International Journal of Clinical Science and Medical Research

ISSN(print): 2770-5803, ISSN(online): 2770-582X

Volume 06 Issue 07 July 2026

DOI: https://doi.org/10.55677/IJCSMR/V6I7-05/2026, Impact Factor: 8.005

Page No : 278-285

Malaria Surveillance Performance and Persistent Transmission During the Elimination Phase in Mizoram, India, 2017-2024

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Published Online: July 23, 2026

ABSTRACT

Background: Despite substantial progress towards malaria elimination in India, Mizoram continues to experience persistent and fluctuating transmission. Previous studies have established the spatial concentration of malaria in high-burden districts. However, recent changes in transmission in relation to routine surveillance performance remain insufficiently understood.

Objectives: To assess temporal changes in malaria transmission and surveillance performance in Mizoram during 2017-2024 and examine the relationship between surveillance indicators and malaria incidence

Methods: A retrospective ecological study was conducted using district-level malaria surveillance data from the National Vector Borne Disease Control Programme for 2017-2024. Annual Parasite Incidence (API), Annual Falciparum Incidence, Slide Positivity Rate (SPR), Plasmodium falciparum percentage, Annual Blood Examination Rate (ABER), blood-slide collection and examination, confirmed cases, and malaria deaths were analysed. Temporal trends and district-level variation were assessed using descriptive statistics, Spearman's rank correlation, and multivariate linear regression.

Results: Malaria transmission declined during 2017-18 but resurged from 2019, with marked increases during 2022-2024. Transmission remained concentrated in Lawngtlai, Mamit and Lunglei, while several districts maintained low incidence. Rising API coincided with increasing SPR, whereas ABER declined after 2022, indicating that increased malaria burden was accompanied by higher parasite positivity despite changing surveillance intensity. SPR showed the strongest positive association with API ($\rho=0.99$, $p<0.001$) and remained statistically significant after adjustment. Falciparum-related mortality persisted, although the case fatality rate declined from 0.09 per cent in 2019 to 0.05 per cent in 2024.

Conclusion: Malaria resurgence in Mizoram during the elimination phase reflects persistent focal transmission despite sustained routine surveillance. The close association between API and SPR indicates continuing transmission intensity, while changing surveillance patterns highlight the need to strengthen timely diagnostic processing and case detection. Elimination strategies should prioritise surveillance responsiveness and targeted transmission reduction in persistently affected districts.

KEYWORDS:
Malaria, surveillance, elimination, transmission, Mizoram, NVBDCP

INTRODUCTION

Malaria remains a major vector-borne disease in India, with transmission patterns exhibiting marked regional variation (WHO, 2023). Although national malaria burden has declined in recent years, northeastern states continue to account for a disproportionately high share of cases relative to their population size (NVBDCP, 2021). Among these, Mizoram represents a uniquely persistent transmission setting requiring focused epidemiological attention (MOHFW, 2016).

Mizoram's vulnerability to malaria extends beyond its hilly and forested terrain. The state receives high annual rainfall, maintains dense forest cover exceeding 80 per cent, and shares porous international borders with Myanmar and Bangladesh, regions with ongoing malaria transmission (Lalchhandama & Saitluanga, 2024; Laldinsanga et al., 2019; Lalmalsawma et al., 2023; Vanlalhriata et al., 2024; Zomuanpuii et al., 2020). These cross-border linkages

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Cite this Article: Pautunthang, N. (2026). Malaria Surveillance Performance and Persistent Transmission During the Elimination Phase in Mizoram, India, 2017-2024. International Journal of Clinical Science and Medical Research, 6(7), 278-285. https://doi.org/10.55677/IJCSMR/V6I7-05/2026

promote parasite importation and sustained transmission cycles. Additionally, scattered rural settlements, difficult terrain, poor road connectivity, and dependence on forest-based livelihoods lead to delayed healthcare access and vector exposure (Das et al., 2012; Mopuri et al., 2025; Sarma et al., 2019; Sharma et al., 2015). Shifting cultivation practices (jhum), temporary housing structures, and outdoor occupational activities further increase human-vector contact. The ecological sustainability for Anopheles breeding, combined with persistent dominance of Plasmodium falciparum, promotes transmission intensity and disease severity in specific districts (NVBDCP, 2021; WHO, 2023).

Previous studies in north-eastern India have documented falciparum predominance, climate-malaria associations, and localised outbreaks. However, most investigations have focused on short time frames, outbreak episodes, or ecological correlates without conducting longitudinal district-level analysis using standard programmatic indicators. Few studies have examined post 2017 trends, a period marked by intensified elimination efforts and disruptions during the COVID-19 pandemic. Consequently, evidence on recent spatial-temporal dynamics and surveillance performance in Mizoram remains limited.

This study was guided by the following research questions:

1. How did malaria transmission and epidemiological indicators change in Mizoram during 2017-2024?
2. To what extent did malaria burden and transmission patterns vary across districts during the study period?
3. How did malaria surveillance and diagnostic performance change during the malaria elimination phase?
4. What relationship exists between malaria incidence and key surveillance and transmission indicators, including ABER, SPR, and Pf%?
5. How did malaria-related mortality and case fatality change during the study period?

The study objectives are:

1. To analyse temporal trends in malaria burden and transmission using API, AFI, SPR, and Pf% from 2017 to 2024
2. To assess district-level variation and persistence of malaria transmission across Mizoram
3. To evaluate malaria surveillance and diagnostic performance using ABER, blood slides collected, blood slides examined, and confirmed malaria case detection.
4. To examine the association between API and selected surveillance and transmission indicators, including ABER, SPR, and Pf%.
5. To assess temporal patterns in malaria-related deaths and case fatality rates.

MATERIALS AND METHODS

Study Design and Data Source

A retrospective ecological study was undertaken using district-level routine malaria surveillance data from the National Vector Borne Disease Control Programme (NVBDCP) for Mizoram from 2017 to 2024 (NVBDCP, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024). The district-year constituted the primary unit of analysis. The dataset included malaria incidence, parasite species distribution, blood examination statistics, confirmed malaria cases, and malaria-related deaths.

Study Indicators

Malaria transmission and surveillance performance were assessed using standard programme indicators. Annual Parasite Incidence (API), defined as the number of confirmed cases per 1,000 population per year, was used as the principal measure of malaria burden. Annual Falciparum Incidence (AFI) represented the incidence of Plasmodium falciparum malaria per 1,000 population, while Slide Positivity Rate (SPR) represented the percentage of examined blood slides positive for malaria parasites. The proportion of P. falciparum cases (Pf%) was used to assess parasite species composition.

Surveillance performance was assessed using the Annual Blood Examination Rate (ABER), Blood Slides Collected (BSC), and Blood Slides Examined (BSE). ABER represented the proportion of the population examined for malaria during a given year. The ratio of BSE to BSC was calculated to assess the proportion of collected blood slides that were examined.

Malaria mortality was evaluated using reported malaria-related deaths. The case Fatality Rate (CFR) was calculated as:

$$CFR\ (\%) = \frac{\text{Malaria Deaths}}{\text{Confirmed Cases}} x\ 100$$

Assessment of Temporal and District-Level Patterns

Temporal changes in API, AFI, SPR, Pf%, and ABER were assessed for the period 2017-2024. Year-to-year changes were examined to identify periods of declining, increasing, or resurgent malaria transmission.

District-level variation was assessed by comparing malaria indicators across the reporting districts of Mizoram. Districts with persistently elevated API, SPR, AFI, and confirmed case burden across multiple years were interpreted as areas of sustained malaria transmission. The analysis focused on persistence of transmission rather than formal spatial hotspot detection.

Assessment of Surveillance and Diagnostic Performance

Surveillance performance was evaluated by examining temporal and district-level patterns in ABER, BSC, and BSE. Changes in ABER were interpreted as variations in population-level surveillance intensity, while BSC and BSE were used to assess malaria testing and diagnostic processing.

The BSE/BSC ratio was calculated as:

$$\frac{BSE}{BSC} Ratio = \frac{\text{Blood Slides Examined}}{\text{Blood Slides Collected}}$$

Values approaching 1 indicated a high proportion of collected blood slides were examined. Temporal changes in the ratio were assessed to identify possible gaps between sample collection and diagnostic examination.

Mortality and Case Fatality Analysis

Malaria-related deaths were analysed by district and year for 2017-2024 to assess temporal and geographical patterns in mortality. CFR was calculated for 2019-2024, corresponding to the period for which confirmed malaria case data were consistently available. Changes in CFR were interpreted as an indicator of malaria case outcomes and programme response, while recognising that routine surveillance data did not permit assessment of individual-level treatment or clinical factors.

Statistical Analysis

Descriptive statistics were used to summarise malaria burden, surveillance indicators, diagnostic activity, and mortality patterns. Temporal trends were examined using annual indicator values from 2017 to 2024.

Spearman's rank correlation analysis was performed using district-level data for 2024 to assess associations between API and ABER, SPR, and Pf%. Spearman's correlation was selected because of the small number of district-level observations and the potential non-normal distribution of malaria indicators.

A multivariate linear regression model was fitted with API as the dependent variable and ABER, SPR, and Pf% as independent variables. Regression coefficients, standard error, 95 % confidence intervals, and p-values were established. Statistical significance was set at $p<0.05$.

Because API and SPR are derived from related malaria surveillance counts, associations involving these indicators were interpreted cautiously and were not considered evidence of causality. The regression analysis was based on district-level cross-sectional data for 2024 and therefore represented ecological associations.

The overall study period covered 2017-2024. However, blood-slide collection and examination, confirmed malaria cases, and case fatality analyses were restricted to 2019-2024 because these indicators were consistently available only from 2019 onwards.

RESULTS

The results of the data analyses are discussed below.

Temporal Changes in Malaria Transmission, 2017-2024

Malaria transmission in Mizoram showed a fluctuating rather than consistently declining pattern during 2017-2024 (see Figure 1). API declined from 4.79 in 2017 to 3.58 in 2018 but increased to 6.98 in 2019. After remaining relatively stable during 2020-2021, API increased to 8.90 in 2022 and peaked at 14.20 in 2023 before declining slightly to 12.89 in 2024.

SPR broadly followed the temporal pattern of API. It declined from 2.68 per cent in 2017 to 1.97 per cent in 2018 and increased to 3.67 per cent in 2019. Following lower levels during 2020-2022, SPR increased sharply to 4.90 per cent in 2023 and reached 5.49 per cent in 2024, indicating increased malaria positivity among examined blood slides during the later study period.

Falciparum-specific indicators showed a different temporal pattern. AFI fluctuated substantially, declining from 4.17 in 2017 to 3.28 in 2018, increasing to 6.54 in 2019, and reaching 6.83 in 2024. In contrast, Pf% peaked at 93.76 per cent in 2019 and subsequently declined consistently to 52.96 per cent in 2024. Thus, although the proportional contribution of P.falciparum declined, falciparum-specific incidence remained substantial and increased in 2024.

Table 1. Temporal Changes in Malaria Transmission Indicators, Mizoram, 2017-2024

Year	API	SPR (%)	AFI	Pf (%)
2017	4.79	2.68	4.17	87.03
2018	3.58	1.97	3.28	91.64
2019	6.98	3.67	6.54	93.76
2020	6.43	2.66	5.37	83.43
2021	6.51	2.05	4.99	76.65
2022	8.90	2.42	6.58	73.97
2023	14.20	4.90	3.20	64.30
2024	12.89	5.49	6.83	52.96

Source: Epidemiological Situation Report of Mizoram, 2017-2024

District-Level Variation in Malaria Transmission, 2024

Malaria transmission varied markedly across districts in 2024 (Table 2). API ranged from 0.09 in Aizawl East to 56.81 in Lawngtlai district, compared with the state-level API of 12.89. Lawngtlai district recorded the highest API (56.81), SPR (16.59%), AFI (33.67), and number of confirmed malaria cases (8,067). Mamit district also reported elevated API (32.34), SPR (12.32%), and AFI (14.54), while Lunglei district recorded an API of 21.57 and AFI of 13.23. Saiha showed high API (23.29) and SPR (9.82%), although its AFI and Pf% were comparatively lower. In contrast, Aizawl East, Aizawl West, Kolasib, Champhai and Serchhip districts recorded API values below 0.5 and low parasite positivity. These findings demonstrate substantial district-level heterogeneity in malaria transmission during 2024.

Table 2: District-level Variation in Malaria Transmission Indicators, Mizoram, 2024

Districts	API	SPR	AFI	Confirmed Cases	Pf%
Aizawl East	0.09	0.05	0.02	30	20.00
Aizawl West	0.21	0.12	0.09	41	43.90
Lunglei	21.57	8.40	13.23	3775	61.32
Saiha	23.29	9.82	4.65	1607	19.98
Kolasib	0.17	0.09	0.02	16	12.50
Mamit	32.34	12.32	14.54	3299	44.95
Champhai	0.21	0.09	0.06	31	25.81
Lawngtlai	56.81	16.59	33.67	8067	59.27
Serchhip	0.48	0.15	0.23	33	48.48
State Total	**12.89**	**5.49**	**6.83**	**16899**	**52.96**

Source: Epidemiological Situation Report of Mizoram, 2024

Changes in Malaria Surveillance Performance

Surveillance Intensity Measured by ABER

Surveillance intensity, as measured by ABER, increased during the early and middle study periods and reached its highest level in 2022 before declining during 2023-2024. In 2024, ABER varied considerably between districts, ranging from 17.61 per cent in Aizawl West to 34.24 per cent in Lawngtlai district. High-transmission districts generally maintained moderate-to-high blood examination rates. The relatively high ABER observed in several districts with persistent malaria transmission indicates greater surveillance activity in areas reporting higher malaria burden.

Table 3. District-wise Annual Blood Examination Rate (ABER), Mizoram, 2017-2024

Districts	2017	2018	2019	2020	2021	2022	2023	2024
Aizawal East	19.42	23.11	23.12	21.42	22.26	48.41	24.10	19.8
Aizawal West	14.98	17.79	17.89	22.27	21.21	25.39	18.20	17.61
Lunglei	19.28	14.74	16.48	22.56	36.04	21.34	30.20	25.67
Saiha	9.54	11.63	14.62	30.08	20.19	32.61	67.20	23.73
Kolasib	21.42	17.01	16.23	20.09	22.97	23.12	24.10	19.19
Mamit	23.03	19.58	22.41	25.47	39.17	21.75	29.10	26.24
Champhai	9.43	10.91	13.24	19.23	24.84	22.24	26.80	23.26
Lawngtlai	23.23	21.16	20.89	27.7	64.72	81.56	33.80	34.24
Serchhip	18.89	22.26	23.28	44.53	49.18	41.91	38.50	31.66
State Total	**17.89**	**18.17**	**19.03**	**24.16**	**31.75**	**36.84**	**29.00**	**23.49**

Source: Epidemiological Situation Report of Mizoram, 2017-2024

Blood-Slide Collection and Examination

Blood-slide collection and examination showed substantial temporal variation during 2019-2024 (Table 4). At the state level, both Blood Slides Collected (BSC) and Blood Slides Examined (BSE) declined sharply from 232,916 in 2019 to 92,238 in 2020. BSC subsequently declined to 76,150 in 2021 before increasing markedly to 187,199 in 2022. A similar pattern was observed for BSE, which increased from 67,168 in 2021 to 151,819 in 2022. Both indicators declined during 2023-2024.

Although BSC and BSE were identical in 2019 and 2020, a numerical gap emerged from 2021 onwards. The difference between slides collected and examined increased from 8,982 in 2021 to 35,380 in 2022 and remained substantial in 2023 (29,271) and 2024 (26, 818). District-level variation in the BSC-BSE gap was also observed, particularly in selected districts during the later study period. These findings indicate divergence between reported blood-slide collection and examination after 2020.

Table 4. Temporal Changes in Blood Slides Collected and Examined, Mizoram, 2019-2024

Year	BSC	BSE	Difference
2019	232,916	232,916	0
2020	92,238	92,238	0
2021	76,150	67,168	8,982
2022	187,199	151,819	35,380
2023	152,752	123,481	29,271
2024	112,282	85,464	26,818

Source: Epidemiological Situation Report of Mizoram, 2019-2024

Proportion of Blood Slide Examined

The proportion of collected blood slides examined changed markedly during 2019-2024 (Table 5). All reported blood slides collected were examined in 2019 and 2020, corresponding to an examination proportion of 100 per cent. From 2021 onwards, however, the proportion declined progressively from 88.2 per cent in 2021 to 81.1 per cent in 2022 and 80.8 per cent in 2023, reaching 76.1 per cent in 2024. Thus, the proportion of collected slides reported as examined decreased by 23.9 percentage points between 2020 and 2024. This declining pattern indicates an increasing numerical discrepancy between blood slide collection and examination during the later study period.

Table 5. Proportion of Collected Blood Slides Examined in Mizoram, 2019-2024

Year	BSC	BSE	Slides Examined (%)
2019	232,916	232,916	100.0
2020	92,238	92,238	100.0
2021	76,150	67,168	88.2
2022	187,199	151,819	81.1
2023	152,752	123,481	80.8
2024	112,282	85,464	76.1

Source: Epidemiological Situation Report of Mizoram, 2019-2024

Confirmed Malaria Case Detection

Confirmed malaria cases showed substantial temporal and district-level variation during 2019-2024 (Table 6). At the state level, the number of confirmed cases declined from 8,543 in 2019 to 7,781 in 2020 before increasing to 8,018 in 2021 and 11,156 in 2022. A marked increase was observed in 2023, when 18,077 cases were reported, followed by a modest decline to 16,899 in 2024.

The detected case burden was concentrated in a limited number of districts. Lawngtlai district consistently reported the largest number of confirmed cases, increasing from 3,780 in 2019 to 8,067 in 2024. Lunglei district also maintained a substantial case burden, while Mamit district recorded an increase from 1,258 cases in 2021 to 3,299 in 2024. Saiha showed a similar increase during the later study period, reaching 1,681 cases in 2023 and 1,607 in 2024. In contrast, Aizawl East, Aizawl West, Kolasib, Champhai, and Serchhip districts consistently reported relatively few confirmed malaria cases.

The increase in confirmed cases during 2022-2024 corresponded with the rise in API and SPR observed during the same period, indicating an increased detected malaria burden during the later elimination phase.

Table 6. District-wise Confirmed Malaria Cases in Mizoram, 2019-2024

District	2019	2020	2021	2022	2023	2024
Aizawl East	37	15	28	20	29	30
Aizawl West	53	27	42	43	74	41
Lunglei	2430	3193	2465	2888	4959	3775
Saiha	279	413	446	963	1681	1607
Kolasib	24	35	35	22	29	16
Mamit	1903	727	1258	1474	3288	3299
Champhai	19	20	28	46	42	31
Lawngtlai	3780	3333	3671	5664	7927	8067
Serchhip	18	18	45	36	48	33
State Total	**8543**	**7781**	**8018**	**11156**	**18077**	**16899**

Source: Epidemiological Situation Report of Mizoram,2019- 2024

Malaria Mortality and Case Fatality

A total of 54 malaria-related deaths were reported during 2019-2024. Annual deaths increased from 6 in 2020 to a peak of 13 in 2023 before declining to 7 in 2024. The malaria case fatality rate remained below 0.15 per cent throughout 2019-2024. CFR increased from 0.09 per cent in 2019 to a peak of 0.12 per cent in 2021 before declining to 0.09 per cent in 2022, 0.07 per cent in 2023, and 0.04 per cent in 2024. The decline in CFR during 2022-2024 occurred despite a substantial increase in confirmed malaria cases, indicating a reduction in the proportion of detected malaria cases resulting in reported deaths.

Table 7. Malaria Case Fatality Rate in Mizoram, 2019-2024

Year	Confirmed Cases	Malaria Deaths	CFR (%)
2019	8,543	8	0.09
2020	7,781	6	0.08
2021	8,018	10	0.12
2022	11,156	10	0.09
2023	18,077	13	0.07
2024	16,899	7	0.04

CFR (%) = (Malaria deaths ÷ Confirmed malaria cases) × 100

Association Between Malaria Incidence and Surveillance Indicators

Bivariate Associations

Spearman's rank correlation analysis showed a strong positive association between API and SPR (ρ=0.99, $p<0.001$), indicating that districts with higher malaria incidence also reported higher parasite positivity. API was positively associated with ABER (ρ=0.79, $p<0.05$), suggesting that districts with greater malaria incidence tended to have higher blood examination rates. A moderate positive association was observed between API and Pf% (ρ=0.58, $p<0.05$). ABER was also positively correlated with SPR (ρ=0.75, $p<0.05$) and Pf% (ρ=0.68, $p<0.05$).

Table 8. Spearman's Rank Correlation Between Malaria Incidence and Selected Surveillance Indicators, Mizoram, 2024

Variable	API	ABER	SPR	Pf%
API	1.00	0.79*	0.99**	0.58*
ABER	0.79*	1.00	0.75*	0.68*
SPR	0.99**	0.75*	1.00	0.56*
Pf%	0.58*	0.68*	0.56*	1.00

$p < 0.05$, ** $p < 0.001$

Multivariate Associations

The multivariable linear regression model explained 97% of the district-level variation in API (R^2=0.97; adjusted R^2=0.95) and was statistically significant (F=56.86, $p<0.001$). After adjustment for ABER and Pf%, SPR showed the strongest statistical association with API (β=2.82, 95% CI:

2.05-3.59; p<0.001). ABER (β=0.35, p=0.423) and Pf% (β=0.02, p=0.883) were not statistically significant in the adjusted model.

Table 9. Multivariable Linear Regression of API and Selected Surveillance Indicators, Mizoram, 2024

Variable	β-coefficient	Standard Error	p-value	95% CI
Constant	-9.11	7.82	0.297	-29.21 to 10.99
ABER	0.35	0.40	0.423	-0.68 to 1.37
SPR	2.82	0.30	<0.001	2.05 to 3.59
Pf%	0.02	0.11	0.883	-0.27 to 0.31

Model statistics: R^2=0.97; adjusted R^2=0.95; F=56.86; p<0.001.

These associations represent district-level ecological relationships and should not be interpreted as causal effects.

DISCUSSION

Malaria transmission in Mizoram showed a fluctuating rather than consistently declining pattern during 2017-2024. The resurgence in API and SPR during 2022-2024 indicates renewed transmission during the elimination phase. Although increased case detection may partly reflect surveillance activity, the concurrent rise in SPR suggests that the increase in reported cases was accompanied by greater parasite positivity. These ecological and operational factors may explain why malaria transmission persisted despite ongoing elimination activities.

Marked district-level variation remained evident, with malaria burden concentrated in Lawngtlai, Mamit, Lunglei and increasingly Saiha districts. The present findings do not identify new Malaria hotspots; rather, they demonstrate that transmission has persisted in previously recognised high-burden areas despite ongoing elimination efforts.

Surveillance performance also changed during the study period. State-level ABER increased and peaked in 2022 before declining during 2023-2024. The positive association between API and ABER may indicate intensified surveillance in districts with greater malaria burden. However, the proportion of collected blood slides reported as examined declined from 100 per cent in 2019-2020 to 76.1 per cent in 2024. The available aggregate data cannot determine whether this discrepancy reflects diagnostic processing constraints, reporting delays, or data reconciliation issues. Nevertheless, the increasing BSC-BSE gap warrants programme-level investigation because complete and timely surveillance is essential for malaria elimination (WHO, 2018).

Confirmed malaria cases increased substantially after 2021 and peaked in 2023, with the majority of cases concentrated in a limited number of districts. The simultaneous increase in confirmed cases, API, and SPR suggests that the rising burden was unlikely to be explained solely by increased testing. This persistence of transmission in recognised high-burden areas highlights the need for more responsive and geographically targeted surveillance, consistent with the stratified approach advocated by the National Framework for Malaria Elimination in India (MOHFW, 2016).

The decline in Pf% from 93.76 per cent in 2019 to 52.96 per cent in 2024 indicates a changing parasite composition. However, AFI remained substantial and increased in 2024, suggesting that the declining proportional contribution of P. falciparum did not correspond to the elimination of falciparum transmission. These findings emphasise the need to interpret Pf% alongside species-specific incidence rather than as an isolated indicator.

Malaria mortality remained concentrated in high-transmission districts, particularly Lawngtlai district. Despite increased confirmed cases during the later study period, CFR declined to 0.04 per cent in 2024. This may reflect improvements in diagnosis, treatment access, or case management; however, these mechanisms could not be assessed using aggregate surveillance data. Continued malaria-related deaths nevertheless indicate the importance of timely diagnosis and treatment, particularly in areas with sustained falciparum transmission.

SPR showed the strongest statistical association with API, whereas ABER and Pf% were not independently associated with API after adjustment. This finding should be interpreted cautiously because API and SPR are calculated from related surveillance counts and may exhibit mathematical coupling. Therefore, the association does not establish SPR as a causal predictor of malaria incidence. Rather, the concurrent elevation of API and SPR identifies districts experiencing both high incidence and high parasite positivity.

CONCLUSION

Malaria transmission in Mizoram remained uneven and showed resurgence during the later elimination phase, with sustained burden in a limited number of districts. Changes in ABER and the declining proportion of collected blood slides reported as examined indicate potential gaps in surveillance performance requiring further programme-level assessment. Despite declining Pf% and case fatality, falciparum incidence and malaria-related deaths persisted. The results highlight the need to strengthen surveillance completeness and timely case detection.

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