Section: Community Medicine

Original Research Article

CHANGING DISTRICT-LEVEL SPATIAL PATTERNS OF ANAEMIA AMONG NON-PREGNANT WOMEN IN ODISHA, INDIA: AN ECOLOGICAL ANALYSIS OF NFHS-4 AND NFHS-5

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Received : 10/06/2026
Received in revised form : 06/08/2026
Accepted : 21/08/2026

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DOI: 10.70034/ijmedph.2026.3.551

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (3); 3517-3522

ABSTRACT

Background: State-level averages can conceal district-level geographic patterning in anaemia. We compared the distribution and spatial autocorrelation of anaemia among non-pregnant women aged 15–49 years across Odisha districts in two National Family Health Survey (NFHS) rounds.

Materials and Methods: This ecological study used published district estimates from NFHS-4 (2015–16) and NFHS-5 (2019–21) for all 30 districts of Odisha. Anaemia was defined as altitude-adjusted haemoglobin below 12.0 g/dL in non-pregnant women. Prevalence was mapped using common class intervals. Global Moran's I quantified overall spatial autocorrelation using queen contiguity, and univariate Local Indicators of Spatial Association identified high–high, low–low, high–low, and low–high patterns. Statistical significance was assessed with 999 permutations at a pseudo-p value below 0.05.

Results: The Odisha estimate increased from 51.2% in NFHS-4 to 64.4% in NFHS-5, a difference of 13.2 percentage points. Global Moran's I was 0.66 (pseudo-p=0.001) in NFHS-4 and 0.14 (pseudo-p=0.040) in NFHS-5, indicating strong positive spatial autocorrelation in the earlier round and weaker positive autocorrelation in the later round. Seven high–high districts were identified in NFHS-4, mainly in western Odisha with Koraput in the south. Four high–high districts were identified in NFHS-5—Sundargarh, Deogarh, Sambalpur, and Keonjhar—and Sambalpur was the only high–high district common to both rounds.

Conclusions: Anaemia became more prevalent across Odisha while its district-level spatial autocorrelation weakened. This does not demonstrate reduced inequality; rather, it suggests that high prevalence became less geographically concentrated. Anaemia control should therefore combine universal statewide coverage with intensified action in persistent and emerging high-burden districts.

Keywords: anaemia; women of reproductive age; spatial autocorrelation; Moran's I; LISA; National Family Health Survey; Odisha; India.

INTRODUCTION

Anaemia remains a major public health problem among women of reproductive age. Globally, an estimated 30% of non-pregnant women aged 15–49 years were anaemic in 2019, and progress has been insufficient to meet international nutrition targets.[1]

Anaemia has multiple and context-dependent causes, including deficiencies of iron and other micronutrients, infection and inflammation, blood loss, and inherited haemoglobin disorders.[2] Its consequences extend beyond symptoms and reduced work capacity to adverse maternal and perinatal outcomes.

India carries a particularly high burden. The National Family Health Survey (NFHS) provides nationally representative haemoglobin estimates and, since NFHS-4, district-level estimates that permit examination of sub-state variation.[3,4] National analyses have documented increases in anaemia among women between NFHS-4 and NFHS-5 and substantial geographic heterogeneity.[7-9] These patterns are relevant to Anaemia Mukt Bharat and other nutrition programmes because programme implementation and health-system action are substantially organised at district level.[5]

Maps alone show where prevalence is high, but they do not establish whether neighbouring districts share similar values more often than expected under spatial randomness. Global Moran's I quantifies overall spatial autocorrelation, while Local Indicators of Spatial Association (LISA) identify local clusters and spatial outliers.[6] Such methods have been used to study anaemia in Indian districts and other subnational settings.[10-12] However, comparative evidence focused specifically on the 30 districts of Odisha is limited.

This study therefore compared district-level anaemia prevalence among non-pregnant women aged 15–49 years in Odisha between NFHS-4 (2015–16) and NFHS-5 (2019–21). The objectives were to describe the geographic distribution of prevalence, quantify global spatial autocorrelation in each round, and identify high–high clusters, low–low clusters, and spatial outliers. Because these are repeated ecological cross-sections, the analysis was intended to describe spatial re-patterning rather than estimate programme effects or causal determinants.

MATERIALS AND METHODS

Study design and setting

We conducted a repeated cross-sectional ecological spatial analysis of all 30 districts of Odisha, an eastern Indian state with marked geographic, tribal, socioeconomic, and health-system diversity. The district was the unit of analysis. The study compared two survey periods: NFHS-4 (2015–16) and NFHS-5 (2019–21).

Data sources and outcome definition

District-level prevalence estimates were transcribed from the Odisha NFHS-4 and NFHS-5 district fact sheets published by the International Institute for Population Sciences and the Ministry of Health and Family Welfare.[3,4] We used the district-level total prevalence estimate of anaemia among non-pregnant women aged 15–49 years. In both NFHS-4 and NFHS-5, anaemia in non-pregnant women was defined as a haemoglobin concentration <12.0 g/dL, with haemoglobin values adjusted for altitude and smoking status, if known, according to the survey protocol. Haemoglobin was measured on-site from finger-prick capillary blood using a battery-operated portable HemoCue Hb 201+ analyser. Published state estimates were used to describe the overall Odisha burden; they were not calculated as unweighted means of the 30 district estimates.

A digital boundary file representing Odisha's 30-district administrative structure was linked to the prevalence dataset after standardising district names. The same district topology was used for both rounds, and the boundary file was used to derive adjacency and prepare the maps.

Spatial Analysis

District prevalence was displayed in choropleth maps using common class boundaries (35–<50%, 50–<60%, 60–<70%, and 70–80%) to facilitate visual comparison. A first-order queen contiguity spatial weights matrix defined districts as neighbours when they shared either a boundary segment or a vertex.

Global Moran's I was calculated separately for NFHS-4 and NFHS-5. Values above zero indicate that districts with similar prevalence tend to be adjacent; values near zero indicate weak spatial patterning under the chosen weights matrix; and values below zero indicate spatial dispersion. Statistical significance was evaluated using 999 random permutations, with pseudo-$p<0.05$.

Univariate Local Moran's I was used to classify statistically significant local patterns as high–high (a district with above-average prevalence adjacent to districts with above-average prevalence), low–low, high–low, or low–high. High–high and low–low classifications are local clusters, whereas high–low and low–high classifications are spatial outliers. LISA findings were treated as exploratory because multiple local tests were performed and no multiplicity correction was applied.

Software

Data preparation and preliminary visualisation were performed in R version 3.6.3, and spatial autocorrelation and LISA analyses were performed in GeoDa version 1.16. The analysis used only aggregate, published estimates; individual-level NFHS microdata were not analysed.

Ethical considerations

The study used publicly available, de-identified, aggregate district estimates and involved no interaction with human participants. Institutional ethics approval and individual informed consent were therefore not required for this secondary analysis. The original NFHS protocols obtained the relevant ethical approvals and participant consent.[3,4]

RESULTS

Prevalence across survey rounds

The published Odisha prevalence estimate among non-pregnant women aged 15–49 years increased from 51.2% in NFHS-4 to 64.4% in NFHS-5, an absolute difference of 13.2 percentage points (Table 1). In each round, 14 of 30 districts were above the corresponding state estimate. In NFHS-4, the highest reported district estimates were in

Sambalpur (73.0%), Nabarangpur (71.5%), Sundargarh (71.4%), and Malkangiri (71.3%). In NFHS-5, the highest estimates were in Angul (75.8%), Deogarh (72.2%), Mayurbhanj (72.2%), and Malkangiri (71.9%) (Table 2; Figures 1 and 3). Twenty-nine districts in NFHS-5 had prevalence greater than the earlier NFHS-4 state estimate of 51.2%, showing how broadly the high burden was distributed by the later round; this comparison should not be interpreted as proof that 29 individual districts increased without examining district-specific paired values.

Table 1: State burden and global spatial autocorrelation of anaemia among non-pregnant women aged 15–49 years, Odisha

Survey round	Odisha prevalence (%)	Global Moran's I	Permutation pseudo-p	Interpretation
NFHS-4 (2015–16)	51.2	0.66	0.001	Strong positive spatial autocorrelation
NFHS-5 (2019–21)	64.4	0.14	0.040	Weak positive spatial autocorrelation

The 13.2-percentage-point difference is based on published state estimates. Moran's I values were calculated using queen contiguity and 999 permutations. No formal statistical test compared the two Moran's I coefficients.

Table 2: Districts with the highest reported anaemia prevalence in each NFHS round

NFHS-4 district	Prevalence (%)	NFHS-5 district	Prevalence (%)
Sambalpur	73.0	Angul	75.8
Nabarangpur	71.5	Deogarh	72.2
Sundargarh	71.4	Mayurbhanj	72.2
Malkangiri	71.3	Malkangiri	71.9

Values are published total district estimates for non-pregnant women aged 15–49 years.

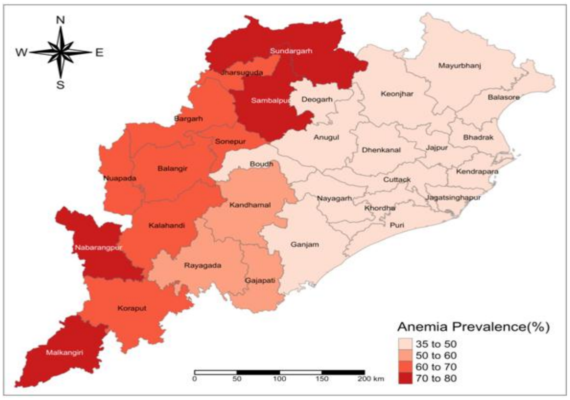

Figure 1: District-level prevalence of anaemia among non-pregnant women aged 15–49 years in Odisha, NFHS-4 (2015–16). Common prevalence categories were used to support comparison with NFHS-5

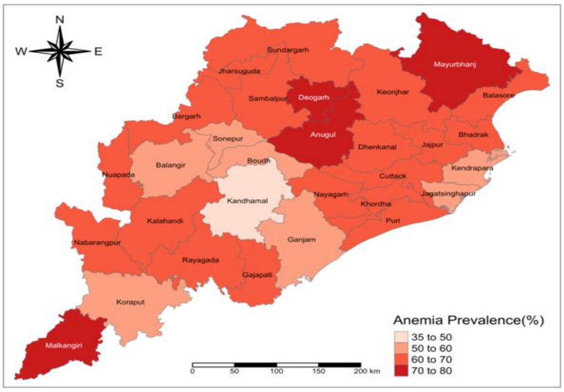

Figure 2: District-level prevalence of anaemia among non-pregnant women aged 15–49 years in Odisha, NFHS-5 (2019–21). Common prevalence categories were used to support comparison with NFHS-4.

Global spatial autocorrelation

Anaemia prevalence showed strong positive spatial autocorrelation in NFHS-4 (Global Moran's I=0.66; pseudo-p=0.001). In NFHS-5, the statistic was smaller but remained positive and statistically significant (Global Moran's I=0.14; pseudo-p=0.040). Thus, districts with similar prevalence were much more strongly clustered in the earlier round under the specified spatial weights matrix. The difference between the two coefficients is descriptive because a formal between-round test was not performed.

Local spatial patterns

In NFHS-4, LISA identified seven high–high districts: Jharsuguda, Sambalpur, Bargarh, Balangir, Nuapada, Kalahandi, and Koraput. Six formed a western cluster, while Koraput represented a southern extension. Ten districts formed low–low clusters, and no high–low or low–high outliers were shown (Table 3; Figure 2).

In NFHS-5, four high–high districts were identified: Sundargarh, Deogarh, Sambalpur, and Keonjhar. Sambalpur was the only high–high district common to both rounds. Two low–low districts, Kandhamal and Balangir, and two high–low spatial outliers were also identified; no low–high outlier was shown (Table 3; Figure 4). The local pattern therefore became less extensive and changed geographically, even as the statewide burden rose.

Table 3: Local Moran's I classifications by survey round

LISA category	NFHS-4, n	NFHS-5, n	Named high–high districts
High–high	7	4	NFHS-4: Jharsuguda, Sambalpur, Bargarh, Balangir, Nuapada, Kalahandi, Koraput; NFHS-5: Sundargarh, Deogarh, Sambalpur, Keonjhar
Low–low	10	2	—
High–low	0	2	—
Low–high	0	0	—
Not significant	13	22	—

LISA classifications used 999 permutations and pseudo-$p<0.05$. Local results are exploratory because no correction for multiple testing was applied.

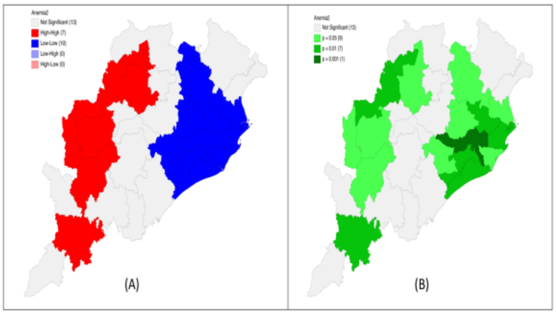

Figure 3: Univariate LISA results for district-level anaemia prevalence in Odisha, NFHS-4 (2015–16): (A) cluster and spatial-outlier classification; (B) permutation significance map. High–high and low–low denote local clusters; high–low and low–high denote spatial outliers

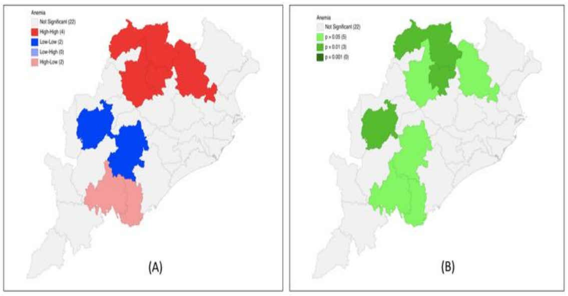

Figure 4: Univariate LISA results for district-level anaemia prevalence in Odisha, NFHS-5 (2019–21): (A) cluster and spatial-outlier classification; (B) permutation significance map. High–high and low–low denote local clusters; high–low and low–high denote spatial outliers

DISCUSSION

This ecological analysis found two concurrent changes between NFHS-4 and NFHS-5: the published Odisha estimate of anaemia among non-pregnant women increased by 13.2 percentage points, while global spatial autocorrelation weakened from 0.66 to 0.14. The LISA pattern also contracted from seven to four high–high districts and changed composition, with only Sambalpur remaining a high–high district in both rounds. Together, these findings indicate that anaemia remained locally clustered but became less geographically concentrated as high prevalence spread more broadly across the state.

The distinction between spatial autocorrelation and inequality is important. Moran's I quantifies whether neighbouring districts have similar values; it is not a measure of the dispersion, range, variance, or socioeconomic inequality of prevalence. Therefore, the lower Moran's I in NFHS-5 should not be described as proof that district inequality declined. In a setting where the statewide prevalence increased and 29 districts exceeded the earlier state estimate, weaker autocorrelation is more plausibly interpreted as diffusion of a high burden beyond the earlier western and southern cluster pattern.

The rise in Odisha is consistent with national analyses showing that anaemia among women increased between NFHS-4 and NFHS-5 and that the burden is not confined to a small number of districts.[7-9] Analyses of Aspirational Districts likewise reported substantial between-district heterogeneity and widespread increases.[7] Studies using spatial methods in Indian districts have demonstrated that anaemia clusters are geographically structured and associated at ecological level with social composition, deprivation, education, nutritional status, and health-related behaviours.[10-12] These studies support the value of district-level mapping but do not establish the causes of Odisha's changing pattern.

The replacement of several western and southern high–high districts by a smaller north-western and north-central configuration illustrates why static hotspot lists can become outdated. District classification is relative to the statewide distribution and the chosen neighbour matrix: a district may leave a high–high cluster even if its absolute prevalence remains high, because its own value or the values of its neighbours change. Consequently, cluster membership should be interpreted together with the underlying prevalence map and not as a stand-alone performance ranking.

The results favour a two-tier response. First, the broad rise in prevalence calls for reliable statewide implementation of the six-by-six-by-six Anaemia Mukt Bharat strategy, including age-appropriate iron–folic acid supplementation, deworming, behaviour-change communication, testing and treatment, fortified foods, and action on non-nutritional causes.[5] Second, persistent and emerging high–high districts require intensified microplanning, supply-chain review, screening and referral pathways, and district-specific investigation of dietary, infectious, menstrual, genetic, and health-service determinants.

Spatial surveillance can help prioritise these investigations, but it should be paired with programme coverage and determinant data. Future analyses could evaluate bivariate spatial associations with Scheduled Tribe population, women's education, poverty, food security, malaria and haemoglobinopathy burden, sanitation, and iron–folic acid coverage. Spatial regression using comparable district covariates would be needed before attributing geographic patterns to these factors.

Strengths and limitations

A strength of this study is the use of a comparable anaemia indicator across all 30 Odisha districts in two nationally standardised survey rounds, combined with global and local measures of spatial dependence. The use of common choropleth categories and a consistent district topology facilitates visual comparison.

Several limitations require caution. First, the ecological design cannot support individual-level or causal inference. Second, published district point estimates were analysed without incorporating their survey standard errors; districts with smaller NFHS samples may have less precise prevalence estimates. Third, Moran's I is sensitive to the spatial weights specification, and the two coefficients were not formally tested for a between-round difference. Fourth, LISA involves multiple local tests; the maps are exploratory because no multiplicity adjustment was applied. Fifth, only two survey rounds and one outcome were analysed, so the study cannot attribute change to Anaemia Mukt Bharat, POSHAN Abhiyaan, the COVID-19 pandemic, or any other programme or event. Sixth, capillary HemoCue measurements may differ from venous laboratory measurements, although the same general survey approach supports comparison between NFHS-4 and NFHS-5. Finally, the released NFHS-6 (2023–24) fact sheets do not include haemoglobin or anaemia estimates,[13] consequently, a comparable third-round district analysis was not possible. Any future venous-blood estimates should be assessed for measurement comparability before being appended to this time series.

CONCLUSION

Between NFHS-4 and NFHS-5, anaemia among non-pregnant women in Odisha increased substantially while district-level spatial autocorrelation weakened. High–high clusters became fewer and shifted geographically, with Sambalpur as the only high–high district common to both rounds. The weaker autocorrelation should not be equated with reduced inequality or programme success; it indicates that the burden was less spatially concentrated. A universal statewide anaemia-control platform, complemented by intensified and periodically updated district action in persistent and emerging clusters, is warranted.

Declarations

Ethics approval and consent to participate: Not applicable. This study analysed publicly available, de-identified, aggregate data.

Consent for publication: Not applicable.

Availability of data and materials: NFHS fact sheets and reports are publicly available from the International Institute for Population Sciences NFHS portal (https://www.nfhsiips.in/). The derived district-level dataset, spatial weights file, and analytical code are available from the corresponding author on reasonable request.

Competing interests: The author declares no competing interests.

Funding: No specific funding was received for this study.

Author contributions: DP: conceptualization, methodology, data curation, formal analysis, visualization, and writing—original draft. SSR: supervision, methodology, interpretation, and writing—review and editing. SKP: validation, interpretation, and writing—review and editing. All authors reviewed and approved the final manuscript.

Acknowledgements: None.

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