Effect of pregnancy on exposure to malaria mosquitoes

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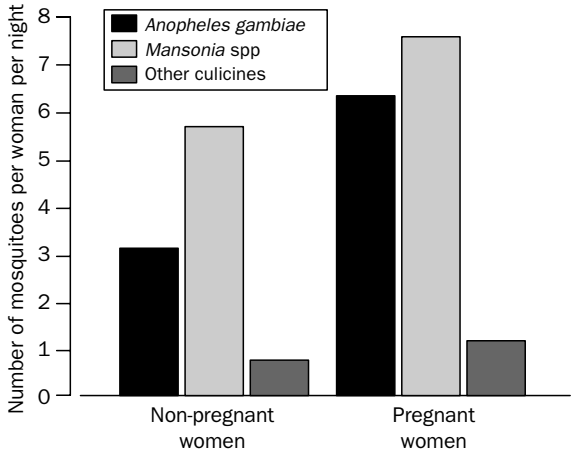
Pregnant women attracted twice the number of *Anopheles gambiae* complex—the predominant African malaria-carrying mosquito—than did their non-pregnant counterparts. We postulate that physiological and behavioural changes that occur during pregnancy are responsible for increased attractiveness, which could be important in intervention strategies aimed at protecting this high-risk group against malaria.

Malaria is a major cause of illness and an indirect cause of death for pregnant women. It is also an important cause of stillbirths, low birthweight, and early infant mortality.[1] In Africa, where transmission and adult immunity to falciparum malaria is generally high, these debilitating effects are confined largely to primigravidae, in whom a subpopulation of parasites may sequester in the placenta. Immune responses during the first pregnancy are protective against these parasites in subsequent pregnancies, and rates of maternal malaria decline accordingly in multiparous women.[2,3] Nutritional factors may also affect the susceptibility of pregnant women to malaria infection.[1] However, there may be other mechanisms operating during pregnancy that predispose pregnant women to infection. For example, it is well known that some individuals are more attractive to mosquitoes than others, although the reasons for this variation are incompletely understood. We postulated that physiological and behavioural changes taking place during pregnancy could increase biting by malaria mosquitoes, and thus increase the exposure of pregnant women to malaria parasites.

We compared the relative attractiveness of pregnant and non-pregnant women to mosquitoes in rural Gambia. Each night, three pregnant and three non-pregnant women slept alone under a bednet in six identical huts.[4] They were given malaria chemoprophylaxis and received few, if any, bites under the net. In the morning, the number of mosquitoes collected from each hut was used to estimate the relative attractiveness of each woman. This procedure was carried out with the same group of women for three consecutive nights and was repeated with 12 different groups of women. Data were analysed by ANOVA, adjusting for variation between huts and trials.

Twice as many *Anopheles gambiae* mosquitoes—the main malaria vectors in Africa—were attracted to pregnant women (mean 6·3 per night [95% CI 4·5–8·7]) than to their non-pregnant counterparts (3·1 [2·1–4·5]; p=0·0002; figure). Similar findings were also found with *Mansonia* spp (7·6 [5·8–10·0] *vs* 5·7 [4·1–7·8]; p=0·0008), but differences were of borderline significance with other culicines, which included *Aedes aegypti*, *Culex quinquefasciatus*, and *C tritaeniorhynchus* (1·2 [0·7–1·8] *vs* 0·7 [0·4–1·1]; p=0·056). All these mosquitoes are important disease vectors in different parts of the tropics.



Relative attractiveness of pregnant and non-pregnant women to mosquitoes

The mechanisms underlying increased attractiveness during pregnancy are likely to be related to at least two physiological factors. First, we found that women in the advanced stages of pregnancy (mean gestational age 28 weeks) produced 21% more exhaled breath than their non-pregnant counterparts (as measured with an infrared CO_2 analyser, Morgan Medical Ltd). There are several hundred different components in human breath, some of which are likely to be used by mosquitoes for detecting a host. At close range, body warmth, moist convection currents, host odours and visual stimuli, allow the insect to locate its target. During pregnancy, blood flow to the skin increases, which helps heat dissipation, particularly in the hands and feet. In our study, we found that the abdomen of each pregnant women was on average 0·7°C hotter than that of non-pregnant women. Thus, the second reason for increased attractiveness may be that these hotter pregnant women increase the release of volatile substances from the skin surface and produce a larger host signature which allows mosquitoes to detect them more readily at close range. Not only do pregnant women appear to be physiologically more attractive to mosquitoes, but changes in their behaviour can also increase exposure to night-biting mosquitoes, since pregnant women left the protection of their bednet at night, probably to urinate, twice as frequently as non-pregnant women (two times *vs* one time per night, Mann-Whitney *U* test p=0·019).

This study shows that pregnant women are at increased risk of malaria, and perhaps other mosquito-borne diseases, and underlines the importance of protecting this vulnerable group against biting by vectors. While the important role of immunity and nutrition is recognised, here we suggest that physiological and behavioural changes which occur during pregnancy could partly explain this increased risk of infection.

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