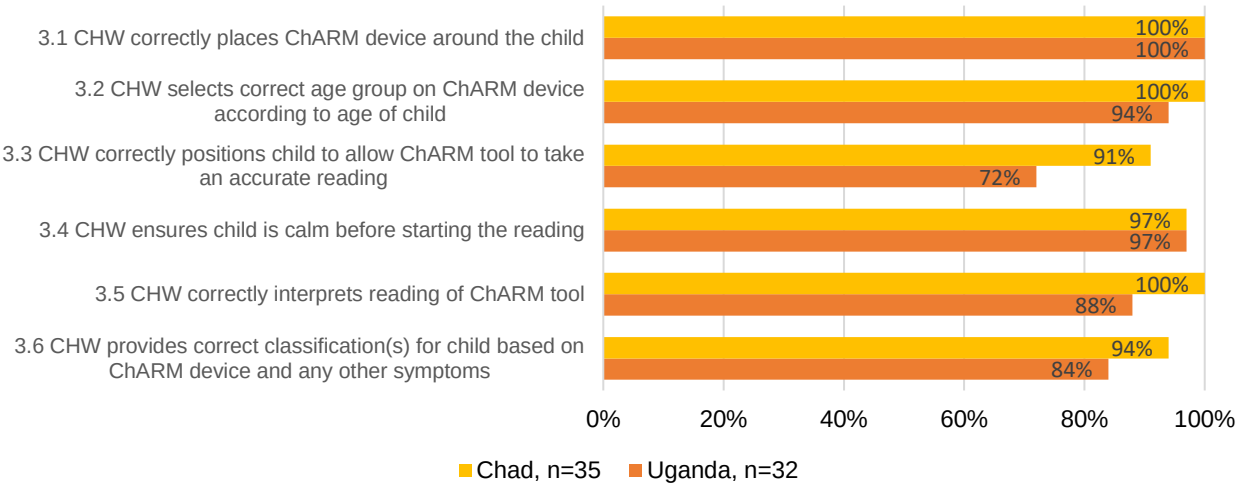
Assessment and classification of respiratory rates

CHWs using the ChARM device (Intervention Group)

All CHWs in Uganda and Chad were able to correctly place the ChARM device around the child, however nine CHWs in Uganda (28%) were not able to correctly position the child to allow the device to take an accurate reading (Figure 1). Only three out of 35 CHWs in Chad had this challenge. In each country, one CHW did not ensure the child was calm before starting the reading. Majority of CHWs also used the correct age group for the ChARM device, apart from two cases in Uganda.

All CHWs in Chad were able to correctly interpret the reading from the device, whereas in Uganda only 88% did so correctly. Similarly, 84% of CHWs in Uganda were able to correctly classify the child based on the reading from the ChARM device. In Chad, nearly all CHWs were able to correctly classify the child, except for two cases.

Figure 1: CHWs using ChARM device to assess and classify respiratory rates

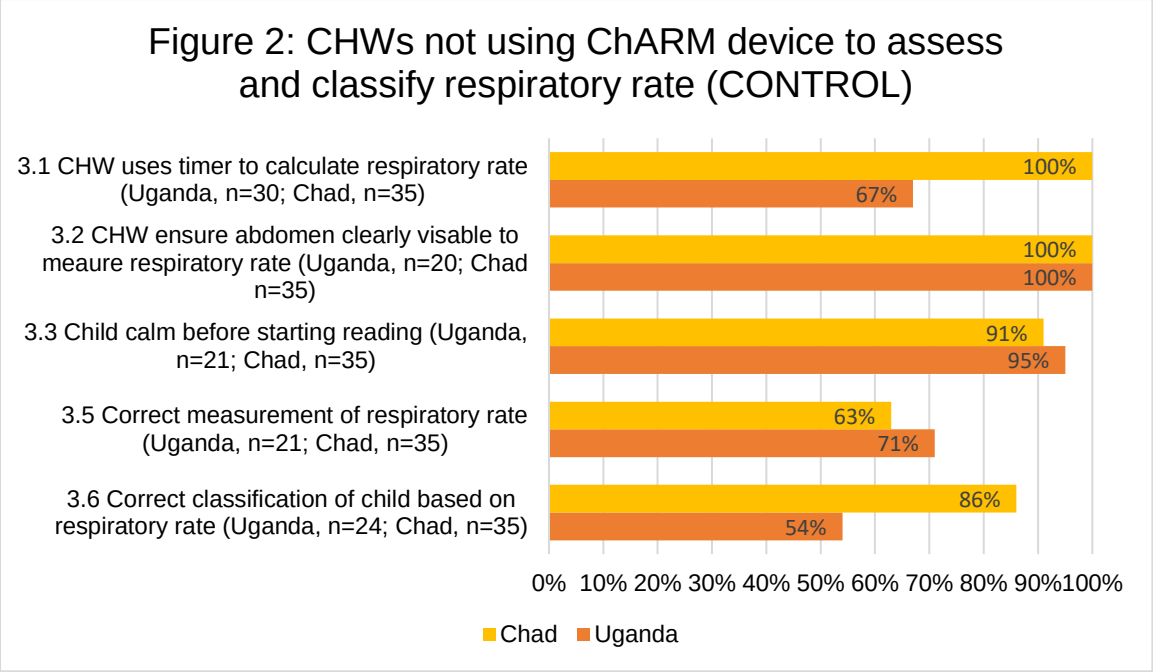


CHWs not using the ChARM device (Control Group)

All CHWs in the control group in Chad used a timer and manually counted breaths to measure the respiratory rate of children (see Figure 2). In Uganda, however, only 67% of CHWs in the control group measured the RR of the child using a timer while counting. All CHWs in both countries ensured they could clearly see the abdomen to accurately measure the RR.

Ninety-five percent of CHWs in the control group in Uganda ensured the child was calm before starting the RR reading – only one CHW failed to do so. In Chad, 91% of CHWs in the control group ensured the child was calm, with only three CHWs failing to do so.

Of the cases identified as having pneumonia, majority of CHWs in Uganda correctly measured the RR of the child (71%), whilst only half (54%) correctly classified the child based on the RR. In Chad, only 63% of CHWs correctly measured the RR, however 86% correctly classified the child based on the RR.



Treatment:

Overall, majority of CHWs in both Chad and Uganda provided the appropriate treatment in both arms of the study. All CHWs across both groups in Uganda were able to provide the correct dosage of ORS and Amoxicillin for those cases needing treatment. The exceptions were for treatment with Zinc, where one CHW failed to provide the appropriate dosage in the intervention group (12%, n=8), whilst all CHWs in the control group were able to provide the correct dosage (see Table 7). The other exception was for treatment with ACT, where again, one CHW failed to provide the appropriate dosage in the intervention group (7%, n=14) compared to the control group, where all CHWs administered the correct treatment when applicable. In Chad, all 14 CHWs in the intervention group provided the correct dosage of ORS, while three (75%, n=4) provided the correct dosage in the control group. CHWs in Chad performed better in the control group however, when providing the correct dosage of Amoxicillin (100% compared to 88%). All CHWs across both study groups in Chad provide the correct dosage of Zinc and ACT.

Table 7: CHW ability to provide appropriate treatment based on diagnosis in Uganda and Chad

	Uganda		Chad		Cumulative	
Treatment Type	CONTROL GROUP % (n)	INTERVENTION GROUP % (n)	CONTROL GROUP % (n)	INTERVENTION GROUP % (n)	CONTROL GROUP % (n)	INTERVENTION GROUP % (n)
ORS	100% (11)	100% (14)	75% (4)	100% (14)	88% (15)	100% (28)
Zinc	100% (3)	89% (8)	100% (3)	100% (4)	100% (6)	95% (12)
ACT	100% (13)	93% (14)	100% (15)	100% (6)	100% (28)	97% (20)
Amoxicillin	100% (3)	100% (9)	100% (6)	88% (14)	100% (9)	94% (23)

ACCEPTABILITY

The following themes relating to the acceptability of the ChARM device were identified amongst CHWs and caregivers.

Attitudes toward use of device and perceived effectiveness

FGDs were conducted with 22 CHWs in Uganda (13 males and nine females) and 18 CHWs in Chad (14 males and four females) on their experience using and perception of the ChARM device. Overall, the device was well-received by CHWs. CHWs found the device easy to use and that it helped with diagnostics in comparison to the current method of using a timer to count breaths.

"It is very easy to use, even if you don't have the job aid and know whether the child is in danger [as] it shows red and green" (Uganda - Zone 1, Block 4)

"Yes, it has made our work easier" (Uganda - Zone 1, Block 4)

"The automated touch is very easy to use, there is no need for you to set the timer" (Uganda – Zone 1, Block 4)

Majority of CHWs felt that the device was broadly accepted by community members, particularly given the immediate diagnosis which they perceived as more reliable than use of a respiratory timer in counting. They also thought that the device allowed them to build trust with caretakers and empowered them in explaining diagnoses to caregivers.

The device has a light – that turns red or green – that indicates if the child has fast breathing (pneumonia) or does not have fast breathing. In Uganda, CHWs thought the red/green light reading was particularly helpful in explaining to parents why the child does not have pneumonia and does not need antibiotic treatment. It was mentioned that there were only a minimal number of cases where caregivers did not trust the red/green light reading on the device, assuming that all coughs were due to pneumonia.

In Chad, CHWs found the device was particularly helpful in distinguishing between a cough and pneumonia. It allowed them to better explain to caregivers why the child does not need antibiotic treatment if only a simple cough was detected, and the device reassured caregivers that the appropriate diagnosis and treatment was provided.

"They accept and are very happy [to] work with the tool, indeed they even call us doctors now" (Uganda - Zone 1, Block 4)

However, some CHWS in Chad perceived that there was some resistance from community members who were skeptical about the quality of CHW services given the services and medicines provided are free of charge. The skepticism could be explained by their confidence in the skills of CHWs who perform this function in a short period of time and also by the community's preference for injections because some people believe that injections are the most effective. Additionally, some cultural barriers were mentioned regarding undressing their child in public, which makes the use and positioning of the ChARM device difficult (this was reported despite it not being necessary for the child to be completely undressed).

Additionally, it was perceived that there is resistance from some caregivers in Chad when medicines (antibiotics) are not prescribed for children diagnosed with a simple cough. It was perceived that caregivers were dissatisfied with this and felt their children were not being treated appropriately or fairly. In other cases, CHWS indicated that caregivers were relieved that their child was not diagnosed with pneumonia.

FGDs were also conducted with 18 community members/caregivers in Uganda (16 females and 2 males) and 46 community members/caregivers (28 male and 18 female) in Chad. Overall, the ChARM device was also well accepted by community members. Community members indicated that the tool helped provide them with a stronger sense of confidence in diagnosis and why a child may not require medicine (antibiotics). They also had confidence in the capacity of the CHWs to use the device.

"The tool helps us understand the CHWs do not need to treat all coughs." (Uganda – Zone 7, Block 3)

"The VHTs are trained to use the tool and I feel comfortable when they use [it] on our children." (Uganda, Zone 7, Block 3)

"The ChARM tool is much better than the timers they [CHWS] used before. It is effective at helping them do their work […] The results they give are correct, there are no complications, worries or hesitation on the results." (Chad community member)

Challenges affecting use of device

Most CHWs in Uganda and Chad felt comfortable using the device, however majority of the CHWs were unsatisfied with the training. They felt the training was rushed, the training groups were too large and that there was too much information packed into the limited timeframe. The CHWs also felt the training could benefit from more hands-on practice in the field, as well as supportive supervision. In Chad, one CHW also mentioned that they could benefit from refresher trainings. Only one of the FGD groups in Uganda felt the training was adequate and that there was no need for a refresher training.

Majority of the CHWs found the tying of the belt to be a difficult step. They felt that the belt was too loose or could too easily slip off. Positioning of the device was also particularly difficult for children with 'big tummies'.

"I would change the belt since it's not good, it can easily get off"

Additionally, CHWs claimed that the time allotted for the reading which was about 30 seconds, was too short and some missed the results. It was recommended that the display showed the reading for a longer time before it disappeared. Some CHWs found the device hard to use when a child was distressed. There were also some challenges reported in positioning the child and selecting the right age group.

"Yes, it gives you time to do other things" but "the tool is hard to use when a child is crying" (Uganda - Zone 1, Block 4)

Another improvement CHWs mentioned was related to battery life. While the device is supposed to be enough for 200 assessments, it was reported as only lasting for 50 assessments. They felt the device could be improved by extending the overall battery life or including a built-in charging system. The provision of solar panels was also suggested as an option for onsite battery charging.

"It doesn't take a lot of time; the only challenge is how to charge"

In Chad in particular, charging the battery can incur additional costs to the CHWs. CHWs often do not have immediate access to a power source and need to pay for transportation to get to the source and pay for charging the device. It can take up to two to three days to travel back and forth from the power source to charge the device, which means the CHWs cannot perform their work during this time.

DISCUSSION

Overall, the findings showed that the ChARM device improved CHW's ability to accurately diagnose pneumonia versus cough/cold. In Chad, there were 18% less misdiagnosed cases of cough/cold and 26% less misdiagnosed cases of pneumonia in the intervention group compared to the control group. In Uganda, the difference was even greater with more than 50% less misdiagnosed cases of cough/cold in the intervention group, though the intervention group did not perform better on pneumonia diagnosis, misclassifying two cases compared to no cases in the control group. When children with simple cough/cold are misdiagnosed and given antibiotics, it is a dangerous situation which can lead to antibiotic resistance in communities. Additionally, there were notable differences in the assessment and classification of respiratory rates between the intervention and control groups in both countries. In Uganda, correct measurement of RR was 20% higher in the intervention group (71% in the control group compared to 88% in the intervention group). Results from Chad were even more impressive, with the intervention group correctly measuring RR 37% more than the control group (63% correct measurement in the control group compared to 100% correct measurement in the intervention group). Correct classification of pneumonia based on the RR was also better in the intervention group across both countries. Correct classification was 8% in the intervention group in Chad (86% in the control group compared to 94% in the intervention group) and 36% higher in the intervention group in Uganda (54% in the control group compared to 84% in the intervention group). The ChARM tool also helped lessen the pressure on CHWs to provide antibiotics when a child was shown to not have pneumonia, as the results coming from the devise helped the caregivers and community members accept this fact.

While use of the ChARM device proved effective in pneumonia classification, it is concerning to observe the poor outcome of the intervention group in Uganda in recognizing danger signs. The intervention group performed worse than the control group in inquiring about several danger signs, including the child's capability of drinking/breastfeeding, if the child vomits everything they consume, if the child has had convulsions and measuring the MUAC. Overall, outside of measuring MUAC, less than half of the CHWs in the intervention group in Uganda asked about the relevant danger signs. The ChARM tool is not supposed to help CHWs in recognizing danger signs and should not have any impact on identification of danger signs, case management of diarrhea or malaria. However, these observed weaknesses do highlight the importance of continuing on-the job-training and supportive supervision to reinforce capacity of CHWs.

Accurate diagnosis of pneumonia is only one component of tackling the disease. The ability to adequately treat children diagnosed with pneumonia is also critical. Access to essential medicines, including antibiotics, is necessary for comprehensive care. The ChARM device is a pneumonia diagnostic tool and so access to medicines was not fully explored through this study, however its impact is still worth mentioning. In both Chad and Uganda, majority of CHWs across both study arms were able to appropriately treat children with the correct dosage of medicines based on their diagnosis whether in the intervention or control group. However, during the FGDs, community members in both countries commented on the poor availability of medicines [antibiotics] to treat pneumonia, noting that CHWs often don't have enough quantity. It's notable in Chad in particular, some CHWs perceived some resistance from caregivers when antibiotics were not prescribed for children diagnosed with a simple cough. It is unclear whether the availability of medicines is indeed an issue in the study areas or if this was a perceived reality since they were not provided. No data was collected on stockouts during the study to confirm the reality of access to essential medicines.

Limitations

There were a few limitations to the study. This evaluation was expected to take place after six months of the ChARM tool being in use. However, due to delays in receiving ethical approval, the ChARM tool was only implemented from April 2021. The evaluation was then only conducted after four to five months after the tool was in use due to study timeline constraints. Additionally, in Uganda, 35 participants in the control and intervention group were expected however, only 30 CHWs in the control group and 32 CHWs in the intervention group were interviewed. This was due to the availability of CHWs during the time of the assessment. Lastly, data collection for the QoC assessments in Chad needed to be conducted a second time due to questions around the accuracy of data in the first round. There is the potential that this may have influenced CHW performance in the intervention group, since the CHWs may have known the purpose and questions of the study, rather than being observed on the spot.

The Health Unit Technical Team was not able to travel and directly supervise the data collection process for the final evaluation. This resulted in the team having to re-do the assessment in Chad due to poor quality of data and not having properly trained enumerators with the relevant background. It also resulted in some losses of contextual data about the evaluation, which is gained from the evaluators also being the team who are writing the report.

RECOMMENDATIONS

Program Implementation

- Training on ChARM device should be longer and more comprehensive, including the addition of sessions for practical training. Refresher trainings on using the device should also be considered alongside refresher trainings on iCCM. Trainings should also focus more on correct classification and how to use the ChARM device to improve classification.
- To provide comprehensive prevention, diagnosis, and treatment for children with pneumonia, IRC programs should also consider CHWs access and supply of appropriate medicines.
- To ensure that CHWs are providing correct case management of all three conditions and are asking about/identifying danger signs, it is essential that CHWs are receiving supportive supervision visits on a monthly basis that include on-the-job coaching.

ChARM device specifications

- The ChARM tool that was used for this study was designed to be used in health facilities and not communities. It needs to be plugged in and charged. There is also another one designed specifically for the community. The following changes are recommended if the ChARM tool that was designed for the health faciltieis, is to be used at the community level:
    - Battery life of ChARM device should be extended to the actual 200 children as mentioned in the brochure and other options for recharging tool (e.g., solar) should be considered for low-resource settings
    - Improved design for belt on ChARM device to make it tighter and more secure on a child's abdomen. The current strap is very narrow and troublesome for restless children
    - ChARM reading display should show results for longer period
    - Provide healthcare sites with solar systems to charge the batteries on site or incorporate a solar charging system into the devices (ChARM tools)

Future research

The findings from this study support rationale for further research on CHW performance and the impact of better-quality supervision.

Additionally, future research should consider conducting a baseline QoC observation to compare change in knowledge and behavior of the intervention group, not just comparison with control group. A longer period between introduction and assessment should also be considered to measure the longer-term impact on CHW knowledge and skills when using the ChARM device.

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