Occupational Activities Associated with a Reported History of Malaria among Women Working in Small-Scale Agriculture in South Africa

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Abstract. Malaria-endemic agricultural communities are at risk for this disease because of crop and agricultural activities. A cross-sectional survey among women in small-scale agriculture on irrigated and dryland areas in Makhatini Flats, KwaZulu-Natal South Africa explored associations with self-reported history of malaria, including demographics, crop production, and specific agricultural activities. Ninety-eight (15.2%) of 644 women reported malaria while working in agriculture. More women working in drylands than women working in irrigation scheme reported disease (18.4% versus 10.9%; $P < 0.05$). Working self or family-owned farms (prevalence ratio [PR] = 2.6, 95% confidence interval [CI] = 1.3–5.2), spraying pesticides (PR = 2.3; 95% CI = 1.4–3.8), cultivating sugar cane (PR = 1.6, 95% CI = 1.1–2.3), and cultivating cotton and mangoes (PR = 1.7, 95% CI = 1.1–2.6) were positively associated with a history of malaria while working in agriculture. This study suggests that certain agricultural activities and types of crop production may increase the risk for malaria among women working in small-scale agriculture.

INTRODUCTION

An estimated 225 million cases of malaria were reported worldwide in 2009 and the highest burden of disease and death was in Africa. Although there has been a downward trend in the number of malaria cases globally (233 million in 2000 to 225 million in 2009) in Africa, the number of malaria cases has increased in the past 10 years (32 million in 2000 to 68 million in 2009).¹ South Africa is classified by the World Health Organization as a country having low endemic malaria transmission areas and an estimated 6,072 malaria cases were reported in 2009.¹ The malaria-endemic areas in South Africa are Mpumalanga, Limpopo, and Umkhanyakude in Northern KwaZulu-Natal. A malaria control program involving indoor residual spraying of homes with dichlorodiphenyltrichloroethane and the use of artemisinin-based combination therapies has reduced malaria infection in malaria-endemic areas of South Africa.^{2,3} Despite an effective malaria control program, the malaria incidence in Umkhanyakude, KwaZulu-Natal was 5.6 per 100 000 population in 2007.⁴ Human immunodeficiency virus infection has been associated with an increased risk of malaria in northern KwaZulu-Natal, suggesting that infection with this virus may be causing an increase in malaria incidence in the area.⁵

Rural agricultural communities in malaria-endemic areas tend to be most at risk for malaria infection, particularly in the presence of intensive irrigation, which provides an ideal breeding ground for the *Anopheles* mosquito, the vector responsible for malaria transmission.^{6,7} Environmental factors such as the distance a person lived from a water source, house typology, and living in a house for more than four years have been associated with an increased risk of developing malaria.^{8–10}

Agricultural activities including land clearing for crop production, which enables surface water pooling suitable for vector breeding, have been associated with an increased

incidence of malaria.¹¹ Cultivation of crops that require considerable irrigation, such as rice, cotton, maize, and sugar cane, have been associated with an increased risk for developing malaria.^{12–15} Studies in central Côte d'Ivoire reported an association between an interruption in irrigated-rice cultivation and changes in malaria transmission, decreases in *Plasmodium* prevalence, and the number of malaria cases.^{16,17}

With the goal of increasing agricultural production in several developing countries, arid land has been reclaimed and artificial irrigation schemes have been created.^{18,19} Failure to properly maintain irrigation schemes can lead to water stagnation, which provides the ideal environment for increased malaria transmission.²⁰

This study contributes to the existing knowledge on associations between agricultural activities and malaria and highlights the association between pesticide spraying and a history of having malaria in women working in small-scale agriculture. The Makhatini Flats provide a useful opportunity to examine agricultural occupational activities that may be associated with malaria and contribute to the increase in the disease in the population. The area is located in the malaria-endemic Umkhanyakude District in northern KwaZulu-Natal, South Africa, and consists of an artificial irrigation scheme and a dryland area on which intensive small-scale agricultural activity is practiced. Several studies have reported on the burden and disease trend of malaria in the region and a reduction in recent years.^{2,3,21} Thus, as part of a larger study examining the occupational health of women working in small-scale agriculture,^{22,23} this study examined the association of demographics, agricultural activities, and crop production with a reported history of having had malaria while working in agriculture among women farmers. We hypothesized that working on the irrigation scheme would result in more malaria in women than working on the dryland area of the Makhatini Flats of South Africa.

MATERIALS AND METHODS

An interview survey of women ($n = 913$) involved in small-scale farming on the Makhatini Flats, northern KwaZulu-Natal, South Africa, was conducted in 2006.

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Study area, population, and recruitment of participants.

Details of the study area, population, recruitment of study participants, and data collection procedure have been reported.^{22,23} The Makhatini Flats consists of farms on an artificial irrigation scheme ($n = 276$; 1–10 hectares) and a dryland area ($n = 1,200$; 1–5 hectares). All farmers are involved in raising mixed crops. Farmers on the irrigation scheme have enjoyed considerably more government support and resources than those on the drylands.^{24,25} An estimated 2–3 women worked per farm, and approximately 4,400 women worked in agriculture on the Makhatini Flats. Before the survey, farmer unions and the community were informed about the study through workshops. Meeting points regularly used by the farmers were identified and 13 were randomly chosen as sites at which a questionnaire survey would be held on different days over a three-month period. Sites were visited more than once. All women ≥ 18 years of age were invited directly and through farmer unions to voluntarily participate in interviews. A total of 913 women volunteered to participate in the study; they represented approximately 20% of the estimated number of women working in agriculture on the Makhatini Flats.²²

Data collection. Researchers developed a questionnaire of open-ended and closed-ended questions covering demographic details, crop production, agricultural activities, pesticide use and safety, and health outcomes.²² The questionnaire was translated into isiZulu and back-translated to ensure correctness of translation. Two research assistants piloted the questionnaire on the Makhatini Flats two months before the survey and the necessary corrections were made. A team of six experienced (four women and two men) field workers, all fully conversant in isiZulu, were trained to administer the questionnaire by the research team. Data collection at the different sites took place from 11:00 AM onwards because most women started their agricultural activities by 6:00 AM and completed them by midday. By scheduling the interviews in the middle of the day, we were able to ensure greater participation in the survey. Before data collection, the field workers solicited signed informed consent from participants.²² The University of KwaZulu-Natal Biomedical Research Ethics Committee approved the study (ethics no. E035/05).

Data analysis. Exposure and health outcome information were collected during a single contact session; exposure information was collected before information on health outcomes. In addition to collecting information on age and the highest level of education obtained, women were asked to report on the following factors: location of their farm (irrigation scheme versus dryland); length of residence on the Makhatini Flats; whether they resided on their farms; distance they lived from their farms; whether they worked on a farm that either they or their family owned (farm ownership); and their length of employment in agriculture. Information on length of residence on the Makhatini Flats and employment in agriculture were obtained because studies have shown associations with malaria.^{8,26} Information on residence was obtained because it has been shown that residing close to malaria breeding sites increased the risk of malaria.¹⁰ Farm ownership was used as an indirect measure of socioeconomic status. Women reported on the types of crops that they had cultivated and their agricultural activities. The agricultural activities that they reported participation in included plowing, planting, weeding, irrigating, and harvesting of crops.

They also reported on whether they sprayed pesticides on their crops and the frequency with which they sprayed their crops.

Women reported on whether they had ever been treated for malaria diagnosed by a health care provider, the ages at which they had been treated, the number of times treated, the health care provider from whom they sought treatment from (hospital, primary health clinic, or a private physician), hospitalization for the malaria, and absence from work because of infection.

The data collected were coded and captured in EPIDATA and analyzed using STATA version 10 (StataCorp LP, College Station, TX). Of the 913 women participating in the questionnaire survey, two questionnaires were discarded and data for 911 women were considered for further analysis.

Using the women's responses to questions on the age at which they had malaria and their length of employment in agriculture, we created a dependent variable, a history of having malaria while working in agriculture, for each study participant. Women given a diagnosis of malaria when not working in agriculture ($n = 94$, 10.3%) and women with incomplete information on age when they were given a diagnosis of malaria ($n = 171$, 18.7%) were removed from the analysis, resulting in 644 (70.5%) women being retained in the sample. If women had > 4 years of education, they were categorized as being educated.

Women who planted cotton also reported planting mangoes, resulting in a strong association between these two variables. Thus, a single variable was created for women who planted both crops. Because women sprayed pesticides on several crops, the median frequency of pesticide spraying of crops was calculated and used as the spray frequency for each woman. A separate variable categorizing spray frequency into high and low spray frequency was created by dichotomizing around the median. Medians and ranges were calculated for continuous variables, and frequencies were used to describe categorical variables. The independent samples Student's t test and Pearson's chi-square test were used for continuous and categorical variables, respectively, to test for significant differences between women with and without a history of having had malaria while working in agriculture.

Because the prevalence of malaria reported by the women was $> 10\%$, prevalence ratios (PRs) were estimated as the measure of association and 95% confidence intervals (CIs) were calculated. Generalized log binomial regression models were created to test whether demographics, agricultural activities, and crop production were significantly associated with reporting a history of having malaria while working in agriculture. Independent variables that were significantly associated with a history of having malaria while working in agriculture in univariate analyses among women in both areas were included in multivariate regression models. The variable location was included in the model to draw a comparison between the two areas and a history of having malaria while working in agriculture. Independent variables that were highly correlated with each other were analyzed in separate models. The accepted level of significance was 0.05 ($\alpha = 0.05$).

RESULTS

Demographics. The median age of women participating in the study was 41 years (range = 18–82 years). Among those

women who had attended school ($n = 368, 57.1\%$), the median number of years of school attendance was 7 years (range = 1–12 years). Women from the irrigation scheme were significantly longer educated than their dryland counterparts (8 versus 7 years; $P < 0.05$), and women on the drylands had resided much longer on the Makhatini Flats than women on the irrigation scheme (26 versus 18 years; $P < 0.01$). There was no statistically significant difference between women from both areas with respect to their median age (40 versus 41 years), median distance residing away from their farms (10 km), and median length of employment in agriculture (5 versus 7 years).

Crop production and agricultural activities. Women from the drylands were significantly more involved in agricultural activities than women from the irrigation scheme. Significantly more women from the irrigation scheme cultivated sugar cane than women from the drylands, and significantly more women from the drylands cultivated cotton and mangoes than women from the irrigation scheme (Table 1).

History of malaria. More than 15% of the women ($n = 98, 15.2\%$) reported having had malaria while working in agriculture. The median age of diagnosis was 34 years (range = 14–62 years), and there were no significant differences between women from both areas. Most women sought treatment at a primary health care clinic ($n = 57, 58.2\%$), and the remaining women visited a government run hospital ($n = 39, 39.8\%$) and private general practitioner ($n = 2; 2.0\%$), respectively.

Significantly more women in the drylands reported having had malaria while working in agriculture than women in the irrigation scheme (18.4% versus 10.9%). Significantly more women sprayed pesticides ($n = 81, 82.7\%$) than women who did not spray insecticides ($n = 17, 17.3\%$) among the 98 women reporting a history of malaria while working in agriculture (odds ratio = 3.1, 95% CI = 1.9–5.0). Thirty-five (43.2%) of the 81 women who sprayed pesticides also mixed pesticides. Of the women given a diagnosis of malaria while working in agriculture, 30.6% ($n = 30$) were hospitalized and 44.9% ($n = 44$) stayed away from work. There was no significant difference with respect to hospitalization and being absent from work

because of malaria between women from both areas. Women who were hospitalized spent a median of 4 days (range = 1–21 days) in a hospital.

Association of demographics, agricultural activities, and crop production with a history of malaria. Most independent variables that were significantly associated with having a history of malaria while working in agriculture by univariate analysis (Table 2) remained significantly associated by multivariate analysis, with the exception of a woman's length of employment in agriculture. Residing on the drylands as opposed to the irrigation scheme was significantly associated with having a history of malaria while working in agriculture in all models. Spraying pesticides was significantly associated with a history of having malaria (PR = 2.3, 95% CI = 1.4–3.8). Similarly, cultivating cotton and mangoes (PR = 1.7, 95% CI = 1.1–2.6) and sugar cane (PR = 1.6, 95% CI = 1.1–2.3) were significantly associated with a history of having malaria while working in agriculture. Plowing was weakly associated with a history of having malaria while working in agriculture (PR = 2.3, 95% CI = 1.0–5.2) (Table 3).

DISCUSSION

Our study on the Makhatini Flats in a malaria-endemic area in northern KwaZulu-Natal has shown that working on the drylands was significantly associated with a history of having malaria among participants. Women from the drylands reported having more malaria while working in agriculture than women from the irrigation scheme. This finding differs from that of a study in Ethiopia by Kibret and others, in which

TABLE 1
Prevalence of agricultural activities, crops produced, and reported history of Malaria among women working in small-scale agriculture on the Makhatini Flats, South Africa, by location ($n = 644$)

Activity	Location	
	Irrigation scheme, % ($n = 274$)	Drylands, %, ($n = 370$)
Agricultural activities (ever involved: yes)		
Plowing*	73.7	95.1
Planting*	78.8	94.6
Manual irrigation*	15.0	33.0
Spraying pesticides*	52.2	67.3
Weeding†	92.3	96.2
Harvesting*	78.1	89.7
Frequency of pesticide spraying (high)*	27.0	39.2
Crop production (ever cultivated: yes)		
Maize	52.9	61.1
Cotton and mangoes*	21.2	65.1
Sugar cane*	25.2	10.5
Mixed vegetables	50.0	43.0
Malaria (diagnosed when working in agriculture: yes)		
Reported history of malaria†	10.9	18.4

* $P < 0.01$ by chi-square test.

† $P < 0.05$ by chi-square test.

TABLE 2
Crude prevalence ratios of demographics, agricultural activities, and crops produced with reported history of malaria among women working in small-scale agriculture on the Makhatini Flats, South Africa, by location ($n = 644$)*

Characteristic	Location	
	Irrigation scheme ($n = 274$), PR (95% CI)†	Drylands ($n = 370$), PR (95% CI)‡
Demographics		
Age > 40 years	1.3 (0.7–2.5)	0.8 (0.5–1.2)
Educational level > 4 years	1.4 (0.7–3.0)	1.2 (0.8–1.8)
Duration of residence > 10 years	2.5 (0.9–6.8)	1.5 (0.7–3.0)
Distance residing from farm > 10 km	0.8 (0.4–1.7)	0.8 (0.5–1.3)
Length of employment in agriculture > 10 years	2.1 (1.1–4.0)	1.2 (0.8–1.8)
Farm ownership	2.4 (1.0–5.8)	2.6 (0.7–10.0)
Agricultural activities (ever involved: yes)		
Plowing	3.2 (1.1–10.3)	1.1 (0.4–3.2)
Planting	2.4 (0.8–7.7)	3.8 (0.6–26.2)
Manual irrigation	2.1 (1.0–4.3)	1.0 (0.6–1.5)
Spraying pesticides	3.7 (1.5–8.7)	2.5 (1.4–4.6)
Weeding	2.4 (0.3–16.8)	0.9 (0.3–2.4)
Harvesting	1.8 (0.7–5.0)	1.2 (0.6–2.6)
Frequency of spraying pesticides (high)	1.2 (0.6–2.4)	1.2 (0.8–1.8)
Crop production (ever cultivated: yes)		
Maize	1.3 (0.7–2.7)	1.3 (0.8–2.0)
Cotton and mangoes	2.2 (1.1–4.3)	1.6 (1.0–2.7)
Sugar cane	1.5 (0.7–3.0)	2.2 (1.4–3.6)
Mixed vegetables	0.7 (0.4–1.5)	1.3 (0.8–1.9)

* PR = prevalence ratio; CI = confidence interval.

† Malaria cases ($n = 30$).

‡ Malaria cases ($n = 68$).

TABLE 3

Adjusted prevalence ratios of demographics, agricultural activities, and crops produced with reported history of malaria among women working in small-scale agricultural on the Makhatini Flats, South Africa, stratified by location (n = 644)*

Characteristic	History of malaria†			
	Model 1,‡ PR (95% CI)	Model 2,§ PR (95% CI)	Model 3,¶ PR (95% CI)	Model 4,# PR (95% CI)
Demographics				
Age > 40 years	1.1 (0.8–1.6)	1.1 (0.8–1.5)	1.1 (0.8–1.5)	1.1 (0.7–1.5)
Educational level > 4 years of school attendance	1.1 (0.8–1.5)	1.0 (0.7–1.4)	1.0 (0.7–1.4)	1.0 (0.7–1.4)
Location (drylands)	2.2 (1.5–3.2)	2.2 (1.5–3.3)	2.0 (1.3–2.9)	2.0 (1.3–3.0)
Length of employment in agriculture > 10 years	1.2 (0.8–1.7)	1.2 (0.8–1.7)	1.2 (0.9–1.8)	1.2 (0.8–1.7)
Farm ownership (yes)			2.6 (1.3–5.2)	
Agricultural activities (ever involved: yes)				
Plowing		2.3 (1.0–5.2)		
Spraying pesticides	2.3 (1.4–3.8)			
Crop production (ever cultivated: yes)				
Cotton and mangoes				1.7 (1.1–2.6)
Sugar cane	1.5 (1.0–2.2)	1.6 (1.1–2.3)		1.4 (1.0–2.0)

* PR = prevalence ratio; CI = confidence interval.

† All models included age > 40 years, educational level > 4 years of school attendance, length of employment in agriculture, and location (drylands vs. irrigation scheme).

‡ Model included spraying pesticides and cultivating sugar cane.

§ Model included plowing and cultivating sugar cane.

¶ Model included farm ownership (owned ones farm/family owned farm).

Model included cultivating cotton and mangoes and cultivating sugar cane.

they found a higher prevalence of malaria, in particular during the dry season in a village with an irrigation scheme than in a village that was not irrigated.⁷ However, in our study, women on the drylands were more involved in agricultural activities than women in the irrigation scheme and this factor may have contributed to the higher number of malaria cases among women on the drylands. The malaria vectors *Anopheles arabiensis* and *An. funestus* are found uniformly in northern KwaZulu-Natal.²⁷

Associations between agricultural activities such as land clearing and production of crops such as cotton and sugar cane and having malaria have been reported.^{11–15} Sugar cane and cotton cultivation have been associated with having malaria.¹¹ Cotton crops require considerably large amounts of water,²⁸ and sugar cane, if not correctly irrigated, will result in water logging, which provides an ideal environment for malaria transmission.²⁹ In addition, a poorly maintained irrigation scheme provides an ideal breeding site for malaria. During our field work, observations on the irrigation scheme suggest that maintenance is not ideal and water logging occurs, which would enable mosquito breeding.

Plowing was weakly associated with a history of malaria (PR = 2.3, 95% CI = 1.0–5.2). Plowing of the fields by our study population is performed either manually or with animal assistance. It was not uncommon practice in our study to find women bare footed in the field walking through pools of stagnant water. Although plowing has not been associated with having malaria, land clearing has shown an association.¹⁰ When plowing the land, women may also clear land that has been covered with growth and weeds, which generally provide breeding grounds for mosquitoes that transmit malaria.

Our study found a significant association between spraying pesticides and a history of having malaria while working in agriculture, which to the best of our knowledge, has not been previously reported. Spraying was a strong risk factor reporting a history of malaria (odds ratio = 3.1, 95% CI = 1.9–5.0). Women spraying the fields spend a longer period outside than women who mix pesticides or who are involved in other agricultural activities, which increases their risk for contracting malaria. In addition, the latter women may more frequently pass through stagnant water and in the absence of per-

sonal protective equipment³⁰ are exposed to mosquito bites. Pesticide exposure can modulate the human immune system³¹ and this may be an alternate explanation for the increased risk among the sprayers.

In Burkina Faso, Diabate and others reported increased malaria resistance to permethrin and dichlorodiphenyltrichloroethane in cotton-growing areas where there was extensive insecticide use, suggesting that excessive agriculture insecticide use may increase the risk of malaria transmission.³² In our study, a high frequency of spraying pesticides was not significantly associated with a history of having malaria by univariate analysis and remained non-significant by multivariate analysis, even though the estimate was > 1 (PR = 1.1, 95% CI = 0.7–1.5). This finding may be the result of the small number of women who reported a high frequency of spraying pesticides (n = 219, 34.0%) compared with those who reported a low frequency of pesticide spraying (n = 425, 66%).

Employment in agriculture in malaria-endemic areas has been described as a risk for developing malaria. In southern Mexico, the seroprevalence of malaria was highest among agricultural workers.²⁶ Because of higher temperatures on the Makhatini Flats, women tend to start working in the fields early in the morning (6:00 AM), which increases the potential for contact with mosquitoes.

Women who worked on their own farms or family-owned farms were more likely to report a history of having had malaria (PR = 2.6, 95% CI = 1.3–5.2). These women are more likely to be financially better off and are thus probably more likely to seek medical care, as shown in a previous study.³³ A small percentage of women reported being hospitalized (4.7%) and staying away from work (6.8%) because of malaria. In South Africa, only complicated cases of malaria, i.e., patients with cerebral malaria, hematuria, or temperatures > 40°C, are hospitalized, and persons with uncomplicated malaria are treated as outpatients. This finding may account for the low prevalence of hospital admissions seen in our study.³⁴ Furthermore, because of high levels of poverty in rural KwaZulu-Natal³⁵ and limited financial income derived from small-scale agriculture, women are unlikely to stay away from work unless extremely ill. Also, despite associations between length of residence⁸ and residing close to malaria breeding sites¹⁰ with an increased risk

of malaria reported in the literature, these findings were not evident in our study.

The findings of our study are limited by the cross-sectional nature of our study design because women recalling information from several years ago increases the possibility of misclassification of exposure and disease presentation. However, by confining our analysis to women given a diagnosis of malaria when working in agriculture, we limited the potential for exposure misclassification. Because of the unchanging nature of small-scale agriculture on the Makhathini Flats, women's reporting of agricultural activities would be consistent with activities at the time of being given a diagnosis of malaria.

The dependent outcome in our study was based on a woman's reporting of being given a diagnosis of malaria and not a current hematologic diagnosis, which could have led to an incorrect or under-reporting of disease history by the participants. However, we believe that the effect of this factor would have been minimal because malaria diagnostic techniques are freely accessible at public sector clinics and hospitals,³³ and research in South Africa has shown that populations in malaria-endemic areas recognize the symptoms of malaria and seek treatment for the disease.³⁶

In the analysis, we excluded women who could not recall the age at which their malaria was diagnosed (18.7%) because we could not determine if they were working in agriculture at the time of their diagnosis. A comparison of these women to those with malaria who were included in the analysis found that those excluded were older, less educated, had worked for less than 10 years in agriculture, and were less likely to spray pesticides.

The South Africa Malaria Control Program has been successful in using a multi-pronged approach involving indoor residual spraying and easy diagnosis and readily available anti-malarial treatment in public sector facilities.²¹ Vector and human behavior and environmental conditions have been implicated as factors responsible for increased malaria transmission. Our study describing associations between agricultural activities and a reported history of malaria contributes valuable information on agricultural activities and crops, which can result in increased transmission of malaria in rural-working populations.

In addition to current malaria control initiatives, a hierarchy of control based on occupational hygiene principles can be used to reduce exposure to mosquitoes among these agricultural workers. These principles would include engineering and personal protective controls. The farmers' unions in the area enjoy considerable support among the small-scale farmers. Working through the farmers unions will facilitate that government-funded initiatives supporting appropriate engineering methods to improve water drainage and prevent water pooling are more likely to be implemented in this area. This implementation would reduce breeding and exposure to mosquitoes and malaria transmission. In addition, initiatives by the government that either provide small-scale farmers with the necessary personal protective equipment or finances to obtain such equipment would help to reduce their exposure when working in the fields. Encouraging the use of boots and long-sleeved garments with trousers would be beneficial. Local government structures and district officials from the Department of Health and Labor would have to be used to monitor such initiatives. In doing so, the South Africa Malaria Control Program will be further strengthened.

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