Malaria in Sundargarh district, Odisha, India: Epidemiological and behavioral aspects from surveys

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ABSTRACT

To characterize malaria and assist in prevention efforts, we conducted a series of epidemiological studies in Sundargarh district, India, as part of an NIH-funded International Center of Excellence for Malaria Research. In a published survey around Rourkela in 2013-2014 (N = 1307), malaria prevalence was found to be 8.3%. Using these data, villages were divided into low (<2%), medium (2-10%) and high (>10%) malaria prevalence, and risk factors assessed by type of village. In the six low malaria villages, four persons were positive by PCR; in the four medium malaria villages, prevalence was 7% (35 infections, 7 P. vivax); and in the three high malaria villages, prevalence was 21% (62 infections, 10 P. vivax and 5 mixed with P. vivax and P. falciparum). A total of 30.6% infections were submicroscopic and 40.6% were asymptomatic. Our analyses showed that the rainy season and male gender were risk factors for malaria; in high malaria villages, young age was an additional risk factor, and indoor and outdoor spraying was protective compared to no spraying. We undertook a subsequent behavioral survey in four of the medium and high malaria villages in 2017 to investigate the behavioral aspects of malaria risk. Among 500 participants in 237 households, adult men (15+ years) were more likely to be outside in the evening (34.5% vs. 7.9% among adult women 15+ years and 0.7% among children, p < 0.001), or to sleep outside (7.5% vs. 0.5% and 0%, respectively, p < 0.001). Although women were more likely to get up before 6 a.m. (86.6% vs. 70.5% among men, 50.7% among children, p < 0.001), men were more likely to be outside in the early morning (77.6% among men, 11.2% among women, and 11.1% among children, p < 0.001). More children used insecticide treated nets the previous night (73.4%) than men (45.6%) or women (39.6%), and repellents were used by 29.5% of 234 households (insecticide creams were not used at all). Malaria control and elimination in India will need local approaches, and the promotion of repellent cream use by at-risk groups could be further explored in addition to mass-screen or treat programs in high-risk villages.

1. Introduction

Malaria imposes health and socio-economic burdens on affected communities. Although the major burden is in Africa, Asian countries suffer as well. India, the second most populous country in the world, accounted for about 4% of all malaria cases and deaths from malaria and 47% of all P. vivax cases globally in 2018 (World Health Organization, 2019). However, India is on its way to eliminating malaria and reported the largest absolute reduction in cases for any country in 2018 (World Health Organization, 2019). In an ambitious plan, India has pledged to eliminate malaria by 2027, three years earlier than planned for the region, by using an approach that varies by malaria transmission intensity at the district level (Narain and Nath, 2018). Many challenges to malaria elimination in India remain. For example, regions differ in their dominant malaria species, malaria vectors, and insecticide and drug resistance of the parasite (Wangdi et al., 2016). In addition, there are differences in sources and accessibility of health care, and cultural approaches to the disease (Lal et al., 2019). Malaria transmission levels vary widely throughout India, with Odisha contributing 16.5% of all cases in 2019 (https://nvbdcp.gov.in). And within states, the burden of malaria varies; e.g., malaria transmission is very low in the coastal region of Odisha, but high in the northern and western districts (Pradhan et al., 2016). The region around Rourkela in Sundargarh...
district is one of these areas in Odisha with persistent malaria.

To understand when and where remaining transmission is occurring and persisting, it is important to evaluate both vector behavior as well as human behavior (Monroe et al., 2019). The behavior of malaria vectors in Asia can differ from vectors in Africa by their primary source of feeding (animals or humans) and primary biting hours (Subbarao et al., 2019; Waite et al., 2017). Human behavior can be even more complex. To characterize malaria transmission and assist in malaria prevention efforts, we conducted a series of epidemiological studies in Sundargarh district, India, as part of an NIH-funded International Center of Excellence in Malaria Research (van Eijk et al., 2019). During these studies, children and males were found to be at higher risk of malaria than older people and females. Using a survey of individuals and households in villages with a higher prevalence of malaria, we subsequently examined how behavior of children and male and female adults differed, to assess how that may impact on malaria acquisition by gender and age. These data and analyses are presented here.

2. Methods

2.1. Study site

Rourkela city is located in the Sundargarh district of the eastern state of Odisha. Rourkela receives rains during the southwest monsoon season (June-September) and some rainfall during the retreating northeast monsoon (December-January) (Attri and Tyagi, 2010). Malaria displays hypo- to hyper-endemic transmission in this region, with *P. falciparum* as the major infecting species, accounting for > 40% of the total cases in the country. *Anopheles culicifacies* and *Anopheles fluviatilis* are the main vectors in this area (Waite et al., 2017). The malaria survey was conducted in peri-urban and rural areas around Rourkela (van Eijk et al., 2019), whereas the behavioral survey was conducted in the four villages found to have the highest prevalence of malaria during the malaria survey.

2.2. Study procedures and surveys

Census data were collected for each household to obtain demographics of the household members (van Eijk et al., 2016). Four malaria cross-sectional surveys were conducted over two years (2013-2014), spread over the seasons and each drawing households from a different random selection from the census. Procedures are described by van Eijk et al. (van Eijk et al., 2019), but briefly, subjects aged 12 months to 69 years with or without complaints were eligible for enrolment, while pregnant women were excluded. After obtaining consent, participants were interviewed using a structured questionnaire with sections on malaria history and use of mosquito protection; blood was collected for microscopy, a rapid malaria test, and PCR testing. The latitude and longitude of each household was taken using a handheld GPS device. If a household was not available to survey, the next household on the list was used. All members available in the household were sampled during the hours of 7 a.m. to 3 p.m. We did not return to a household to find missing household members.

The behavioral survey was conducted in 2017 in four villages with a higher prevalence of malaria (Birikera, Jharbeda, Rampur, and Rangamati), and was a convenience sample during the dry season. The questionnaire contained questions about location (inside or outside) and timing of activities of participants, focusing on the evening and night, and behavior towards malaria treatment; blood was obtained by finger prick, and tested for the presence of parasites by microscopy and rapid diagnostic malaria test (RDT). All participants who were positive by microscopy or RDT in any survey were treated as per national guidelines (*P. vivax*: chloroquine 25 mg/kg over three days and primaquine 0.25 mg/kg for 14 days; *P. falciparum*: artemesunate 4 mg/kg for 3 days in combination with sulfadoxine 25 mg/kg and pyrimethamine 1.25 mg/kg on the first day and primaquine 0.75 mg/kg). The first dose of treatment only was directly observed.

2.3. Laboratory tests for the behavioral survey

Thin and thick smears obtained from blood collected via a finger prick were stained using Giemsa, and at least 300 fields in the thick smear were examined using the 100 × oil immersion before a slide was deemed negative for malaria. Parasites were counted on the thick smear against 200–500 white blood cells (WBCs). The results were expressed as parasites per microliter of blood, using the WBC count if known, or assuming 8,000 WBCs per microliter of blood. Slides were routinely read by two independent microscopists and a third was used if there was disagreement. In addition, 10% of the slides were re-checked for quality control. A rapid diagnostic test was conducted in the field as per guidelines.

2.4. Statistical analysis

A secure, web-based REDCap (Research Electronic Data Capture) database was used to capture and store all participant data and test results [25]. Subsequently, data were exported into Stata (Stata/SE version 14.2, Stata-Corp LP, College Station, USA) for analysis. In the malaria survey, analyses were weighted by age and gender, using the household information obtained from the census (svy procedure in Stata 14.2). Among the 13 included villages, a considerable difference in malaria prevalence was noted, and for this reason they were divided into low (<2%), medium (2-10%) and high (>10%) malaria villages (Fig. 1). We examined the association between malaria detected by PCR and the following factors by village type: age, gender, season, ITN use, use of repellents (coils, mats, vaporizers or creams), and a history of malaria in the past year or malaria treatment in the past two weeks. Parasite infections detected by PCR but not by microscopy were classified as ‘submicroscopic’, and infections detected by PCR but not by RDT as ‘subpatent’; asymptomatic infections were malaria infections in the absence of any symptom or a history of fever in the past 48 hours. In the behavioral survey, times of evening activities were described. Factors significant in univariate analysis were included in the multivariate analysis.

![Fig. 1. Prevalence of malaria by location in and around Rourkela, Sundargarh district 2013-2014 Data for the cross-sectional studies are available in the Clinical Epidemiology Database, ClinEpiD (https://clinepidb.org), under “Study: India ICEMR Cross-Sectional”, and for the behavioral study under “Study: India ICEMR Behavioral”. Satellite Imagery via Google Maps. Imagery © 2018 VNES/Airbus, Digital Globe, Landsat/Copernicus.](image-url)
analysis; factors were removed from the multivariate model if the p-value was >0.5; however, ITN use was kept in because it was a factor of interest. Because of the pattern of malaria by age and gender in the malaria survey, the results in the behavioral survey were evaluated by age and gender: children (<15 years), adult men (15+ years) and adult women (15+ years), and results were compared using chi-square tests (proportions) and t-tests (means). However, where differences were noted by gender among children, this was reported separately. Generalized linear regression with a log link and binomial distribution was used for multivariate analyses, and Poisson regression with a robust variance estimator was used for models which did not converge for both types of surveys (Cummings, 2009). A p-value <0.05 was considered significant.

3. Results

3.1. Malaria survey: characteristics

Among the 1307 participants of the malaria survey conducted between 2013-2014, 50.5% were male and 69.9% were 15 years or older (Table 1). There were significant differences in age, season of survey, ITN use, use of repellents, house sprayed and history of malaria in the past year when comparing the low, medium, and high malaria villages (Table 1); ITN use was more common in high malaria villages, and repellent use (coils, mats, vaporizers or creams) in low and medium prevalence villages.

3.2. Malaria survey: malaria outcomes

The overall malaria prevalence by PCR was 8.3%: 6.5% P. falciparum, 1.5% P. vivax, and 0.4% mixed infections (Fig. 1). In low malaria villages (6 villages), by PCR only 4 persons were infected (1%), 3 with...
Three of these persons were aged 6-14 years (unweighted asymptomatic) and one with \( P. falciparum \) mixed infections (Fig. 2). For microscopic infections, no difference in geometric mean parasite density was seen for \( P. falciparum \) by village type, whereas for \( P. falciparum \) the parasite density in high prevalence villages was higher (geometric mean 2541 parasites/μL, 95% CI 1392-4638, \( n = 50 \)) compared to the other villages (medium: 734, 420-1284, \( n = 32 \), \( p = 0.005 \); low prevalence 404, 143-1139, \( n = 4 \), \( p = 0.09 \)). Among malaria infected persons, the proportions of asymptomatic or submicroscopic or subpatent infections were not significantly different by type of village (Fig. 2). For both medium and high malaria villages, rainy season and male gender were risk factors for malaria by PCR in multivariate models. In medium malaria villages, outdoor spraying only (compared to no spraying at all) and recent antimalarial use were additional risk factors for malaria, whereas in high malaria villages young age was an additional risk factor; IRS either with or without outdoor spraying (compared to no IRS) was protective (Table 2). Patterns by age and gender differed by species in medium and high malaria villages (Fig. 3), with higher prevalence of \( P. falciparum \) among males in the age-groups 15+ (29/256 or 11.3% of males infected and 16/349 or 4.6% of females infected, \( p = 0.002 \)) and higher prevalence of \( P. vivax \) among males in the age group 6-14 (4/68 or 5.9% among males vs. 0/73 females, \( p = 0.036 \)). No differences in use of ITNs by age or gender were detected (<6 years: male 17/74 or 23.0%, female 9/44 or 20.5%; 6-14 years: male 23/68 or 33.8%, female 9/44 or 20.5%); results were equally divided by age and gender and were all in high malaria villages. Five of them (two \( P. falciparum \) cases) had complaints of fever; only two had a history of malaria in the past year (one \( P. falciparum \) and one \( P. vivax \) infection).

### 3.3. Behavioral survey: characteristics and malaria

The behavioral survey was conducted in three high malaria villages and one medium malaria village in the dry season of 2017. Electricity was reported to be present in 64.1% of the 235 households, with no difference by type of village (medium 64.8% and high malaria village 63.9%). Five hundred persons were enrolled, with 143 participants less than 15 years old (28.6%), 218 adult women (15+ years), and 139 adult men (15+ years). Participants in high malaria villages were younger but other differences were not significant (Table 1). Four individuals had malaria by microscopy (all \( P. falciparum \)), and eight by RDT (2 \( P. vivax \)); results were equally divided by age and gender and were all in high malaria villages. Five of them (two \( P. vivax \) cases) had complaints of fever; only two had a history of malaria in the past year (one \( P. falciparum \) and one \( P. vivax \) infection).

### 3.4. Behavioral survey: habits

Most participants reported dining inside (96.4%); 21.2% before or at 7.30 p.m., 41.2% around 8 p.m., and 37.6% at or after 8.30 p.m. Children (44.1%) and men (36.7%) were more likely to sleep before 9 p.m. than women (28.4%, \( p = 0.009 \)). Men were more likely to be outside in the evening (41.0% vs. 11.2% among women and 21.1% among children, \( p < 0.001 \)), or to sleep outside (7.5% vs. 0.5% and 0%, respectively, \( p < 0.001 \)). Although women were more likely to get up before 6 a.m. (86.6%, vs. 70.5% among men, and 50.7% among children, \( p < 0.001 \)), men were more likely to be outside in the early morning (among persons up before 6 a.m.: 77.6% among men vs. 11.2% among women, and 11.1% among children, \( p < 0.001 \)). Toilet visits at night were less common among children (66.9%) than adults (93.5% for men, 91.2% for women, \( p < 0.001 \)). Although older children (6-14 years) were more likely to go to bed after 9 p.m and to be up before 6 a.m than children < 6 years, other behavior was similar to the younger age group (data not shown).
3.5. Behavioral survey: Malaria prevention

Coils, vaporizers, and mats were used by 18.0%, 12.0%, and 4.3% of 234 households, respectively. Other measures which were used to control mosquitoes at the household level included keeping windows closed in the evening (78.6%), clearing stagnant water pools (66.2%) or bushes (62.4%) around the house, burning neem leaves or cow dung (26.1%), screening the windows (27.5%), or using insecticide spray (18.8%). Screening of windows and clearing stagnant water around the house was significantly more common in the medium malaria village (38.9% and 77.8%, respectively, of 54 households) compared to the high transmission villages (24.0% and 62.8% of 180 households, \(p = 0.032\) and \(p = 0.041\), respectively). Children used more ITNs the previous night (73.4%; 72.0% among boys and 75.0% among girls, \(p = 0.685\)) than women (45.4%) or men (39.6%, men as reference value, \(p < 0.001\)). The majority of the 241 non-ITN-users reported that a net was not available (63.9%); others thought it too hot (19.5%) or did not give a reason (16.6%).

### Table 2

Risk factors for malaria by PCR in medium and high prevalence villages, Sundargarh district, 2013-2014.

<table>
<thead>
<tr>
<th></th>
<th>Medium prevalence villages</th>
<th>High prevalence villages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR, 95% CI</td>
<td>P-value</td>
</tr>
<tr>
<td>Male gender</td>
<td>1.83, 1.01-3.31</td>
<td>0.048</td>
</tr>
<tr>
<td>Age group (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>0.92, 0.39-2.15</td>
<td>0.839</td>
</tr>
<tr>
<td>5-14</td>
<td>1.21, 0.60-2.46</td>
<td>0.588</td>
</tr>
<tr>
<td>15+</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Rainy season</td>
<td>2.57, 1.38-4.76</td>
<td>0.003</td>
</tr>
<tr>
<td>ITN use</td>
<td>2.39, 1.31-4.34</td>
<td>0.004</td>
</tr>
<tr>
<td>Used repellents</td>
<td>1.69, 0.94-3.04</td>
<td>0.077</td>
</tr>
<tr>
<td>House sprayed in last year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor +/- outdoor</td>
<td>0.92, 0.45-1.85</td>
<td>0.806</td>
</tr>
<tr>
<td>Outdoor only</td>
<td>3.97, 1.99-7.91</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Travel in last 2 weeks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor +/- outdoor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malaria in the past year</td>
<td></td>
<td>1.01, 0.54-1.91</td>
</tr>
<tr>
<td>Antimalarials past two weeks</td>
<td></td>
<td>3.86, 1.26-11.85</td>
</tr>
<tr>
<td>Male</td>
<td>1.91, 1.09-3.34</td>
<td>0.023</td>
</tr>
<tr>
<td>Age group (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>0.81, 0.37-1.75</td>
<td>0.590</td>
</tr>
<tr>
<td>5-14</td>
<td>1.22, 0.62-2.40</td>
<td>0.565</td>
</tr>
<tr>
<td>15+</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Rainy season</td>
<td>3.32, 1.87-5.89</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ITN</td>
<td>1.58, 0.83-3.02</td>
<td>0.162</td>
</tr>
<tr>
<td>House sprayed in last year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor +/- outdoor</td>
<td>0.80, 0.40-1.61</td>
<td>0.528</td>
</tr>
<tr>
<td>Outdoor only</td>
<td>4.65, 2.30-9.40</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>None</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Antimalarials past two weeks</td>
<td></td>
<td>5.70, 1.44-22.49</td>
</tr>
</tbody>
</table>

CI: confidence interval, ITN: insecticide treated net, RR: risk ratio

Notes: Significant factors indicated in bold. Factors significant in one group but not in the other were kept in the model to allow comparison between the two types of villages. The use of ITNs was kept in in the model because it was a factor of interest.

* None of the participants with malaria had travelled in the past two weeks.

** Further exploration of interaction between gender and age in the high prevalence villages showed that females have a significant different risk of malaria compared to males from 15+ years onward.

### 3.5. Behavioral survey: Malaria prevention

Coils, vaporizers, and mats were used by 18.0%, 12.0%, and 4.3% of 234 households, respectively. Other measures which were used to control mosquitoes at the household level included keeping windows closed in the evening (78.6%), clearing stagnant water pools (66.2%) or bushes (62.4%) around the house, burning neem leaves or cow dung (26.1%), screening the windows (27.5%), or using insecticide spray (18.8%). Screening of windows and clearing stagnant water around the house was significantly more common in the medium malaria village (38.9% and 77.8%, respectively, of 54 households) compared to the high transmission villages (24.0% and 62.8% of 180 households, \(p = 0.032\) and \(p = 0.041\), respectively). Children used more ITNs the previous night (73.4%; 72.0% among boys and 75.0% among girls, \(p = 0.685\)) than women (45.4%) or men (39.6%, men as reference value, \(p < 0.001\)). The majority of the 241 non-ITN-users reported that a net was not available (63.9%); others thought it too hot (19.5%) or did not give a reason (16.6%). More girls (29.4%) reported covering...
their arms and legs to prevent mosquito bites during morning and evening hours than boys (18.7%), women (12.8%), and men (8.6%, \( p = 0.001 \)), but none of the participants reported using repellent skin creams. Only six (2.6%) of the 234 households reported keeping anti-malarials at home. Among 498 participants with information, 199 (40.0%) reported to sleep in a bedroom that had been sprayed with insecticide in the past year (IRS), with no difference by age and gender; IRS was more common in medium malaria villages (Table 1).

3.6. Behavioral survey: Malaria treatment

Participants were asked where they would go if they thought they had malaria; the community health worker (Accredited Social Health Activist, or ASHA) was reported by 46.4%, and the government clinic by 43.2%. In the medium malaria village 59.5% reported they would go to the ASHA first compared to 41.7% in the high malaria villages \( (p < 0.001) \). The majority reported that they would seek help within one day (72.2%; 79.4% in medium and 69.7% in high malaria villages, \( p = 0.033 \)). A history of malaria in the past year was reported by 176 participants (35.2%, no difference by age or gender); 58.0% sought help within one day. For young males the proportion seeking help in one day was higher; 87.5% of 24 males <15 years, versus 50% of 24 females <15 years \( (p = 0.005) \). There was no difference by gender among adults (57.8% among 45 males and 51.3% among 76 females, \( p = 0.491) \). Ninety percent of the children were brought for treatment to a health facility; among adults this was 55.7%, with 18.9% visiting the ASHA \( (9.1\% \) for male adults and 24.4% for female adults, \( p = 0.04) \). Only three participants knew what treatment they received. For the 176 participants who reported a malaria episode in the past year, we compared their reported health care choices for a malaria episode with the actual behavior for their last episode (Fig. 4). Although about half of the adults reported they would go to the ASHA first, in reality, government facilities were more likely to be visited first. For children, government facilities were the main source of treatment in both cases.

4. Discussion

In a region with persistent malaria in Sundargarh district in Odisha, villages differed strongly in malaria risk. Among participants in medium prevalence villages, risk factors for malaria included rainy season, male gender, outdoor spraying only compared to no spraying with insecticide, and antimalarial use in the past week, whereas in high prevalence malaria villages, age and gender were more prominent in addition to rainy season, and IRS was a protective factor. To investigate these risk factors further, we undertook a behavioral survey in four medium-to-high prevalence villages. We found that men were more likely to be involved in outside activities in the evening and early morning, compared to women and children. The use of repellents and creams was low, and screening of windows and IRS was more common in medium compared to high transmission villages. Children were more likely to use ITNs in the previous nights than adults, and local government health facilities and ASHAs were the most common sources mentioned for malaria treatment in the future and past.

This study confirms some findings from a similar study conducted in the area from 2001-2003, with low malaria transmission in the plains compared with the forested areas \( (1.7\% \) vs. 14.0% by microscopy, respectively, in 2001-2003), and a similar proportion of contribution of \( P. falciparum \) (85% by microscopy in both studies) \( (Sharma et al., 2006) \). The study concluded that villages in forest and plain areas separated by short geographical distance can still have a very distinct malaria epidemiology \( (Sharma et al., 2006) \). Effectiveness of regular malaria control methods are dependent on characteristics of the local mosquito population. Malaria transmitting mosquitoes in Sundargarh \( (An. culicifacies and An. fluviatilis) \) have been reported to be primarily zoophilic, feeding more on cattle than humans; it has been suggested that both indoor- and outdoor spraying is needed in environments where zoophilic vectors dominate \( (Waite et al., 2017) \). This would fit with our results in high malaria villages where combined in- and outdoor spraying was associated with protection of malaria. In medium transmission villages, outdoor spraying only was more a marker for malaria risk, which could indicate diversion of mosquitoes from the shed to the house, but it is not clear why combined in- and outdoor spraying does not have a stronger association with malaria protection in these villages.

Children and pregnant women are known to be more susceptible to malaria because of differences in their development of immunity to the parasite. We noted malaria patterns which differed by gender, with a higher risk of \( P. falciparum \) among adult males, and a higher risk of \( P. vivax \) among male children 5-14 years compared to females. A higher risk of malaria among males has been reported before in India and Asia, with differences in exposure given frequently as an explanation \( (Edwards et al., 2019; Kumar et al., 2007; Nguitragool et al., 2019; Pathak et al., 2012) \). Monroe et al (2017) summarized night-time behavior in the African setting and noted that common night-time activities across settings included household chores and entertainment during evening hours, as well as livelihood and large-scale socio-cultural events that can last throughout the night \( (Monroe et al., 2019) \). Shifting sleeping patterns were associated with travel, visitors, illness, farming practices, and outdoor sleeping. In our setting, adult males were more likely to be involved in activities outside the house in the evening and early morning hours and may be at higher risk because of...
the earlier biting hours and outdoor resting mosquitoes which have been described for mosquito populations in Asia (Edwards et al., 2019). It is not clear why there was a gender difference for P. vivax among children <15 years of age when the risk of P. falciparum seemed similar in the same age group; this may be a chance finding. Boys were more likely to visit a health clinic within one day of symptoms compared to girls, and so they may receive treatment earlier than girls.

As limitations to our studies, it is of note that the malaria surveys in the low malaria villages were more likely to be in the dry season, so this may have affected the results described. Additionally, the behavioral survey was conducted during the dry season, when malaria prevalence was very low by microscopy; no PCR tests were conducted for the behavioral study, so we cannot correlate behavior directly with malaria risk.

4.1. Public health implications

These studies show that malaria is a localized disease in India and needs the development of local prevention plans whereby behavior-related factors need to be taken into account. If adult males are at risk because of forest related activities or activities outside the house at optimum mosquito-biting hours, this may be a group that needs to be targeted with special types of prevention, e.g. insecticide creams for use in the evening or early morning to supplement indoor and outdoor spraying and use of ITNs. A study in Myanmar is evaluating if topical repellents can improve current arsenal of prevention; however, study results have not yet been published (Win Han et al., 2018). As part of a strategy to reduce the asymptomatic and submicroscopic burden, Odisha has already introduced the “Durgama Anchalare Malaria Nir-akarana (DAMaN)” program; mass-screening and treatment is conducted in high burden villages with enforcement of IRS and ITN use at the same time, at regular intervals, with promising results (Pradhan and Meherda, 2019). Local mass-treatment may be an alternative option, to reduce the transmission risk.

5. Conclusions

Malaria in villages around Rourkela differs within short distances, and 30-40% may be asymptomatic and below the detection level of microscopy; men are at higher risk. Malaria control and elimination will need a focal approach and new approaches, such as the promotion of use of repellent creams by special at-risk groups, and mass screen and treat or mass treatment programs may be needed to eliminate remaining foci.

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CRediT authorship contribution statement


Declaration of Competing Interest

The authors declare that they have no competing interests.

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Supplementary materials


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