BMJ Global Health

Acceptability of the routine use of pulse oximetry by healthcare workers and caregivers within primary healthcare in West Africa: mixed-methods study

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To cite: Louart S, Hedible KGB, Balde H, *et al*. Acceptability of the routine use of pulse oximetry by healthcare workers and caregivers within primary healthcare in West Africa: mixed-methods study. *BMJ Glob Health* 2025;**10**:e017302. doi:10.1136/bmjgh-2024-017302

Handling editor Emma Veitch

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjgh-2024-017302).

Received 10 September 2024
Accepted 30 October 2025

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ABSTRACT

Introduction To better identify severe hypoxaemia as a major risk factor for specific illnesses in children aged under 5 years, the Améliorer l'Identification des détresses Respiratoires chez l'Enfant (AIRE) project implemented routine use of pulse oximetry within implementation of Integrated Management of Childhood Illness (IMCI) guidelines at primary health centres (PHCs) in Burkina Faso, Guinea, Mali and Niger. We aimed to measure and understand the acceptability of pulse oximeter (PO) use among healthcare workers (HCWs) and children's families (CFs).

Methods Based on an original conceptual framework, we conducted a convergent mixed methods study to assess acceptability. We conducted repeated cross-sectional studies among all HCWs on duty within the 202 PHCs involved in the AIRE project, using quantitative Likert-scale questionnaires. These were administered at four key time points: (1) just before the PO use training, (2) immediately after the training, (3) 6 months after the introduction of PO devices in PHCs and (4) 2 months after the completion of all AIRE project activities. We also conducted semistructured interviews with HCWs (n=100) and CFs (n=59). Quantitative data were analysed using descriptive statistics and multivariable ordinal logistic regression. Qualitative data were thematically analysed with NVivo, and both were interpreted in light of the conceptual framework to explore convergence and divergence across acceptability dimensions.

Results From March 2021 to December 2022, 486, 537, 538 and 476 HCWs completed the four acceptability surveys. Overall, 31% of HCWs had mixed feelings about PO use before the training, 46% found it somewhat acceptable and 23% strongly acceptable. At the end of the project, it was respectively 15%, 34% and 51%. PO training was consistently associated with greater HCWs acceptability. HCWs reported many advantages in using PO, such as a more accurate diagnosis and a boost in their confidence in sick child management. Nevertheless, challenges reported by HCWs included perceived increased workload and consultation time, as well as difficulties in referring children to hospital. CFs did not necessarily understand the device's purpose, but their opinions of the technology were generally positive.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Even though the effectiveness of pulse oximetry in diagnosing hypoxaemia is well established, integration of new medical technologies in primary healthcare settings in low-resource countries often faces challenges, including acceptability among healthcare workers (HCWs) and children's families (CFs).

⇒ Previous studies that have examined acceptability of pulse oximeter (PO) were mostly hospital-based and did not use comprehensive methods to investigate acceptability in depth.

WHAT THIS STUDY ADDS

⇒ To our knowledge, this is the first study to examine the acceptability of PO use by HCWs and CFs at the primary care level, drawing on a comprehensive theoretical framework, a mixed-methods approach and an innovative acceptability score.

⇒ This study provides empirical evidence on the high acceptability of PO use for HCWs and CFs at a decentralised level in Burkina Faso, Guinea, Mali and Niger.

⇒ Training and supervision significantly improved HCWs acceptability of PO use, with increased confidence in childcare management. However, challenges such as increased workload and consultation time, as well as referral difficulties, persist despite the overall positive opinion.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings support the need for comprehensive training and supervision programmes to enhance acceptability among HCWs.

⇒ Policymakers should work towards addressing the operational challenges identified, especially those related to the referral of children, which could hinder the sustainability of PO use.

⇒ Research aiming to evaluate acceptability should be based on conceptual frameworks or theories that allow for an indepth exploration of the different dimensions of acceptability.

Conclusion PO use, integrated into IMCI consultations, was reported to be accepted by HCWs and CFs, although sustainable challenges in implementation remain.

INTRODUCTION

Acute respiratory infections (ARIs) are among the leading causes of death in children under the age of 5 years, mainly in low-and-middle-income countries.[1 2] Technological innovations in healthcare can enhance prevention and treatment capacities and the overall quality of services.[3] Among these devices, the pulse oximeter (PO) is crucial for measuring oxygen saturation levels and identifying hypoxaemia (low oxygen saturation in the blood). Severe hypoxaemia, common in ARIs and illnesses like malaria and malnutrition, is a life-threatening condition that requires urgent treatment. Therefore, improving access to hypoxaemia diagnostic tools (oximetry) and treatment (oxygen therapy) has long been considered crucial.[4] However, many studies highlight significant gaps in oximetry and oxygen access in Africa.[5–9] While POs are used daily in high-resource countries, their use in frontline facilities remains relatively unexplored in West Africa.

The Améliorer l'Identification des détresses Respiratoires chez l'Enfant (AIRE) project, carried out between 2019 and 2022 implemented the routine use of PO into Integrated Management of Childhood Illness (IMCI) algorithms in 202 primary health centres (PHCs) and eight hospitals in Burkina Faso, Guinea, Mali and Niger.[10] The PO model used in this project was Acare Technology (Taiwan; AH-M1 S0002033) that works with probes. The successful introduction of new devices is closely linked to their acceptability, which is a multidimensional concept[11–13] crucial for understanding the processes involved in healthcare innovations dissemination.[14] Acceptability analysis must go beyond mere satisfaction with the technology; it includes factors like perceived ease of use and compatibility with local health routines. It is influenced by individual experiences, societal norms, the healthcare system's infrastructure and other factors.[15]

Few studies have explored the acceptability of PO in low-and-middle-income countries. Existing research is often focused on the hospital level rather than at a decentralised level of care.[8 16 17] Some emerging studies explore the barriers and facilitators of PO use among community health workers and PHCs.[18–20] However, to our knowledge, no studies on PO use exist at the PHC level in West Africa. Furthermore, not all studies directly address acceptability, and none use a solid conceptual framework. This gap highlights the need for more research to understand the broader applicability and challenges of implementing PO in these settings. Our study aimed to evaluate the acceptability of PO use among healthcare workers (HCWs) and children's families (CFs), identifying both barriers and facilitators to its use.

METHODS

This study was based on a conceptual framework and used mixed methods to ensure completeness and enhance explanations.[21] We employed a convergent design and the Mixed Methods Appraisal Tool to ensure accurate reporting of the various elements.[22]

Conceptual framework

We used a conceptual framework that identifies six dimensions of the acceptability of technological healthcare innovations[23]: compatibility, perceived advantages, personal emotions, social influence, perceived disadvantages and perceived complexity, all influenced by the context and the form of the intervention. For this study, we also adopted three temporal perspectives for acceptability[15]: prospective (assessed before implementation, focusing on initial perceptions and willingness to engage), concurrent (during use, capturing real-time experiences and attitudes) and retrospective acceptability (after completion of intervention, reflecting on overall experience and satisfaction).

Study sites

The study was conducted by the AIRE research study group, in two health districts per country,[10] in 202 PHCs. All children attending IMCI consultations, except those aged 2–59 months, classified as IMCI green cases without respiratory symptoms, were eligible for PO use. Those with severe hypoxaemia (defined by SpO2 <90%) should be transferred to hospital for urgent oxygen therapy. Further details on the PO usage guidelines and the overall intervention can be found in the protocol.[10] The size of PHCs was determined by the number of consultations for children under 5 years in 2019, classified as small (≤1000 visits), medium (1001–3000 visits) or large (>3000 visits).[24]

The quantitative study on the acceptability of PO use covered all PHCs and their referral district hospital (n=8). Qualitative data collection involved all district hospitals and 16 PHCs selected as research sites (four per country).[10]

Study design and inclusion process

We conducted repeated cross-sectional individual surveys for quantitative data from March 2021 to December 2022. For the prospective acceptability survey, all PHC managers, their deputies and HCWs involved in IMCI consultations were included. They received classroom training on PO use and an IMCI practice update over 6 days–2 weeks, depending on the country. Data were collected before and after training. The other two surveys were conducted 6 months after the start of the project (concurrent acceptability) and 2 months after the project's end (retrospective acceptability). All HCWs from the PHCs who were responsible for consultations with children under 5 years of age, and therefore for using the PO, and who were available at the time of the survey were included. From June 2021 to December

2022, we also measured the proportion of PO use among eligible children using monthly aggregated data from IMCI consultation registers (electronic or paper-based) in all PHCs.

The qualitative study was conducted in two phases. The concurrent acceptability period (T1) involved semi-structured interviews with HCWs and CFs seen in consultations. The retrospective acceptability period (T2) included interviews only with HCWs to understand how their acceptability changes over time. Observations of PO use during consultations were also conducted to assess HCWs familiarity and proficiency, interactions with CFs and children's reactions to PO. All HCWs in the research sites, conducting consultations with children under 5 years, and those available at the time of the survey were interviewed. To select CFs, we used purposive sampling[25] to ensure representativeness according to variables such as sex, age, relationship with the child, distance to the PHC and the child's health status. Empirical saturation determined the final number of participants.[26]

Data collection

Quantitative data were collected using REDCap software, focusing on HCW's sociodemographic characteristics, prior IMCI practices, knowledge and previous use of PO and specific data to assess PO acceptability. Aggregated data included the number of children eligible for PO use and the frequency of its use by HCWs.

National co-investigators conducted qualitative interviews in local languages or French, fully transcribed and translated when necessary.

Calculation of an acceptability score

Quantitative questions for five of the dimensions[23] (ranging 2–5), except for the 'social influence' dimension, were combined to construct each acceptability dimension (online supplemental appendix 1). They were based on a five-modalities Likert scale.[27] Each option was assigned a score from −10 to 10. By compiling and averaging the scores for questions in each dimension, we obtained a score for each acceptability dimension. Composite reliability was assessed to evaluate the consistency of questions included within each dimension[28] (online supplemental appendix 2). Dimensions scores were then aggregated using the same logic and averaged to derive the overall acceptability score, categorised according to the Likert scale as 'strongly unacceptable', 'unacceptable', 'mixed feelings', 'acceptable' and 'strongly acceptable'. Data collection on the social influence dimension was not entirely conducted using the Likert scale format and proved challenging to measure prospectively. Therefore, we will only describe the various possible influences observed.

Data analysis

We described and compared by country the sociodemographic characteristics of the HCWs enrolled in the concurrent study, the most representative of the four surveys. We described the dimensions of acceptability and the overall score's evolution over time and by country. Quantitative variables were described using means and SD. Categorical data were presented as proportions with their 95% CIs and compared using Pearson's χ^2 or Fisher's exact tests. Using an ordinal logistic regression model with a random effect for the health district (only for the model combining data from the four countries), we explored the factors associated with 'strongly acceptable' versus lower acceptability levels. The main variables included in the modelling were age, sex, profession, years of experience, type of IMCI support (electronic vs paper-based), prior knowledge of PO, previous training on PO use and the size of PHCs. Sex and age were forced in all models. Analysis was performed using R software V.4.3.0 and considered statistically significant with a p value <0.05.

All qualitative data were analysed using NVivo V.12 software. A common codebook was developed collaboratively by the research team, drawing on both the conceptual framework and an initial immersion in the data. A thematic analysis was then conducted to compare the empirical findings with the codebook.[29] In each country, the researcher who supervised data collection also coded the interviews using the shared guidelines. Another member of the research team then reviewed the coding for the four countries, checked for consistency across datasets and conducted the cross-country comparative analysis.

We then analysed acceptability by integrating qualitative and quantitative results across the various dimensions of acceptability and its associated factors. This approach allowed for comparison of data, analysing convergence, divergence and explanation, facilitating a richer and more comprehensive interpretation.[22]

Patient and public involvement

Individual data were collected with authorisation from the ethics committees and ministries of health. Patients were not involved in the analysis, interpretation of results or writing of the manuscript.

RESULTS

The quantitative surveys included 486 (pre-training), 537 (post-training), 538 (concurrent) and 476 (retrospective) HCWs over time. Interviews were conducted with 47 HCWs and 59 CFs (concurrent), then 53 HCWs (retrospective) (figure 1).

HCW sociodemographic characteristics

Out of the 538 HCWs enrolled in the concurrent acceptability survey, 53.2% were aged 25–35 years, ranging from 41.9% in Niger to 61.2% in Guinea. Women represented 47.8% overall, with significant country variations (table 1). All worked in rural settings, except for Guinea and Niger, where 52.9% and 25.6% of HCWs, respectively, were from urban areas. Overall, 44.8% of HCWs had 1–5 years of experience. Medical doctors and nurses

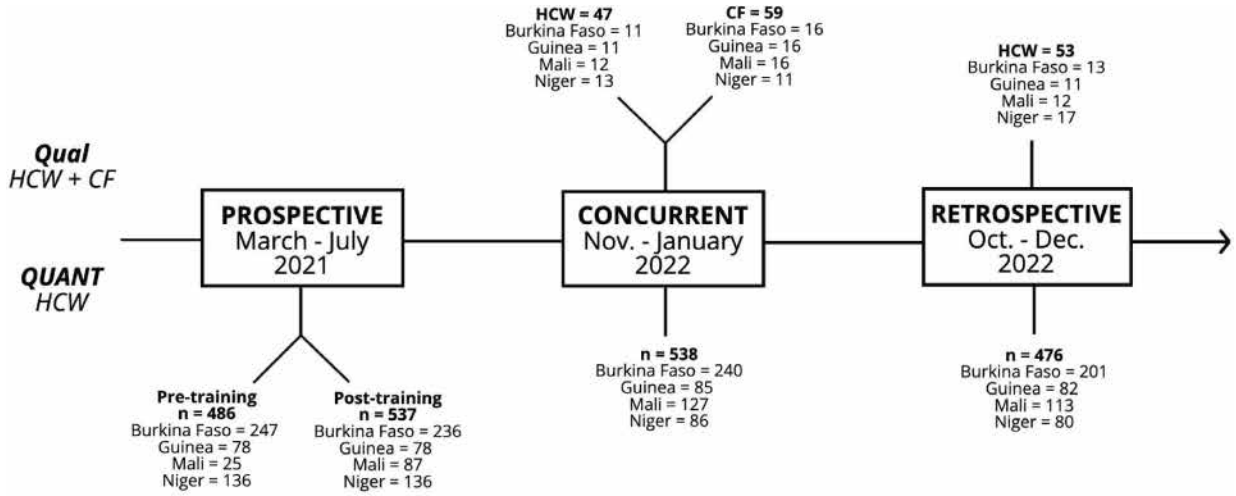

Figure 1 Timeline of data collection phases and number of participants. CF, children's families; HCW, healthcare workers.

accounted for 63.0% of all HCWs. Before the initial PO training, 75.5% of HCWs were unaware of the PO. Six months after the intervention started, 77.1% had been trained overall.

PO uptake

Monthly trends of PO use show that it quickly reached and exceeded 80% for eligible children, except in Burkina Faso, where it took around 6 months to reach this target. Overall, PO use reached 93.4% of the 381 874 eligible children attending PHCs over the study period (online supplemental appendix 3).

HCW acceptability

Overall acceptability

Overall acceptability scores for the PO were high across data collections (table 2). No HCW found the PO 'not at all acceptable' or 'not acceptable'. The proportion of HCWs with mixed feelings decreased over time, while those finding the PO 'strongly acceptable' increased from 22.6% (pretraining) to 51.3% (retrospective) (p value <0.001). However, the paths diverge depending on the country. In Burkina Faso, this improvement was rather linear. In contrast, in the other three countries, there was a notable improvement after the training followed by a decline during the concurrent data collection. Finally, the paths diverged, with overall acceptability rising significantly in Guinea (which ultimately had the highest acceptability rate) and slightly in Niger for the final collection, while continuing to decrease in Mali.

Factors associated with acceptability of PO use by HCWs

Compared with large or small PHCs, working in a medium-sized PHC was positively associated with highest level of prospective acceptability of the PO among HCWs before training (adjusted OR (aOR) 22.2, 95% CIs 1.19 to 4.15, p=0.012) (online supplemental appendix 4). However, no factor was found to be associated with the HCWs' prospective acceptability of the PO post training (online supplemental appendix 5). The e-IMCI support (aOR 2.82, 95% CI 1.58 to 5.03, p<0.001) and having been trained to use PO (aOR 2.48, CI 95% 1.64 to 3.74, p<0.001) were positively associated with highest levels of concurrent acceptability of the PO (table 3). Finally, being an assistant nurse (aOR 4.2, 95% CI 1.29 to 13.71, p=0.017) compared with a midwife and having been trained to use PO were positively associated with retrospective acceptability among HCWs (table 4). Overall, neither age, sex nor years of experience were associated with highest acceptability among HCWs in the four surveys.

Acceptability by dimension

Online supplemental appendix 6 summarises the quantitative acceptability of PO use among HCWs by dimension, and key qualitative elements are presented in online supplemental appendix 7.

Compatibility

The overall proportion of HCWs who found PO use strongly compatible with their context increased from 36.8% to 50.6% between the pretraining and retrospective survey (p value<0.001). This trend was consistent across all countries except Mali, where the proportion of HCWs decreased from 32.0% to 21.2%. However, this was offset by HCWs finding the PO compatible (but not strongly).

Indeed, HCWs felt that the PO meets the crucial need to improve their PHC's technical capabilities, providing reliable equipment at a decentralised level for better patient care. This feeling was expressed during both qualitative acceptability phases: the concurrent (T1) and retrospective (T2) surveys.

The PO is seen as compatible and complementary to IMCI and existing consultation practices. However, a few HCWs in Mali noted that consultation documents, such as paper registers, were not fully adapted for PO use, as there is no specific space for recording saturation levels. Contextual factors, such as the existing work organisation within the PHC, also

Table 1 Sociodemographic characteristics of healthcare workers from the concurrent survey on the acceptability of pulse oximeter use (N=538), conducted in 202 AIRE primary health centres, November 2021–January 2022

Variable, n (%)	Burkina Faso (N=240)	Guinea (N=85)	Mali (N=127)	Niger (N=86)	Overall (N=538)	P value
Age groups (in years)						
<25	2 (0.8)	5 (5.9)	11 (8.7)	8 (9.3)	26 (4.8)	4.06e-05
25–35	125 (52.1)	52 (61.2)	73 (57.5)	36 (41.9)	286 (53.2)	
35–45	88 (36.7)	17 (20.0)	34 (26.8)	34 (39.5)	173 (32.2)	
45–55	25 (10.4)	7 (8.2)	8 (6.3)	7 (8.1)	47 (8.7)	
>55	0 (0.0)	4 (4.7)	1 (0.8)	1 (1.2)	6 (1.1)	
Sex						
Female	129 (53.8)	31 (36.5)	38 (29.9)	59 (68.6)	257 (47.8)	1.76e-08
Male	111 (46.3)	54 (63.5)	89 (70.1)	27 (31.4)	281 (52.2)	
Years of experience						
<1	45 (18.8)	13 (15.3)	8 (6.3)	11 (12.8)	77 (14.3)	3.23e-06
1–5	110 (45.8)	38 (44.7)	61 (48.8)	32 (37.2)	241 (44.8)	
5–10	18 (7.5)	13 (15.3)	36 (28.3)	12 (14.0)	79 (14.7)	
>10	3 (1.3)	8 (9.4)	5 (3.9)	2 (2.3)	18 (3.3)	
Missing	64 (26.7)	13 (15.3)	17 (13.4)	29 (33.7)	123 (22.9)	
Profession						
Midwife	60 (25.0)	1 (1.2)	19 (15.0)	3 (3.5)	83 (15.4)	3.81e-17
Nurse/medical doctor	105 (43.8)	69 (81.2)	83 (65.4)	82 (95.3)	339 (63.0)	
Assistant nurse	17 (7.1)	0 (0.0)	5 (3.9)	0 (0.0)	22 (4.1)	
Others*	58 (24.2)	15 (17.6)	20 (15.7)	1 (1.2)	94 (17.5)	
Prior knowledge of the PO						
No	175 (72.9)	77 (90.6)	88 (69.3)	66 (76.7)	406 (75.5)	0.00286
Yes	65 (27.1)	8 (9.4)	39 (30.7)	20 (23.3)	132 (24.5)	
Trained in the use of PO						
No	58 (24.2)	11 (12.9)	32 (25.2)	22 (25.6)	123 (22.9)	0.126
Yes	182 (75.8)	74 (87.1)	95 (74.8)	64 (74.4)	415 (77.1)	
Type of IMCI support used						
Electronic-based	240 (100.0)	0 (0.0)	51 (40.2)	0 (0.0)	291 (54.1)	1.19e-89
Paper-based	0 (0.0)	85 (100.0)	76 (59.8)	86 (100.0)	247 (45.9)	
Size of PHC						
Large	72 (30.0)	13 (15.3)	8 (6.3)	36 (41.9)	129 (24.0)	<2.2e-16
Medium	144 (60.0)	26 (30.6)	39 (30.7)	45 (52.3)	254 (47.2)	
Small	24 (10.0)	37 (43.5)	78 (61.4)	3 (3.5)	142 (26.4)	
Missing, n (%)	0 (0.0)	9 (10.6)	2 (1.6)	2 (2.3)	13 (2.4)	
Geographical area						
Rural	240 (100.0)	40 (47.1)	127 (100.0)	64 (74.4)	471 (88.0)	1.02e-41
Urban	0 (0.0)	45 (52.9)	0 (0.0)	22 (25.6)	67 (12.0)	

*Volunteers, laboratory technicians, malnutrition managers, trainees, vaccinators, vaccination programme managers, biologists…
AIRE, Améliorer l'Identification des détresses Respiratoires chez l'Enfant; IMCI, Integrated Management of Childhood Illness; PHC, primary health centres; PO, pulse oximeter.

influence PO's compatibility. In Burkina Faso, it was mentioned that using a single consultation room for both children and adults could complicate PO integration. In Mali and Niger, some PHCs reorganised their working areas by separating children's and adult consultation rooms to integrate the PO more effectively.

Table 2 Overall acceptability score combining the five dimensions except social influence of healthcare workers to pulse oximeters use according to country and time of data collection in the 202 AIRE primary health centres, March 2021–December 2022

Time of data collection, n (%)	Burkina Faso	Guinea	Mali	Niger	Overall	P value
Prospective pretraining (n)	**247**	**78**	**25**	**136**	**486**	
Strongly unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.523
Unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Mixed feelings	74 (30.0)	27 (34.6)	12 (48.0)	39 (28.7)	152 (31.3)	
Acceptable	115 (46.5)	32 (41.0)	9 (36.0)	68 (50.0)	224 (46.1)	
Strongly acceptable	58 (23.5)	19 (24.4)	4 (16.0)	29 (21.3)	110 (22.6)	
Prospective post-training (n)	**236**	**78**	**87**	**136**	**537**	
Strongly unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.007
Unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Mixed feelings	42 (17.8)	13 (16.7)	18 (20.7)	14 (10.3)	87 (16.2)	
Acceptable	111 (47.0)	38 (48.7)	42 (48.3)	49 (36.0)	240 (44.7)	
Strongly acceptable	83 (35.2)	27 (34.6)	27 (31.0)	73 (53.7)	210 (39.1)	
Concurrent (n)	**240**	**85**	**127**	**86**	**538**	
Strongly unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	<0.001
Unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Mixed feelings	15 (6.2)	25 (29.4)	34 (26.8)	24 (27.9)	98 (18.2)	
Acceptable	108 (45.0)	45 (52.9)	57 (44.9)	29 (33.7)	239 (44.4)	
Strongly acceptable	117 (48.8)	15 (17.6)	36 (28.3)	33 (38.4)	201 (37.4)	
Retrospective (n)	**201**	**82**	**113**	**80**	**476**	
Strongly unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	<0.001
Unacceptable	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Mixed feelings	17 (8.5)	0 (0.0)	39 (34.5)	14 (17.5)	70 (14.7)	
Acceptable	65 (32.3)	18 (22.0)	51 (45.1)	28 (35.0)	162 (34.0)	
Strongly acceptable	119 (59.2)	64 (78.0)	23 (20.4)	38 (47.5)	244 (51.3)	

AIRE, Améliorer l'Identification des détresses Respiratoires chez l'Enfant.

HCWs also noted the PO's good compatibility reflected in its acceptance by communities, as it does not contradict any values or beliefs. Some parents even requested its use:

> The mother will tell you that you didn't check the child with the machine (…) According to her, you didn't consult her child properly. You're going to explain it and then take it just to reassure her. (Burkina Faso, T2)

Perceived complexity

We noted an increase in the proportion of HCWs who perceived the PO as very easy to use between the first and last data collection (p value<0.001). Nevertheless, this improvement is not linear, and during the concurrent data collection, the number of HCWs finding the PO very easy to use significantly decreased in all countries except Burkina Faso.

According to the interviews, the perceived ease of use of the PO for HCWs depends on whether they have been trained. Those who received training found it easy to use. However, staff who did not receive formal training found the PO much more complicated, especially in Guinea. This is consistent with the quantitative results, where only 17.6% of Guinean HCWs found the PO very easy to use during the concurrent phase. Feedback sessions from trained HCWs were supposed to be organised but were often insufficient or not held. In some cases, untrained HCWs could use the PO and record oxygen saturation but did not know what the tool was for or how to interpret the data, leaving interpretation to the PHC's head.

> I don't know the parameters, if it's high or not… if the PO shows 99%, I don't know if it's normal, because sometimes you find it's 94%, I don't know the difference, if it's normal or if it's not normal… a number appears and that's what I write. (Guinea, T1)

This situation improved over time, as supervision played a significant role in helping untrained HCWs master the PO. Finally, incorporating the PO into the IMCI algorithm sometimes complicated its use, as the algorithm was not always well-used before the project. However, issues related

Table 3 Factors associated with strong concurrent acceptability of PO use among HCWs, compared with lower levels of acceptability, by time of data collection: ordinal logistic regression modelling

Variables	Levels	Combined Lower Categories	Strongly acceptable	Univariable OR (95% CI, P value)	Multivariable OR (95% CI, P value)
Age groups (in years)	≤35	203 (60.4)	109 (54.2)		
	>35	133 (39.6)	92 (45.8)	1.13 (0.81 to 1.58, p=0.464)	1.01 (0.72 to 1.43, p=0.949)
Sex	Female	164 (48.7)	93 (46.3)		
	Male	173 (51.3)	108 (53.7)	1.24 (0.89 to 1.73, p=0.212)	0.96 (0.66 to 1.4, p=0.845)
Profession	Midwives	53 (15.7)	30 (14.9)		
	Nurses/medical doctor	212 (62.9)	127 (63.2)	1.58 (0.97 to 2.58, p=0.065)	1.33 (0.78 to 2.28, p=0.297)
	Others	56 (16.6)	38 (18.9)	1.57 (0.89 to 2.77, p=0.118)	1.49 (0.82 to 2.73, p=0.194)
	Assistant nurse	16 (4.7)	6 (3.0)	0.86 (0.36 to 2.02, p=0.72)	0.98 (0.4 to 2.36, p=0.957)
Years of experience	≤1	184 (72.2)	32 (20.0)		
	1–5	56 (22.0)	102 (63.8)	0.74 (0.46 to 1.21, p=0.234)	
	>5	15 (5.9)	26 (16.2)	0.52 (0.21 to 1.29, p=0.159)	
IMCI support	Paper-based	181 (53.7)	66 (32.8)		
	Electronic	156 (46.3)	135 (67.2)	3.08 (1.81 to 5.24, p<0.001)	2.82 (1.58 to 5.03, p<0.001)
Prior knowledge of PO	No	264 (78.3)	142 (70.6)		
	Yes	73 (21.7)	59 (29.4)	1.6 (1.09 to 2.35, p=0.017)	1.4 (0.94 to 2.08, p=0.093)
Training in use of PO	No	93 (27.6)	30 (14.9)		
	Yes	244 (72.4)	171 (85.1)	2.69 (1.8 to 4.02, p<0.001)	2.48 (1.64 to 3.74, p<0.001)
Geographical area	Rural	282 (83.7)	189 (94.0)		
	Urban	55 (16.3)	12 (6.0)	0.39 (0.15 to 0.99, p=0.048)	0.57 (0.27 to 1.19, p=0.136)
PHC size	Small	101 (30.8)	41 (20.8)		
	Large	71 (21.6)	58 (29.4)	1.17 (0.69 to 1.99, p=0.556)	
	Medium	156 (47.6)	98 (49.7)	0.96 (0.61 to 1.5, p=0.853)	

HCWs, healthcare workers; PHC, primary health centre; PO, pulse oximeter.

to this inexperience were much less frequent in the retrospective phase.

Perceived advantages

Acceptability scores for this dimension are very high, particularly in the retrospective study in Burkina Faso (87.1%) and in Guinea (96.3%), despite a drop to 45.9% during concurrent data collection. These rates were lower in Mali (47.8%) and Niger (68.8%), but the proportion of those with mixed feelings was extremely low in all countries. According to the qualitative data, HCWs generally found many advantages in using the PO during the two rounds of data collection. First, decentralising diagnostics improves care from the beginning of the process, and HCWs are pleased to access tools previously reserved for higher levels of the health system.

The PO is also perceived as a tool that guides their practices and helps them make decisions. Better diagnosis avoids unnecessary trips between home and PHCs and improves the hospital referral process when necessary.

Table 4 Factors associated with strong retrospective acceptability of PO use among HCWs, compared with lower levels of acceptability, by time of data collection: ordinal logistic regression modelling

Variables	Levels	Combined Lower Categories	Strongly acceptable	Univariable OR (95% CI, P value)	Multivariable OR (95% CI, P value)
Age groups (in years)	≤35	138 (59.5)	116 (47.5)		
	>35	94 (40.5)	128 (52.5)	1.37 (0.94 to 1.99, p=0.103)	1.24 (0.83 to 1.83, p=0.292)
Sex	Female	110 (47.4)	108 (44.3)		
	Male	122 (52.6)	136 (55.7)	1.43 (0.97 to 2.11, p=0.067)	1.16 (0.76 to 1.77, p=0.505)
Profession	Midwives	25 (10.8)	10 (4.1)		
	Nurses/medical doctor	142 (61.2)	169 (69.3)	2.56 (1.26 to 5.18, p=0.009)	2.03 (0.95 to 4.31, p=0.067)
	Others	58 (25.0)	50 (20.5)	2.12 (0.97 to 4.6, p=0.058)	2.13 (0.96 to 4.7, p=0.061)
	Assistant nurse	7 (3.0)	15 (6.1)	3.97 (1.27 to 12.45, p=0.018)	4.2 (1.29 to 13.71, p=0.017)
Years of experience (in years)	≤1	154 (75.5)	43 (18.5)		
	1–5	37 (18.1)	140 (60.3)	1.18 (0.69 to 2.03, p=0.543)	
	>5	13 (6.4)	49 (21.1)	0.83 (0.33 to 2.13, p=0.702)	
IMCI support	Paper-based	111 (47.8)	115 (47.1)		
	Electronic	121 (52.2)	129 (52.9)	1.05 (0.33 to 3.29, p=0.938)	
Prior knowledge of PO	No	183 (78.9)	186 (76.2)		
	Yes	49 (21.1)	58 (23.8)	1.44 (0.92 to 2.28, p=0.114)	1.26 (0.77 to 2.04, p=0.355)
Training in use of PO	No	39 (16.8)	39 (16.0)		
	Yes	193 (83.2)	205 (84.0)	2.66 (1.54 to 4.62 p<0.001)	2.56 (1.44 to 4.53, p=0.001)
Geographical area	Rural	218 (94.0)	199 (81.6)		
	Urban	14 (6.0)	45 (18.4)	12.83 (2.16 to 76.05, p=0.005)	4.2 (0.91 to 19.39, p=0.066)
PHC size	Small	78 (33.9)	50 (21.2)		
	Large	47 (20.4)	62 (26.3)	1.44 (0.77 to 2.69, p=0.259)	1.23 (0.64 to 2.36, p=0.533)
	Medium	105 (45.7)	124 (52.5)	1.64 (1 to 2.7, p=0.051)	1.57 (0.94 to 2.61, p=0.084)

HCWs, healthcare workers; IMCI, Integrated Management of Childhood Illness; PHC, primary health centre; PO, pulse oximeter.

> Before the PO, doctors were slow to make decisions to refer cases. They kept them at the center, believing that they could find a solution. But with the PO, if it's a case that needs to be referred, we know right away and don't take long to decide. (Mali, T1)

The PO allows HCWs to be more confident about their diagnoses. Good saturation reassures them, while low saturation facilitates rapid decision-making. Several HCWs also highlighted that new equipment like the PO improves their credibility and the PHC's image in the community.

Perceived disadvantages

We noted an increase in the proportion of HCWs who perceived disadvantages in using the PO; varying overall from 10.5% to 21.2% (p value<0.001) and markedly observed in Guinea. The main difficulty identified from interviews was using the PO with agitated children, as it can be time-consuming or impossible. This agitation is often linked to their fear of being pricked, as with the malaria rapid diagnostic test (mRDT), since the sensor is placed on the finger. HCWs employ strategies to calm the child, such

as asking the mother for help, demonstrating on their own finger or taking the saturation before using the mRDT.

Another perceived disadvantage was the increased workload due to integrating PO use within the IMCI algorithm. HCWs must take a lot of parameters (weight, temperature, arm circumference, etc). However, this impression was partly due to HCWs' inexperience with the PO and IMCI. With time and practice, they perceived the PO much less as an additional workload.

An increased number of tests to diagnose children can lead to longer consultation times, which is challenging when human resources are limited or during busy periods in the PHCs, and sometimes lead to patient dissatisfaction.

> Children are often agitated, which makes it difficult for the PO to give the result, and that makes you late. The people waiting yell at you, saying you're slow. (Mali, T2)

However, these difficulties were more emphasised during the first qualitative data collection. Improved control of the PO, recognition of its importance and community awareness-raising reduced complaints about the increase in consultation time.

Some HCWs view the longer consultation time positively, as it allows for better identification of health problems, a perception influenced by contextual factors such as the busyness of the PHCs.

Another challenge is the high turnover of HCWs. Proper use of the device requires training, and frequent staff changes mean constant retraining is necessary. Finally, the low socioeconomic resources of the population can lead to difficulties for HCWs because CFs sometimes refuse referrals. This is often due to the fear of hospital referrals, which highlight the severity of their child's condition and incur expenses they often cannot afford.

Personal emotions

Positive or very positive feelings about the PO remained high in all four countries during the four surveys. The proportions of HCWs with very positive feelings increased from 50.2% in the first survey to 80.6% in the last survey in Burkina Faso and from 56.4% to 81.7% in Guinea. However, these proportions decreased in the other two countries (p value<0.001). Nevertheless, the declines were offset by those finding the PO 'acceptable' with only three people having mixed feelings in the last data collection compared with 29 in the first survey.

This was reflected in the interviews; overall, HCWs expressed positive feelings about the PO over time. It improved their self-confidence, as they felt more assured in their diagnoses. Many reported trusting the device to provide reliable results.

> I feel at ease, it gives me confidence in what I'm doing, because I know that the device isn't going to lie to me. It gives me the correct result. (Mali, T2)

Receiving new technology to assist them in their daily work also brings satisfaction and joy. They feel rewarded by having access to a device that is rare in these contexts. However, a few HCWs remain apprehensive about their ability to use the tool correctly or whether the PO provides reliable data. This concern is linked to specific conditions for using the PO (clean fingers, no cold hands, etc) and whether they received adequate training.

Social influence

Most HCWs interviewed felt that others couldn't influence their opinion of the PO because they understood its usefulness and importance. This sentiment was reaffirmed during the retrospective phase.

However, some HCWs, particularly in Guinea, stated that a contrary opinion from their superior in the PHC or health district team could influence their use of the tool, even if they wished to use it.

Some PHC' managers recognise their influence and understand they must model the desired behaviour.

> As the manager, if you consult without using it, you should know that it will never be used. So, every time you lead by example, you have to do it so that others see you're serious about using it. (Burkina Faso, T1)

The long-term involvement of project teams through supervision also contributed to the positive perception of the PO, reinforcing the importance of using it to HCWs.

In the quantitative data, almost no HCWs reported negative influences from health authorities, colleagues or PHC heads during the concurrent acceptability survey. Positive reactions from children, mothers or caregivers were common, though a minority reported negative influences in Burkina Faso and Mali. Negative influences decreased in these two countries in the retrospective survey but increased by 10.0% in Guinea and 15.4% in Niger (p value=2.2e-05) (online supplemental appendix 8).

CFs' qualitative acceptability by dimension

Online supplemental appendix 9 highlights key elements of CFs' qualitative acceptability by dimension.

Compatibility

Generally, CFs found the PO compatible with existing values, customs and practices. The PO's non-invasive nature facilitates its acceptance by CFs. Moreover, the PO complements existing practices without altering them. HCWs also reported that patients visiting PHCs are rarely hesitant about new equipment.

Perceived complexity

Few CFs had any information or knowledge about the PO's usefulness and the project's objectives. Several HCWs emphasised the importance of raising awareness among CFs to help them understand and accept the PO. However, during consultation observations, we noted that very little or no information was provided to CFs about the device's purpose and usage. CFs often avoid questioning HCWs due to several barriers, like language and health literacy.

> All I see is a mobile phone, which I think is for consultation purposes, but I don't know what it's for. When it was placed

on my child, it displayed something, but I can't read to understand. And the nurse doesn't speak Zarma so we can't understand each other. (Niger)

Perceived advantages

CFs believe that having new tools at the peripheral level improves the quality of care and treatment, enabling the detection of illnesses that could not be identified before.

> Human beings have their limits, so to be more efficient at work, they need a device that complements these human limits. The machine quickly produces the result; it shows you straight away what your patient's problem is. (Mali)

The PO optimises care pathways. It helps avoid round trips to the PHC and quickly identifies whether a child needs to be referred to the hospital.

However, the real benefits of the tool can sometimes be overestimated, with some CFs perceiving the PO as capable of detecting or even curing all diseases. Other elements, such as donations of medicines and follow-up care for children (as part of another research component), may also have contributed to community acceptability.

Perceived disadvantages

Many CFs, like HCWs, felt that consultation times had increased. While some found this disruptive, especially on market days, others felt it was the most important thing if it was necessary for the child's well-being.

> When they conduct the consultation with the new device (…) it's more work and it delays the consultation a bit. But I understand that they're doing something else that they weren't doing before. (Guinea)

A few CFs even noticed that waiting times had decreased since the introduction of the PO. In addition, as already mentioned by HCWs, some CFs noted their child's reluctance towards the device and highlighted issues related to hospital referrals, mainly due to their costs.

Personal emotions

Overall, CFs expressed positive feelings about the PO, showing confidence in the device and the HCW's ability to use it correctly. Many CFs felt joy, either because their child's health improved, or because they could understand the seriousness of their child's condition thanks to the device.

> I felt nothing but joy in my heart. A joy in knowing that my daughter is being treated. (Niger)

A few parents expressed fears after seeing HCWs struggle to use the device on their child or due to concerns about misreading affecting their child's health. However, such issues were rare (few cases of refusal) and raising awareness of the PO's usefulness usually alleviated these fears.

Social influence

CFs stated that they relied heavily on the advice of HCWs, who are seen as trusted health experts. In any case, they often have no other option but to take their child to the PHC in case of a health problem and accept what will be offered there.

DISCUSSION

To our knowledge, this study is the first comprehensive assessment of the acceptability of routine PO use integrated into IMCI guidelines at the PHC level in West Africa. Conducted in diverse settings, our research used a robust conceptual framework and mixed methods over time, significantly enhancing our understanding of PO acceptability.

The overall acceptability (ie, the aggregation of all dimensions) is high, despite variations over time and between countries. The integration of quantitative and qualitative data reveals convergences. The results relate to the different dimensions that overlap between the qualitative and the quantitative data. Moreover, the factors associated with higher acceptability at the quantitative level, such as the influence of PHC size, use of e-IMCI, profession and the crucial role of training in PO use, also emerged at the qualitative level. Interviews revealed that using the PO can be more complicated in busy centres due to extended consultation time. In PHCs using e-IMCI, HCWs were more familiar with IMCI and electronic devices, reducing the perceived workload of PO use. Training and supervision were crucial factors in the evolution of acceptability over time. Training often prioritises individuals for political and institutional reasons,[30] typically involving heads of PHC and their deputies, who may not always engage directly in the tasks they were trained for. In Guinea, where PO was little known before the project (only 9.4% of HCWs), intense supervision significantly enhanced acceptability over time, allowing HCWs to ask questions, receive feedback and master the device.

Interviews also emphasised the importance, for acceptability, of the improvement of confidence in the diagnosis. This aligns with other studies, such as in India, where a PO increased HCW's confidence in their decision-making regarding child management.[19] Another study found that introducing PO in Malawi and Bangladesh increased confidence, especially for frontline workers who often lack diagnostic tools and have less confidence in their clinical judgement.[18] This boost in confidence also led to increased hospital referrals in India.[19] Similarly, in the AIRE project, we observed a higher proportion of hypoxemic children being referred compared with severe cases without hypoxaemia,[31] as also observed in Malawi.[32] This is crucial given the challenges of diagnostic accuracy and correct referral from PHC.[33] The importance of good training, regular feedback and continuous support in using PO is also highlighted in several studies, both at the hospital level[8 16] and in decentralised settings.[20]

The integration of quantitative and qualitative results did not reveal any divergent factors. However, some acceptability challenges were not specifically sought quantitatively but emerged qualitatively. Increased consultation times and

workload, especially with agitated children, and difficulties with hospital referrals for children with hypoxaemia were recurrent themes in interviews. The challenges related to child agitation are also reported in other studies.[18] Referral difficulties, even when HCWs detects illness severity, are well known in these contexts.[34 35] A study in Burkina Faso showed that only 41.5% of referred patients visited the referral hospital within 7 days after the HCW's decision.[36] Oxygen is often unavailable at decentralised levels, which may discourage HCWs if only the diagnosis of hypoxaemia improves without access to treatment. These contextual and systemic challenges are further examined in complementary publications stemming from the same research project.[37 38]

Finally, CFs generally accepted PO with minimal resistance despite limited knowledge of its actual benefits. This aligns with other studies showing high acceptability among patients' families and an increased trust in HCWs and their diagnoses.[18 19 39]

Our study also highlighted the importance of distinguishing between acceptability and use or participation, concepts often conflated in analyses.[23] These dimensions should be analysed separately, as they reflect different underlying processes.[40 41] In our study, despite initial variability, PO uptake rates exceeded 90% in the last 10 months, with no significant differences between countries. However, this uptake appears somewhat disconnected from acceptability rates. The project's context, its benefits (equipment donations, medicines, incentives, etc) and regular supervision funded by the project may compel HCW to report usage due to pressure for positive outcomes.[42] Reframing expectations around results and fostering openness to failure, through stronger accountability structures and greater transparency in reporting and evaluation processes, could help mitigate such pressures.[43] Such dynamics call for caution when interpreting high uptake figures, as observed use may reflect adherence to project expectations rather than genuine integration into routine practice. Understanding the device's acceptability beyond usage rates provides deeper insight into whether it is truly valued and likely to be sustained without external support.[14] However, its long-term continuation remains uncertain and warrants further study, especially given the well-documented challenges in maintaining and replacing medical equipment in these settings.[44 45] To address this, the AIRE project implemented several strategies in collaboration with the Ministries of Health of the countries involved in the project, including the establishment of supply chains for PO and the integration of their use into IMCI guidelines. Despite these efforts, questions persist regarding long-term follow-up, budget allocation and national ownership once external support ends.

Considering these challenges and based on our findings, we suggest that inclusive and ongoing training, combined with regular supervision, should be prioritised to support the acceptability of PO among HCWs. However, the persistence of challenges such as increased workload and referral difficulties suggests that broader organisational and systemic factors should also be addressed to facilitate sustainable use. We also encourage future research on acceptability to be grounded in explicit conceptual frameworks or theories in order to capture its multiple dimensions and inform more tailored implementation strategies.

Our study has some limitations. Qualitative data were collected only in the research PHC, where HCWs were more closely monitored, potentially skewing the representativeness and generalisability of results. Interview responses may reflect social desirability bias despite mitigation efforts,[46] especially given the NGO-led project's benefits. Separating opinions on PO from the broader project context, which inevitably impacts acceptability, is challenging. It is also necessary to interpret CFs acceptability results considering the power dynamics and psychosocial pressures that may limit the expression of negative critiques from patients and their families.[47] In the quantitative study, high turnover made maintaining cohort follow-up difficult. Instead, we used repeated cross-sectional surveys, limiting our ability to track acceptability changes over time. Another limit was the uniform weighting of questions and dimensions in calculating acceptability scores, which may not reflect their actual impact. This article is the first attempt to test our conceptual framework empirically,[23] and further research is needed to refine our methodology and potentially introduce weighting coefficients.

CONCLUSION

We found that both HCWs and CFs generally accept the PO. While CFs did not always understand the device's utility, their overall perception was positive. HCWs who received proper training had significantly higher acceptability. Perceived advantages of PO included improved childcare, more accurate diagnoses and enhanced self-confidence. However, challenges such as repeated training needs, increased workload, longer consultation time and referral difficulties to hospitals could impact the sustainability of PO use in West Africa.

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Funding The AIRE project is funded by UNITAID (Grant number 2019-34-AIRE), with in-kind support from Institut National de la Santé et de la Recherche Médicale (INSERM, France) and Institut de Recherche pour le Développement (IRD, France). UNITAID was not involved in the design of the study, the collection, analysis and interpretation of the data nor in the writing of the manuscript.

Competing interests VR is a member of the Editorial Board of the journal BMJ Global Health. He was not involved in the peer review or handling of the manuscript. All other authors have no competing interest to declare.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Ethics approval and consent to participate. The AIRE research protocol, the information notice (translated in vernacular languages), the written consent form and any other relevant document have been submitted to each national ethics committee, to the Inserm Institutional Evaluation Ethics Committee (IEEC) and to the WHO Ethics Review Committee (WHO-ERC). All the aforementioned ethical committees reviewed and approved the protocol and other key documents (Comité d'Ethique pour la Recherche en Santé (CERS), Burkina Faso n°2020–4-070; Comité National d'Ethique pour la Recherche en Santé (CNERS), Guinea n°169/CNERS/21; Comité National d'Éthique pour la Santé et les Sciences de la vie (CNESS), Mali n°127/MSDS-CNESS; Comité National d'Ethique pour la Recherche en Santé (CNERS) Niger n°67/2020/CNERS; Inserm IEEC n°20–720; WHO-ERC n° ERC.0003364). This study has been retrospectively registered by the Pan African Clinical Trials Registry on 15 June 2022, under the following Trial registration number: PACTR202206525204526. Participants gave informed consent to participate in the study before taking part. To reduce any perception of obligation to participate in the study, research teams made it clear to HCWs that they were independent from the implementation team and emphasised that participation was both confidential and voluntary. For caregivers, interviews were conducted after the child had received care, with a clear explanation that participation would in no way affect any further care.

Provenance and peer review Commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The datasets generated and analysed during the current study are not publicly available. Access to processed deidentified participant data will be made available to any third party after the publication of the main AIRE results stated in the Pan African Clinical Trial Registry Study statement (PACTR202206525204526, registered on 06/15/2022), upon a motivated request (concept sheet) and after the written consent of the AIRE research coordinator (Valériane Leroy, valeriane.leroy@inserm.fr, Inserm U1295 Toulouse, France, orcid.org/0000-0003-3542-8616), obtained after the approval of the AIRE publication committee, if still active.

Author note The reflexivity statement for this paper is linked as an online supplemental file 2.

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