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Beyond Food Insecurity: Multidimensional Determinants of Moderate and Severe Acute Malnutrition Among Children Aged 6–60 Months in Rural India—A Community-Based Case–Control Study

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ABSTRACT :

Background: Acute malnutrition remains a leading preventable cause of child morbidity and mortality in India. Most local evidence on its determinants is cross-sectional, so strengths of association are poorly quantified. We identified risk and protective factors for moderate (MAM) and severe (SAM) acute malnutrition among rural children aged 6–60 months.

Methods: We conducted a community-based, age-matched case–control study (January–October 2024) in Anganwadi catchment areas of a rural block in Karimnagar, using four-stage sampling (1 block, 2 primary health centres, 4 sub-centres, 28 Anganwadi centres). Cases (n = 133) were children with weight-for-length/height Z-score < −2 (WHO standards); controls (n = 133) had Z-scores between −2 and +2 and were selected from the same villages within the same age band (6–24 or 25–60 months). Exposures were collected by pretested questionnaire. Associations were assessed using χ^2 tests and crude odds ratios (OR); variables significant on univariate analysis entered a multivariable logistic regression to obtain adjusted ORs (aOR) with 95% confidence intervals (CI).

Results: In the final model, the strongest independent risk factors were indoor air pollution (aOR 8.7; 95% CI 5.9–17.3), birth interval ≤24 months (6.8; 3.3–12.3), low birth weight (4.65; 2.52–8.5), absent proper waste disposal (4.2; 2.3–7.3), unsafe hand-washing (4.14; 1.56–10.9), incomplete vitamin A supplementation (3.58; 1.4–8.8), non-use of a sanitary latrine (3.3; 1.89–5.4), and continued breastfeeding for <1 year (3.1; 1.7–5.7). Overcrowding, nuclear family, late breastfeeding initiation, non-exclusive breastfeeding, bottle feeding, failure to meet minimum dietary diversity, meal frequency and acceptable diet, untrained caregivers in infant and young child feeding (IYCF), and frequent illness were also independently associated (aOR 1.9–2.9). Higher socioeconomic status (0.33; 0.16–0.67), safe drinking water (0.35; 0.20–0.62) and normal vaginal delivery (0.44; 0.24–0.80) were protective. Sex, religion, parental occupation and type of housing were not associated.

Conclusions: Acute malnutrition in rural India is driven by a cluster of modifiable household-environment, maternal-birth and feeding-practice factors. Integrating clean-household-energy, sanitation and hygiene promotion, birth-spacing and low-birth-weight prevention, and IYCF counselling into Anganwadi and POSHAN Abhiyaan platforms may deliver the largest gains.

Keywords: acute malnutrition; wasting; severe acute malnutrition; case–control study; risk factors; infant and young child feeding; indoor air pollution; India

1. Introduction

Malnutrition encompasses undernutrition (wasting, stunting, underweight and micronutrient deficiencies), overweight and obesity, and diet-related non-communicable disease.[1,2] Undernutrition underlies a substantial share of deaths in children under five years, and children with severe acute malnutrition (SAM) face a markedly higher mortality risk than well-nourished peers.[5,22] Sustainable Development Goal 3.2 aims to reduce under-five mortality to at least 25 per 1,000 live births by 2030,[26] and SDG 2.2 targets the elimination of all forms of malnutrition. The 2025 edition of the UNICEF–WHO–World Bank Joint Child Malnutrition Estimates indicates that the world remains off track for the 2030 nutrition targets, with global wasting prevalence of roughly 6.6% in 2024.[3]

India carries a disproportionate share of this burden. In the National Family Health Survey 5 (NFHS-5, 2019–21), 35.5% of children under five were stunted, 19.3% wasted and 32.1% underweight, only modest improvements over NFHS-4 (38.4%, 21.0% and 35.1%, respectively; Figure 1).[4] Wasting

prevalence varied widely between states.[4] Despite the Integrated Child Development Services, Anganwadi network, Nutrition Rehabilitation Centres and the POSHAN Abhiyaan (launched March 2018),[25] acute malnutrition persists, and unidentified or under-addressed risk factors in the community are likely contributors.

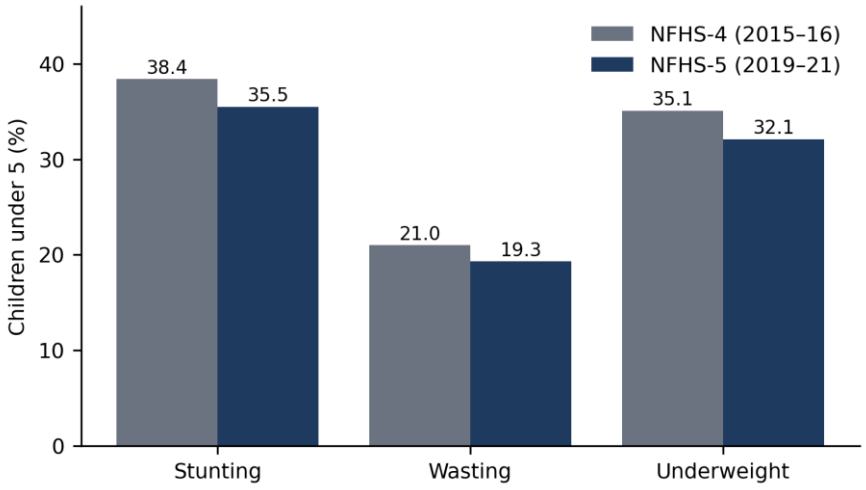


Figure 1. National trends in child undernutrition in India, NFHS-4 versus NFHS-5 (children under five years).[4]

Existing Indian studies of acute malnutrition determinants are predominantly cross-sectional or facility-based, which limits inference on the strength of association and may over-represent children who reach hospitals.[11,13,14,18] A community-based case–control design, with controls drawn from the same villages, can quantify associations while remaining logistically feasible. We therefore studied sociodemographic, environmental, maternal, nutritional and child-health factors associated with MAM and SAM in children aged 6–60 months in rural India and estimated the strength of each association.

Research question, hypothesis and objectives

Which factors are associated with MAM/SAM among rural children aged 6–60 months, and how strong are these associations? The null hypothesis was that exposure to these factors does not differ between children with and without MAM/SAM. The objectives were (i) to determine sociodemographic and epidemiological risk factors for MAM/SAM; (ii) to estimate the strength of association between these factors and MAM/SAM; and (iii) to suggest evidence-based recommendations.

2. Methods

2.1 Study design, setting and period

This was a community-based, age-matched case–control study, reported according to the STROBE statement.[28] It was conducted between January and October 2024 in a rural area of Karimnagar, India, through Anganwadi centres (AWCs).

2.2 Sampling and participants

Sampling proceeded in four stages (Figure 2): (1) one block was selected by simple random sampling from the ten blocks of the district; (2) two of the eight primary health centres (PHCs) in the block were randomly selected; (3) two sub-centres per PHC were randomly selected, yielding four sub-centres (population 38,542) served by 28 AWCs; and (4) cases and controls were recruited from all AWCs in these sub-centres until the target sample was reached.

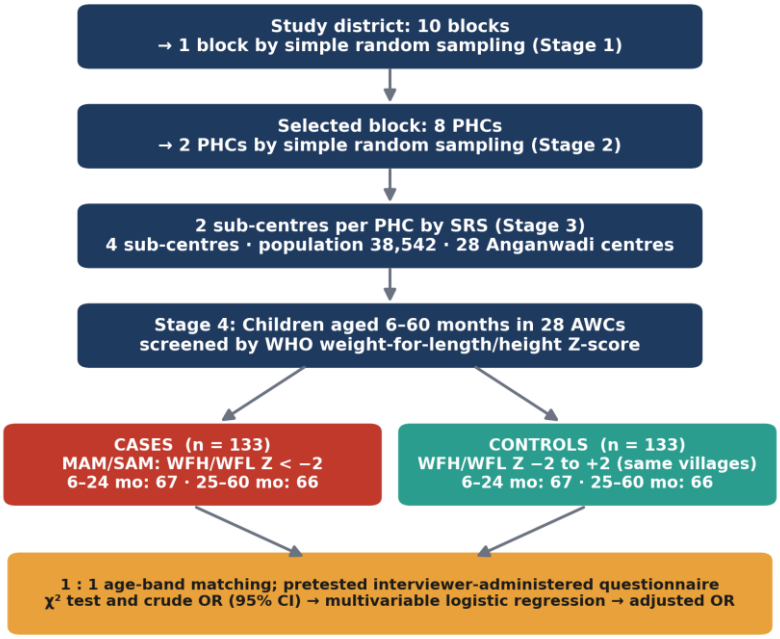


Figure 2. Four-stage sampling and participant selection (PHC, primary health centre; AWC, Anganwadi centre; WFH/WFL, weight-for-height/length).

Cases were children aged 6–60 months with weight-for-length/height Z-score < −2 on the WHO Child Growth Standards,[6] classified as MAM (−3 ≤ Z < −2) or SAM (Z < −3, MUAC < 115 mm, or bilateral pitting oedema).[1,6] Controls were children with Z-scores between −2 and +2 from the same villages and the same age band (6–24 or 25–60 months, aligned with IMNCI/NRC age grouping). Children with genetic illness, physical or mental disability, other major illness, or whose caregivers did not consent were excluded from both groups.

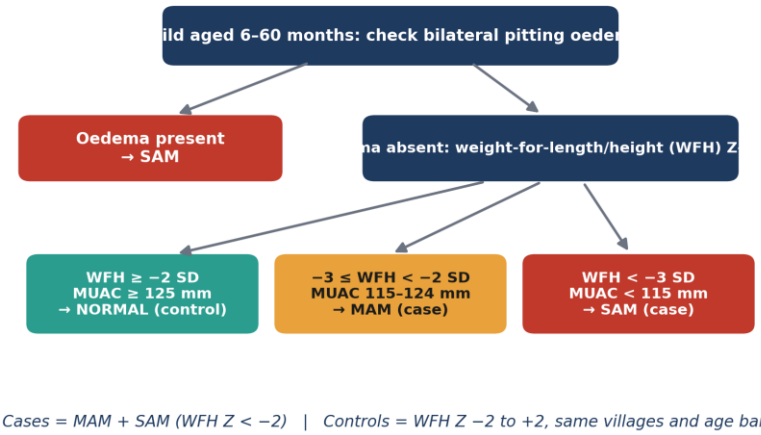
2.3 Sample size

Sample size for an unmatched case–control comparison was based on bottle feeding as the exposure in a reference case–control study,[11] with assumed exposure of 32% among cases and 16.5% among controls, 80% power, two-sided α = 0.05 and a 1:1 ratio. This was verified with OpenEpi version 3 and yielded a final sample of 266 children (133 cases and 133 controls).

2.4 Data collection and measurements

After permission from the district authority and institutional ethics committee approval, trained investigators conducted face-to-face interviews with parents/caregivers using a pretested, semi-structured questionnaire (local language and English) covering sociodemographic and housing characteristics, antenatal and delivery factors, feeding practices, birth weight, immunisation, and recent morbidity. Weight was measured to 0.1 kg with a calibrated digital scale; length (<24 months, lying) or height (standing) with a length board or stadiometer; and mid-upper arm circumference (MUAC) of the left arm with Shakir's tape. Bilateral pitting oedema was assessed by firm thumb pressure on both feet for three seconds. The anthropometric classification algorithm is summarised in Figure 3.

Figure 3. Anthropometric classification algorithm used to identify normal, MAM and SAM children (WHO criteria).



2.5 Operational definitions

Socioeconomic status and parental education/occupation were classified using the modified Kuppuswamy scale. Safe hand-washing meant washing with soap and water at critical times. Infant and young child feeding (IYCF) indicators—early initiation of breastfeeding (within one hour of birth), exclusive breastfeeding (first six months), minimum dietary diversity (MDD), minimum meal frequency (MMF) and minimum acceptable diet (MAD)—followed WHO/UNICEF definitions.[7] Low birth weight (LBW) was <2,500 g. Frequent illness was ≥2 episodes of acute respiratory infection, diarrhoea or fever in the preceding six months.

2.6 Statistical analysis

Data were entered in Microsoft Excel 2019 and analysed using IBM SPSS Statistics v21. Categorical variables are presented as frequencies and percentages and continuous variables as mean ± SD. Differences between cases and controls were tested with the χ^2 test, and crude ORs with 95% CIs were computed for every exposure. Variables significant at $p < 0.05$ on univariate analysis were entered together into a multivariable logistic regression model[29] to estimate adjusted ORs; variables retaining significance were considered independent risk (aOR > 1) or protective (aOR < 1) factors. Two-sided $p < 0.05$ denoted statistical significance.

3. Results

3.1 Participants and sociodemographic characteristics

A total of 266 children were enrolled (133 cases, 133 controls), with identical age distributions by design (67 aged 6–24 months and 66 aged 25–60 months in each group). Sex, religion, father's education, maternal occupation, paternal addiction and type of housing did not differ between groups (Table 1). Cases were more likely to belong to lower-middle and lower socioeconomic classes (Figure 4) and to nuclear families.

Table 1. Sociodemographic characteristics of cases and controls (n = 266)

Characteristic	Cases n (%) (n = 133)	Controls n (%) (n = 133)	p-value (χ^2)
Sex			
Male	63 (47.4)	55 (41.4)	0.32
Female	70 (52.6)	78 (58.6)	
Religion			
Hindu	66 (49.6)	74 (55.6)	0.73
Muslim	42 (31.6)	36 (27.1)	
Buddhist	22 (16.5)	19 (14.3)	
Others	3 (2.3)	4 (3.0)	
Socioeconomic class (modified Kuppuswamy)			
Upper	8 (6.0)	30 (22.6)	<0.001
Upper-middle	16 (12.0)	29 (21.8)	
Middle	24 (18.0)	24 (18.0)	
Lower-middle	53 (39.8)	36 (27.1)	
Lower	32 (24.1)	14 (10.5)	
Type of family			
Nuclear	86 (64.7)	58 (43.6)	0.003
Joint	22 (16.5)	36 (27.1)	
Three-generation	25 (18.8)	39 (29.3)	
Father's education			
Illiterate	26 (19.5)	21 (15.8)	0.14
Primary	26 (19.5)	28 (21.1)	
Middle	23 (17.3)	11 (8.3)	
High school	24 (18.0)	31 (23.3)	
Intermediate	11 (8.3)	22 (16.5)	
Graduate	12 (9.0)	11 (8.3)	
Postgraduate	11 (8.3)	9 (6.8)	
Mother's education			
Illiterate	34 (25.6)	22 (16.5)	<0.001‡
Primary	26 (19.5)	21 (15.8)	
Middle	31 (23.3)	11 (8.3)	
High school	11 (8.3)	31 (23.3)	
Intermediate	22 (16.5)	28 (21.1)	
Graduate	5 (3.8)	12 (9.0)	
Postgraduate	4 (3.0)	8 (6.0)	
Paternal addiction			
Present	84 (63.2)	72 (54.1)	0.14
Absent	49 (36.8)	61 (45.9)	
Type of house			
Pucca	46 (34.6)	52 (39.1)	0.68
Semi-pucca	63 (47.4)	61 (45.9)	

Kuccha	24 (18.0)	20 (15.0)	

‡ Omnibus χ^2 across seven education categories ($\chi^2 = 27.1$, df = 6). In the dichotomised analysis, maternal education was not significant (OR 1.73; 95% CI 0.95–3.16) and was not carried into the multivariable model. Percentages may not sum to 100 because of rounding.

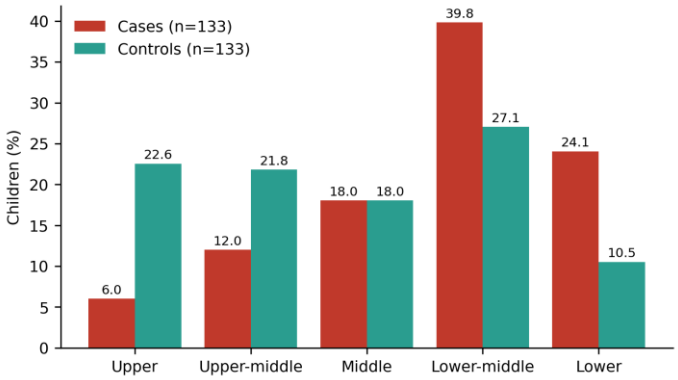


Figure 4. Socioeconomic class distribution among cases and controls (modified Kuppuswamy scale).

3.2 Univariate associations

Twenty-eight exposures were significantly associated with MAM/SAM on univariate analysis (Table 2). The largest crude associations were for indoor air pollution (OR 9.18), birth interval ≤24 months (7.39), improper waste disposal (3.91), low birth weight (3.65) and non-use of a sanitary latrine (3.14). Exposure prevalence for the most discriminating factors is shown in Figure 5. Birth order was not associated with MAM/SAM.

Table 2. Univariate (crude) associations of significant exposures with MAM/SAM

Exposure	Cases n (%)	Controls n (%)	Crude OR (95% CI)	p-value
Environmental and household				
Higher socioeconomic status (upper + upper-middle)	24 (18.0)	59 (44.4)	0.27 (0.15–0.48)	<0.001
Nuclear family	86 (64.7)	58 (43.6)	2.30 (1.44–3.87)	<0.001
Indoor air pollution	109 (82.0)	44 (33.1)	9.18 (5.19–16.25)	<0.001
No proper waste disposal	96 (72.2)	53 (39.8)	3.91 (2.34–6.54)	<0.001
Overcrowding	84 (63.2)	53 (39.8)	2.55 (1.57–4.24)	<0.001
Safe drinking water available	n/r†	n/r†	0.23 (0.15–0.42)	<0.001
No sanitary latrine use	65 (48.9)	31 (23.3)	3.14 (1.85–5.32)	<0.001
Unsafe hand-washing	81 (60.9)	53 (39.8)	2.35 (1.43–3.84)	0.001
Maternal and birth				
Maternal age ≤19 years	34 (25.6)	20 (15.0)	1.94 (1.04–3.58)	0.033
Normal vaginal delivery (ref. caesarean)	60 (45.1)	86 (64.7)	0.44 (0.27–0.73)	0.001
Birth interval ≤24 months (n = 105/91)	75 (71.4)	23 (25.3)	7.39 (3.90–13.90)	<0.001
Low birth weight	79 (59.4)	38 (28.6)	3.65 (2.29–6.09)	<0.001
Infant and young child feeding				
Late initiation of breastfeeding	32 (24.1)	16 (12.0)	2.31 (1.20–4.46)	0.011
Colostrum not given	43 (32.3)	28 (21.1)	1.79 (1.03–3.11)	0.038
Exclusive breastfeeding not given	n/r†	n/r†	2.02 (1.20–3.37)	0.007
Bottle feeding	57 (42.9)	36 (27.1)	2.02 (1.20–3.37)	0.007
Prelacteal feeding given	54 (40.6)	36 (27.1)	1.84 (1.10–3.10)	0.020
Continued breastfeeding <1 year (n = 109/109)	57 (52.3)	31 (28.4)	2.75 (1.50–4.80)	<0.001
No minimum dietary diversity	88 (66.2)	55 (41.4)	2.77 (1.60–4.56)	0.004
No minimum meal frequency	93 (69.9)	62 (46.6)	2.63 (1.60–4.40)	<0.001
No minimum acceptable diet	n/r†	n/r†	2.70 (1.60–4.50)	<0.001
No iron-rich/fortified food	103 (77.4)	88 (66.2)	1.75 (1.02–3.02)	0.041
Caregiver untrained in IYCF	90 (67.7)	72 (54.1)	1.77 (1.07–2.91)	0.020
Child health				
History of difficult feeding	26 (19.5)	12 (9.0)	2.45 (1.17–5.09)	0.014
Incomplete immunisation	35 (26.3)	17 (12.8)	2.40 (1.20–5.10)	0.005
Deworming not given (n = 109/109)	74 (67.9)	54 (49.5)	2.10 (1.20–3.70)	0.006
Incomplete vitamin A supplementation (n = 112/112)	50 (44.6)	32 (28.6)	2.01 (1.10–3.50)	0.012
Frequent illness (≥2 episodes/6 months)	55 (41.4)	34 (25.6)	2.05 (1.20–3.40)	0.006

OR, odds ratio; CI, confidence interval. Denominators are 133/133 unless stated. n/r†, cell counts under verification against source data; ORs as reported by the authors. Not significant (not tabulated): sex, religion, parental education and occupation, paternal addiction, type of house, birth order (all p > 0.05).

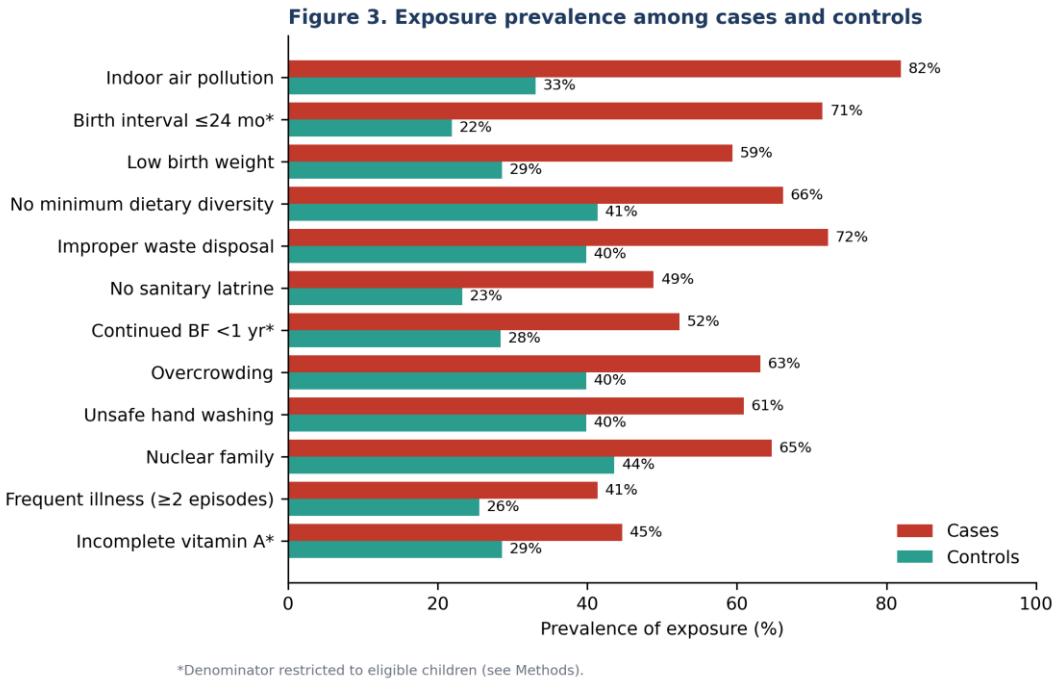


Figure 5. Prevalence of key exposures among cases (red) and controls (teal).

3.3 Multivariable analysis

After adjustment, 21 factors remained independently associated with MAM/SAM (Table 3, Figure 7). Indoor air pollution (aOR 8.7; 95% CI 5.9–17.25) and birth interval ≤24 months (6.8; 3.3–12.3) showed the strongest associations, followed by low birth weight (4.65), absence of proper waste disposal (4.2), unsafe hand-washing (4.14), incomplete vitamin A supplementation (3.58), non-use of a sanitary latrine (3.3) and continued breastfeeding for <1 year (3.1). Crude and adjusted estimates are compared in Figure 6. Higher socioeconomic status (aOR 0.33), safe drinking water (0.35) and normal vaginal delivery (0.44) were protective. Colostrum avoidance, prelacteal feeding, iron-rich food consumption, difficult feeding, immunisation status, deworming and maternal age lost significance after adjustment.

Table 3. Multivariable logistic regression: independent factors associated with MAM/SAM

Factor	Adjusted OR (95% CI)	p-value	Direction
Socioeconomic and household			
Higher socioeconomic status	0.33 (0.16–0.67)	0.002	Protective
Nuclear family	2.59 (1.24–5.40)	0.011	Risk
Indoor air pollution	8.70 (5.90–17.25)	<0.0001	Risk
Overcrowding	2.90 (1.70–4.70)	<0.001	Risk
Water, sanitation and hygiene			
Safe drinking water	0.35 (0.20–0.62)	<0.0001	Protective
Absence of proper waste disposal	4.20 (2.30–7.30)	<0.0001	Risk
Non-use of sanitary latrine	3.30 (1.89–5.40)	<0.0001	Risk
Unsafe hand-washing	4.14 (1.56–10.90)	0.004	Risk
Maternal and birth			
Normal vaginal delivery	0.44 (0.24–0.80)	0.007	Protective
Birth interval ≤24 months	6.80 (3.30–12.30)	<0.0001	Risk
Low birth weight	4.65 (2.52–8.50)	<0.0001	Risk
Infant and young child feeding			
Late initiation of breastfeeding	2.43 (1.10–5.27)	0.02	Risk
Exclusive breastfeeding not given	2.09 (1.10–3.90)	0.02	Risk
Bottle feeding	1.90 (1.10–3.50)	0.02	Risk
Continued breastfeeding <1 year	3.10 (1.70–5.70)	<0.001	Risk
No minimum dietary diversity	2.73 (1.60–4.60)	<0.001	Risk
No minimum meal frequency	2.63 (1.60–4.40)	<0.001	Risk
No minimum acceptable diet	2.45 (1.50–4.50)	<0.001	Risk
Caregiver untrained in IYCF	2.01 (1.15–4.22)	0.04	Risk
Child health			
Incomplete vitamin A supplementation	3.58 (1.40–8.80)	0.005	Risk
Frequent illness (≥2 episodes/6 months)	2.05 (1.20–3.40)	0.006	Risk

aOR, adjusted odds ratio. Reference categories: absence of the exposure, except where the protective factor is listed.

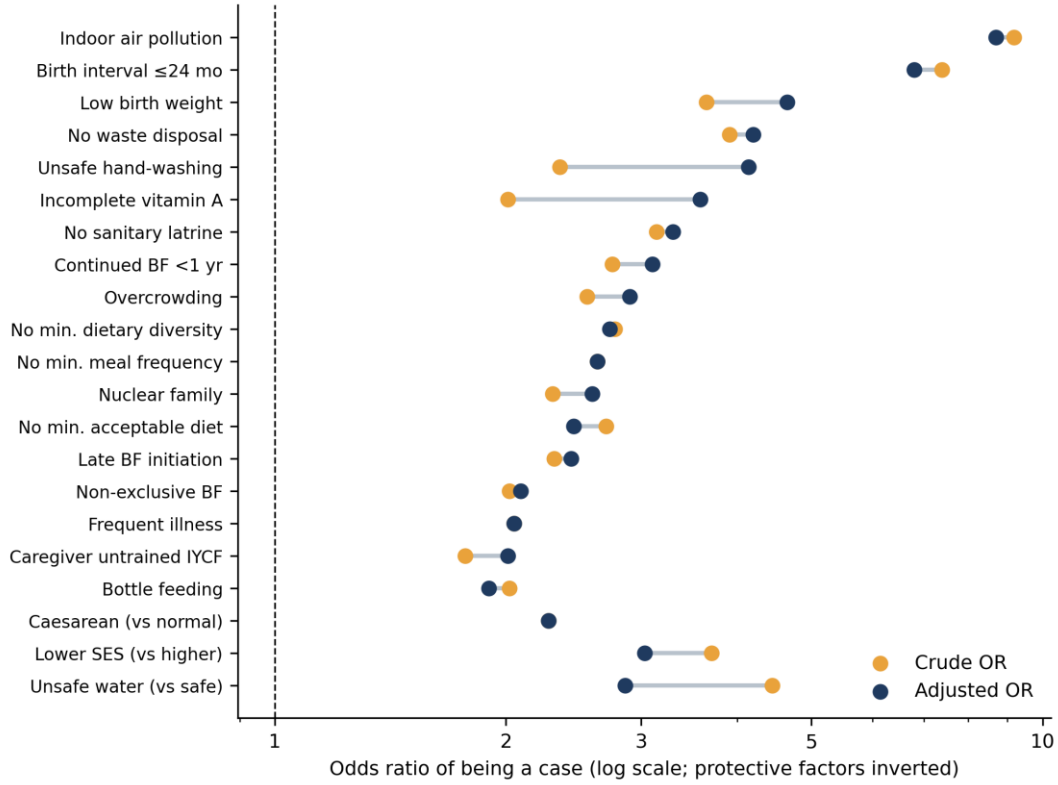


Figure 6. Crude versus adjusted odds ratios for factors in both analyses. Adjustment generally strengthened environmental and hygiene associations (e.g. hand-washing, vitamin A) and left feeding indicators largely unchanged.

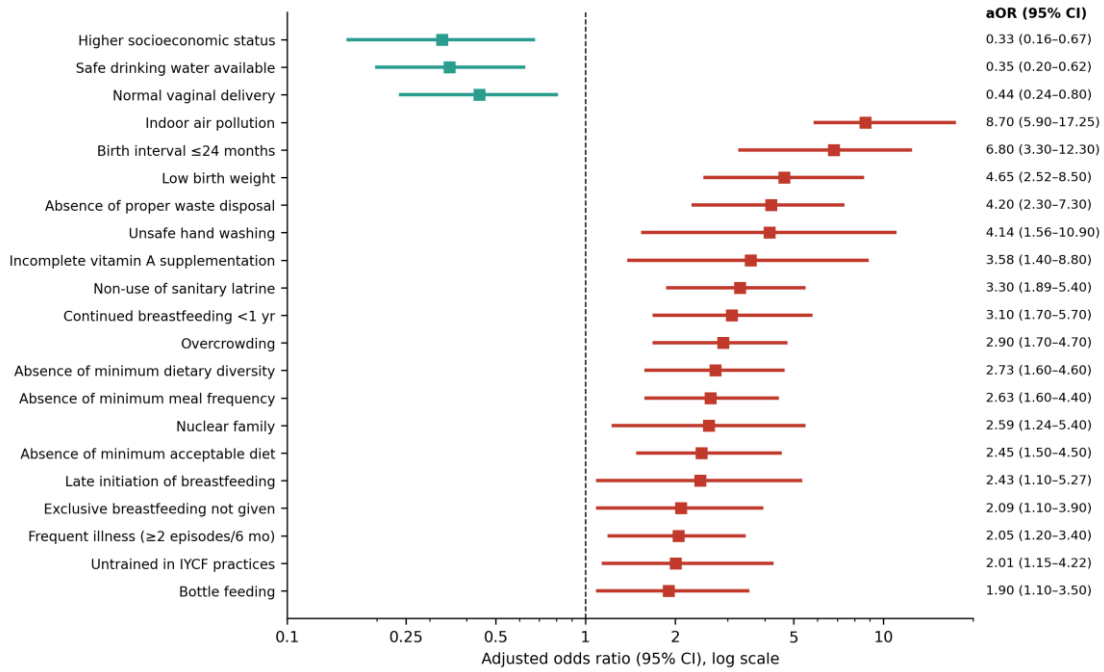


Figure 7. Forest plot of adjusted odds ratios (log scale). Teal, protective; red, risk factors.

4. Discussion

In this community-based case–control study, a cluster of modifiable household-environment, maternal-birth and feeding-practice factors independently predicted MAM/SAM in rural children, whereas child sex, religion, parental occupation and house type did not. The pattern (Figure 8) points to multi-sectoral drivers extending beyond food availability alone, consistent with the conceptual understanding of undernutrition as the end-product of inadequate diet, disease and underlying household, maternal and environmental constraints.[5,24]

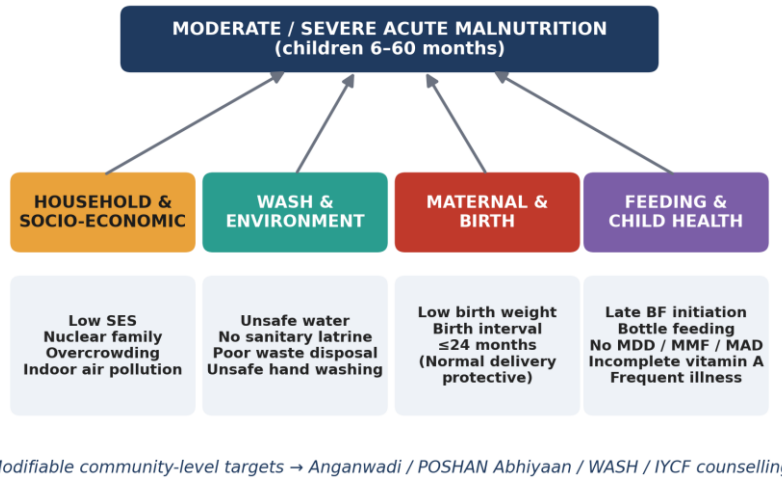


Figure 8. Conceptual framework summarising factors independently associated with MAM/SAM.

4.1 Household, socioeconomic and environmental factors

Higher socioeconomic status was strongly protective (aOR 0.33), in line with studies reporting a socioeconomic gradient in undernutrition in India and neighbouring countries.[19,20,21] Nuclear family structure was associated with a 2.6-fold higher odds, similar to the direction reported in rural Maharashtra,[8] possibly reflecting fewer caregivers available to support infant feeding and care. Indoor air pollution, largely from solid-fuel cooking, was the strongest association in our data (aOR 8.7). Although the interval is wide, the direction is biologically plausible through increased respiratory infection, reduced appetite and impaired growth, and it underlines clean cooking energy as an under-recognised nutrition intervention. Overcrowding, improper waste disposal, absence of a latrine, unsafe hand-washing and unsafe drinking water all carried significantly elevated odds. Ambadekar and Zodpey similarly reported higher odds of SAM with non-use of latrines and hand-washing without soap in rural Maharashtra,[8] and reduced faecal–oral exposure is a recognised pathway through which environmental enteropathy and repeated diarrhoea erode nutritional status.[5,20] Collectively, these findings support integrating water, sanitation and hygiene (WASH) with nutrition programming.

4.2 Maternal and birth factors

Low birth weight (aOR 4.65) and a short birth interval (aOR 6.8) were among the strongest risk factors, echoing evidence that intrauterine growth restriction and maternal depletion carry into early childhood undernutrition.[5,24] Short birth spacing was also associated with SAM in a hospital-based Karnataka study.[11] Normal vaginal delivery was protective relative to caesarean section, possibly through earlier breastfeeding initiation and fewer feeding difficulties; this association should be interpreted cautiously, as delivery mode may proxy for maternal or neonatal complications.

4.3 Feeding practices and child health

Delayed initiation of breastfeeding, non-exclusive breastfeeding, bottle feeding, stopping breastfeeding before one year, and failure to meet MDD, MMF and MAD each approximately doubled to tripled the odds of MAM/SAM, and children whose caregivers had not received IYCF training were also at higher risk. These findings reinforce WHO and UNICEF recommendations on early, exclusive and continued breastfeeding and on timely, adequate complementary feeding,[1,7] and agree with earlier work identifying bottle feeding and feeding practices as determinants of SAM.[11,12,14] Incomplete vitamin A supplementation (aOR 3.58) and frequent illness (aOR 2.05) highlight the bidirectional relationship between infection and malnutrition, in which each worsens the other.[5,17] Bhadoria et al. reported a male excess in SAM in northern India,[13] but we found no sex difference, indicating that sex-specific effects may vary across settings.

Table 4. Comparison of selected findings with previous Indian studies

Factor	This study	Previous study	Agreement
Nuclear family	aOR 2.59 (1.24–5.40)	OR 1.2 [8]; OR 1.52 [13]	Consistent
Non-use of sanitary latrine	aOR 3.30 (1.89–5.40)	OR 4.4 (1.8–10.8) [8]	Consistent
Unsafe hand-washing	aOR 4.14 (1.56–10.90)	OR 4.7 (2.1–10.7) [8]	Consistent
Caesarean delivery	OR 2.27 (crude)	OR 1.5 [8]	Consistent
Short birth interval	aOR 6.80 (3.30–12.30)	Significant association [11]	Consistent
Lower socioeconomic class	aOR 0.33 for higher class	OR 1.89 for middle/lower class [13]; significant [12]	Consistent
Kuccha house	No association	OR 3.4 (2.3–3.9) [8]	Inconsistent
Male sex	No association	OR 1.52 (1.24–1.86) [13]	Inconsistent

Comparator estimates are as reported in the cited studies; study settings, designs (hospital-based, survey or case–control) and outcome definitions differ.

4.4 Public-health implications

Several of the strongest associations are amenable to existing platforms. Anganwadi workers, ASHAs and village health and nutrition days can deliver (i) IYCF counselling for caregivers, (ii) birth-spacing and antenatal counselling, (iii) vitamin A supplementation and deworming, and (iv) household WASH and clean-fuel promotion, within the framework of POSHAN Abhiyaan (Figure 9, Table 5).[25] Early identification of low-birth-weight infants and targeted follow-up could also reduce progression to acute malnutrition.

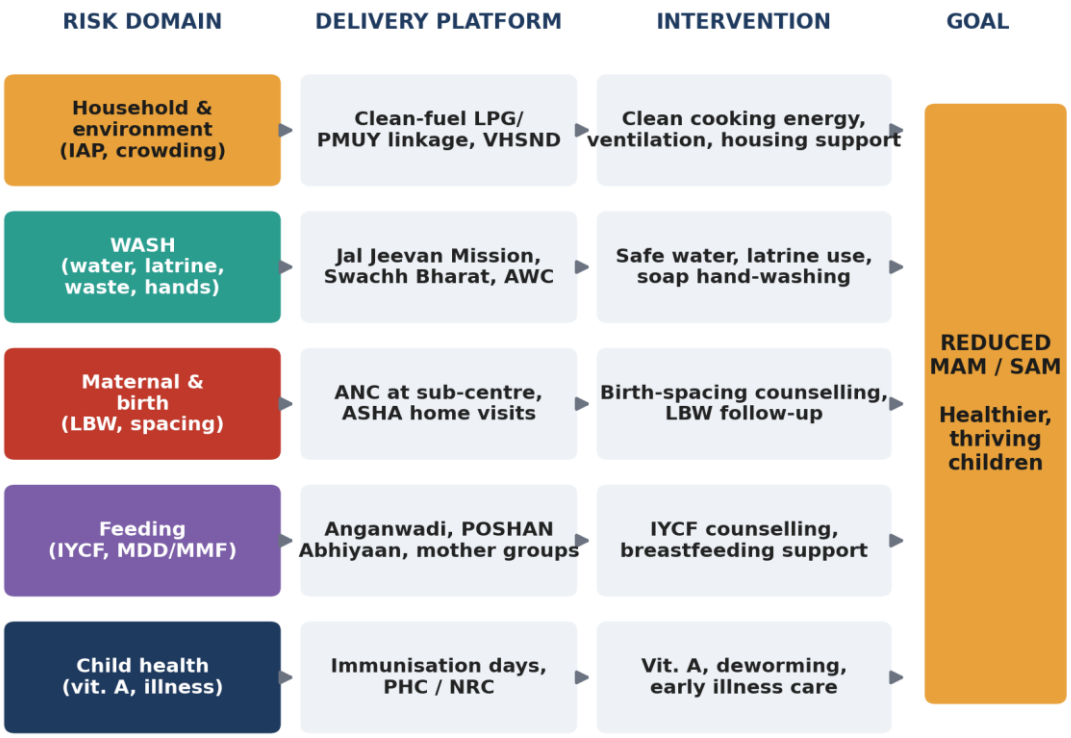


Figure 9. Proposed action pathway linking modifiable risk domains to existing delivery platforms and programme interventions.

Table 5. Priority actions derived from adjusted associations

Factor	aOR	Suggested action	Platform
Indoor air pollution	8.7	Clean-fuel linkage (PMUY/LPG), ventilation advice	Household-level
Short birth interval	6.8	Postpartum family-planning counselling	ASHA, ANC clinics
Low birth weight	4.65	Antenatal nutrition, LBW follow-up register	Sub-centre, AWC
Waste disposal / latrine / hand-washing	3.3–4.2	Village sanitation drives, soap hand-washing demonstrations	Gram Panchayat, AWC
Incomplete vitamin A	3.58	Biannual vitamin A and deworming rounds	VHSND, PHC
Feeding practices (MDD, MMF, MAD, BF)	1.9–3.1	IYCF counselling, mother support groups	Anganwadi, POSHAN Abhiyaan

Priorities are ordered by strength of association and programmatic feasibility; causal effect sizes should be confirmed in intervention studies.

4.5 Strengths and limitations

Strengths include community-based recruitment of cases and controls from the same villages, age-band matching, WHO-standard anthropometry with oedema assessment, a probability-based multistage selection of the study area, and multivariable adjustment. Limitations include recall bias in maternal reports of past feeding and illness; the case–control design, which cannot separate causes from consequences (reverse causation is plausible for feeding difficulty and frequent illness); a single-block setting that limits generalisability; combined analysis of MAM and SAM; and wide confidence intervals for some estimates (e.g. indoor air pollution, hand-washing), indicating imprecision. Matching on age bands, rather than individual age, and the use of unmatched analysis may also slightly bias estimates.

5. Conclusions

Acute malnutrition among rural Indian children aged 6–60 months is associated with modifiable factors across environmental, maternal and feeding domains. Clean household energy, safe water, sanitation and hand hygiene, short-interval pregnancy and low-birth-weight prevention, optimal

breastfeeding and complementary feeding, vitamin A supplementation and infection control should be prioritised within community nutrition programmes. Prospective studies and intervention trials are needed to confirm causality and quantify the population-level benefit.

Recommendations

- Strengthen mother and caregiver education on IYCF—early initiation, exclusive breastfeeding for six months, continued breastfeeding to ≥1 year and diverse complementary diets—through Anganwadi and ASHA platforms.
- Integrate WASH (safe water, sanitary latrine use, waste disposal, hand-washing with soap) and clean cooking-fuel promotion into nutrition programming.
- Provide antenatal counselling on birth spacing, prevention of low birth weight, and early identification and follow-up of low-birth-weight infants.
- Ensure complete immunisation, biannual vitamin A supplementation and deworming, with prompt management of childhood illness.
- Monitor under-five children regularly with community-based growth monitoring and MUAC screening for early detection.

Declarations

Ethics approval: Institutional Ethics Committee was obtained before commencement of study.
Consent: Written informed consent was obtained from parents/caregivers of all participants.
Funding: None
Conflicts of interest: None
Author contributions: AGA: conceptualisation, study design, supervision, data analysis, manuscript drafting. AA: data interpretation, literature review, manuscript revision. Both authors approved the final manuscript.
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