Discover Public Health

RESEARCH Open Access

Evaluating the performance of community health care providers in detecting fast breathing in children using a reference video expert panel in Bangladesh

Ahad Mahmud Khan[1,2*], Md Shafiqul Islam[1], Nabidul Haque Chowdhury[1], Salahuddin Ahmed[1], Rezwana Tabassum[1], Kazi Sazzadul Haque[1], Sadia Afrin[1], Zannatul Ferdush Amin[1], Afroza Yeasmin Rumi[1], Jawata Rahman[1], Rakib Bhuiyan[3], Rizouan Ur Rashid[3], Kamrun Nahar[4], Robynne Simpson[5], Ayaz Ahmed[5], Ting Shi[2], Abdullah H. Baqui[6], Steve Cunningham[7], Eric D. McCollum[6,8] and Harry Campbell[2]

*Correspondence:
Ahad Mahmud Khan
ahad_mahmud@hotmail.com
[1]Projahnmo Research Foundation, Dhaka, Bangladesh
[2]Usher Institute, University of Edinburgh, Edinburgh, UK
[3]University of Greenwich, London, UK
[4]Department of Paediatrics, Shaheed Suhrawardi Medical College Hospital, Dhaka, Bangladesh
[5]Royal Hospital for Children, Glasgow, UK
[6]Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA
[7]Centre for Inflammation Research, University of Edinburgh, Edinburgh, UK
[8]Global Program in Paediatric Respiratory Sciences, Eudowood Division of Paediatric Respiratory Sciences, Department of Paediatrics, School of Medicine, Johns Hopkins University, Baltimore, MD, USA

Abstract

Background The World Health Organization's Integrated Management of Childhood Illness guidelines emphasise respiratory rate (RR) counting for diagnosing childhood pneumonia. Community health workers (CHWs) play a crucial role in managing pneumonia in children in low- and middle-income countries (LMICs). In Bangladesh, community clinics (CCs) are the lowest tier of health facilities, where services are provided by CHWs designated as Community Health Care Providers (CHCPs). This study evaluated the ability of CHCPs to measure RR and identify fast breathing for the diagnosis of pneumonia.

Methods We conducted a cross-sectional study of children aged 0–59 months presenting with suspected pneumonia at three purposively selected CCs in Bangladesh. CHCPs from respective CCs counted RR manually, with chest movements simultaneously videotaped. Six physicians were trained to form a video expert panel (VEP) that interpreted the RR from the recorded videos. We assessed the ability of CHCPs to count RR and identify fast breathing, using VEP as the reference standard.

Results Among the 123 enrolled children, CHCPs were able to count an RR of 110 children (89.4%). VEP reached a consensus (i.e., RR count difference within two breaths per minute (bpm) between two VEP members) for 103 out of 110 children (93.6%). CHCPs and VEP reached consensus (RR counts within two bpm) for 80 of these 103 children (77.7%), with a mean difference of 0.8 bpm and limits of agreement ranging from −4.9 to 6.5 bpm. The CHCPs classified fast and normal breathing with a sensitivity of 100% (95% CI 73.5–100.0) and a specificity of 95.6% (95% CI 89.1–98.8), demonstrating an agreement of 96.1% (95% CI 90.4–98.9) and a kappa of 0.84.

Conclusions CHCPs demonstrated safe and reliable RR counting, with a tendency to overestimate fast breathing, yet they did not miss any cases. However, challenges such as the failure to measure RR in some children and the lack of consensus on RR

© The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

count among VEP members point to potential limitations in the assessment process. Moreover, the selection of well-trained health workers and the recruitment of patients with relatively less severe conditions in CCs limit the generalisability of these findings.

Keywords Pneumonia, Respiratory rate, Fast breathing, Community health care provider, Video expert panel, Reference standard

1 Introduction

Pneumonia is a significant global health concern and a leading cause of mortality among children under five years of age [1]. In 2015, it was responsible for an estimated 138 million cases and 0.9 million deaths worldwide [2]. Low- and middle-income countries (LMICs) bear the highest burden, with approximately 102 million pneumonia cases reported among children in 2015, corresponding to an incidence rate of 0.15 episodes per child-year [3]. In Bangladesh, pneumonia stands as the leading infectious cause of death in children, accounting for approximately 17% of all under-five mortality [4].

According to the World Health Organization (WHO) Integrated Management of Childhood Illness (IMCI) guidelines, pneumonia in children is recognised by the presence of cough and/or breathing difficulty, along with fast breathing or chest indrawing. The guidelines rely primarily on manual counting of a child's respiratory rate (RR) by observing chest movements at the costal margin for 60 s while the child is calm. The measured RR is then compared to age-specific thresholds to identify fast breathing. Fast breathing is defined as ≥ 60 breaths per minute (bpm) for infants aged < 2 months, ≥ 50 for children aged 2–11 months, and ≥ 40 for children aged 12–59 months [5]. In LMICs, community health workers (CHWs) play a vital role in the diagnosis and treatment of common childhood illnesses, including pneumonia. CHWs work at community-based health centres or provide household-level services [6, 7]. With their knowledge of local cultures and languages and standardized training, CHWs aim to deliver culturally appropriate health care services – meaning care that is respectful of and responsive to the beliefs, practices, and needs of the communities they serve [7]. Their efforts are instrumental in the early recognition of pneumonia, contributing significantly to the reduction of child mortality [8].

Accurate RR measurement and identification of fast breathing by CHWs are essential for effective pneumonia diagnosis [9]. However, the accuracy of health workers in measuring RR has shown variability across studies [10]. A community-based study demonstrated high sensitivity (87.5%) and specificity (98.0%) among CHWs in identifying fast breathing compared to physicians [11]. Another study reported moderate sensitivity (78.0%) and low specificity (69.0%) of CHWs compared to a paediatrician in identifying fast breathing among young infants in a hospital-based study [12]. In a training environment, CHWs demonstrated a sensitivity and specificity of 75% and 83%, respectively, when compared to a study coordinator [13]. Another study showed both sensitivity and specificity of 81% when compared to an expert panel reviewing video-recorded RR measurements in children [14].

Bangladesh has established about 13,000 community clinics (CCs), with each clinic serving approximately 6,000 people. CCs represent the lowest tier of health facilities in the country and typically manage patients with mild illnesses. Each CC is staffed by a Community Health Care Provider (CHCP), a type of CHW employed by the government. CHCPs typically have completed at least a 12th - grade education and undergo a

three-month pre-service training programme by the Ministry of Health and Family Welfare. This training covers IMCI, basic clinical skills, maternal and child health, and common communicable diseases, using nationally developed training manuals and job aids. Competency is assessed through written tests and practical evaluations at the end of the training. They receive a fixed monthly salary of around 16,700 BDT (approximately 137 USD) from the government. CHCPs are responsible for delivering primary health care services, including diagnosis and treatment of common childhood illnesses, to the population within their catchment areas [15]. As frontline government-employed CHWs, CHCPs play a crucial role in improving access to health care in Bangladesh, similar to CHWs in other LMICs, by bringing communities and the formal health system. Despite their important role, to the best of our knowledge, no previous studies have assessed the performance of CHCPs in diagnosing pneumonia in children.

Currently, there is currently no universally recognized gold standard for evaluating the accuracy of RR measurement [16]. Most studies have relied on manual counts performed by trained professionals, such as physicians or nurses, as a reference standard [17]. However, manual counting is often considered unreliable owing to potential biases, including difficulty in simultaneously measuring RR and inconsistencies among human raters [16, 18]. Automated RR monitors have also been used as reference standards [19, 20], but these devices are also unreliable as they typically infer RR indirectly through other variables, such as carbon dioxide levels, pulse oximeter signals, or photoplethysmography, rather than directly measuring chest movements [17, 21–23].

Videography of a child's chest movements and interpretation by a standardised video expert panel (VEP) could be used as a reference standard [16, 18]. However, there may be variability in the accuracy of RR counts among experts when interpreting RR from video recordings. If high quality videos could be recorded and the interpretation of RR from these videos could be systematically conducted by a VEP, it could be an ideal and non-biased reference standard.

Our study aimed to evaluate the ability of CHCPs to measure RR and identify fast breathing in children for pneumonia diagnosis in Bangladesh using VEP-determined RR as the reference standard.

2 Methods

2.1 Study design and setting

The detailed methodology of this study has been published previously [24]. This cross-sectional study was conducted in 2022 in three purposively selected CCs located in the Zakiganj sub-district of Sylhet, Bangladesh. Zakiganj was chosen because of its rural setting, high burden of childhood illness, and established collaboration with local health authorities, which facilitated the study implementation. The three CCs were selected based on accessibility, patient volume, and operational functionality, to ensure that a feasible number of eligible cases could be enrolled within the study timeline. Each clinic had one CHCP, totalling three CHCPs, all of whom had previously completed standard government pre-service training, including modules on IMCI. No additional training was provided specifically for the study. The selected CHCPs had recently been involved in a project focused on childhood pneumonia [25]. To establish a reference standard for RR evaluation, six physicians with a Bachelor of Medicine and Bachelor of Surgery (MBBS) degree were trained and standardized to form a VEP. Video recordings of the

children were obtained at the CCs and later interpreted by the VEP for accuracy in the RR measurement.

2.2 Study population

The study population included infants aged 0–2 months presenting with any illness such as fever, poor feeding, respiratory symptoms, jaundice, diarrhoea, and skin infections, and children aged 2–59 months who presented with cough and/or difficulty breathing. Infants and children with any danger signs (unable to drink or feed, vomit everything, convulsions, lethargic or unconscious), or whose parents declined to provide consent, were excluded from the study.

2.3 Sample size and sampling method

During the study period, 209 children visiting CCs were screened consecutively, of whom 123 were enrolled. The sample size was determined using a web-based sample size calculator [26] by incorporating disease prevalence into the calculation of sensitivity and specificity, following Buderer's method, which adjusts sample size calculations for diagnostic accuracy studies by accounting for the expected prevalence of the condition and the desired precision around sensitivity and specificity estimates [27]. Assumptions included an expected sensitivity of 78%, specificity of 86%, disease prevalence of 34% [10], precision of 13.5%, 95% confidence level and 10% dropout rate.

2.4 Study procedure

A Canon EOS M50 camera [28] was used to record videos of the children's chest movements. Once the child was calm, the CHCP counted the RR for one minute while the video recording was performed simultaneously. On average, each video was approximately 1 min and 15 s long. The study PI (AMK) was present during RR counting and video recording in the role of an observer. After counting the RR, the CHCP proceeded with routine clinical assessment and management, following the IMCI guidelines. This included classifying illness severity, and providing appropriate treatment or referral as per the protocol [5]. The videos were transferred to a password-protected computer. Video editing was performed using Adobe Premiere Pro software solely to remove unnecessary portions of the recording, eliminate sound, mask any identifiable features, and reduce file size, without modifying the visual content relevant to RR assessment. After editing, each video was randomly assigned to two VEP members for RR interpretation. If both panel members agreed that the video was uninterpretable, it was excluded from the study. A video was classified as uninterpretable if one or more of the following criteria were present: the child was not calm or exhibited excessive movement; the chest and upper abdomen were inadequately exposed; the camera angle was inappropriate; lighting was insufficient; or overall video quality was poor, including excessive camera movement. For interpretable videos, if the RR difference between the two panel members was ≤ 2 bpm, their average RR was considered to be final. However, if the RR difference exceeded 2 bpm or there was disagreement regarding interpretability, the video was reviewed by a third panel member. In cases where discrepancies persisted among all three members (i.e., no two members had an RR difference of ≤ 2 bpm), the video was sent to a fourth panel member. If the fourth panel member agreed with any previous member, the average RR of the agreeing pair was taken as the final value. Videos for

which no agreement could be reached among any two panel members were excluded from the analysis (Supplementary Fig. 1).

2.5 Operational definitions

Agreement in RR count between CHCPs and VEP: Defined as a difference in RR counts between the CHCPs and the VEP of ± 2, ±3 and ± 5 bpm.

Fast breathing: Defined as a RR equal to or exceeding the WHO IMCI age-specific thresholds: ≥60 bpm for infants aged < 2 months, ≥ 50 bpm for children aged 2–11 months, and ≥ 40 bpm for children aged 12–59 months [5].

Agreement in fast breathing classification between CHCP and VEP: Defined as both the CHCP and the VEP independently identifying the presence or absence of fast breathing in a child, based on age-specific RR cut-offs as per IMCI guidelines [5].

2.6 Statistical analysis

A Bland-Altman plot was generated to illustrate the relationship between RR counts recorded by CHCPs and those determined by the VEP. The percentage agreement between the CHCPs and VEP RR counts was calculated for differences within ± 2, ±3, and ± 5 bpm. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) for identifying fast breathing were evaluated using the VEP as the reference standard. Additionally, the Cohen's kappa statistic was computed.

3 Results

Among the 123 children enrolled, CHCPs were able to count the RR in 110 children. Among them, VEP reached a consensus in 103 children, who were included in the analysis (Fig. 1).

3.1 Basic characteristics of the children

Table 1 presents the basic characteristics of the children. The median age was 31 months (inter-quartile range, IQR 15–48 months), with a male-to-female ratio of 1:0.7. The most common condition during the assessment was awakening and calmness (74.8%), followed by asleep (21.4%). The RR of most children (82.5%) was < 40 bpm.

3.2 Agreement in respiratory rate count between CHCPs and video expert panel

The Bland-Altman plot shows the agreement in RR between the CHCP RR count and VEP count (Fig. 2). The mean difference in RR counts between CHCPs and the VEP was 0.8 bpm, with limits of agreement ranged from – 4.9 to 6.5 bpm.

Table 2 presents the proportion of agreement in the RR between the CHCP and VEP. The overall agreement was 77.7%, 83.5%, and 92.2% at ± 2 bpm, ± 3 bpm, and ± 5 bpm, respectively. The agreement was lower for children aged 36–59 months, male children, children with some movements, and those with an RR ≥ 60 bpm.

3.3 Accuracy of CHCP in classifying fast breathing

Table 3 shows the accuracy of the CHCP classification of fast breathing considering the VEP classification as the reference standard. About 15.5% of the children (16/103) were classified as having fast breathing by CHCP compared to 11.7% (12/103) by VEP. According to a kappa-statistic of 0.84, the overall agreement was substantial. The accuracy of

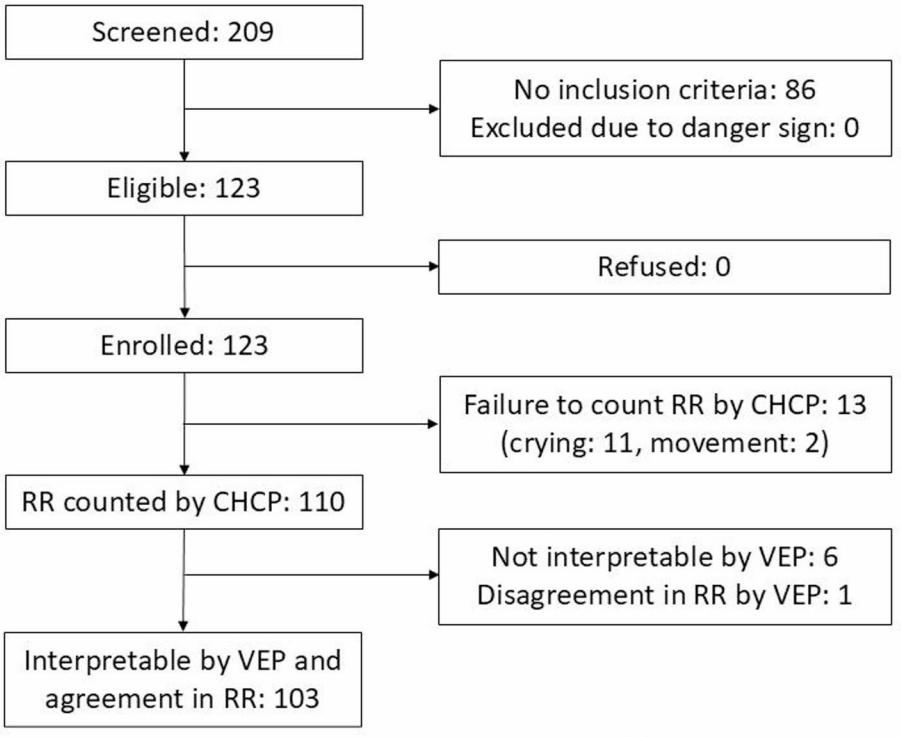


Fig. 1 CONSORT diagram, CHCP: Community Health Care Provider, RR: Respiratory rate, VEP: Video expert panel

Table 1 Basic characteristics of the children

Characteristics	Frequency (%)
Age (months)	
0–2	0 (0.0)
2–11	20 (19.4)
12–35	35 (34.0)
36–59	48 (46.4)
Mean (SD)	31.3 (17.8)
Median (IQR)	31.0 (15.0–48.0)
Sex	
Male	60 (58.3)
Female	43 (41.7)
Child condition during assessment	
Asleep	22 (21.4)
Awake and calm	77 (74.8)
Awake with some movements	4 (3.9)
RR interpreted by VEP (bpm)	
<40	85 (82.5)
40–59	16 (15.5)
≥60	2 (1.9)
Fast breathing interpreted by VEP	
Yes	12 (11.7)
No	91 (88.3)
Total	103 (100.0)

bpm breaths per minute, *IQR* inter-quartile range, *RR* respiratory rate, *SD* standard deviation, *VEP* video expert panel

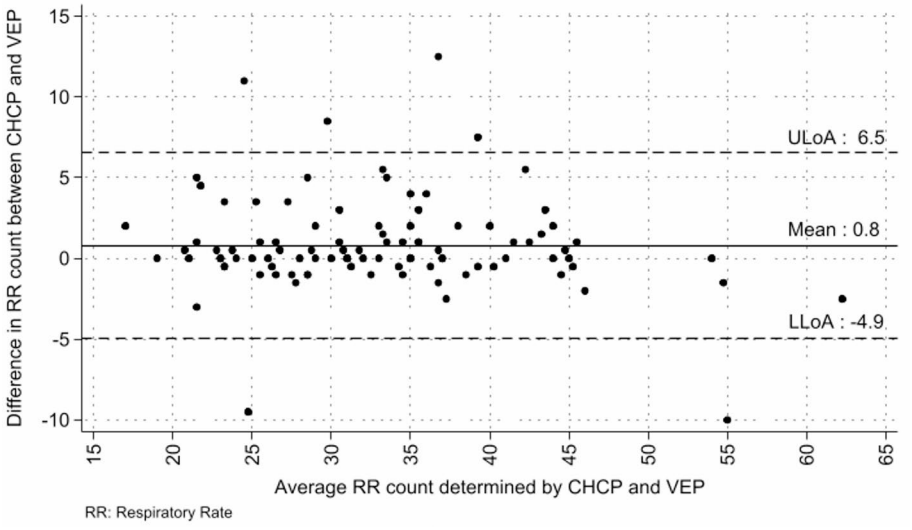


Fig. 2 Bland Altman plot showing the relationship between respiratory rate count by CHCPs and respiratory rate count by video expert panel, bpm: breaths per minute, CHCP: Community Health Care Provider, RR: Respiratory rate, VEP: Video expert panel

Table 2 Agreement in respiratory rate count between CHCPs and video expert panel

Characteristics	Frequency	Agreement in RR count		
		Within ± 2 bpm, *n* (%)	Within ± 3 bpm, *n* (%)	Within ± 5 bpm, *n* (%)
Age (months)				
2–11	20	16 (80.0)	17 (85.0)	19 (95.0)
12–35	35	30 (85.7)	30 (85.7)	31 (88.6)
36–59	48	34 (70.8)	39 (81.3)	45 (93.8)
Sex				
Male	60	43 (71.7)	48 (80.0)	55 (91.7)
Female	43	37 (86.0)	38 (88.4)	40 (93.0)
Community clinics				
CC-1	37	22 (59.5)	23 (62.2)	30 (81.1)
CC-2	47	41 (87.2)	44 (93.6)	46 (97.9)
CC-3	19	17 (89.5)	19 (100.0)	19 (100.0)
Child condition				
Asleep	22	21 (95.5)	21 (95.5)	22 (100.0)
Awake and calm	77	58 (75.3)	64 (83.1)	71 (92.2)
Awake with some movements	4	1 (25.0)	1 (25.0)	2 (50.0)
RR interpreted by VEP				
<40	85	65 (76.5)	69 (81.2)	78 (91.8)
40–59	16	15 (93.8)	16 (100.0)	16 (100.0)
≥60	2	0 (0.0)	1 (50.0)	1 (50.0)
Total	103	80 (77.7)	86 (83.5)	95 (92.2)

bpm breaths per minute, *CC* community clinic, *CHCP* Community Health Care Provider, *RR* respiratory rate, *VEP* video expert panel

Table 3 CHCP classification of fast and normal breathing compared to video expert panel classification

CHCP classification	VEP classification		
	Fast breathing, *n*	**Normal breathing, *n***	**Total, *n***
Fast breathing	12	4	16
Normal breathing	0	87	87
Total	12	91	103
Agreement (95% CI)	96.1% (90.4–98.9)		
Kappa	0.84		
Sensitivity (95% CI)	100.0% (73.5–100.0)		
Specificity (95% CI)	95.6% (89.1–98.8)		
PPV (95% CI)	75.0% (47.6–92.7)		
NPV (95% CI)	100.0% (95.8–100.0)		

CHCP Community Health Care Provider, *CI* confidence interval, *NPV* negative predictive value, *PPV* positive predictive value, *VEP* video expert panel

CHCPs in identifying fast breathing compared to VEP and kappa values was consistent in terms of age and sex. However, the agreement was poor (kappa = 0.20) when the child had some movement during the assessment (Supplementary Table 1).

4 Discussion

We evaluated the ability of CHCPs working in selected CCs in Bangladesh to measure RR and identify fast breathing compared to the reference VEP assessment. The CHCPs demonstrated high accuracy in identifying fast breathing, with a sensitivity of 100%, specificity of 95.6%, and Cohen's kappa value of 0.84. Importantly, the CHCPs did not miss any cases of fast breathing identified the VEP. However, they classified 4 out of 91 children as having fast breathing when the VEP determined their breathing to be within the normal range, indicating false positive classifications.

Previous studies have shown considerable variations in the performance of health workers in measuring and classifying fast breathing [10, 14, 29, 30]. Compared to these studies, the CHCPs in our study demonstrated better performance. It is important to consider the differences in reference standards when making comparisons. For instance, Mukanga et al. reported sensitivity and specificity of 81% and 87%, respectively, compared to paediatricians conducting in-person assessments in a facility-based study in Uganda [29]. Similarly, Cardemil et al. documented a sensitivity of 61% and specificity of 82% against expert clinicians conducting in-person assessments in a community-based study [30]. In contrast, Sinyangwe et al. used a VEP as the reference standard and observed both sensitivity and specificity of 81% in a community-based study in Zambia [14]. A systematic review and meta-analysis further highlighted that non-physician health workers in LMICs could identify fast breathing with an average sensitivity of 78% and specificity of 86%, although the reference standards across the included studies varied, encompassing both in-person expert assessments and VEPs [10].

Our study also revealed a good agreement between the RR counts measured by CHCPs and the VEP. Agreement levels were 77.7% within ± 2 bpm, 83.5% within ± 3 bpm, and 92.2% within ± 5 bpm. The mean difference in RR counts between CHCPs and VEP was only 0.8 (95% CI −4.9 to 6.5). These narrower limits of agreement indicate a good agreement. When compared to prior studies, the performance of the CHCPs was notably better. For example, Sinyangwe et al. and Mukanga et al. reported agreements of 46% [14] and 64% [29], respectively, within ± 2 bpm, whereas Kallander et al. observed

71% agreement within ± 5 bpm [13]. The variability in results across studies may be influenced by differences in study settings, health worker training, and case mix, all of which could impact the RR measurement and classification.

We included children who had some movements during the assessment, as long as the CHCP and VEP could count the RR through in-person observation and video review, respectively. However, our findings showed poorer agreement between the CHCPs and VEP among these children. The IMCI guidelines emphasize that RR should be measured while the child is calm [31], as movement can interfere with the accurate observation of chest wall motion. It is likely that the overall performance of CHCPs would have been better if children who were not calm had been excluded from the analysis.

A key strength of our study was the use of VEP as a reference standard for RR measurements. Most existing studies used an expert's manual count as a reference standard [10]. An expert's RR count may not always be accurate. Moreover, simultaneous RR counting by healthcare workers and experts may be challenging. The videography of the child's chest movements and subsequent interpretation following standardized methodology in this study allowed for simultaneous comparisons between manual counts and a more rigorously established reference standard. This approach mitigated the biases associated with manual RR counting by experts. The VEP systematically assessed video recordings to provide accurate and reliable RR measurements, thereby enhancing the robustness of the findings. This methodology has been validated in previous research [14, 32] and underscores the utility of VEP as a reliable tool for RR assessment in paediatric populations.

Although the performance of the CHCPs in this study was impressive, these findings must be interpreted with caution. Several factors likely contributed to the improved performance of CHCPs in our study. First, the participating CHCPs were a relatively well-trained and well-remunerated group, and their performance may not reflect that of health workers in other settings. Second, the study was conducted in only three CCs and the CCs and CHCPs were not randomly selected. Third, the participating CHCPs had also recently participated in a project related to childhood pneumonia [25]. Fourth, most children presenting to the CCs had mild illnesses, with RR typically within normal ranges and a limited number of children exhibiting fast breathing. Fifth, the presence of an observer and video recording may have influenced the performance of the CHCPs through the Hawthorne effect, potentially resulting in better-than-usual performance [33]. Sixth, interpretations were drawn from a small sample size, resulting in a lower statistical power to detect a true effect. Finally, during the assessment, some children were excluded because they were agitated, making it impossible to measure their RR. Certain videos were excluded from the analysis because they were uninterpretable or the VEP could not agree on the RR count. These exclusions may have introduced bias into the analysis.

This study was conducted in rural community settings in Bangladesh, where CHCPs serve as frontline healthcare workers for primary care, including childhood illness management. These findings have important implications for similar low-resource settings, suggesting that with standard pre-service training, CHCPs can reliably assess RR and identify fast breathing, which is an essential step in pneumonia diagnosis. However, the study limitations may affect the generalizability of the results to other settings or routine operational conditions without similar support or oversight.

5 Conclusions

The study results demonstrated that the CHCPs performed well in measuring RR and identifying fast breathing. Their counting was safe; they tended to overestimate fast breathing but did not miss any cases. However, the inability of CHCPs to measure RR in some children and the lack of consensus among VEP members in certain cases indicate the challenges in assessing RR in specific situations. These issues may reflect limitations in the study design or contextual factors affecting CHCP performance. Additionally, the selection of well-trained and well-experienced health workers using a non-random sampling technique, and the recruitment of relatively less severely ill patients in CCs limit the generalizability of the results. Future studies should evaluate the performance of CHCPs in a broader range of contexts and under routine operational conditions to validate these findings further.

Abbreviations

bpm	Breaths per minute
CC	Community Clinic
CHCP	Community Health Care Provider
CHW	Community Health Worker
CI	Confidence Interval
IMCI	Integrated Management of Childhood Illness
IQR	Inter-Quartile Range
LMICs	Low- and Middle-Income Countries
NPV	Negative Predictive Value
PPV	Positive Predictive Value
RR	Respiratory Rate
SD	Standard Deviation
VEP	Video Expert Panel
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12982-026-01513-0.

Supplementary Material 1.

Acknowledgements

We extend our deepest gratitude to the Projahnmo Research Foundation, the National Newborn Health Program, and the selected community clinics in Zakiganj, Sylhet, for their invaluable assistance in facilitating the data collection activities for this research. We also thank the RESPIRE collaboration, including UK Grant holders, partners, and research teams, as listed on their website (www.ed.ac.uk/usher/respire), including Harish Nair, for their contributions. Some sections of this article were previously included in a thesis authored by AMK [34]. We acknowledge the use of the AI language model developed by OpenAI, to assist in improving the readability and language of this manuscript.

Author contributions

Conception: AMK, HC; Design of work: AMK, HC; Acquisition, analysis of data: NHC, MSI, KN, RS, AA, RT, SA, ZFA, KSH, AYR, JR, RB, RUR; Interpretation of data: AMK, MSI, HC; Drafted the work or substantively revised it: AMK, HC, SC, AHB, EDM, TS, SA, MSI. All the authors critically reviewed and approved the final manuscript prior to submission.

Funding

This research was funded by the UK National Institute for Health Research (NIHR) (Global Health Research Unit on Respiratory Health (RESPIRE); 16/136/109) using UK aid from the UK Government to support global health research. The views expressed in this publication are those of the author(s) and not necessarily those of the NIHR or the UK Government.

Data availability

De-identified extracted datasets, including de-identified video recordings generated and analysed during the present study, are available from the corresponding author upon reasonable request. All shared data have been anonymised to remove personal identifiers in accordance with ethical approval and consent provisions.

Declarations

Ethics approval and consent to participate

We obtained ethical approval from the National Research Ethics Committee of the Bangladesh Medical Research Council (BMRC), Bangladesh (Registration Number: 39315022021), and the Edinburgh Medical School Research Ethics Committee (EMREC), Edinburgh, UK (REC Reference: 21-EMREC-040). All study procedures were conducted in accordance

with the ethical standards of the respective institutional review boards and with the principles of the Declaration of Helsinki. Informed written consent was obtained from parents or legal guardians of all participating children prior to enrolment. The consent process included explicit permission for video recording during data collection and the use of de-identified recordings for research and expert panel assessment.

Consent for publication
Consent for publication was obtained from the parents or guardians of each child.

Competing interests
The authors declare no competing interests.

Received: 20 February 2025 / Accepted: 3 February 2026
Published online: 14 February 2026

References

1. Perin J, Mulick A, Yeung D, Villavicencio F, Lopez G, Strong KL, Prieto-Merino D, Cousens S, Black RE, Liu L. Global, regional, and National causes of under-5 mortality in 2000-19: an updated systematic analysis with implications for the sustainable development goals. Lancet Child Adolesc Health. 2022;6:106–15.
2. McAllister DA, Liu L, Shi T, Chu Y, Reed C, Burrows J, Adeloye D, Rudan I, Black RE, Campbell H, Nair H. Global, regional, and National estimates of pneumonia morbidity and mortality in children younger than 5 years between 2000 and 2015: a systematic analysis. Lancet Glob Health. 2019;7:e47–57.
3. Marangu D, Zar HJ. Childhood pneumonia in low-and-middle-income countries: an update. Paediatr Respir Rev. 2019;32:3–9.
4. Rahman AE, Hossain AT, Siddique AB, Jabeen S, Chisti MJ, Dockrell DH, Nair H, Jamil K, Campbell H, El Arifeen S. Child mortality in Bangladesh - why, when, where and how? A National survey-based analysis. J Glob Health. 2021;11:04052.
5. World Health Organization. Revised WHO classification and treatment of childhood pneumonia at health facilities. Geneva: World Health Organization; 2014. p. 6–14.
6. Whidden C, Thwing J, Gutman J, Wohl E, Leyrat C, Kayentao K, Johnson AD, Greenwood B, Chandramohan D. Proactive case detection of common childhood illnesses by community health workers: a systematic review. BMJ Glob Health. 2019;4:e001799.
7. Olaniran A, Smith H, Unkels R, Bar-Zeev S, van den Broek N. Who is a community health worker? - a systematic review of definitions. Glob Health Action. 2017;10:1272223.
8. Sazawal S, Black RE. Effect of pneumonia case management on mortality in neonates, infants, and preschool children: a meta-analysis of community-based trials. Lancet Infect Dis. 2003;3:547–56.
9. Das JK, Lassi ZS, Salam RA, Bhutta ZA. Effect of community based interventions on childhood diarrhea and pneumonia: uptake of treatment modalities and impact on mortality. BMC Public Health. 2013;13:1–10.
10. Khan AM, O'Donald A, Shi T, Ahmed S, McCollum ED, King C, et al. Accuracy of non-physician health workers in respiratory rate measurement to identify paediatric pneumonia in low- and middle-income countries: a systematic review and meta-analysis. J Glob Health. 2022. https://doi.org/10.7189/jogh.12.04037.
11. Baqui AH, Arifeen SE, Rosen HE, Mannan I, Rahman SM, Al-Mahmud AB, Hossain D, Das MK, Begum N, Ahmed S, et al. Community-based validation of assessment of newborn illnesses by trained community health workers in Sylhet district of Bangladesh. Trop Med Int Health. 2009;14:1448–56.
12. Brady JP, Awan FB, Wafula EM, Onyango FE. Recognition of illness in very young infants by inexperienced health workers. Ann Trop Paediatr. 1993;13:401–7.
13. Källander K, Tomson G, Nsabagasani X, Sabiiti JN, Pariyo G, Peterson S. Can community health workers and caretakers recognise pneumonia in children? Experiences from Western Uganda. Trans R Soc Trop Med Hyg. 2006;100:956–63.
14. Sinyangwe C, Graham K, Nicholas S, King R, Mukupa S, Källander K, et al. Assessing the quality of care for pneumonia in integrated community case management: a cross-sectional mixed methods study. PLoS One. 2016;11:e0152204.
15. Riaz BK, Ali L, Ahmad SA, Islam MZ, Ahmed KR, Hossain S. Community clinics in Bangladesh: a unique example of public-private partnership. Heliyon. 2020. https://doi.org/10.1016/j.heliyon.2020.e03950.
16. Ansermino JM, Dumont G, Ginsburg AS. How uncertain is our reference standard for respiratory rate measurement? Am J Respir Crit Care Med. 2019;199:1036–7.
17. Ginsburg AS, Lenahan JL, Izadnegahdar R, Ansermino JM. A systematic review of tools to measure respiratory rate in order to identify childhood pneumonia. Am J Respir Crit Care Med. 2018;197:1116–27.
18. Ward C, Baker K, Marks S, Kallander K. Selecting a reference standard for evaluating respiratory rate devices to diagnose symptoms of pneumonia in children under 5: lessons learned from resource-poor settings in Sub-Saharan Africa and Asia. Am J Trop Med Hyg. 2017;97:178–178.
19. Baker K, Alfvén T, Mucunguzi A, Wharton-Smith A, Dantzer E, Habte T, Matata L, Nanyumba D, Okwir M, Posada M, et al. Performance of four respiratory rate counters to support community health workers to detect the symptoms of pneumonia in children in low resource settings: A Prospective, Multicentre, Hospital-Based, Single-Blinded, comparative trial. EClinicalMedicine. 2019;12:20–30.
20. Becker C, Achermann S, Rocque M, Kirenko I, Schlack A, Dreher-Hummel T, Zumbrunn T, Bingisser R, Nickel CH. Camera-based measurement of respiratory rates is reliable. Eur J Emerg Med. 2018;25:416–22.
21. Charlton PH, Bonnici T, Tarassenko L, Clifton DA, Beale R, Watkinson PJ. An assessment of algorithms to estimate respiratory rate from the electrocardiogram and photoplethysmogram. Physiol Meas. 2016;37:610–26.
22. Li W, Liu J, Yu L. [Study on respiratory rate monitoring method based on breath Sounds]. Zhongguo Yi Liao Qi Xie Za Zhi. 2018;42:391–4.
23. Daw W, Kingshott R, Saatchi R, Burke D, Holloway A, Travis J, Evans R, Jones A, Hughes B, Elphick H. Medical devices for measuring respiratory rate in children: a review. J Adv Biomedical Eng Technol. 2016;3:21–7.

24. Khan AM, Ahmed S, Chowdhury NH, Islam MS, McCollum ED, King C, Shi T, Nahar K, Simpson R, Ahmed A, et al. Developing a video expert panel as a reference standard to evaluate respiratory rate counting in paediatric pneumonia diagnosis: protocol for a cross-sectional study. BMJ Open. 2022;12:e067389.
25. Ahmed S, Mitra DK, Nair H, Cunningham S, Khan AM, Islam AA, et al. Digital auscultation as a novel childhood pneumonia diagnostic tool for community clinics in Sylhet, Bangladesh: protocol for a cross-sectional study. BMJ Open. 2022;12:e059630.
26. Sample size calculator (web). http://wnarifin.github.io. Accessed 1 Feb 2022.
27. Buderer NMF. Statistical methodology: I. Incorporating the prevalence of disease into the sample size calculation for sensitivity and specificity. Acad Emerg Med. 1996;3:895–900.
28. Canon EOSM50. https://www.canon-europe.com/cameras/eos-m50/. Accessed 21 June 2021.
29. Mukanga D, Babirye R, Peterson S, Pariyo GW, Ojiambo G, Tibenderana JK, et al. Can lay community health workers be trained to use diagnostics to distinguish and treat malaria and pneumonia in children? Lessons from rural Uganda. Trop Med Int Health. 2011;16:1234–42.
30. Cardemil CV, Gilroy KE, Callaghan-Koru JA, Nsona H, Bryce J. Comparison of methods for assessing quality of care for community case management of sick children: an application with community health workers in Malawi. Am J Trop Med Hyg. 2012;87:127–36.
31. World Health Organization. Integrated management of childhood illness: chart booklet. Geneva: World Health Organization; 2014.
32. Stratil AS, Ward C, Habte T, Maurel A, Antson M, Naydenova E, et al. Evaluating the interrater agreement and acceptability of a new reference tool for assessing respiratory rate in children under five with cough and/or difficulty breathing. J Trop Pediatr. 2021. https://doi.org/10.1093/tropej/fmab046.
33. McCambridge J, Witton J, Elbourne DR. Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects. J Clin Epidemiol. 2014;67:267–77.
34. Khan AM. Developing a video expert panel as a reference standard to evaluate respiratory rate counting in paediatric pneumonia diagnosis. Edinburgh: University of Edinburgh; 2023.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.