Altitude, temperature, and malaria vectors in Nainital and Udham Singh Nagar districts of Uttarakhand, India: An evidence-based study

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ABSTRACT

Background & objectives: The relationship between altitude, temperature and malaria are poorly understood. Hence, a study was undertaken at three sites of Udham Singh Nagar (erstwhile Nainital district) and Nainital district (Uttarakhand) during 2010–11 for the generation of evidences in the context of potential threat of climate change.

Methods: Data on temperature and relative humidity (RH) were recorded through data-logger device in study villages at the altitudes of 166, 226 and 609 m were selected for detailed work. Mosquito collections were made fortnightly during 0600–0800 hrs. Malaria incidence data were procured from concerned Primary Health Centres.

Results: The study provides evidences of decrease in temperature with increase in altitude, even within a district resulting in variation in temporal distribution of malaria vector. With the increase of 67 m altitude between plains and foothill village, there was a reduction in temperature to the tune of 1.1°C and with further increase in altitude of 416 m between foothill and hilly villages, the temperature decreased by 0.27°C. The difference in temperature at three altitudes affects the Transmission windows (TWs) of both Plasmodium vivax (Pv) and P. falciparum (Pf), and opening of TWs are inversely proportional to altitude. In the plains, the TW for Pv and Pf were open for 11 and 10 months respectively, while 10 and 9 months in the foothills and 9 and 8 months, respectively for both the parasites at hilly altitude. Comparison of malaria vectors in plains, foothills, and hilly villages showed that the availability of Anopheles culicifacies and An. fluviatilis decreased with an increase in altitude from foothills to hilly areas.

Interpretation & conclusion: This study may be extrapolated to know the suitability of occurrence of malaria vectors and transmission of parasites at different altitudes from the viewpoint of temperature as limiting factor in unknown areas.

Key words Altitude; malaria; man hour density; Plasmodium falciparum; P. vivax; temperature; transmission window

INTRODUCTION

Environmental parameters are important drivers of malaria transmission as they affect malaria vectors’ life cycle and extrinsic development of malaria parasite in vectors. As we know, the required temperature for development of malaria parasite in mosquitoes is between 14 and 18°C¹–³. The biological activities of mosquitoes ceases at a temperature lower than 8°C⁴. It is well-known that as the altitude increases, chances of transmission of indigenous malaria also reduces⁵. At high altitudes, the minimum required temperature for development of malaria parasite as well as the biological activities of mosquito vectors are not met, due to which indigenous cases do not occur. Even if the temperature is suitable for one or two months, it may not lead to indigenous transmission of malaria as adequate time of at least three consecutive months⁶ is required for buildup of mosquito popula-

tion, transmission to human host, and thereafter reporting/recording of cases. In India, there has been awareness about the link between altitude and malaria since long⁵ which found indigenous malaria up to the elevation of 5400 feet (1646 m). Malaria epidemics have also been reported from the altitude as high as 2550 m⁷–⁸ and from 1500 m⁹ from Africa. Studies undertaken on climatic factors and malaria³–⁴, ⁹–¹¹ have provided projections of malaria in view of the climate change. Impact of high altitudes on malaria parasites transmission in Africa has also been studied recently¹²–¹⁵, however, there is negligible work from India. Recently, a study undertaken on the impact of climate change on malaria revealed that Himalayan region is likely to have new foci of malaria transmission, and the intensity of transmission has been projected to increase in northeastern states¹⁶. These studies have opened new vistas of thinking and warrant further work on the subject. In order to understand the relation-
ship between altitudes, temperature, and to generate evi-dences of changing climatic conditions and their impact on malaria vectors in vulnerable areas, the present study was undertaken.

MATERIAL & METHODS

Study was planned at three study sites in Districts Nainital and Udham Singh Nagar (Uttarakhand) in the year 2010. Villages were selected for generation of evidences of change in temperature, RH, and rainfall in ascending altitudes vis-a-vis malaria vectors density. Data on temperature and relative humidity (RH) were recorded through data-logger device from MicroDaq, USA. Village Sarkari (PHC: Kelakheda), Raikhalkhatta (PHC Motahaldu) and Bhorsa (PHC: Bhimtal) at the altitudes of 166, 226 and 609 m were selected for detailed work. The malaria prevalence in the study areas was also analyzed by collected data from all the three concerned Primary Health Centres (PHCs). HOBO Data loggers (MicroDaq, USA) were installed in Stevenson screen for recording of outdoor temperature and RH at every 4 h of interval. Fortnightly visits to the study sites were made for collection of mosquitoes and to check the functionality of the devices. Mosquitoes were collected from 0600-0800 hrs with the help of aspirator and torch as per stand-

RESULTS

Maximum temperature (32.08°C) was encountered in the month of June in plains (Fig. 1a), 32.05°C in foothill in June (Fig.1b), and 31.46°C in hilly area in June (Fig. 1c). The generated data on temperature at three altitudes revealed that the average maximum temperature of the years 2010 and 2011, 30.89, 30.56, and 28.98°C was encountered in the month of June in plains, foothills, and hilly village, respectively. When the monthly data of 2010 and 2011 were compared, discernible change (reduction as well increase) was noticed (Fig. 1a–c). Reduction in temperature was noticeable up to August, while there was an increase in 2011 as compared to 2010 in temperature from September to December.

In plains, i.e. Sarkari village, the minimum temperature (11.38°C) was recorded in January, which continuously decreased with increase in altitude, i.e. 10.78°C at Raikhalkhatta and 10.01°C at Bhorsa in January, which shows that with the increase of 67 m altitude between Sarkari and Raikhalkhatta, there was a reduction to the tune of 1.1°C and with further increase in altitude of 416 m between Raikhalkhatta and Bhorsa, the temperature decreased by 0.27°C.

There was a difference in temperature even within

![Fig. 1: Temperature (°C) variation during the years 2010 and 2011: (a) Sarkari (plains 166 m); (b) Raikhalkhatta (foothills 226 m); and (c) Bhorsa (hilly areas 609 m)]
2010 and 2011 years also, but the increase/decrease is not affecting the transmission window (TW) based on the minimum threshold of temperature required for \( P_v \) as 14.5°C and for \( P_f \) as 16°C. In the years 2010 and 2011, temperature value shows the closing of TWs for \( P_v \) Table 1 in January at Sarkari village while at Raikhalkhatta, TW was closed for two months and at Bhorsa village, window was closed for three months. Average temperature data revealed that TW for \( P_f \) was open for transmission for 10 months (from February to November) at Sarkari, 9 months (from March to November) at Raikhalkhatta, and at Bhorsa for 8 months as TW was closed due to lower than required temperature in November also (Table 2).

The difference in temperature at three altitudes affects the TWs of both the \( P_v \) and \( P_f \), and opening of TWs are inversely proportional to altitude. In plains, the TW for \( P_v \) and \( P_f \) was open for 11 and 10 months, respectively (Tables 1 and 2), while 10 and 9 months in Raikhalkatta and 9 and 8 months, respectively, for both the parasites at hilly altitude. The incidence of malaria for both the \( P. \) vivax and \( P. \) falciparum recorded by concerned PHCs for the years 2010 and 2011 also showed decrease with an increase in altitude (Table 3).

As regards to the man hour density Table 4 of \( A. \) culicifacies for the years 2010 and 2011, it was highest (62) in plains while \( A. \) fluviatilis density was highest (15) in April. In case of foothill areas, \( A. \) culicifacies and \( A. \) fluviatilis were collected almost every month, with highest density of 73 and 38.5 in May and April, respectively. At hilly area, i.e. Bhorsa, density of \( A. \) culicifacies and \( A. \) fluviatilis was highest (16 and 7.5,

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<tr>
<th>Village (altitude in m)</th>
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<th>Month</th>
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<tr>
<td></td>
<td>Jan</td>
<td>Feb</td>
<td>Mar</td>
<td>Apr</td>
<td>May</td>
</tr>
<tr>
<td>Bhorsa (609 m)</td>
<td>10.0</td>
<td>13.9</td>
<td>21.0</td>
<td>26.0</td>
<td>29.5</td>
</tr>
<tr>
<td>Raikhalkhatta (226 m)</td>
<td>10.7</td>
<td>15.0</td>
<td>19.9</td>
<td>26.8</td>
<td>28.1</td>
</tr>
<tr>
<td>Sarkari (166 m)</td>
<td>11.3</td>
<td>16.3</td>
<td>21.7</td>
<td>29.1</td>
<td>31.1</td>
</tr>
</tbody>
</table>

Table 2. Transmission windows for \( P. \) falciparum based on minimum required temperature (average of 2010 and 2011) at Bhorsa, Raikhalkhatta, and Sarkari villages (Shaded areas indicate blocked TWs)

<table>
<thead>
<tr>
<th>Village (altitude in m)</th>
<th>Month</th>
<th>Village (altitude in m)</th>
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<td>31.1</td>
</tr>
</tbody>
</table>

Table 3. PHCs-wise epidemiological data of malaria for the years 2010 and 2011

<table>
<thead>
<tr>
<th>Village/PHC (altitudes in m)</th>
<th>2010</th>
<th>2011</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>( P. ) vivax</td>
<td>( P. ) falciparum</td>
</tr>
<tr>
<td>Bhorsa/Bhimtal (609)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Raikhalkhatta/Motahaldu (226)</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>Sarkari/Kelakheda (166)</td>
<td>205</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Concerned PHCs.

Table 4. Average man hour density (2010 and 2011) of \( A. \) culicifacies and \( A. \) fluviatilis in Bhorsa, Raikhalkhatta, and Sarkari villages of Uttarakhand

<table>
<thead>
<tr>
<th>Village (altitude in m)</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<tr>
<td></td>
<td>Ac</td>
<td>Af</td>
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<td>Af</td>
<td>Ac</td>
<td>Af</td>
<td>Ac</td>
<td>Af</td>
</tr>
<tr>
<td>Bhorsa (609 m)</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4.5</td>
<td>6.5</td>
<td>16</td>
<td>7.5</td>
<td>4.5</td>
<td>7</td>
<td>8.5</td>
</tr>
<tr>
<td>Raikhalkhatta (226 m)</td>
<td>9</td>
<td>30</td>
<td>2.5</td>
<td>10</td>
<td>59.5</td>
<td>38.5</td>
<td>73</td>
<td>18.5</td>
<td>28</td>
<td>0.5</td>
<td>8.5</td>
<td>9</td>
</tr>
<tr>
<td>Sarkari (166 m)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>62</td>
<td>15</td>
<td>23.5</td>
<td>0</td>
<td>4</td>
<td>0.5</td>
<td>15</td>
</tr>
</tbody>
</table>

\( Ac = A. \) culicifacies; \( Af = A. \) fluviatilis.
respectively) in May. Overall, the results showed that there was an impact of altitude on temperature even with a difference of 67 m, and it affects the density of malaria vectors significantly.

**DISCUSSION**

The findings revealed that there is an increase as well as decrease in temperature in some months from year to year. The increase was pronounced, mostly coinciding with peak transmission season of malaria, i.e. from August to October. The decrease in temperature from March to August and increase from September to December in 2010 and 2011, though do not affect the TWs, are likely to affect the accelerated rate of transmission from September to November. However, the temperature affects the TWs of *Pv* and *Pf*, i.e. for *Pv*, window is open for 11, 10, and 9 months at Sarkari, Raikhalkhatta, and Bhorsa villages, respectively, and 10, 9 and 8 months for *Pf* due to low temperature in hilly area; 3 months are blocked for *Pv* while 4 months for *Pf*, which got reduced with the decrease in altitude.

In the hilly areas, *An. culicifacies* was not available from January to March, while in foothills, density of *An. culicifacies* was found in 10 months and that too with a high density from October to December (Table 3). It indicates that as the altitude increases, the temporal distribution of *An. fluviatilis* also increases with availability in colder months, i.e. January and March. During the present study, *An. fluviatilis* was collected for 4, 11, and 9 months from plain, foothill, and hilly areas, respectively, while in 1998–99, this vector species was collected only in 4 and 6 months, respectively, in three physiological areas. The MHD and temporal distribution of *An. culicifacies* was also found higher / wider in foothill area than in plain area, possibly due to change in climatic conditions. In plain, the peak density of *An. culicifacies* was in April, while in foothill and hilly areas, the peak of density shifted to May due to availability of suitable temperature for vector survival. *Anopheles culicifacies* and *An. fluviatilis* are proven vectors of malaria in terai area of Uttarakhand. The high density of *An. fluviatilis* for several months in foothill and hilly areas suggested that *An. fluviatilis* might also be playing considerable role in transmission of malaria. Deforestation due to industrialization and urbanization is also taking place continuously in hilly areas, affecting the ecological conditions.

It has been invariably accepted that any considerable increase in elevation would have an influence on malaria and is the main factor for freedom of high altitude for malaria. In England also, indigenous malaria occurred at mean temperature of 16.6°C during July-August in the years 1917–19. The present study has generated the evidence of reducing temperature with an increase in altitude and its effect on density of malaria vector. However, it has been proved experimentally in Himachal Pradesh that spread of malaria may occur at the altitude of 7000 feet. It is to mention here that experimental conditions are not likely to be available in nature as the development of mosquitoes and their required density is affected by external climatic conditions and availability of host. That is why just suitability of temperature for one or two months for malaria transmission may not result in indigenous malaria as evidenced by the absence of malaria from nine districts including Uttarkashi and other eight districts of Uttarakhand (Source: http://www.ukhfws.org/detail.php?progID=5), which though have suitability for transmission from the temperature point of view.

This study provides the link based on monthly generated evidences of temperature, altitude, and density of malaria vectors. Based on this information, the potential vulnerable areas from the viewpoint of temporal availability of malaria vectors continuously for three months would help in identifying the vulnerable areas for potential malaria transmission in the hilly areas. With extension of this study, based on temperature, projection of the availability of vector density should also be possible at different altitudes.

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