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Notification-mortality mismatch in acute malnutrition surveillance among children under five in Colombia: a national ecological and individual-level analysis, 2022-2024

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Abstract

Background. Acute malnutrition notification counts reflect both underlying need and the pathways by which children reach and are recorded by health services. We assessed whether municipal notification levels tracked registered undernutrition mortality, an independently produced marker of severe burden, in Colombia.

Methods. We conducted a nationwide ecological study at municipal level, with a complementary analysis among notified records. We analysed 24 017 acute-malnutrition notification records with a valid municipality of residence in 2024 (24 221 source records) and 916 registered undernutrition deaths with valid residence in 2022–2024 (959 source deaths) across 1122 municipal-level units. Global empirical Bayes estimators smoothed standardised notification and mortality ratios. Spatial clustering was assessed with Moran's I. Negative binomial models estimated deprivation gradients with department-cluster-robust confidence intervals. Municipalities with above-reference mortality and below-reference notification were labelled silent for screening. Among notification records, municipality-clustered logistic models examined hospitalisation at notification and delay over seven days.

Results. Mortality rose from 2.0 to 30.9 deaths per 100 000 child-years between the least and most deprived quintiles, while notification rose from 5.4 to 10.8 records per 1000 children. The adjusted incidence rate ratio for the most versus least deprived quintile was 22.31 (95% CI 8.89–55.98) for mortality and 2.16 (1.43–3.26) for notification. Notification records per death declined from 90 to 12. Ninety-three municipalities met the silent screening definition and contained 207 of 916 deaths. Smoothed notification and mortality ratios were spatially clustered (Moran's I 0.291 and 0.311; permutation p = 0.001). Among complete notification records, hospitalisation was associated with Indigenous ethnicity (odds ratio 1.86, 1.47–2.35), no insurance (2.59, 1.65–4.07), and migrant status (1.63, 1.16–2.31).

Conclusions. Notification increased with deprivation but much less steeply than registered undernutrition mortality. The resulting notification-mortality mismatch identifies municipalities for local validation and possible intensified case-finding, but it does not by itself estimate notification completeness or establish a causal detection failure.

Background

Wasting remains one of the largest contributors to preventable mortality in children under five worldwide, and its distribution within countries tracks structural inequality rather than national averages [1, 2]. In Colombia, child undernutrition persists as a marker of territorial and ethnic exclusion, concentrated in Indigenous, Afro-descendant and dispersed rural populations, and it has repeatedly reached the national political agenda following clusters of child deaths, with an estimated societal cost of some USD 60 million per year [3], in La Guajira and Chocó [4, 5].

Since 2016, moderate and severe acute malnutrition in children under five has been a mandatorily notifiable event, event 113, within the Colombian Public Health Surveillance System (Sistema de Vigilancia en Salud Pública, SIVIGILA), operationalised through Resolution 2465 of 2016 [6, 7]. Every notifying unit in the country is required to report children meeting anthropometric criteria, producing an annual, individually resolved, geographically coded record, published each year as an aggregate national event report [8], across the country's 1122 municipalities.

Colombian evidence on child undernutrition has developed along two largely separate lines. A first body of work has characterised mortality attributable to undernutrition using vital statistics, documenting persistent departmental disparities and rising rates in La Guajira, Vichada and Chocó [4, 9]. A second has examined determinants of malnutrition in local clinical or community samples, typically restricted to a single city, department or ethnic group [5, 10–13]. Both lines treat the surveillance record as a transparent window onto disease. Neither has interrogated the window itself.

This distinction matters because notified cases are not incident cases. A notification requires that a child reach a health service, that the service apply the anthropometric criteria correctly, and that the notifying unit report. Each of these steps is socially and geographically patterned, and each has been shown to fail selectively in other notifiable conditions and settings, with completeness ranging from a few per cent to over 80% across systems and diseases [14–17]. Under-reporting is consistently worse for children than for adults [18], and timeliness and completeness of routine weekly reporting are themselves unequal across territories within countries [19, 20]. Country-level analyses further show that underreporting is predicted by health-system preparedness rather than by disease frequency [21]. Consequently, the spatial distribution of notified cases confounds the distribution of disease with the distribution of health-system capacity.

Where undernutrition mortality is high but notification is low, the two routine systems are discordant. Such discordance is compatible with under-ascertainment but is not a direct estimate of completeness: differential case fatality, access to treatment, death certification, and temporal alignment can also contribute. Comparing registry counts with an independent source is conceptually related to established completeness methods [14–16]; here it is used as a screening signal rather than a capture–recapture estimator.

We therefore examined SIVIGILA event 113 as one component of a two-system surveillance signal. Our objectives were: (i) to estimate smoothed municipal notification and undernutrition-mortality rates and their spatial clustering; (ii) to quantify their associations with municipal deprivation and rurality; (iii) to identify municipalities combining above-reference mortality with below-reference notification as candidates for local review; and (iv) among notified records, to examine inequalities in hospitalisation at notification and notification delay.

Methods

Study design and setting

We conducted a nationwide ecological study at municipal level, with a complementary analysis among notified records. The study frame contained 1122 municipal-level territorial units, referred to as municipalities for readability, and 3 732 354 children under five in 2024. Colombia's health system includes contributory and state-financed subsidised insurance regimes. Reporting follows STROBE recommendations [22].

Data sources

Notification records. De-identified microdata for all event-113 notification records in epidemiological year 2024 (n = 24 221) were obtained from the SIVIGILA Web Portal on 23 July 2026 [23]. The surveillance protocol operationalises the anthropometric criteria of Resolution 2465 of 2016 [6, 7]. Anthropometric measurements are not included in the public release; eligibility reflects the notifying unit's recorded classification.

Deaths. DANE non-fetal death microdata for 2022, 2023, and 2024 were used [24]. Eligible deaths were in children under five whose underlying cause was E40–E46 or E64.0. A three-year window stabilised sparse municipal counts. Residence was the deceased child's usual residence, except that for infants the field records the mother's residence.

Denominators and contextual variables. Municipal population by area, sex, and single year of age came from DANE 2024 projections [25]. Rurality was the under-five share in populated centres and dispersed rural areas. The census-source MPI was available for 1121 of 1122 study units [26]; Nuevo Belén de Bajirá lacked MPI. The MGN 2024 municipality layer supplied 1121 polygons and also lacked Nuevo Belén de Bajirá [27].

Variables

Individual-level variables comprised age in completed months, sex, area of residence, self-reported ethnicity, health insurance regime, socio-economic stratum, migrant status, hospitalisation at notification, and days from reported symptom onset to notification. Hospitalisation was treated as an indirect severity and health-care-use outcome, not as a validated measure of late detection. Notification delay over seven days was the second outcome.

Statistical analysis

Municipal notification rates were per 1000 children in 2024 and mortality per 100 000 child-years over 2022–2024. Expected counts applied the corresponding national analytic-frame rate to each exposure. Global empirical Bayes rates used the Marshall method-of-moments estimator [28]; smoothed standardised ratios divided these rates by the national rate. The notification-mortality ratio was the smoothed notification ratio divided by the smoothed mortality ratio. A conditional autoregressive model was not fitted [29]; residual spatial autocorrelation is reported explicitly.

Spatial dependence was assessed with global Moran's I on a row-standardised first-order queen matrix using 999 random permutations [30]. San Andrés and Providencia were retained under a zero-neighbour policy. Municipal counts were modelled with NB2 regression; dispersion was estimated jointly. Offsets were log population for notification and log three-year child-years for mortality. Models included MPI quintile and rurality; 95% confidence intervals used a department-clustered sandwich estimator. Moran's I on Pearson residuals assessed remaining spatial pattern.

Municipalities were classified by crossing smoothed ratios at the national reference value of 1: silent (mortality > 1 and notification < 1), responsive (mortality > 1 and notification ≥ 1), and two low-burden categories (mortality ≤ 1). This was a screening rule rather than a diagnostic definition of under-reporting. Individual associations were estimated with marginal logistic regression using an independence working correlation and sandwich confidence intervals clustered by municipality. Models included age group, sex, area, ethnicity, insurance, observed stratum, migrant status, and municipal MPI; records with missing model variables were excluded. Analyses used Python 3.11 with a fixed permutation seed (20260731).

Sensitivity analyses

Nine analyses examined robustness: (i) mortality restricted to 2024; (ii) a broader death definition adding D50-D53 and P07; (iii) notification assigned to the notifying municipality; (iv) exclusion of the five largest cities; (v) Poisson rather than negative binomial models; (vi) stricter and laxer classification thresholds; (vii) median rather than national-reference thresholds; (viii) symptom-onset-date missingness across surveillance classes; and (ix) individual models excluding the five largest cities.

Data curation

Records were screened for invalid municipality codes, ages outside 0–59 months, and inconsistent dates. The 2024 population workbook contained Mapiripana (94663), labelled an Área No Municipalizada; it was outside the pre-specified MGN-2024-based municipal frame, absent from the municipality layer, and had no eligible notification or death. The final frame comprised 1122 units. Of 24 221 notification records, 24 017 (99.2%) had a residence code in this frame. Of 959 eligible undernutrition deaths, 916 (95.5%) had a valid residence code: 385 in 2022, 304 in 2023, and 227 in 2024. Blank socio-economic stratum was retained as missing (n = 524). No public identifier permitted linkage of repeat notifications; the unit is a notification record, not necessarily a unique child or episode.

Use of generative AI assistance

OpenAI ChatGPT/Codex was used in July 2026 to assist with English-language editing, code refactoring, and reproducibility checks. The authors specified the analyses, reviewed the source data, code, and outputs, resolved all identified discrepancies, and retain full responsibility for the manuscript.

Ethics

This secondary analysis used pre-existing, publicly available, de-identified administrative records. The authors had no access to direct identifiers, and no participants were recruited, contacted, or intervened upon. The authors classified the study as research without risk under Article 11[(a)] of Colombian Ministry of Health Resolution 8430 of 1993 [31]. No ethics committee review was sought or obtained. Individual informed consent was not applicable.

Results

Characteristics of notification records

The public 2024 file contained 24 221 notification records, of which 24 017 mapped to 989 study municipalities. Median age was 12 months (IQR 9–24); 60.7% were under two years and 14.3% under six months. Male records accounted for 56.0%. The subsidised regime accounted for 71.7%; among 23 697 records with observed stratum, 66.7% were stratum 1. Indigenous ethnicity was recorded in 19.8% and Afro-descendant ethnicity in 6.6%; 26.5% lived in dispersed rural areas. Overall, 29.0% were hospitalised at notification. Among 20 625 records with an onset date, 26.1% had a delay over seven days and 12.4% over 30 days; onset date was missing in 14.8% of all records.

Table 1
Characteristics of acute malnutrition notification records, Colombia, 2024

Characteristic	Category	n/N (%)	Hospitalised, %
Age group	< 6 months	3 474/24 221 (14.3)	46.8
Age group	6–11 months	4 324/24 221 (17.9)	35.6
Age group	12–23 months	6 902/24 221 (28.5)	31.4
Age group	24–35 months	4 180/24 221 (17.3)	20.8
Age group	36–47 months	2 945/24 221 (12.2)	16.1
Age group	48–59 months	2 396/24 221 (9.9)	14.7
Sex	Female	10 649/24 221 (44.0)	29.4
Sex	Male	13 572/24 221 (56.0)	28.7
Area of residence	Urban centre	15 589/24 221 (64.4)	26.8
Area of residence	Populated centre	2 215/24 221 (9.1)	26.0
Area of residence	Dispersed rural	6 417/24 221 (26.5)	35.4
Ethnicity	No ethnic affiliation	17 779/24 221 (73.4)	25.5
Ethnicity	Indigenous	4 801/24 221 (19.8)	42.1
Ethnicity	Afro-descendant	1 602/24 221 (6.6)	28.7
Ethnicity	Other	39/24 221 (0.2)	12.8
Insurance regime	Contributory	5 755/24 221 (23.8)	19.8
Insurance regime	Subsidised	17 359/24 221 (71.7)	31.1
Insurance regime	Uninsured	734/24 221 (3.0)	49.2
Insurance regime	Special or exception	373/24 221 (1.5)	35.1
Socio-economic stratum	1	15 814/23 697 (66.7)	30.9
Socio-economic stratum	2	6 125/23 697 (25.8)	26.1
Socio-economic stratum	3+	1 758/23 697 (7.4)	22.3
Migrant	Yes	517/24 221 (2.1)	42.4
Internally displaced	Yes	292/24 221 (1.2)	24.7
Notification delay	> 7 days	5 374/20 625 (26.1)	—
Notification delay	> 30 days	2 565/20 625 (12.4)	—
Missing data	Symptom-onset date missing	3 596/24 221 (14.8)	—
Missing data	Socio-economic stratum missing	524/24 221 (2.2)	—

Values are n/N (%) unless otherwise indicated. Socio-economic-stratum percentages exclude 524 missing records (N = 23 697). Delay percentages use the 20 625 records with a non-missing symptom-onset date. “Other” ethnicity combines Roma, Raizal, and Palenquero categories

Municipal notification and mortality

The analytic-frame notification rate was 6.43 per 1000 children under five. Mortality was 8.18 per 100 000 child-years, based on 916 valid-residence deaths: 385 in 2022, 304 in 2023, and 227 in 2024. Two hundred and forty municipalities recorded at least one death, and La Guajira contained 220 deaths (24.0%). No notification record was assigned to 133 municipalities; 127 also had no eligible death, whereas six had at least one death.

The smoothed ratios were spatially clustered. Moran's I was 0.291 for notification, 0.311 for mortality, and 0.136 for the notification-mortality ratio (all permutation p = 0.001; Fig. 1A-C).

Deprivation gradients

From the least to the most deprived quintile, mortality increased from 2.0 to 30.9 deaths per 100 000 child-years, whereas notification increased from 5.4 to 10.8 records per 1000 children (Table 2; Fig. 2). Notification records per death declined from 90 to 12, a 7.7-fold contrast.

Table 2
Municipal notification and mortality by deprivation quintile

MPI quintile	Municipalities	Median MPI	Children < 5	Notification rate	Mortality rate	Notification IRR (95% CI)	Mortality IRR (95% CI)	Records/death
Q1 (least deprived)	229	19.9	2 053 133	5.37	2.00	1 (reference)	1 (reference)	90
Q2	223	32.0	404 667	4.44	5.11	1.05 (0.87–1.27)	2.33 (1.61–3.36)	29
Q3	221	40.8	380 047	6.69	10.44	1.28 (1.04–1.59)	5.09 (3.02–8.60)	21
Q4	224	49.8	407 895	8.36	13.32	1.35 (1.00-1.81)	7.28 (4.25–12.46)	21
Q5 (most deprived)	224	64.3	483 899	10.81	30.93	2.16 (1.43–3.26)	22.31 (8.89–55.98)	12

Rates use aggregated counts and under-five denominators. Incidence rate ratios compare each quintile with Q1 in separate NB2 models adjusted for rural under-five share; alpha is estimated. Confidence intervals use a department-clustered sandwich estimator.

After adjustment for rurality, the incidence rate ratio for Q5 versus Q1 was 22.31 (95% CI 8.89–55.98) for mortality and 2.16 (1.43–3.26) for notification. Estimated NB2 dispersion was 1.817 and 0.449, respectively. Residual Moran's I remained 0.255 for mortality and 0.278 for notification (both p = 0.001), so these associations are descriptive and not fully spatially adjusted.

Notification–mortality classification

Ninety-three municipalities met the silent screening definition. They contained 386 658 children under five, 207 deaths (22.6% of the analytic total), and 1524 notification records (3.94 per 1000). The 104 responsive municipalities had a similar median MPI (54.4 versus 52.4) but 16.53 notification records per 1000 (Fig. 1C). The largest numbers of silent municipalities were in Bolívar and Magdalena (10 each), Córdoba (8), Cauca (7), and Cesar (6).

Table 3 lists the 20 silent municipalities with the highest crude mortality among those with at least 1000 children under five. Puerto Nariño recorded 74.1 deaths per 100 000 child-years and 5.19 notifications per 1000; Ciénaga recorded 14 deaths and 57 notifications; and Buriticá recorded one death and no notification. These comparisons are prioritisation signals requiring local validation.

Table 3
Silent municipalities with the highest undernutrition mortality

Municipality	Department	Children < 5	Deaths, 2022–2024	Mortality rate	Notifications, 2024	Notification rate	MPI
Puerto Nariño	Amazonas	1 350	3	74.1	7	5.19	70.4
Hato Corozal	Casanare	1 342	2	49.7	5	3.73	56.1
Distracción	La Guajira	1 418	2	47.0	4	2.82	40.2
Nueva Granada	Magdalena	2 396	3	41.7	15	6.26	66.4
Ciénaga	Magdalena	11 956	14	39.0	57	4.77	44.6
Nuquí	Chocó	2 566	3	39.0	12	4.68	72.9
La Virginia	Risaralda	1 733	2	38.5	10	5.77	19.0
Tierralta	Córdoba	10 612	11	34.6	58	5.47	63.8
Buriticá	Antioquia	1 020	1	32.7	0	0.00	51.3
El Retén	Magdalena	2 110	2	31.6	7	3.32	63.6
Puerto Escondido	Córdoba	2 195	2	30.4	5	2.28	67.9
Íquira	Huila	1 102	1	30.2	4	3.63	49.6
Juradó	Chocó	1 118	1	29.8	3	2.68	71.8
San Fernando	Bolívar	1 179	1	28.3	7	5.94	64.3
Ponedera	Atlántico	2 536	2	26.3	6	2.37	46.7
Manzanares	Caldas	1 292	1	25.8	6	4.64	37.5
San Onofre	Sucre	5 209	4	25.6	28	5.38	69.0
Patía	Cauca	2 648	2	25.2	2	0.76	44.1
Mahates	Bolívar	2 665	2	25.0	8	3.00	54.3
Bolívar	Valle del Cauca	1 368	1	24.4	7	5.12	29.7

Limited to silent municipalities with at least 1000 children under five. Silent is a screening definition: smoothed standardised mortality ratio > 1 and smoothed standardised notification ratio < 1.

Individual-level outcomes among notified records

Hospitalisation at notification declined with age: compared with infants under six months, adjusted odds ratios were 0.44 (95% CI 0.39–0.49) at 12–23 months and 0.19 (0.16–0.23) at 48–59 months. Hospitalisation was associated with Indigenous ethnicity (1.86, 1.47–2.35), no insurance (2.59, 1.65–4.07), the subsidised versus contributory regime (1.59, 1.34–1.89), and migrant status (1.63, 1.16–2.31). Municipal MPI was not independently associated (1.00 per 10 points, 0.94–1.07; Table 4). These associations concern severity and health-care use among notified records, not the probability of being notified.

Table 4
Adjusted associations with hospitalisation and notification delay

Characteristic	Hospitalisation OR (95% CI)	Delay > 7 days OR (95% CI)
Age < 6 months	1 (reference)	1 (reference)
6–11 months	0.57 (0.51–0.63)	1.25 (1.10–1.42)
12–23 months	0.44 (0.39–0.49)	1.25 (1.10–1.41)
24–35 months	0.28 (0.24–0.32)	1.31 (1.12–1.53)
36–47 months	0.21 (0.18–0.25)	1.31 (1.07–1.60)
48–59 months	0.19 (0.16–0.23)	1.43 (1.16–1.76)
Male sex	0.95 (0.90–1.01)	0.95 (0.90–1.01)
Populated centre	0.76 (0.58–1.00)	1.57 (0.94–2.62)
Dispersed rural	0.93 (0.80–1.08)	1.09 (0.86–1.37)
Indigenous	1.86 (1.47–2.35)	1.42 (0.89–2.26)
Afro-descendant	1.22 (0.62–2.38)	1.30 (0.84–2.01)
Other ethnicity	0.42 (0.15–1.13)	1.79 (0.90–3.57)
Subsidised insurance	1.59 (1.34–1.89)	1.06 (0.88–1.28)
Uninsured	2.59 (1.65–4.07)	1.38 (0.96–1.98)
Special or exception insurance	1.94 (1.40–2.69)	1.65 (1.11–2.45)
Stratum 2 (vs 3+)	1.15 (0.99–1.34)	0.97 (0.86–1.10)
Stratum 1 (vs 3+)	1.02 (0.86–1.20)	0.89 (0.69–1.15)
Migrant	1.63 (1.16–2.31)	0.77 (0.55–1.08)
Municipal MPI, per 10 points	1.00 (0.94–1.07)	1.03 (0.93–1.14)

Marginal logistic models with municipality-clustered sandwich confidence intervals. Hospitalisation: n = 23 488 records in 986 municipalities; delay: n = 20 016 in 968. Reference categories: age < 6 months, female, urban centre, no ethnic affiliation, contributory insurance, stratum 3+, and non-migrant.

For delay over seven days, special or exception insurance was associated with higher odds than contributory insurance (1.65, 95% CI 1.11–2.45), as were older age groups. Adjusted associations with Indigenous ethnicity (1.42, 0.89–2.26), no insurance (1.38, 0.96–1.98), and migrant status (0.77, 0.55–1.08) included the null.

Sensitivity analyses

The Q5-versus-Q1 mortality incidence rate ratio was 21.67 (95% CI 7.21–65.11) with 2024 deaths only, 22.94 (9.33–56.40) after excluding the five largest cities, and 7.96 (3.90-16.24) under the broad cause definition (Table 5). The notification estimate was 2.16 (1.43–3.26) after excluding the five largest cities, 2.50 (1.61–3.88) by notifying municipality, and 2.51 (1.48–4.26) under Poisson regression.

Table 5
Sensitivity analyses of deprivation gradients and classification stability

Analysis	Notification IRR (95% CI)	Mortality IRR (95% CI)	Silent, n (agreement)
Main analysis	2.16 (1.43–3.26)	22.31 (8.89–55.98)	93 (100.0%)
Mortality restricted to 2024	—	21.67 (7.21–65.11)	44 (37.6%)
Broad death definition	—	7.96 (3.90-16.24)	120 (91.4%)
Notifying municipality	2.50 (1.61–3.88)	—	126 (94.6%)
Exclude five largest cities	2.16 (1.43–3.26)	22.94 (9.33–56.40)	—
Poisson model	2.51 (1.48–4.26)	19.06 (7.11–51.05)	—
Strict thresholds	—	—	46 (49.5%)
Lax thresholds	—	—	217 (100.0%)
Median thresholds	—	—	266 (69.9%)

IRR, incidence rate ratio; SMR, smoothed standardised mortality ratio; SNR, smoothed standardised notification ratio. Agreement is the percentage of the 93 main-analysis silent municipalities retained. Complete output is provided in Additional file 2.

The one-year mortality specification classified 44 municipalities as silent and retained 35 (37.6%) of the main set. The broad definition retained 85 (91.4%); assigning notifications to the notifying municipality retained 88 (94.6%). A strict threshold selected 46 main-set municipalities, whereas a lax threshold selected 217 and retained all 93. Median thresholds selected 266 and retained 65 (69.9%). Forty-six municipalities were silent under the main, strict-threshold, and broad-cause specifications (Additional file 1).

Onset-date missingness ranged from 11.9% to 16.9% across surveillance classes ($p < 0.001$) and was 11.9% in silent municipalities. Excluding the five largest cities attenuated the hospitalisation associations with Indigenous ethnicity to 1.75 (1.41–2.18), no insurance to 1.87 (1.26–2.78), and migrant status to 1.48 (1.00-2.19) (Additional file 2).

Discussion

Notification and registered mortality both increased with deprivation, but their gradients differed markedly. Notification records per death declined from 90 to 12, and 93 municipalities combined above-reference mortality with below-reference notification. This mismatch is spatially structured and useful for prioritising local review, but it is not a direct estimate of surveillance completeness.

The results extend Colombian evidence on geographical undernutrition mortality [4, 9], neighbourhood deprivation [10], and clinical or community profiles [5, 11, 12]; related concentration in Indigenous and rural populations has been described elsewhere in the region [32]. Pairing notifications with deaths at the same scale adds a reproducible audit signal, but it does not establish which surveillance or care mechanism caused the mismatch.

Individual-level results address a different question. Among records already notified, hospitalisation was more frequent for Indigenous, uninsured, subsidised-regime, and migrant children. Because hospitalisation depends on clinical severity, admission practice, and access, it cannot identify when a child first became detectable or whether unnotified children share these characteristics. The findings nevertheless identify inequalities in the circumstances under which notifications occur.

Interpretation and rival explanations

The principal alternative explanation is higher case fatality in deprived municipalities despite similar notification completeness. This is plausible because mortality in severe acute malnutrition is influenced by treatment timing and comorbidity [33], and facility series show elevated risk in young or clinically complex children [34]. The present data cannot separate ascertainment from fatality, access, or treatment quality; the classification should therefore prompt local investigation of all these pathways rather than be read as proof of non-detection.

Second, geographical differences in cause-of-death certification could either inflate or attenuate the observed mortality gradient. The available files cannot quantify that direction or magnitude.

Third, any ratio of sparse municipal rates is unstable. We reduced, but did not eliminate, this problem by smoothing each component separately, classifying only above-reference mortality as high burden, and examining alternative mortality windows, cause definitions, and thresholds.

Implications

The list of 93 municipalities is a reproducible triage tool. It can direct audits of case ascertainment, mortality certification, referral pathways, and treatment access before resources are reallocated. Where local review corroborates under-ascertainment, active case-finding, community mid-upper-arm circumference screening, and support to notifying units are plausible responses. The classification can be recomputed as new data are released, but year-to-year changes should be interpreted with the instability of sparse deaths in mind.

The approach may be transferable where notification and cause-specific mortality are independently registered. However, unlike inventory or capture–recapture studies [14, 16], it cannot estimate completeness. Its appropriate role is low-cost, repeatable, hypothesis-generating triage.

Strengths and limitations

Strengths include national coverage, inclusion of zero-notification municipalities, transparent separation of source and valid-residence counts, an independently produced severe-outcome comparator, small-count smoothing, and fully reproducible sensitivity analyses.

The design is ecological and cannot support individual or causal inference. Notification records are neither incident cases nor necessarily unique children. Anthropometric measurements were unavailable, and imperfect concordance among anthropometric definitions can change classification [35]. Hospitalisation reflects severity, admission practice, and access, so it is not a validated marker of late detection. Death residence for infants is maternal residence; ethnicity fields are internally inconsistent; and onset date was missing for 14.8%. Mortality and notification windows differ. Cause certification and case fatality may vary geographically. Residual spatial autocorrelation remained after MPI and rurality adjustment, and department-clustered confidence intervals do not constitute a full spatial model. Finally, the individual analysis contains only notified records and cannot characterise children absent from surveillance.

Conclusions

Municipal acute-malnutrition notification increased with deprivation, but far less steeply than registered undernutrition mortality. The notification-mortality mismatch identifies a reproducible set of candidate municipalities for local surveillance and care-pathway review. It should be used as a screening signal, not as a direct estimate of completeness or proof that deaths occurred without notification.

Abbreviations

DANE
Departamento Administrativo Nacional de Estadística
GEE
generalised estimating equation
ICD-10
International Classification of Diseases,10th Revision
IRR
incidence rate ratio
MGN
National Geostatistical Framework
MPI
Multidimensional Poverty Index
NB2
negative binomial model with quadratic variance
OR
odds ratio
SIVIGILA
Colombian Public Health Surveillance System
SMR
standardised mortality ratio
SNR
standardised notification ratio.

Declarations

Clinical trial number: not applicable.

Ethics approval and consent to participate

The study analysed only pre-existing, publicly available, de-identified administrative records. There was no participant recruitment, contact, intervention, or access to direct identifiers. The authors classified the study as research without risk under Article 11(a) of Colombian Ministry of Health Resolution 8430 of 1993. No ethics committee review was sought or obtained, and individual informed consent was not applicable.

Consent for publication

Not applicable.

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Author Contribution

SJGA conceived and designed the study, obtained and curated the data, developed the analytical strategy, wrote and validated the analysis code, performed the statistical and spatial analyses, produced the figures and tables, and drafted the manuscript. MLR, ALR, LEGM, and FTSG critically reviewed the manuscript for important intellectual content and contributed to interpretation. All authors read and approved the final manuscript and agree to be accountable for the work.

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Data Availability

The derived municipal dataset, executable code, model and sensitivity-analysis outputs, source manifest, and figures are available in the Zenodo repository at https://zenodo.org/records/21727522. No individual-level records are redistributed in the repository. The primary SIVIGILA and DANE files are publicly

available from the sources cited in references 23-27, and the derived dataset can be reconstructed using the archived download script.

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Figures

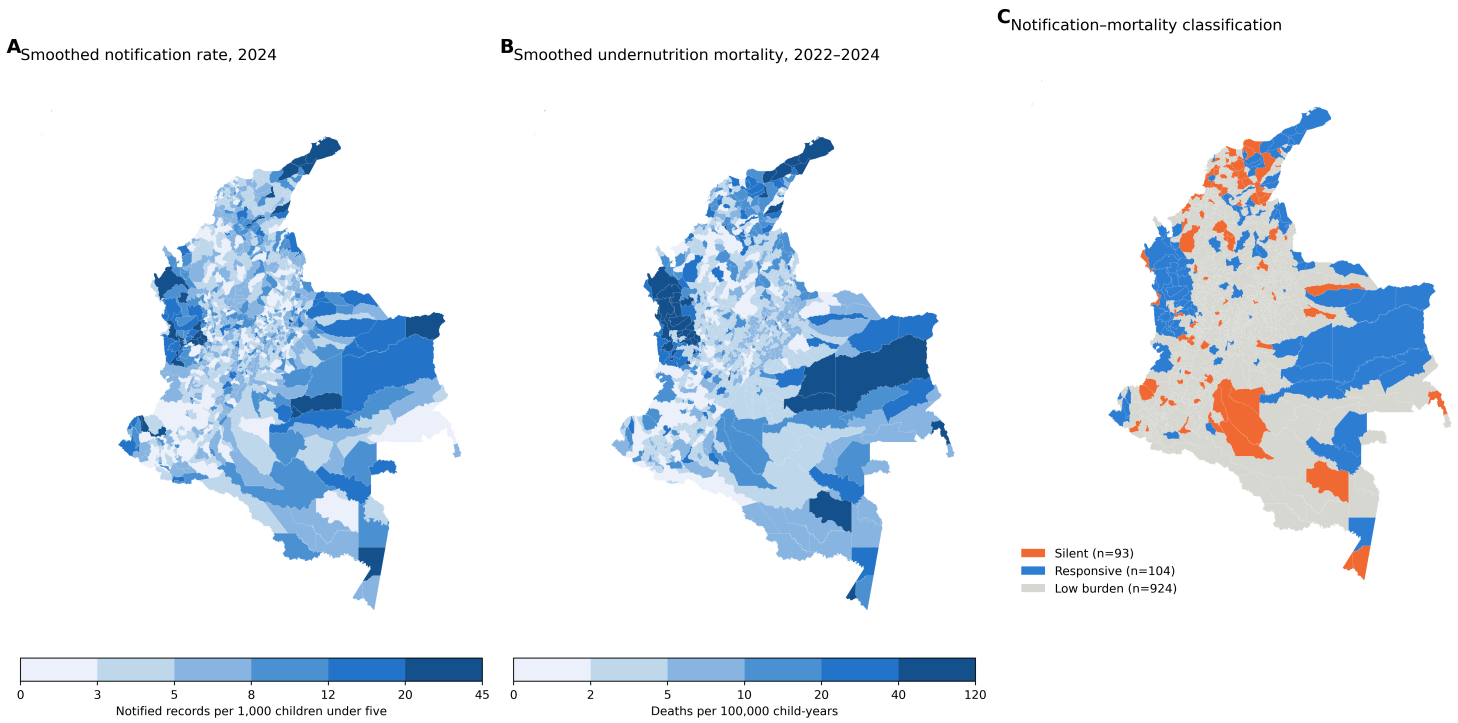


Figure 1

Municipal notification, undernutrition mortality and notification–mortality classification. (A) Global empirical Bayes smoothed notification rate, 2024. (B) Global empirical Bayes smoothed undernutrition mortality, 2022-2024. (C) Screening classification among the 1121 municipalities represented in MGN 2024: silent (n=93), responsive (n=104), and low burden (n=924). Nuevo Belén de Bajirá is included in non-map analyses but has no polygon in that layer

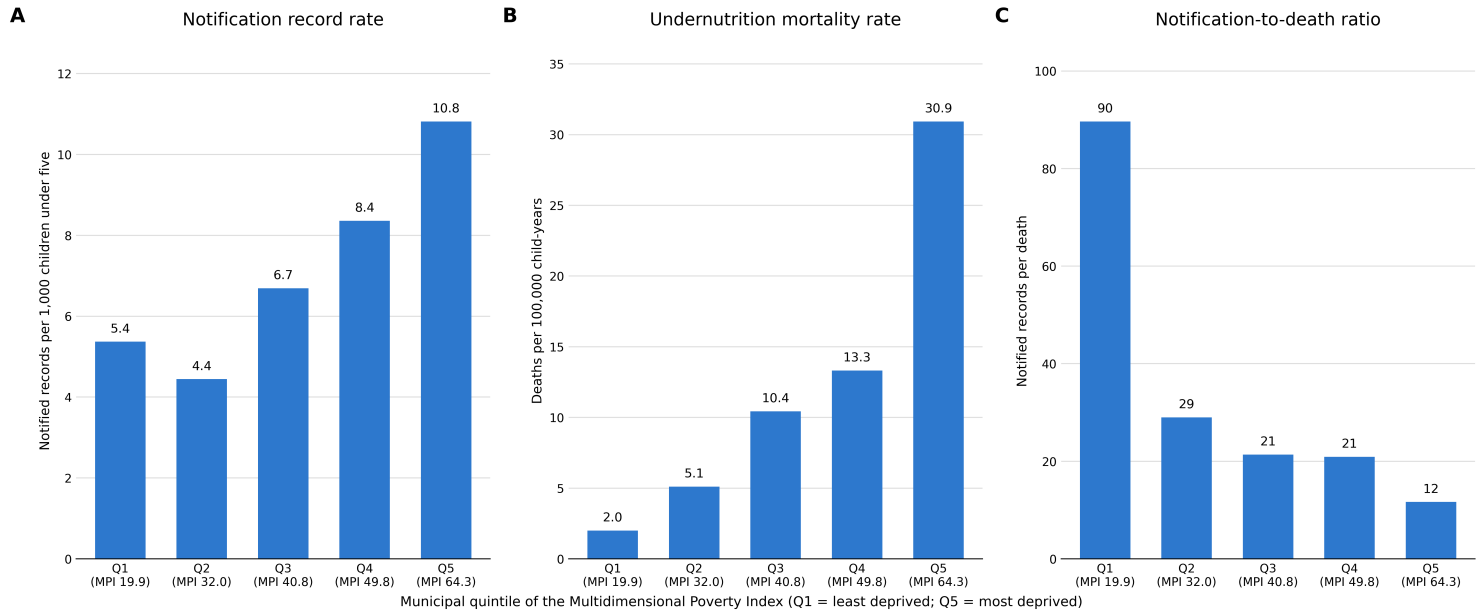


Figure 2

Notification, mortality and notification-to-death ratio by municipal deprivation quintile. (A) Notification records per 1000 children under five, 2024. (B) Undernutrition deaths per 100 000 child-years, 2022-2024. (C) Notification records per undernutrition death. Labels show median municipal MPI.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1silentmunicipalities.csv
- Additionalfile2sensitivityanalyses.csv
- Additionalfile3dataandcode.txt