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Prevalence of pneumonia and malnutrition among children in Jigawa state, Nigeria: a community-based clinical screening study

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ABSTRACT

Objective To estimate the point prevalence of pneumonia and malnutrition and explore associations with household socioeconomic factors.

Design Community-based cross-sectional study conducted in January–June 2021 among a random sample of households across all villages in the study area.

Setting Kiyawa Local Government Area, Jigawa state, Nigeria.

Participants Children aged 0–59 months who were permanent residents in Kiyawa and present at home at the time of the survey.

Main outcome measures Pneumonia (non-severe and severe) defined using WHO criteria (2014 revision) in children aged 0–59 months. Malnutrition (moderate and severe) defined using mid-upper arm circumference in children aged 6–59 months.

Results 9171 children were assessed, with a mean age of 24.8 months (SD=15.8); 48.7% were girls. Overall pneumonia (severe or non-severe) point prevalence was 1.3% (n=121/9171); 0.6% (n=55/9171) had severe pneumonia. Using an alternate definition that did not rely on caregiver-reported cough/difficult breathing revealed higher pneumonia prevalence (n=258, 2.8%, 0.6% severe, 2.2% non-severe). Access to any toilet facility was associated with lower odds of pneumonia (aOR: 0.56; 95% CI: 0.31 to 1.01). The prevalence of malnutrition (moderate or severe) was 15.6% (n=1239/7954) with 4.1% (n=329/7954) were severely malnourished. Being older (aOR: 0.22; 95% CI: 0.17 to 0.27), male (aOR: 0.77; 95% CI: 0.66 to 0.91) and having head of compound a business owner or professional (vs subsistence farmer, aOR 0.71; 95% CI: 0.56 to 0.90) were associated with lower odds of malnutrition.

Conclusions In this large, representative community-based survey, there was a considerable pneumonia and malnutrition morbidity burden. We noted challenges in the diagnosis of Integrated Management of Childhood Illness-defined pneumonia in this context.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Reliable estimates of pneumonia incidence and prevalence from Northern Nigeria are not available, but this region has been identified as a high burden context for under-5 mortality, paediatric pneumonia mortality and malnutrition.

WHAT THIS STUDY ADDS

⇒ Based on standardised clinical assessments of a random sample of children within the community in Jigawa state, Nigeria, the point prevalence of pneumonia was 1.3% and malnutrition was 15.6%, indicating a large burden of disease.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The current WHO Integrated Management of Childhood Illness guidelines for diagnosing pneumonia rely on the recognition of cough and/or difficulty breathing, which in this context may not be reliable and result in the underdiagnosis of pneumonia. There is a need to identify and implement interventions to improve child health in this setting given the high burden of disease.

INTRODUCTION

Pneumonia remains a leading cause of child mortality globally.[1 2] Nigeria has the largest absolute number of annual paediatric pneumonia deaths globally with pneumonia accounting for 20% of under-5 deaths nationally.[3 4] Northern Nigeria is reported as a clear hotspot for pneumonia mortality.[5] However, accurate data on the incidence, prevalence and health systems burden is limited to periodic Demographic Health Surveys (DHS) without clinical assessments (most recently in 2018 reporting 2-week pneumonia prevalence 2.6%).[6 7]

DHS questions have been shown to lack sensitivity in determining recent pneumonia infections and suffer from recall bias in treatments.[8] Furthermore, while a number of clinical and individual risk factors (eg, age, hypoxaemia, altered conscious state, malnutrition) are associated with pneumonia morbidity and mortality, there has been much less investigation of demographic and social factors.[9] Indeed, when exploring demographic and social associations with pneumonia using DHS datasets in Nigeria, our findings were inconsistent and inconclusive.[6]

Malnutrition is a key risk factor for poor pneumonia outcomes and premature death.[9] Nigeria has one of the highest prevalence of childhood malnutrition in the Africa region,[10] with an estimated 37% of children stunted and 9% malnourished and higher burden in the North.[7] Demographic and social factors (eg, crowding, poverty, low maternal education) are consistently identified as risk factors for childhood malnutrition,[11–13] so we wondered whether risk factors for pneumonia and malnutrition may be similar when investigated systematically within a population.

We aimed to measure the point prevalence of WHO pneumonia and malnutrition among children aged 0–59 months in Jigawa state, Nigeria, and explore socioeconomic risk factors for disease. These data will provide an objective measure of disease burden in this context and identify possible associations with under-reported household risk factors. These data will thereby support more accurate disease modelling and health service planning.

METHODS

We conducted a cross-sectional household survey, January–June 2021, in Kiyawa Local Government Authority (LGA), Jigawa state, as part of the larger INSPIRING Project cluster randomised controlled trial (ISRCTN: 39213655).[14]

Setting

Kiyawa LGA has 11 wards and estimated population of 230 000 (57 000 aged under-5 years). It is predominantly rural, with an agricultural economy and predominantly Hausa–Fulani Muslim population. Communities live in compounds, typically comprising multiple households of extended families living together with an element of shared resources. Jigawa under-5 mortality rate is high, 192/1000 live births (2018).[7]

Sampling

Study participants included all children aged 0–59 months residing within eligible study compounds and present at the time of the survey. Compounds were eligible if they had a resident woman aged 16–49 years old. During a formative research phase, all villages in the LGA were mapped to form a sample frame of compounds (January–March 2020). Within each village, we numbered the compounds using an Expanded Programme of Immunization approach.[15] We conducted simple random sampling, proportional to cluster size (with a minimum of 50 compounds in each of the 32 study clusters), to generate a numbered list of compounds for recruitment. The target sample size was 4480 compounds, based on the primary outcome of under-5 mortality reduction for the INSPIRING trial.[14]

Data collection

Research nurses and non-clinical data collectors had 1-week training (covering interviewing techniques, consent, study protocol, and Integrated Management of Childhood Illness (IMCI) pneumonia and anthropometry assessments), followed by supervised piloting in a neighbouring LGA. Non-clinical data collectors collected information on the socioeconomic status and compound structure through an interview with the head of the compound (or their representative in their absence). Research nurses conducted clinical screening for malnutrition and pneumonia, following the WHO IMCI 2014 guidelines, including pulse oximetry. Oxygen saturation and heart rate were measured using Lifebox oximeters (AH-MI, Acare Technology, Taiwan), with universal or paediatric clip probes attached to the child's big toe (online supplemental appendix 1). Malnutrition was assessed through mid-upper arm circumference (MUAC) and checking for oedema. The child's primary caregiver was asked about recent medication and care-seeking. Conducting malaria rapid diagnostic tests, or collecting invasive samples, was outside the scope of the study. Any child identified as having pneumonia or severe pneumonia was directed to the local health facility for assessment. All data was collected using a custom-built CommCare application on Android Tablets.

Definitions

Pneumonia was defined according to the 2014 WHO IMCI guidelines: children with cough and/or difficult breathing and fast breathing for age and/or chest indrawing were identified as pneumonia (non-severe); or severe pneumonia if they had any signs of severe illness (online supplemental appendix 2).[16] We defined hypoxaemia as peripheral oxygen saturation (SpO_2)<90% and moderate hypoxaemia as SpO_2 90%–93%. We recorded lung sounds with the naked ear and a stethoscope. We conducted a sensitivity analysis using a modified pneumonia definition that included children with very fast breathing (+10 breaths per minute above usual age-specific cut-off) and/or chest indrawing, irrespective of caregiver-reported cough or difficult breathing.

Nutritional status was defined using MUAC and restricted to children aged 6–59 months. We defined well-nourished as an MUAC>125 mm, moderate malnutrition as an MUAC of 115–125 mm and severe malnutrition as an MUAC of <115 mm or presence of oedema.[17] Full definitions of explanatory variables are in online supplemental appendix 2. Caregivers of children with observed

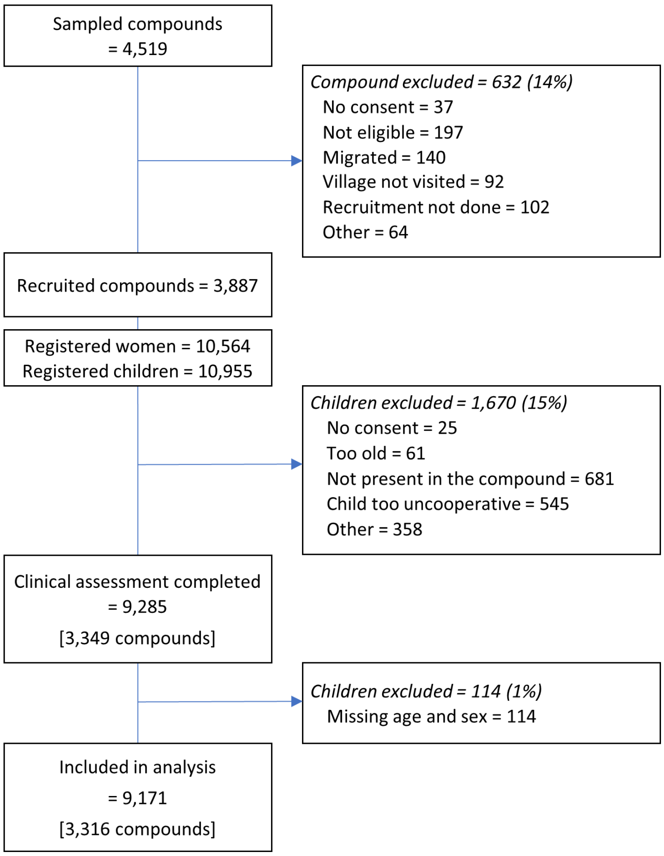

Figure 1 Participant inclusion diagram.

danger signs were informed and supported to go to the nearest health facility.

Analysis

The primary outcomes were the point prevalence of pneumonia (severe and non-severe combined) and malnutrition (severe and moderate combined). We described clinical presentation, compound socioeconomic characteristics, and point prevalence of pneumonia (severe, non-severe and combined) and malnutrition (severe, moderate and combined). Binary and categorical data were described using proportions, normally distributed continuous data as means and SD, and skewed continuous data using median and IQR.

We explored the association between compound socioeconomic factors (exposures) and the primary outcomes of pneumonia (non-severe and severe pneumonia combined) and malnutrition (moderate and severe malnutrition combined) using multilevel mixed effects logistic regression to adjust for compound-level clustering. We planned a sensitivity analysis using multinomial logistic regression with categorical pneumonia and malnutrition outcomes; however, given the small number of pneumonia cases we only did this for malnutrition. The selection of socioeconomic variables to include was decided a priori based on the existing literature. Biologically implausible measurements were excluded from analysis, defined as: MUAC±5 SD from the mean (n=0); oxygen saturation of <50% (n=0); we also excluded age-standardised heart rate of less than the 1st centile (n=205, 2.2%) due to likelihood of measurement error.[18] We used a complete case analysis approach to missing data. Analyses conducted using Stata SE V.14 (StataCorp, College Station, Texas, USA).

Patient and public involvement

The INSPIRING Programme has taken a codesign approach, including project partners, community members and local government representatives during inception, and working with communities to finalise the larger intervention using a community conversations methodology.[19] Prior to data collection, meetings with village leaders were held to explain the study and gain community consent for participation.

Ethics

The study received ethical approval from University College London (reference: 3433/004), Jigawa State Ministry of Health (reference: MOH/SEC.3/S/830/1), University of Ibadan (reference: UI/EC/19/0551). Participants received study information verbally from the data collector and caregivers provided verbal consent prior to child's assessment.

RESULTS

Participant description

We registered 10 955 children under-5 years old in 3887 recruited compounds, of which 9171 (84%) were included in analyses—figure 1. Compounds where we did not clinically assess any children had a lower wealth quintile, poorer water and sanitation status and less crowding (table 1). We included 2–3 children (mean 2.7, range: 1–22) from each compound (mean age 24.8 months, SD: 15.8), with similar numbers of girls and boys (48.7% vs 51.3%)—table 1.

Pneumonia prevalence

The overall pneumonia (severe and non-severe) point prevalence was 1.3% (n=121/9171)—table 2. Severe pneumonia accounted for 45% of cases, with point prevalence of 0.6% (n=55/9171). We observed minimal difference in pneumonia prevalence by child age (1.7%: <2 months; 1.3%: 2–11 months and 12–59 months; p=0.785) or sex (1.3% for both, p value=0.838). In compounds where more than one child was assessed, 0.4% had more than 1 case of pneumonia diagnosed (n=9/2356; intracluster correlation, ICC=0.388).

We obtained successful SpO_2 measurement from 95.5% of children; 0.1% (n=8/9171) had hypoxaemia (SpO_2<90%), 2.0% (n=187/9171) moderate hypoxaemia (SpO_2 90–93%). Biologically implausible measurements (n=205) were higher in younger children (8.7%: aged<2 months; 5.2%: 2–11 months; 1.1%: 12–59 months; p value<0.001) and in children who were agitated/crying vs calm/sleeping (3.1% vs 2.0%; p value=0.006). No children with SpO_2<90% (n=8) met the WHO pneumonia

Table 1 Sociodemographic description of the compounds and children included

	Children recruited from compound		No children from compound		
	N	(%)	N	(%)	P value
Compound factors	(n=3316)		(n=571)		
Wealth quintile					
Lowest	611	(18.40%)	163	(28.60%)	<0.001
Lower	660	(19.90%)	128	(22.40%)	
Middle	641	(19.30%)	111	(19.40%)	
Higher	699	(21.10%)	71	(12.40%)	
Highest	671	(20.20%)	98	(17.20%)	
Missing	34	(1.00%)	0	–	
Water					
Unprotected water source	411	(12.40%)	106	(18.60%)	<0.001
Protected water source	2871	(86.60%)	465	(81.40%)	
Missing	34	(1.00%)	0	–	
Sanitation					
Open defecation	433	(13.10%)	110	(19.30%)	<0.001
Access to toilet facility	2849	(85.90%)	461	(80.70%)	
Missing	34	(1.00%)	0	–	
Crowding					
<3 people per room	1656	(49.90%)	377	(66.00%)	<0.001
≥3 people per room	1626	(49.00%)	170	(29.80%)	
Missing	34	(1.00%)	24	(4.20%)	
Head of compound education					
No education	649	(19.60%)	112	(19.60%)	0.187
Informal/religious education	2031	(61.30%)	344	(60.30%)	
Primary	225	(6.80%)	34	(6.00%)	
More than primary	374	(11.30%)	79	(13.80%)	
Missing	37	(1.10%)	2	(0.40%)	
Head of compound occupation					
Subsistence farmer	1418	(42.80%)	228	(39.90%)	0.039
Manual labour	417	(12.60%)	66	(11.60%)	
Business / professional role	1355	(40.90%)	257	(45.00%)	
Not working	92	(2.80%)	20	(3.50%)	
Missing	34	(1.00%)	0	–	
Child factors	(n=9171)				
Age group					
<2 months	414	(4.50%)			
2–11 months	1818	(19.80%)			
12–59 months	6939	(75.70%)			
Sex					
Female	4463	(48.70%)			
Male	4708	(51.30%)			

P values calculated using Pearson's χ^2 test.

definition (online supplemental appendix 3); 8/187 (4.3%) children with SpO_2 90–93% had WHO-defined pneumonia. Abnormal respiratory sounds were recorded in 4.1% (n=371/9171) of children, much more frequently in those with pneumonia (non-severe 42.4%, n=28/66; severe 56.4%, n=31/55) than those without (3.5%, n=312/9050; p value<0.001)—figure 2.

Fast breathing was common (12.3%), with most of these children not having caregiver reported cough and/or difficulty breathing (n=1061/1127, 94.1%). Of these

Table 2 Description of clinical presentation

Clinical variables	Total (n=9171)		<2 months (n=414)		2–11 months (n=1818)		12–59 months (n=6939)	
	N	(%)	N	(%)	N	(%)	N	(%)
Respiratory assessment								
Respiratory rate* (mean, SD)	34.4	(7.7)	46.4	(8.2)	39.7	(7.9)	32.4	(6.2)
Normal	7910	(86.30%)	380	(91.80%)	1591	(87.50%)	5939	(85.60%)
Fast breathing	1127	(12.30%)	26	(6.30%)	216	(11.90%)	885	(12.80%)
Missing	134	(1.50%)	8	(1.90%)	11	(0.60%)	115	(1.70%)
Cough								
No	8787	(95.80%)	399	(96.40%)	1730	(95.20%)	6658	(96.00%)
Yes	369	(4.00%)	15	(3.60%)	85	(4.70%)	269	(3.90%)
Missing	15	(0.20%)	0		3	(0.20%)	12	(0.20%)
Difficulty breathing								
No	9063	(98.80%)	408	(98.60%)	1786	(98.20%)	6869	(99.00%)
Yes	98	(1.10%)	5	(1.20%)	30	(1.70%)	63	(0.90%)
Missing	10	(0.10%)	1	(0.20%)	2	(0.10%)	7	(0.10%)
Chest in-drawing								
No	9109	(99.30%)	407	(98.30%)	1804	(99.20%)	6898	(99.40%)
Yes	43	(0.50%)	5	(1.20%)	9	(0.50%)	29	(0.40%)
Missing	19	(0.20%)	2	(0.50%)	5	(0.30%)	12	(0.20%)
Oxygen saturation								
≥94%	8568	(93.40%)	349	(84.30%)	1619	(89.10%)	6600	(95.10%)
90–93%	187	(2.00%)	12	(2.90%)	45	(2.50%)	130	(1.90%)
<90%	8	(0.10%)	1	(0.20%)	2	(0.10%)	5	(0.10%)
Missing†	408	(4.50%)	52	(12.60%)	152	(8.40%)	204	(2.90%)
General danger signs‡								
No	8959	(97.70%)	411	(99.30%)	1767	(97.20%)	6781	(97.70%)
Yes	212	(2.30%)	3	(0.70%)	51	(2.80%)	158	(2.30%)
Pneumonia status*								
No pneumonia	9050	(98.70%)	407	(98.30%)	1795	(98.70%)	6848	(98.70%)
Pneumonia	66	(0.70%)	5	(1.20%)	10	(0.60%)	51	(0.70%)
Severe pneumonia	55	(0.60%)	2	(0.50%)	13	(0.70%)	40	(0.60%)
Nutritional assessment	(n=7954)				(n=1015)		(n=6939)	
Mid-upper arm circumference (mean, SD)	140.3	(13.9)			133.4	(13.1)	141.3	(13.8)
<115 mm	231	(2.90%)			52	(5.10%)	179	(2.60%)
115 to 125 mm	923	(11.60%)			229	(22.60%)	694	(10.00%)
>125 mm	6705	(84.30%)			726	(71.50%)	5979	(86.20%)
Missing	95	(1.20%)			8	(0.80%)	87	(1.30%)
Oedema								
Yes	108	(1.40%)			20	(2.00%)	88	(1.30%)
No	7846	(98.60%)			995	(98.00%)	6851	(98.70%)
Nutritional status								
Well nourished	6620	(83.20%)			712	(70.20%)	5908	(85.10%)
Moderate malnutrition	910	(11.40%)			225	(22.20%)	685	(9.90%)
Severe malnutrition	329	(4.10%)			70	(6.90%)	259	(3.70%)
Unable to classify	95	(1.20%)			8	(0.80%)	87	(1.30%)

Continued

Table 2 Continued

Clinical variables	Total (n=9171)		<2 months (n=414)		2–11 months (n=1818)		12–59 months (n=6939)	
	N	(%)	N	(%)	N	(%)	N	(%)
Other clinical signs	(n=9171)		(n=414)		(n=1818)		(n=6939)	
Temperature (mean, SD)	36.2	(0.6)	36.3	(0.6)	36.3	(0.5)	36.2	(0.6)
<35.5	710	(7.70%)	26	(6.30%)	124	(6.80%)	560	(8.10%)
35.5–37.5	8233	(89.80%)	383	(92.50%)	1657	(91.10%)	6193	(89.30%)
>37.5	130	(1.40%)	1	(0.20%)	28	(1.50%)	101	(1.50%)
Missing	98	(1.10%)	4	(1.00%)	9	(0.50%)	85	(1.20%)

*According to 2014 WHO Integrated Management of Childhood Illness guidelines.[16]
†Reasons for missing were: oximeter not functional (n=3), child uncompliant (n=185), caregiver refused (n=5), poor waveform (n=7), biologically implausible (n=205), other (n=3).
‡Includes: lethargy, unconscious, convulsions, unable to feed or drink, vomiting everything, stridor in a calm child.

non-pneumonia fast breathers, 92.7% (n=984/1061) did not have any other signs of acute illness and their median respiratory rate was 60 (<2 months), 52 (2–11 months) and 42 (12–59 months) breaths per minute. Very fast breathing was measured in 1.6% (n=150/9171) of children. Using our alternative pneumonia definition—very fast breathing and/or chest indrawing regardless of cough/difficult breathing, we classified 2.8% (n=258/9171) of children with pneumonia (0.6% severe pneumonia, 2.2% non-severe pneumonia—online supplemental appendix 4).

Malnutrition prevalence

Malnutrition prevalence among children aged 6–59 month was 15.6% (11.4% moderately and 4.1% severely malnourished—table 2). Both moderate (22.2% vs 9.9%) and severe malnutrition (6.9% vs 3.7%, p value<0.001) were more common in children aged 6–11 month than in children aged 12–59 months respectively, and girls than boys (17.1% vs 14.2%, respectively, p value=0.001). In compounds where more than one child was assessed, 10.1% (n=238/2356, ICC=0.463) had more than one malnourished child.

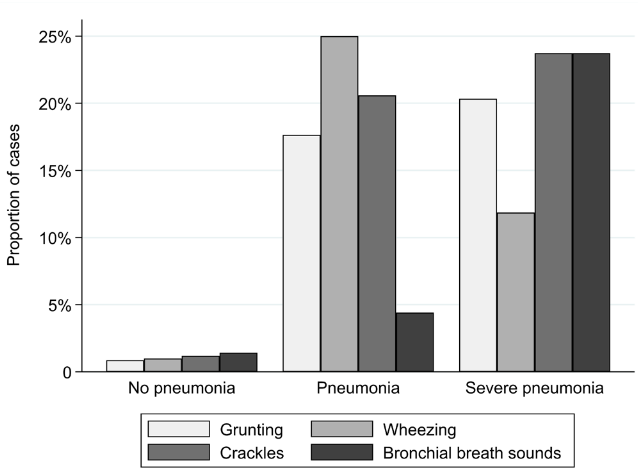

Figure 2 Abnormal lung sounds and pneumonia classification. Note: Given stridor is included in the WHO definition for severe pneumonia, it was not included.

Care-seeking and treatment

In 2 weeks prior to the survey, 12.3% of children had taken some form of medication and 0.5% had been admitted to hospital (including 1/55, 1.8%, of those with severe pneumonia) (table 3). Compared with well children (12.0%), recent treatment was higher among children diagnosed with non-severe pneumonia (24.2%) or severe pneumonia (49.1%, p value<0.001). A similar pattern was seen for malnutrition, fever and hypoxaemia—table 3.

Associations with compound factors

In the pneumonia model, having access to any toilet facility was associated with lower odds of pneumonia (severe or non-severe) (aOR: 0.56; 95% CI: 0.31, 1.01) and having any type of education had higher odds of pneumonia than none. In the malnutrition model, being older (aOR: 0.22; 95% CI: 0.17 to 0.27), male (aOR: 0.77; 95% CI: 0.66 to 0.91) and having a head of compound as a business owner or professional (vs subsistence farmer, aOR 0.71; 95% CI: 0.56 to 0.90) were associated with lower odds of malnutrition—table 4. Using a multinomial model for nutritional status, the findings were similar (online supplemental appendix 5).

DISCUSSION

In this large, representative community survey in a semirural community in northern Nigeria, we measured a pneumonia point prevalence of 1.3%, a malnutrition prevalence of 15.6% and found that 12.3% of children had received some form of medication in the prior 2 weeks. This represents a considerable morbidity burden within the community and a high rate of medication use in children under-5.

Our pneumonia point-prevalence estimate is similar to the 2-week prevalence reported in the 2018 DHS (2.6%). Assuming an average disease duration of 5 days, this translates to an annual pneumonia incidence of 963

Table 3 Recent medication or hospital admission by clinical presentation

	Medication in past 2 weeks (n=1128; 12.3%)		Medication in past 24 hours (n=277; 3.0%)		Hospital admission in past 2 weeks (n=46; 0.5%)*	
Pneumonia (n=9171)						
No pneumonia (n=9050)	1085/9050 (12.0%)	<0.001	256/9050 (2.8%)	<0.001	44/9050 (0.5%)	0.123
Pneumonia (n=66)	16/66 (24.2%)		10/66 (15.2%)		1/66 (1.5%)	
Severe pneumonia (n=55)	27/55 (49.1%)		11/55 (20.0%)		1/55 (1.8%)	
Malnutrition (n=7954)*						
Well malnourished (n=6620)	822/6620 (12.4%)	<0.001	175/6620 (2.6%)	<0.001	31/6620 (0.5%)	0.118
Moderate malnutrition (n=910)	121/910 (13.3%)		30/910 (3.3%)		9/910 (1.0%)	
Severe malnutrition (n=329)	70/329 (21.3%)		25/329 (7.6%)		1/329 (0.3%)	
Missing (n=95)	12/95 (12.6%)		4/95 (4.2%)		2/95 (2.1%)	
Temperature						
<35.5 (n=710)	72/710 (10.1%)	<0.001	10/710 (1.4%)	<0.001	5/710 (0.7%)	0.415
35.5–37.5 (n=8233)	1000/8233 (12.2%)		241/8233 (2.9%)		40/8233 (0.5%)	
>37.5 (130)	44/130 (33.9%)		26/130 (20.0%)		1/130 (0.8%)	
Missing (n=98)	12/98 (12.2%)		0/98 (0%)		0/98 (0%)	
Hypoxaemia† (n=9171)						
≥94% (n=8568)	1014/8568 (11.8%)	<0.001	240/8568 (2.8%)	<0.001	44/8568 (0.5%)	-
90–93% (n=187)	43/187 (23.0%)		15/187 (8.0%)		0/187 (0%)	
<90% (n=8)	2/8 (25.0%)		1/8 (12.5%)		0/8 (0%)	
Missing (n=408)	69/408 (16.9%)		21/408 (5.2%)		2/408 (0.5%)	

*Excludes children<6 months.
†P values calculated using Fishers exact test, all other P values calculated using Pearson's χ^2 test.

per 1000 children, similar to estimates from humanitarian settings (730 to 1460 per 1000 patient-years).[7 20] Almost half the pneumonia cases met criteria for severe pneumonia, suggesting substantial under-recognition of non-severe cases. Additionally, many children with very fast breathing or chest indrawing were not classified as pneumonia because they lacked caregiver-reported cough or difficult breathing. When using these signs in an alternative pneumonia definition that did not rely on caregiver recognition of symptoms, the point-prevalence doubled (2.8%). Given low caregiver knowledge and understanding of pneumonia in this northern Nigerian context,[21] and poor agreement between caregiver reported signs and clinical assessment,[8 22] the WHO IMCI guideline's reliance on caregiver reported cough/difficult breathing is likely missing true pneumonia cases.

Given the large numbers of additional children with slightly fast-breathing and no other signs of illness, and the challenge of respiratory rate assessments,[23] expanding the pneumonia definition to include fast-breathing alone would likely lead to overtreatment. However, 'noisy breathing' may be a useful additional clinical indicator for pneumonia in community and primary care settings.

As expected, we found lower prevalence of hypoxaemia (0.1%) and moderate hypoxaemia (2.0%) than reports from primary care and community clinic contexts.[24–27] However, most of the hypoxaemic children did not have obvious signs of illness, suggesting issues in the accuracy and quality of measurements (despite removing biologically implausible measurements) or missed serious disease. For example, congenital heart disease is often asymptomatic and undiagnosed, with Nigerian data suggesting particularly high prevalence among children with pneumonia.[28] Pulse oximetry screening in low-prevalence populations needs to consider the potential for, and impact of, false positives (and false negatives).[29]

We found substantially higher rates of malnutrition among girls than boys (21% higher), possibly related to gendered provision of food and care-seeking. A pooled analysis of care-seeking for children across sub-Saharan Africa reported an 11% increased odds in care-seeking for boy children with diarrhoea,[30] but studies from Nigeria have found mixed results around care-seeking and child sex.[31–33] A more in-depth contextual understanding is needed of this finding.

We found few associations between sociodemographic factors and pneumonia or malnutrition, and no association with socioeconomic factors we might be expected (eg, crowding or lower socioeconomic status)—similar to previous analysis of 2018 DHS data.[6] We did not explore maternal factors and had fewer children from the poorest compounds, so may be missing key sociodemographic relationships. An interesting finding was the association between malnutrition and subsistence

Table 4 Associations between pneumonia, malnutrition and compound factors, estimated using multilevel mixed effects models

	Pneumonia outcome model (n=9067)						Malnutrition outcome model (n=7782)					
Child factors	**N**	**(%)**	**aOR**	**95% CI**		**P value**	**N**	**(%)**	**aOR**	**95% CI**		**P value**
Child age												
<2 months	7	(1.70%)										
2–11 months*	23	(1.30%)	0.73	(0.29	1.81)	0.5	295	(29.30%)	1			
12–59 months	91	(1.30%)	0.74	(0.32	1.68)	0.468	944	(13.80%)	0.22	(0.17	0.27)	<0.001
Child sex												
Girl	60	(1.30%)	1				665	(17.40%)	1			
Boy	61	(1.30%)	1.01	(0.69	1.48)	0.967	581	(14.40%)	0.77	(0.66	0.91)	0.002
Compound factors												
Wealth quintile												
Lowest	16	(1.20%)	1				166	(14.80%)	1			
Lower	29	(1.80%)	1.49	(0.74	3.00)	0.26	214	(15.50%)	1.01	(0.71	1.44)	0.956
Middle	15	(0.90%)	0.76	(0.35	1.68)	0.503	254	(17.30%)	1.08	(0.76	1.54)	0.664
Higher	29	(1.40%)	1.24	(0.61	2.50)	0.551	286	(15.70%)	1.08	(0.77	1.53)	0.656
Highest	30	(1.30%)	1.32	(0.63	2.74)	0.463	305	(15.30%)	1.12	(0.78	1.60)	0.546
Water												
Unprotected source	15	(1.50%)	1				114	(13.90%)	1			
Protected source	104	(1.30%)	0.87	(0.45	1.66)	0.666	1111	(16.00%)	1.28	(0.91	1.82)	0.157
Toilet												
Open defecation	20	(2.10%)	1				129	(16.20%)	1			
Access to any facility	99	(1.20%)	0.56	(0.31	1.01)	0.054	1096	(15.70%)	0.95	(0.68	1.32)	0.742
Crowding												
<3 people per room	53	(1.20%)	1				546	(14.60%)	1			
≥3 people per room	66	(1.40%)	1.24	(0.81	1.88)	0.327	679	(16.80%)	1.13	(0.92	1.40)	0.247
Head of compound education												
No education	15	(0.80%)	1				169	(10.70%)	1			
Informal/religious	77	(1.40%)	1.81	(0.97	3.39)	0.063	890	(18.50%)	2.16	(1.62	2.88)	<0.001
Primary	15	(2.30%)	3.92	(1.67	9.23)	0.002	77	(13.60%)	1.34	(0.83	2.16)	0.233
More than primary	12	(1.30%)	1.94	(0.79	4.77)	0.149	84	(10.60%)	1.01	(0.64	1.58)	0.982
Head of compound occupation												
Subsistence farmer	60	(1.50%)	1				584	(17.40%)	1			
Manual labour	15	(1.40%)	0.84	(0.43	1.62)	0.595	154	(16.80%)	0.83	(0.59	1.16)	0.276

Continued

Table 4 Continued

Child factors	Pneumonia outcome model (n=9067) N	(%)	aOR	95% CI		P value	Malnutrition outcome model (n=7782) N	(%)	aOR	95% CI		P value
Business/ professional	37	(1.00%)	0.6	(0.37	0.98)	0.042	450	(14.20%)	0.71	(0.56	0.90)	0.005
Not working	7	(1.80%)	1.4	(0.51	3.81)	0.514	37	(11.30%)	0.53	(0.28	1.00)	0.05
	Likelihood ratio test (p value)≤0.001 Compound level intracluster correlation (ICC)=0.388						Likelihood ratio test (p value)<0.001 Compound level intracluster correlation (ICC)=0.463					

*6–11 months for the malnutrition model.

farming. Compounds that rely on subsistence farming for food and income may be more vulnerable to food insecurity and shocks (eg, flooding, drought).[34,35] Additionally, animal husbandry has previously been associated with malnutrition in Northern Nigeria, potentially through increasing exposure to diarrhoeal infections.[36]

While rates of recent medication usage were high, only 1/55 (1.8%) children with severe pneumonia (warranting hospital admission) had been admitted, suggesting a gap between access to medication and access to formal health services, particularly hospital care.[37] Studies from Nigeria and elsewhere have identified a range of cultural, physical and resource-related barriers to accessing care[38] and shown that these barriers are associated with higher risk of child death.[39] We have previously explored these barriers for children with pneumonia in Lagos and Jigawa states, Nigeria,[38] and these new findings add further urgency to efforts to improve access.

Limitations

We had planned to assess malnutrition through weight-for-age z-scores and include children<6 months. However, nearly half of the children were missing a valid weight measurement so we chose not to analyse these data. Practical problems with faulty scales (Seca 354 digital scales) and switching between metric and imperial settings, highlights the challenges of community-based nutrition assessments. We had a large sample size but a small number of severe pneumonia cases, preventing planned secondary analysis using multinomial or ordinal regression. We combined pneumonia and severe pneumonia into a binary outcome but this may have masked important associations between sociodemographic factors and severe illness. In northern Nigeria, pneumonia case numbers are typically higher in the dusty Harmattan season (particularly the cooler, drier Jan-Feb period) and in the peak of the wet season (August),[40] although data regarding this is mixed.[6] Our data reflects this pattern, with higher pneumonia numbers and incidence in January that later months (online supplemental appendix 6). While we do not expect our findings to have varied substantially with a longer sampling frame, climatic and other contextual factors make our prevalence estimates more relevant to other semirural contexts in the lower Saharan region of Africa.

CONCLUSIONS

In this large representative community-based survey, we found a high pneumonia and malnutrition morbidity burden. WHO guidelines for diagnosing pneumonia rely on caregiver recognition of cough and/or difficulty breathing, which in this context may not be reliable and likely results in underdiagnosis of pneumonia.

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Competing interests None.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. The study was approved by University College London (reference: 3433/004), Jigawa State Ministry of Health (reference: MOH/SEC.3/S/830/1) and University of Ibadan (reference: UI/EC/19/0551) research ethics committees. Participants gave informed consent to participate in the study before taking part.

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Supplemental material

Prevalence of pneumonia and malnutrition amongst children in Jigawa state, Nigeria: a community-based clinical screening study

Contents

King C, *et al. BMJ Paediatrics Open* 2022; 6:e001640. doi: 10.1136/bmjpo-2022-001640

Appendix 1: Clinical assessment instructions in standard operating procedures

INSPIRING Project – Point Prevalence Survey

Clinical Assessment

After consent and collecting basic demographic data from the child, ask the caregiver to remove the child's top to expose their chest, and then ask they to put the child in a seated position or hold then in their arms. Wait for the child the settle down so they are calm.

CALM means that the child is not crying, they are still and restful. It is important that the child is calm before taking the respiratory rate and oxygen saturation measurements, and observing their breathing, as movement can make getting these measurements very difficult.

When conducting the clinical assessment, it is **CRITICAL** that all measurements occur only **AFTER** observations are completed.

"OBSERVE FIRST, MEASURE SECOND."

Start with 1. Observing and counting the respiratory rate, followed by any other signs of respiratory distress (e.g., lower chest wall indrawing) and general danger signs. 2. Next listen to the child, first without a stethoscope with your ear to the child's mouth, followed by with a stethoscope on the child's chest (in the order shown below). 3. Finally, complete the remainder of your measurements including measuring the oxygen saturation on the child's toe, followed by temperature, and then anthropometry **LAST** (weight and MUAC). It is **CRITICAL** that this order of the clinical assessment is followed strictly.

Note: temperature and anthropometry are intentionally **LAST** in the order as these measurements usually disturb the child.

1. Respiratory Rate (observe)

Fast breathing is assessed by counting the **respiratory rate**. The respiratory rate is the number of breaths the child takes in one minute. To measure this, use the countdown timer, and set to 60 seconds. Once you set off the timer, watch the child's chest and count the number of breaths until you hear the beep. If the child moves or you lose concentration – ***start the measurement again***.

The normal respiratory rate depends on how old the child is; as younger children take more breaths per minute than older children. Fast breathing is defined as:

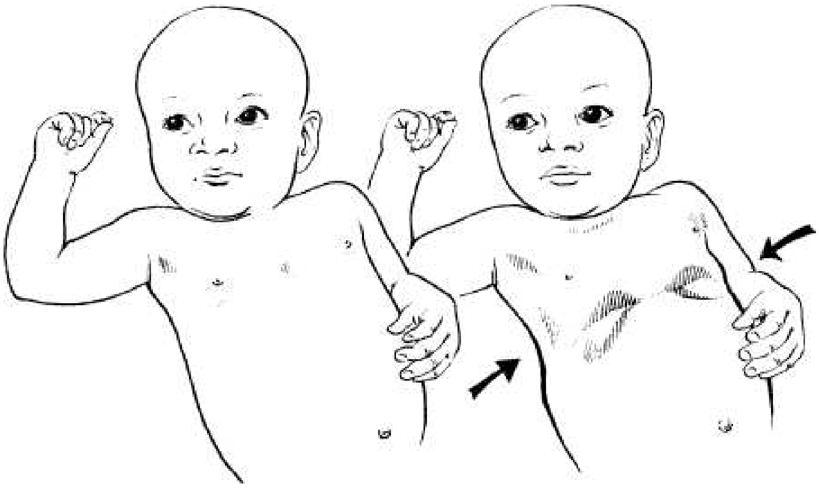
Age	**Respiratory Rate**
0-2 months	60 to 79 breaths per minute (refer to hospital)
2-12 months	50 to 69 breaths per minute
1-5 years	40 to 59 more breaths per minute

When upset, or nervous, or distressed it is normal for a person to start breathing quicker or erratically. So it is very important that the child is calm and relaxed when you measure their respiratory rate, and this is why we take two measurements, to validate the measure. Fast breathing in an infant 0-2 months and is considered respiratory danger signs requiring hospitalization.

2. Danger Signs – part 1 (observe for chest indrawing and convulsions)

When children are sick, they can display a variety of signs which indicate that they are very unwell. For children with pneumonia these danger signs include: chest in-drawing, vomiting everything, not feeding or drinking, convulsions, lethargy or unconscious. This danger sign we will observe for is chest indrawing. The other danger signs will be completed after we finish observing since these signs may require disturbing the child.

- ***Chest indrawing***: In normal breathing, the chest and abdomen will move OUT when the child breathes IN. When children are trying very hard to breathe, their lower chest wall will move IN when breathing IN. This is the opposite of what happens in normal breathing and is called CHEST INDRAWING! Chest indrawing is assessed by looking at the child's chest and abdomen, when they are lying flat. It is very important that you expose the chest and abdomen, while the child is lying flat when assessing for this. It is also extremely important that the child is calm and not agitated or crying during this assessment.



(also see training videos for examples)

- ***Convulsions:*** During a convulsion, the child can have "jerky" movements or the child's limbs and arms become stiff. The child may lose consciousness or not be able to respond to spoken directions. This is also known as a 'fit' or 'spasm'. This should be either observed or reported to have occurred within the previous 24 hours by the caregiver.

3. Lung Sounds

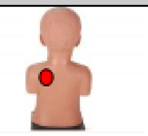
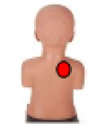
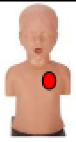
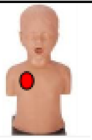
Children with pneumonia, and other common infections of the airway, can make noises when they breath in or out. Some of these noises can be hear without any assistance, but others require a stethoscope to hear them. You will need to both listen for these sounds with your naked ear, and with a stethoscope.

No stethoscope (place your ear close to the child's mouth to listen for these sounds):

- ***Grunting:*** this is a soft, short, repetitive sound made consistently when the child breaths out, usually early in expiration often sounding like an "ugh", and it indicates that the child is having difficulty breathing. Place your ear close to their mouth to listen for this sound.
- ***Wheeze:*** Wheeze is a high-pitched whistling or musical sound heard at the end of the breathing OUT. The child's small air passages narrow to cause wheezing. Place your ear close to their mouth to listen for this sound.
- ***Stridor:*** Stridor is a harsh noise made when a child breathes IN. It occurs when the throat or airways are swollen. These conditions are often called croup. This swelling interferes with air entering the lungs. If the swelling blocks the child's airway, it can be life threatening. Be sure to look and listen for stridor when the child is calm. A child who is not very ill may have stridor only when he is crying or upset. However, a child who is calm and also has stridor has a dangerous situation. Place your ear close to their mouth to listen for this sound.

Stethoscope (regular):

a. The child should be calm and cooperative, as necessary for routine chest auscultation, preferably in the parent's arms.
b. Ideally, the chest piece (diaphragm) should be able to have direct contact with the skin at all four locations described below.
c. Listen to breath sounds at the **FOUR (4) designated locations** in sequential order (illustrated below), listen for **at least 3 FULL RESPIRATORY CYCLES (inspiration + expiration) at each position**. The listening sequence is (in reference to patient): back left first; then back right, then front left on "heart" side, then front right.
d. Make sure that the stethoscope chest piece is **FIRMLY BUT GENTLY** applied directly to the skin, and **DO NOT** move or shift the stethoscope during listening at any individual position.
e. Order of auscultation: (1) back left; (2) back right; (3), left front (cardiac); (4) right front

	POSITION 1 **(patient's BACK LEFT; inferior and medial to scapula)**	**POSITION 2** **(patient's BACK RIGHT; inferior and medial to scapula)**
Patient's BACK		
	POSITION 3 (patient's LEFT FRONT CHEST (HEART))	**POSITION 4 (patient's RIGHT FRONT CHEST)**
Patient's FRONT		

Please refer to these lung sound descriptions when classifying the lung sounds heard at the 4 chest positions when listening with a regular stethoscope. Note that multiple sounds may be present at the same position.

Lung sound	**Description**	**Inspiration**	**Expiration**
Normal	Soft, no musical	Throughout	Early only
Crackle	Short, explosive, not musical, popping, sometimes repetitive	Primarily (but can be variable)	Possible but less common
Wheeze	Muscial, long duration; can be high or low pitch	Possible	Primarily, prolonged
Bronchial breath sounds	Tubular, hollow sounds which are heard when listening over the large airways (i.e., trachea/neck)	Possible	Possible
Uninterpretable	Persistent crying or other reason such that no full breath sounds heard	Yes	Yes
Stridor	May mimic high pitch wheeze	Primarily	Possible
Upper airway sound (not stridor)	May mimic low pitch wheeze or have a "snorting" quality, can be vocalization other than cry	Possible	Possible
Crying, non-persistent	Crying or screaming with full breath sounds between episodes	Possible	Primary

4. Oxygen Saturation and Heart Rate

The proportion of oxygen in the blood is called the **oxygen saturation**. When there is a reduced amount of oxygen in the blood, or low oxygen saturation, this is called **hypoxemia**. Hypoxemia is a very serious condition as oxygen is vital for the body to function properly.

- Normal oxygen saturation is between 93 – 100%
- Moderate hypoxemia is between 90 – 92%
- Severe hypoxemia is less than 90%

The heart rate is number of times the heart beats per minute. Having a fast heart rate or a low heart rate can indicate that a child is sick, but for different reasons. A slow heart rate (**bradycardia**) is a sign of being very sick in most children. A fast heart rate (**tachycardia**) is a common sign in children with infections. The table shows ranges for slow, normal and fast heart rates, which change according to age.

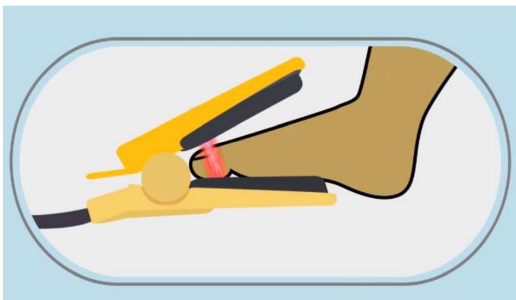
Age group	**Low heart rate**	**Normal heart rate**	**High heart rate**
<1 year	<110	110 – 160	>160
1-2 years	<90	90 – 140	>150
2-5 years	<85	85 – 140	>140

Oxygen saturation and heart rate are measured using a **pulse oximeter**. A pulse oximeter works by passing a light through the skin, which then detects how much oxygen is in the blood and how often the heart beats. To take a measurement, the ‘probe’ (a clip which attaches to the child) is placed on the child’s big toe or finger, with the light passing through the nail.

For children <1 month use the paediatric clip on the BIG TOE

For children < 2 years or <10kg use the BIG TOE

For children > 2 years or >10kg use the BIG TOE or FINGER



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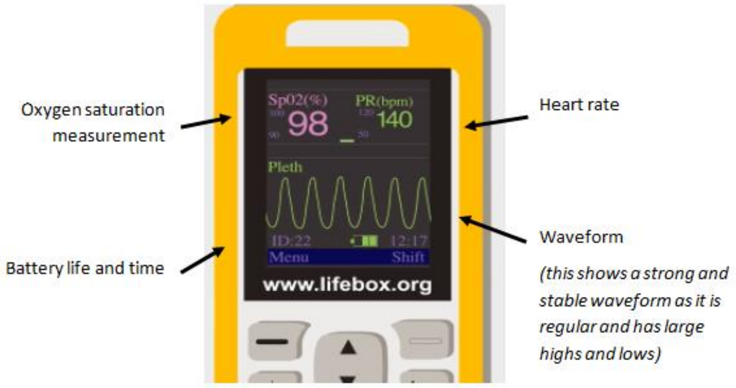


On the oximeter box you will see the result for the oxygen saturation (SpO_2), heart rate (PR) and the waveform (pleth). It will take at least 10 seconds to see a measurement as the machine needs to gather some data. If the child is calm, not moving and the probe is placed well, it should take less than one minute to get a measurement, but if the child is agitated or it is hard to place the probe well (e.g. the child is curling their toes) it can take a few minutes. Before accepting a measurement, follow these rules:

- Use the TOE as the preferred place of measurement
- Open the probe WIDE and place the probe over the toe such that the RED light is on the top of the toe nailbed
  - Note: the end of the toe should reach the end of the clip probe
- HOLD the foot gently but firmly as pictured below, DO NOT let go of the foot!
  - Note: if measuring the LEFT TOE, hold with your LEFT HAND such that your hand is supporting the foot and the toe and probe are resting in your palm as pictured below
- Wait for the oxygen saturation and heart rate to stabilise
  - The oxygen saturation number should NOT change for at least 3 seconds
  - The heart rate WILL change constantly, but SHOULD be plausible (see guidance above)
- Wait for the waveform to be strong (large and distinct waves) and stable (waves are consistent) for a minimum of 3 seconds (same time period as the oxygen saturation number); see examples below
- Wait for the oxygen saturation and heart rate to be biologically plausible
  - For example, an oxygen saturation of <80% is very rare and the child would be very sick, so if you see this for a child that is able to run around, this is probably a mistake. Check the position of the probe and then wait to see if it changes.
- Wait for the child to be calm
  - If a child is crying this can make the oxygen saturation lower than it really is
  - Note: Allow the child to BREAST FEED if this is both culturally appropriate and the child is still breast feeding.

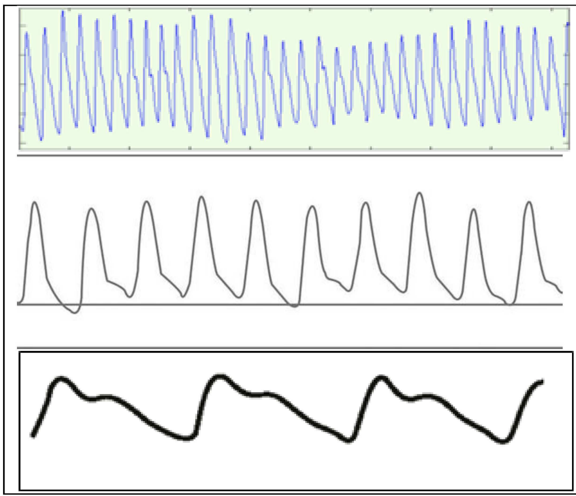
Key point: This is the ONLY part of the respiratory examination when children are encouraged to breast feed.

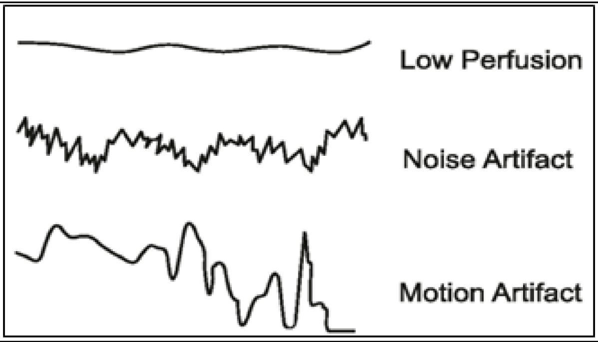
Here are some tips to getting a good measurement:

- Clean the toe or finger– dirt or nail polish can block the light from passing through the nail
- Place the probe on the caregiver to show them it doesn't hurt and explain what you are doing
- Support the foot with one hand to keep it stable
- Position yourself instead of making the child move to try and keep them calm
- Ask the mother to breastfeed the child to calm them down or to hold the probe
- Use a toy or pen to distract the child
- Make sure the foot or hand is not too cold as this means there will not be enough blood

Example for TOE measurement

Pulse oximeter waveform examples

	Good quality pulse oximeter wave forms. Note all are regular and consistent with a distinct wave.

<table>
<tr>
<td>
</td>
<td>Bad quality pulse oximeter wave forms. DO NOT record the oxygen saturation if this waveform is present.</td>
</tr>
</table>

<u>5. Temperature</u>

The temperature is measured using a **thermometer** and is measured by putting it under the child's arm in the armpit. A common reaction to any illness is for the body temperature to increase. This is called fever. A normal body temperature is 36.5 degree Celsius, but body temperatures can vary from 30 to 45 degrees, although these extremes are very rare. A fever is defined as a temperature of over 37.5 degrees. If the temperature goes above 40 degrees, this can be life threatening and means the child is seriously ill.

<u>6. Danger Signs – part 2 (measure)</u>

For these danger signs, only some will require a physical examination of the child, but others will rely on asking the caregiver if the child has had any of these symptoms. Therefore, it is important to make sure you understand them and that the caregiver understands what is being asked as well. The definitions of each sign are:

> ***Vomiting everything:*** A child who is not able to hold anything down at all. What goes down comes back up. A child who vomits everything will not be able to hold down food, fluids or oral drugs. A child who vomits several times but can hold down some fluids does not have this danger sign. An oral challenge test should be failed in order to meet this definition.
>
> ***Not able to feed or drink***: the child is not able to suck or swallow when offered a drink or breast milk. Check the child's nose is not blocked, as this will affect the child's ability to suck and swallow. An oral challenge test should be failed in order to meet this definition.
>
> ***Difficult to wake / Lethargic / Unconscious***: A lethargic child is not awake and alert when they should be. The child is drowsy and does not show interest in what is happening around him. Often the lethargic child does not look at his mother or watch your face when you talk. The child may stare blankly and appear not to notice what is going on around him. An unconscious child cannot be wakened. They do not respond when touched, shaken or spoken to.

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7. Anthropometry

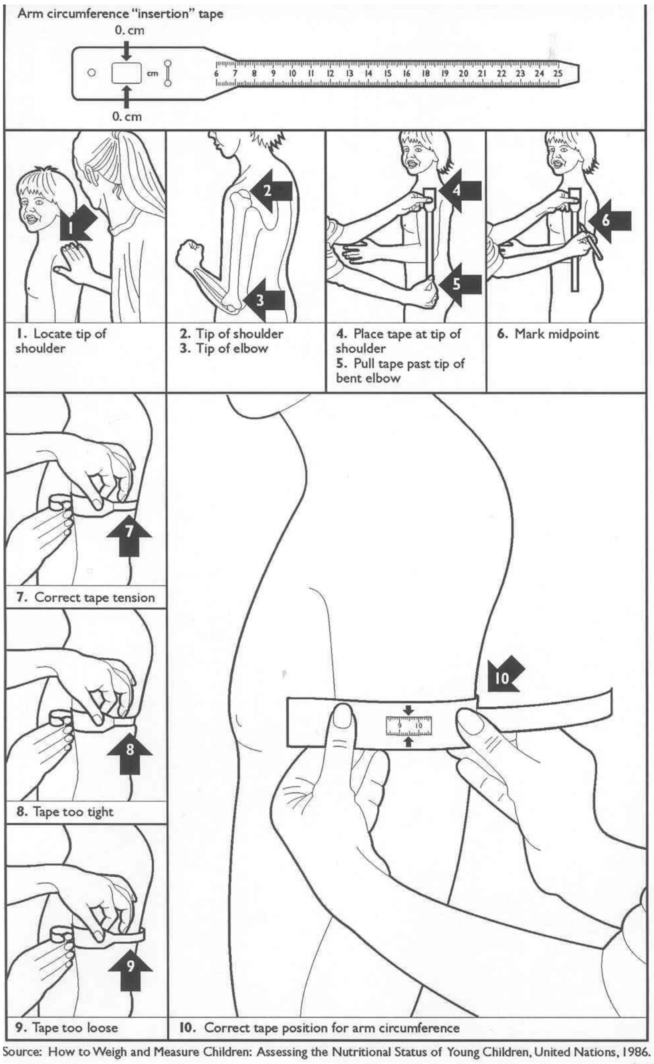
We will use two measurements to assess the child's growth and nutritional status – weight for age z-scores and the mid-upper arm circumference (MUAC).

Weight

Weight will be measured using a scale. For a child able to stand still unaided (2 years and above) they should stand on the scale. For younger children, they should be placed on the scale in the basket. The weight will be given in kilograms.

MUAC (mid-upper arm circumference)

The MUAC measurement will be taken using the specific MUAC tape (with the colour coding). Use a piece of string to find the mid-point between the top of the shoulder and the bottom of the elbow (when the arm is bent to 90 degrees), and then take the MUAC measurement when the child's arm is straightened and hanging loosely on the side. Measurements should always be taken on the **LEFT** arm.



Source: How to Weigh and Measure Children: Assessing the Nutritional Status of Young Children, United Nations, 1986.

Appendix 2: Variable definitions and cleaning notes

Variable	Definition	Cleaning notes
Pneumonia[13]	*Pneumonia (non-severe)*: cough and/or difficult breathing AND fast breathing for age AND/OR chest indrawing *Severe pneumonia*: cough and/or difficult breathing AND general danger sign* OR hypoxaemia (SpO2<90%) OR stridor in a calm child	Missing data for danger signs were assumed to be 'no'
Alternative pneumonia definition	*Pneumonia (non-severe)*: (cough and/or difficult breathing AND fast breathing for age) OR chest indrawing OR very fast breathing *Severe pneumonia*: (cough and/or difficult breathing OR very fast breathing OR chest indrawing) AND general danger sign* OR hypoxaemia (SpO2<90%) OR stridor in a calm child	Missing data for danger signs were assumed to be 'no'
Malnutrition	*Moderate malnutrition*: MUAC of 115-125mm *Severe malnutrition*: MUAC<115mm OR oedema	Only generated for children aged 6-59 months
Crowding	Crowding is defined as more than three people per habitable room, as set by UN-Habitat.[14] The variable was created by dividing the total number of residents in the compound, by the total number of rooms, as reported by the Head of Compound.	Compounds with more than 30 separate dwellings were excluded.
Water and sanitation	Improved water source is defined as access to a protected water source (i.e. piped water, well and pump, and borehole); unimproved water source included open wells, rivers and lakes. Improved sanitation is defined as use of a private toilet facility, such as a flush toilet and household pit latrine. Unimproved sanitation includes: shared pit latrine, and open defecation.	'Don't know' responses to either water source or toilet facility were excluded.
Wealth quintile	Principal components analysis was used to generate a compound Wealth Index, which was split into quintiles, with the bottom 20% having the lowest wealth. The wealth index used the following asset ownership: radio, phone, bicycle, motorbike, car, animal cart, TV; land ownership; animal ownership; electricity access.	Missing data was assumed to be 'no', with all participants retained.
Occupation	Occupation of the Head of Compound, as self-reported by the Head of Compound, or their representative.	'Don't know' responses were excluded.
Education	The highest level of education attained by the Head of Compound, as self-reported by the Head of Compound, or their representative.	'Don't know' responses were excluded.

*General danger signs included: unable to feed/drink; vomiting everything; convulsions; sleepy/lethargic; unconscious.

Appendix 3: Clinical presentation of hypoxaemia children

Child	Age (month)	Sex	Spo2 (%)	Heart rate (bpm)	Respiratory rate*	Chest indrawing	Temperature (°C)	Malnutrition	Danger sign	Noisy breathing
1	0	Male	88	136	64 (fb)	No	36.7	-	No	No
2	6	Female	59	115	37	No	35.3	Well nourished	No	No
3	9	Male	83	111	44	No	36.3	Moderate malnutrition	Yes	No
4	12	Male	82	98	38	No	36.4	Well nourished	No	No
5**	15	Male	88	140	50 (vfb)	No	36.5	Severe malnutrition	No	No
6	22	Female	86	100	48 (fb)	No	35.5	Moderate malnutrition	No	No
7	25	Male	66	87	28	No	35.9	Well nourished	No	No
8	48	Male	84	120	26	No	36.2	Moderate malnutrition	No	No

*Children with WHO defined fast breathing are indicated with (fb) and very fast breathing with (vfb).

**Child was classified as pneumonia using the alternative definition.

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Appendix 4: Sensitivity analysis and description of cases using the alternative pneumonia definition

We used an alternative pneumonia definition, which did not rely on caregiver's reporting of cough and/or difficult breathing, assuming the presence of very fast breathing for age and/or the presence of chest indrawing to be more reliable indicators of respiratory symptoms. With this definition the overall point prevalence of pneumonia was 2.8% (n=258/9171), with 0.6% (n=59/9171) having severe pneumonia and 2.2% (n=199/9171) having pneumonia. The prevalence was the same across age groups (p-value=0.814), and child sex (p-value=0.280).

Abnormal respiratory sounds were recorded in 18.1% (n=36/199) of those with pneumonia and 54.2% (n=32/59) with severe pneumonia. Overall, one case of pneumonia using this definition was hypoxaemic (1/258, 0.4%), and 7.8% (n=20/258) were moderately hypoxaemic.

		Pneumonia outcome model using alternate definition (n=9,067)					
Child factors		**N**	**(%)**	**aOR**	**95% CI**		**p-value**
Child age	<2 months	10	(2.4%)				
	2-11 months*	54	(3.0%)	1.41	(0.65	3.08)	0.389
	12-59 months	194	(2.8%)	1.21	(0.58	2.53)	0.610
Child sex	Girl	117	(2.6%)	1.00			
	Boy	141	(3.0%)	1.18	(0.88	1.58)	0.258
Compound factors							
Wealth quintile	Lowest	35	(2.7%)	1.00			
	Lower	46	(2.9%)	1.11	(0.62	2.01)	0.720
	Middle	33	(1.9%)	0.70	(0.37	1.30)	0.254
	Higher	58	(2.7%)	1.09	(0.62	1.94)	0.757
	Highest	78	(3.4%)	1.59	(0.89	2.85)	0.118
Water	Unprotected source	24	(2.5%)	1.00			
	Protected source	226	(2.8%)	1.12	(0.63	2.00)	0.702
Toilet	Open defecation	25	(2.7%)	1.00			
	Access to any facility	225	(2.8%)	0.95	(0.54	1.68)	0.868
Crowding	<3 people per room	106	(2.4%)	1.00			
	>=3 people per room	144	(3.0%)	1.28	(0.91	1.81)	0.156
Head of Compound Education	No education	29	(1.6%)	1.00			
	Informal/religious	178	(3.2%)	2.37	(1.41	3.96)	0.001
	Primary	18	(2.8%)	2.10	(0.95	4.63)	0.066
	More than primary	25	(2.7%)	1.66	(0.80	3.45)	0.177
Head of Compound Occupation	Subsistence farmer	113	(2.9%)	1.00			
	Manual labour	39	(3.6%)	1.33	(0.80	2.23)	0.275
	Business/professional	87	(2.4%)	0.75	(0.51	1.12)	0.167
	Not working	11	(2.9%)	0.99	(0.38	2.58)	0.988
		Likelihood ratio test (p-value) = <0.001 *Compound level intra-cluster correlation = 0.483*					

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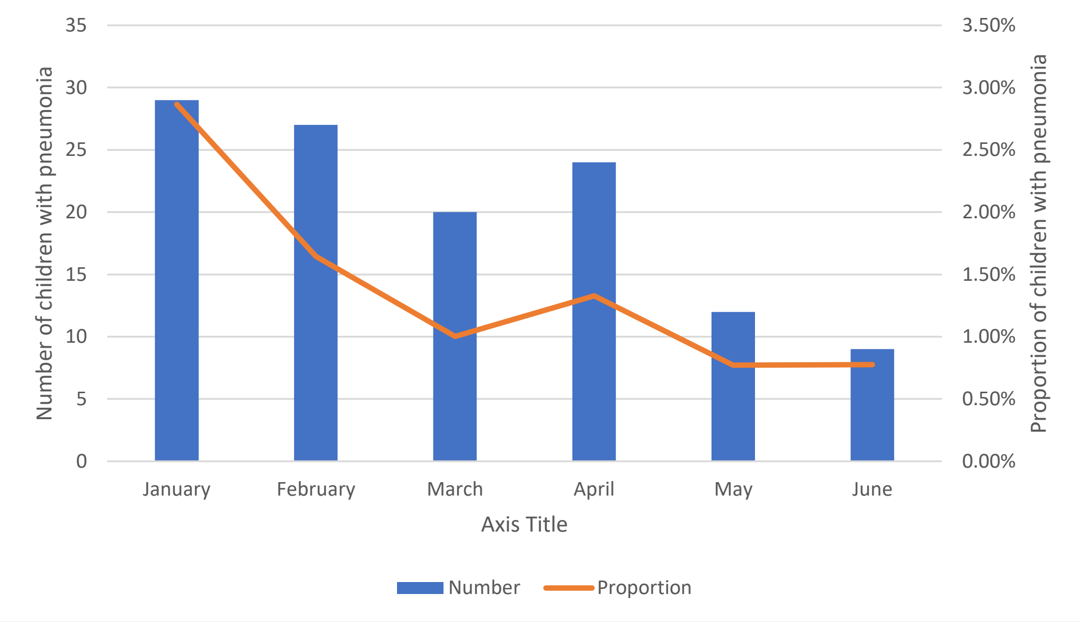
Appendix 5: Multinomial logistic regression model, to estimate associations between child and compound factors with categorical malnutrition status

		Moderate malnutrition (n=894)			Severe malnutrition (n=319)		
		aRR	95% CI	p-value	aRR	95% CI	p-value
Child age	6-11 months	1.00			1.00		
	12-59 months	0.36	(0.30 0.43)	<0.001	0.42	(0.32 0.59)	<0.001
Child sex	Girl	1.00			1.00		
	Boy	0.80	(0.69 0.92)	0.002	0.79	(0.63 1.02)	0.072
Wealth quintile	Lowest	1.00			1.00		
	Lower	0.92	(0.69 1.23)	0.578	1.34	(0.82 2.26)	0.230
	Middle	1.17	(0.89 1.55)	0.262	1.35	(0.80 2.36)	0.253
	Higher	1.18	(0.90 1.55)	0.235	1.08	(0.64 1.93)	0.697
	Highest	1.04	(0.78 1.38)	0.812	1.23	(0.73 2.13)	0.411
Water	Unprotected source	1.00			1.00		
	Protected source	1.11	(0.86 1.45)	0.421	1.55	(0.93 2.54)	0.090
Toilet	Open defecation	1.00			1.00		
	Access to any facility	0.94	(0.73 1.21)	0.637	1.13	(0.72 1.76)	0.609
Crowding	<3 people per room	1.00			1.00		
	>=3 people per room	1.21	(1.02 1.45)	0.033	0.95	(0.69 1.32)	0.767
Head of Compound Education	No education	1.00			1.00		
	Informal education	1.53	(1.21 1.93)	<0.001	3.55	(2.29 5.51)	<0.001
	Primary	1.13	(0.78 1.65)	0.523	2.05	(1.00 4.22)	0.052
	More than primary	0.98	(0.69 1.40)	0.907	1.22	(0.62 2.41)	0.570
Head of Compound Occupation	Subsistence farmer	1.00			1.00		
	Manual labour	1.02	(0.76 1.37)	0.893	0.77	(0.46 1.28)	0.310
	Business/professional role	0.88	(0.72 1.07)	0.205	0.71	(0.49 1.03)	0.071
	Not working	0.72	(0.44 1.18)	0.190	0.51	(0.23 1.16)	0.110

Appendix 6: Number and proportion of children meeting case definition for pneumonia (non-severe or severe) in Jigawa household surveys from Jan-Jun 2021



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