Abstract. Artemisinin combination therapy is recommended for the treatment of multidrug resistant Plasmodium falciparum and Plasmodium vivax. In March 2006, antimalarial policy in Indonesia was changed to a unified treatment with dihydroartemisinin-primaquine for all species of malaria because of the low efficacy of previous drug treatments. In 2013, a randomized cross-sectional household survey in Papua was used to collect data on demographics, parasite positivity, treatment-seeking behavior, diagnosis and treatment of malaria, and household costs. Results were compared with a similar survey undertaken in 2005. A total of 800 households with 4,010 individuals were included in the 2013 survey. The prevalence of malaria parasitemia was 12% (348/2,795). Of the individuals who sought treatment of fever, 67% (348/519) before policy change (P < 0.001). During the 100 visits to healthcare providers, 95% (489/519) included a blood test for malaria and 74% (382/519) resulted in the recommended antimalarial for the diagnosed species, the corresponding figures before policy change were 48% (243/504) and 23% (117/504). The proportion of individuals seeking treatment more than once fell from 14% (70/504) before policy change to 2% (10/504) after policy change (P = 0.006). The mean indirect cost per fever episode requiring treatment seeking decreased from US$44.2 in 2005 to US$33.8 in 2013 (P = 0.006). The implementation of a highly effective antimalarial treatment was associated with better adherence of healthcare providers in both the public and private sectors and a reduction in clinical malaria and household costs.

INTRODUCTION

In Indonesia, the greatest prevalence of malaria is in the eastern provinces of Nusa Tenggara Timur and Papua. Great progress has been made in reducing the burden of malaria with the majority (74%) of the Indonesian population residing in malaria-free areas. However, 12% of the population still reside in areas with a malaria incidence greater than one case per 1,000 per year, and these individuals are at increased risk of malaria associated anemia. Until 2006, the first line policy was chloroquine plus sulfadoxine-pyrimethamine and a single dose of primaquine for uncomplicated Plasmodium falciparum malaria, and chloroquine plus primaquine (total dose 3.5 mg/kg over 14 days) for radical cure for Plasmodium vivax with the exception of infants less than 1 year of age and pregnant or lactating women for whom chloroquine alone was recommended. In 2005, clinical trials in Papua, Indonesia, highlighted very high levels of antimalarial drug resistance to the recommended treatment regimens with recrudescence P. falciparum and recurrent P. vivax infections exceeding 40% by day 28 after treatment. Dihydroartemisinin-primaquine (DHP) was shown to be highly effective against both species. In response, national policy was changed in March 2006 to a unified treatment with dihydroartemisinin-primaquine for all species of malaria because of the low efficacy of previous drug treatments. In 2013, a randomized cross-sectional household survey in Papua was used to collect data on demographics, parasite positivity, treatment-seeking behavior, diagnosis and treatment of malaria, and household costs. Results were compared with a similar survey undertaken in 2005. A total of 800 households with 4,010 individuals were included in the 2013 survey. The prevalence of malaria parasitemia was 12% (348/2,795). Of the individuals who sought treatment of fever, 67% (348/519) before policy change (P < 0.001). During the 100 visits to healthcare providers, 95% (489/519) included a blood test for malaria and 74% (382/519) resulted in the recommended antimalarial for the diagnosed species, the corresponding figures before policy change were 48% (243/504) and 23% (117/504). The proportion of individuals seeking treatment more than once fell from 14% (70/504) before policy change to 2% (10/504) after policy change (P = 0.006). The mean indirect cost per fever episode requiring treatment seeking decreased from US$44.2 in 2005 to US$33.8 in 2013 (P = 0.006). The implementation of a highly effective antimalarial treatment was associated with better adherence of healthcare providers in both the public and private sectors and a reduction in clinical malaria and household costs.

MATERIALS AND METHODS

Household surveys were conducted in Mimika Regency, southern Papua, Indonesia, in 2005 and 2013. The methods in 2013 were based on the 2005 survey which has been reported previously. Minor differences between the questionnaires included the collection of household income as a range rather than a specific estimate and information on bed net use by individuals rather than ownership by the household.
Symptomatic illness was defined as a history of fever in the past 24 hours or an axillary temperature of 37.5°C or higher when examined. Nearly all surveys were conducted in Bahasa Indonesian and the remaining in a local Papuan language. Individuals reporting a history of fever in the preceding 30 days were asked to complete a separate module with detailed questions on treatment-seeking if they were present. This module comprised questions on all of the places where they had sought treatment, whether they had received a blood test, whether they were prescribed antimalarials or other medicines, and any associated costs to the households.

Data analysis. Data were analyzed using the STATA statistical software (version 14.2, StataCorp, College Station, TX) and R (version 3.2.3). A Discriminant Analysis of Principal Components was used to categorize households by socioeconomic status (SES) by data on reported ownership of assets. To ensure that sufficient time had elapsed to capture treatment-seeking behavior, those individuals reporting fever starting within the preceding 2 days were excluded from the analysis of treatment seeking. For the use of diagnostics, laboratory tests, and antimalarial prescriptions, each patient–provider interaction ("visit") was analyzed for public and private healthcare providers.

Frequencies and percentages were used for the descriptive data. Percentages were compared using the χ² test. Differences in outcome distributions were evaluated with the Mann–Whitney test. Continuous variables were compared using the Spearman’s rank for correlation. When less than five observations were seen in a category, categorical outcomes were compared using the Fisher’s Exact test. Simple logistic regression adjusted for clustering by households was used to calculate odds ratios (ORs) for comparisons within the 2013 survey. For the analysis of reported fever in the past month, significant risk factors (P < 0.05) in the univariate analysis were included in a multiple logistic regression model and significant interactions between age, ethnicity, and significant variables were reported. The 2005 and 2013 surveys were compared using adjusted odds ratios (AORs) for age (0–4, 5–14, 15+), gender, household SES, and ethnicity (non-Papuan, highland Papuan, and lowland Papuan). The models were adjusted for clustering by household.

Costs were gathered in Indonesian rupiah converted into United States Dollars (US$) using the average exchange rates and then revised to the 2014 equivalent using the consumer price index for Indonesia. The mean cost and standard deviation (SD) per fever episode are reported. Direct costs included transportation for the patient and care and treatment, which included consultations, diagnosis, medication, overnight stay, and any other payments. Indirect costs included the amount of time that usual activities were reduced for the individual and any companions, caretakers, or substitute laborers. This time was valued using the mean reported wage for all.

RESULTS

Household characteristics. A total of 800 households with 4,010 individuals were included in the 2013 survey (Figure 1). The baseline characteristics for both the 2005 and 2013 surveys are provided in Table 1. In 2013, the
median household size was five individuals (interquartile range [IQR] = 4–6) with a maximum of 13 in one house. The median duration that heads of households reported residing at their current location was 13 years (IQR = 6–20), with 23 (3%) households reporting a move into that location within the previous year. In 2005, the household size was six individuals (IQR = 4–8) with a median duration of 9 years (IQR = 4–15). Of the 781 households in which monthly household income was reported, 52% (403) estimated US$560 or less. The households were categorized into five SES groups, with the number of households in each group ranging from 91 to 296. While poorer households were more likely to grow their own crops and drink rain water, richer households were more likely to own motorcycles and large electrical items and drink bought water (Supplemental Figure 1). The poorest SES group was composed of a greater percentage of highland Papuans (32%, 47/145) compared with 19% (35/189) of lowland Papuans and 3% (15/465) of non-Papuans (P < 0.001). The estimated household general health expenditure was correlated with the number of individuals reporting fever in a household (ρ = 0.488, P < 0.001).

**History of fever and parasite positivity of household members.** Of the 2,830 (71%) individuals present at the time of the interview in 2013, 41% (1,162) were male, 43% (1,225) were under the age of 15, and 46% (1,290) were Papuan (Table 1). Overall, 4% (117/2,830) of individuals reported having had a febrile illness in the preceding month compared with 42% (1,631/3,896) in 2005 (AOR = 0.06, 95% confidence interval [CI] = 0.05–0.08, P < 0.001; Table 2). Non-Papuan participants were at a significantly higher risk for having had a febrile illness compared with highland Papuans (AOR = 1.84, 95% CI = 1.05–3.26, P = 0.035; Supplemental Table 1).

![Flow diagram of household members, interviews, initial location of treatment taking, and whether they took a second treatment in 2013.](image-url)
Overall, 12% (348/2,795) of individuals who consented to blood testing in 2013 were parasitemic, a slight reduction from 16% (634/3,890) in 2005 (AOR = 0.83, 95% CI = 0.69–0.99, \( P = 0.038 \)). The change in prevalence was most apparent in individuals with symptomatic parasitemia which decreased from 5% (200/3,890) in 2005 to 1% (21/2,795) in 2013 (AOR = 0.16, 95% CI = 0.10–0.26, \( P < 0.001 \)), whereas the prevalence of asymptomatic parasitemia was similar in both surveys: 11% (434/3,890) in 2005 and 12% (327/2,795) in 2013 (AOR = 1.20, 95% CI = 0.98–1.45, \( P = 0.073 \)). Individuals reporting a febrile illness in the past month were significantly more likely to be parasitemic in the 2005 survey (OR = 3.81, TABLE 1

Demographic characteristics of all household members and individuals present during surveys in 2005 and 2013

| Characteristic, n (%) | All household members \( N = 5,255 \) | Present during survey \( N = 3,896 \) | All household members \( N = 4,010 \) | Present during survey \( N = 2,830 \) |
|----------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| **Age (years)**      |                                       |                                       |                                       |                                       |
| 0–4                  | 870 (17%)                             | 820 (21%)                             | 629 (16%)                             | 559 (20%)                             |
| 5–14                 | 1,101 (21%)                           | 824 (21%)                             | 970 (24%)                             | 666 (24%)                             |
| 15+                  | 3,284 (62%)                           | 2,252 (58%)                           | 2,404 (60%)                           | 1,604 (57%)                           |
| Not reported         | –                                     | –                                     | 7 (0.2%)                              | 1 (0.04%)                             |
| **Sex (female)**     |                                       |                                       |                                       |                                       |
|                       | 2,409 (46%)                           | 2,019 (52%)                           | 2,035 (51%)                           | 1,668 (59%)                           |
| Pregnant (yes)       | 92 (2%)                               | 87 (2%)                               | *                                      | 45/2,825 (2%)                        |
| **Place of birth**   |                                       |                                       |                                       |                                       |
| Highland Papuan      | 1,494 (28%)                           | 1,045 (27%)                           | 733 (18%)                             | 539 (19%)                             |
| Lowland Papuan       | 1,371 (26%)                           | 1,024 (26%)                           | 1,039 (26%)                           | 751 (27%)                             |
| Non-Papuan           | 2,390 (45%)                           | 1,827 (47%)                           | 2,238 (56%)                           | 1,540 (54%)                           |
| **Resided in lowlands for more than 1 year?** | | | | |
| (yes)                | 4,969 (95%)                           | 3,674 (94%)                           | 3,862 (96%)                           | 2,711 (96%)                           |
| **Subdistrict**      |                                       |                                       |                                       |                                       |
| Banti                | 152 (3%)                              | 119 (3%)                              | 0 (0%)                                | 0 (0%)                                |
| Harapan and Kwamki Lama | 901 (17%)                         | 576 (15%)                             | 111 (3%)                              | 80 (3%)                               |
| Inauga               | 521 (10%)                             | 405 (10%)                             | 383 (10%)                             | 291 (10%)                             |
| Kamoro Jaya          | 354 (7%)                              | 273 (7%)                              | 369 (9%)                              | 257 (9%)                              |
| Kadun Jaya, Kaugapu and Pigapu | 371 (7%)                | 286 (7%)                              | 267 (7%)                              | 210 (7%)                              |
| Limau Asri, Iwaka, Mulla Kencana and Naena Mulpurra | 196 (3%)  | 112 (3%)  | 566 (13%)  | 334 (12%)  |
| Koperapoka           | 957 (18%)                             | 729 (19%)                             | 753 (19%)                             | 521 (18%)                             |
| Timika Jaya, Kwamki and Kwamki Baru | 1,407 (27%)                | 1,046 (27%)                           | 989 (25%)                             | 696 (25%)                             |
| Wonosori Jaya and Nawarip | 122 (2%)                      | 98 (3%)                               | 374 (9%)                              | 267 (9%)                              |
| Karang Senang and Bhintuka | 334 (6%)               | 252 (6%)                              | 258 (6%)                              | 174 (6%)                              |

*Not reported.*

TABLE 2

Fever reporting in those who were present during the survey in 2005 and 2013

| Characteristic, n (%) | Reported fever during previous month \( N = 1,631/3,896, 42\% \) | Reported fever starting > 2 days before survey and took treatment \( N = 834/1,631, 51\% \) | Reported fever during previous month \( N = 117/2,830, 4\% \) | Reported fever starting > 2 days before survey and took treatment \( N = 99/117, 85\% \) |
|----------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| **Age (years)**      |                                                 |                                                 |                                                 |                                                 |
| 0–4                  | 405 (25%)                                       | 205 (25%)                                       | 23 (20%)                                       | 15 (15%)                                       |
| 5–14                 | 306 (19%)                                       | 148 (18%)                                       | 29 (25%)                                       | 26 (26%)                                       |
| 15+                  | 920 (56%)                                       | 481 (58%)                                       | 65 (56%)                                       | 58 (59%)                                       |
| **Sex (female)**     |                                                 |                                                 |                                                 |                                                 |
|                       | 850 (52%)                                       | 433 (52%)                                       | 63 (54%)                                       | 55 (56%)                                       |
| Pregnant (yes)       | 39 (2%)                                         | 23 (3%)                                         | 3/116 (3%)                                     | 3/98 (3%)                                      |
| **Place of birth**   |                                                 |                                                 |                                                 |                                                 |
| Highland Papuan      | 385 (24%)                                       | 172 (21%)                                       | 14 (12%)                                       | 11 (11%)                                       |
| Lowland Papuan       | 463 (28%)                                       | 183 (22%)                                       | 28 (24%)                                       | 19 (19%)                                       |
| Non-Papuan           | 783 (48%)                                       | 479 (57%)                                       | 75 (64%)                                       | 69 (70%)                                       |
| **Resided in lowlands for more than 1 year?** | | | | |
| (yes)                | 1,547 (95%)                                     | 797 (96%)                                       | 111 (95%)                                      | 93 (94%)                                       |
| **Subdistrict**      |                                                 |                                                 |                                                 |                                                 |
| Banti                | 29 (2%)                                         | 18 (2%)                                         | 0 (0%)                                         | 0 (0%)                                         |
| Harapan and Kwamki Lama | 226 (14%)                       | 124 (15%)                                       | 4 (3%)                                         | 2 (2%)                                         |
| Inauga               | 183 (11%)                                       | 106 (13%)                                       | 5 (4%)                                         | 5 (5%)                                         |
| Kamoro Jaya          | 107 (7%)                                        | 77 (9%)                                         | 12 (10%)                                       | 10 (10%)                                       |
| Kadun Jaya, Kaugapu and Pigapu | 108 (7%)                  | 11 (1%)                                         | 23 (20%)                                       | 14 (14%)                                       |
| Limau Asri, Iwaka, Mulla Kencana and Naena Mulpurra | 55 (3%)  | 3 (0.4%)  | 15 (13%)  | 15 (15%)  |
| Koperapoka           | 396 (24%)                                       | 127 (15%)                                       | 13 (11%)                                       | 12 (12%)                                       |
| Timika Jaya, Kwamki and Kwamki Baru | 383 (23%)                | 262 (31%)                                       | 16 (14%)                                       | 14 (14%)                                       |
| Wonosori Jaya and Nawarip | 49 (3%)                        | 39 (5%)                                         | 24 (21%)                                       | 23 (23%)                                       |
| Karang Senang and Bhintuka | 95 (6%)              | 67 (8%)                                         | 5 (4%)                                         | 4 (4%)                                         |
95% CI = 3.10–4.68, \( P < 0.001 \)); however, this was not significant in the 2013 survey (OR = 1.53, 95% CI = 0.89–2.61, \( P = 0.123 \)). The prevalence of parasitemia in each subdistrict is presented in Supplemental Table 2.

**Treatment-seeking behavior.** In 2013, treatment-seeking behavior was assessed in 98% (115/117) of participants reporting a fever in the preceding month, and in 94% (108/115) of these individuals the fever commenced at least 2 days before the survey (Figure 1). Individuals were more likely to take some form of medicine for their fever in 2013 with 92% (99/108) reporting taking medication compared with 78% (834/1,104) of those whose fever commenced at least 2 days before the survey in 2005 (AOR = 2.50, 95% CI = 1.23–5.06, \( P = 0.011 \)). Of the 99 patients who reported taking a medication, only 1% (1) did not seek treatment outside of the home, compared with 8% (70/834) in 2005 (\( P = 0.004 \)). In 2013, 67% (66/98) of individuals seeking treatment outside of the home attended a public provider at least once compared with 46% (349/764) in 2005 (AOR = 4.30, 95% CI = 2.54–7.28, \( P < 0.001 \)). Furthermore, individuals in the three lower SES groups were more likely to seek treatment at a public provider at least once compared with those in the top two SES groups (OR = 6.10, 95% CI = 2.05–18.11, \( P = 0.001 \)); this was also apparent in 2005 (OR = 2.29, 95% CI 1.59–3.32, \( P < 0.001 \)).

**Diagnosis of malaria at healthcare providers.** Of the 100 visits to healthcare providers in 2013, 95 (95%) involved a blood test for malaria compared with 48% (433/894) in 2005 (AOR = 24.42, 95% CI = 9.87–65.43, \( P < 0.001 \)); Table 3. Malaria testing was positive in 92% (87/95) of cases and in one (1%) visit the result was not reported. *Plasmodium falciparum* was diagnosed in 53% (46/87) of cases, *P. vivax* in 43% (37/87), mixed infections in 3% (3/87), and *Plasmodium malariae* in 1% (1/87). The increase in likelihood of individuals being tested for malaria was most apparent in the private sector where 29% (148/519) of individuals were tested in 2005 compared with 97% (313/32) in 2013 (\( P < 0.001 \)).

**Antimalarial treatment at healthcare providers.** In 2013, an antimalarial (alone or with other medicines) was reportedly prescribed during 88% (88/100) of visits to healthcare providers. Most of these prescriptions were given as tablets (95%, 84/88) with one (1%) injection and three (3%) for both an injection and tablets. Of the four malaria injections that were reported, two were at the public hospital and two at private providers. Ninety-nine percent (87/88) of antimalarial prescriptions followed a blood test as per clinical guidelines; all were reportedly positive. This was a significant increase compared with 2005 when only 61% (336/547) of prescriptions followed a blood test (\( P < 0.001 \)). In 2013, the antimalarial treatment regimen was prescribed correctly in 74% (64/86) of healthcare encounters in which *P. vivax*, *P. falciparum*, or mixed infections were diagnosed, a significant increase from 2005 when only 23% (78/336) of individuals were correctly treated according to the prevailing guidelines (AOR = 15.71, 95% CI = 8.18–30.18, \( P < 0.001 \)); Table 3). These improvements in prescribing habits were apparent in both the public (AOR = 15.93, 95% CI = 6.84–37.14, \( P < 0.001 \)) and private sectors (AOR = 12.16, 95% CI = 3.42–43.28, \( P < 0.001 \)).

The reported treatments prescribed for the different species are presented in Table 4. In 2013, 95% (57/60) of patients diagnosed with malaria in a public facility were treated with DHP compared with 52% (14/27) of those treated at a private provider (\( P < 0.001 \)). Between 2005 and 2013, the percentage

| Subdistrict | 2005 | 2013 | AOR (95% CI) | \( P \) value |
|-------------|------|------|--------------|-------------|
| Public      |      |      |              |             |
| DHP         | 76%  | 94%  | < 0.001      | 104/135     |
| CQ          | 25%  | 6%   | < 0.001      | 30/135      |
| Private     |      |      |              |             |
| DHP         | 75%  | 94%  | < 0.001      | 104/135     |
| CQ          | 25%  | 6%   | < 0.001      | 30/135      |
of individuals reportedly being treated with 14 days of primaquine for P. vivax infection (alone or mixed) rose from 9% (16/169) to 63% (25/40); (AOR = 37.49, 95% CI = 9.94–141.41, P < 0.001). Over the same period, the percentage of patients with P. falciparum reporting treatment with a single dose primaquine rose from 19% (31/167) in 2005 to 50% (23/46) in 2013 (AOR = 6.27, 95% CI = 2.68–14.68, P < 0.001).

Cost burden of fever. In 2013, a total of 100 visits to healthcare providers were reported by 98 individuals; hence, nearly all patients reported requiring only one visit compared with 14% (107/764) of individuals who reported seeking medical care at two or more providers before the policy change (P < 0.001). In 2013, the mean total direct cost to the household per visit was US$16.8 (SD = 19.0) at a private provider and US$4.1 (SD = 14.4) at the public sector (P < 0.001). The mean daily wage in 2013 was US$18.2 (SD = 14.0), with a total mean indirect cost per fever episode of US $52.5 (SD = 41.4) for adults and US$7.3 (SD = 16.4) for children.

The results of the household surveys undertaken before and after the implementation of ACT after confirmed diagnosis in Papua, Indonesia, highlight several important changes in treatment-seeking behavior, diagnosis of malaria, and adherence to antimalarial drugs. Only one individual (1%) did not seek treatment outside of the home compared with 8% in 2005 when less efficacious treatments were available in both the public and private sectors. This shift in treatment seeking was associated with more individuals attending public providers at least once, rising from 46% in 2005 to 67% in 2013. Those from households with lower SES were still more likely to seek treatment at public providers than those with higher SES. Before the implementation of ACT, more than 40% of patients failed antimalarial treatment within 42 days, with almost half of these patients doing so within 7 days. The introduction of a 3-day regimen of DHP resulted in rapid parasite clearance and symptom recovery with less than 5% of patients having recurrent malaria, most of which occurred after 28 days. Hence, the observed changes in treatment-seeking behavior likely reflect community awareness of such highly effective treatments and their availability initially in the public sector and subsequently in the private sector.

Table 4
Reported antimalarial treatment of individuals by reported diagnosis

|                      | 2005 (N = 336) |            | 2013 (N = 86) |            |
|----------------------|---------------|------------|---------------|------------|
|                      | Private (N)   | Public (N) | Overall (N)   | Private (N)| Public (N)| Overall (N) |
| Plasmodium falciparum (N) | 68 (0%)       | 99 (1%)   | 167 (1%)      | 14 (0%)    | 32 (1%)   | 46 (1%)     |
| Percentage receiving any ACT | 0% (0)       | 1% (1)    | 1% (1)        | 50% (7)    | 97% (31)  | 83% (38)    |
| Percentage receiving any antimalarial without ACT | 88% (60)     | 94% (93)  | 92% (153)     | 36% (5)    | 3% (1)    | 13% (6)     |
| Percentage receiving unknown antimalarial | 0% (0)       | 3% (3)    | 2% (3)        | 14% (2)    | 0% (0)    | 4% (2)      |
| Percentage receiving primaquine (any dose) | 62% (42)     | 82% (81)  | 74% (123)     | 71% (10)   | 59% (19)  | 63% (29)    |
| Percentage receiving any treatment | 94% (64)     | 98% (97)  | 96% (161)     | 100% (14)  | 100% (32) | 100% (46)   |
| Percentage receiving no treatment | 6% (4)       | 2% (2)    | 4% (6)        | 0% (0)     | 0% (0)    | 0% (0)      |
| Plasmodium vivax (N) | 51 (10%)      | 108 (20%) | 159 (30%)     | 12 (15%)   | 25 (22%)  | 37 (26%)    |
| Percentage receiving any ACT | 0% (0)       | 0% (0)    | 0% (0)        | 50% (6)    | 96% (24)  | 81% (30)    |
| Percentage receiving any antimalarial without ACT | 75% (38)     | 94% (102) | 88% (140)     | 25% (3)    | 0% (0)    | 8% (3)      |
| Percentage receiving unknown antimalarial | 20% (10)     | 5% (5)    | 9% (15)       | 25% (3)    | 4% (1)    | 11% (4)     |
| Percentage receiving primaquine (any dose) | 29% (15)     | 81% (88)  | 65% (103)     | 58% (7)    | 72% (18)  | 68% (25)    |
| Percentage receiving any treatment | 94% (48)     | 99% (107) | 97% (155)     | 100% (12)  | 100% (25) | 100% (37)   |
| Percentage receiving no treatment | 6% (3)       | 1% (1)    | 3% (4)        | 0% (0)     | 0% (0)    | 0% (0)      |
| Mixed infections (N) | 5 (5)         | 5 (5)     | 10 (10)       | 1 (1)      | 2 (2)     | 3 (3)       |
| Percentage receiving any ACT | 0% (0)       | 0% (0)    | 0% (0)        | 100% (0)   | 50% (0)   | 67% (0)     |
| Percentage receiving any antimalarial without ACT | 80% (4)      | 60% (3)   | 70% (7)       | 0% (0)     | 0% (0)    | 0% (0)      |
| Percentage receiving unknown antimalarial | 0% (0)       | 40% (2)   | 20% (2)       | 0% (0)     | 50% (1)   | 33% (1)     |
| Percentage receiving primaquine (any dose) | 60% (3)      | 60% (3)   | 60% (6)       | 100% (1)   | 50% (1)   | 67% (2)     |
| Percentage receiving any treatment | 80% (4)      | 100% (0)  | 90% (9)       | 100% (1)   | 100% (2)  | 100% (3)    |
| Percentage receiving no treatment | 20% (1)      | 0% (0)    | 10% (1)       | 0% (0)     | 0% (0)    | 0% (0)      |

ACCT = antimalarial combination therapy.
In parallel with the shift in where patients sought treatment, there were also significant changes in the way in which healthcare services were provided, particularly the treatment of malaria only after laboratory confirmation and adherence to antimalarial policy. Rapid diagnostic tests were introduced at public health facilities without microscopists in 2006–2007 and were used for half of the outpatient visits to one of the hospitals, whereas microscopy remained the main diagnostic for patients requiring admission to hospital. In 2013, individuals who attended healthcare facilities were almost twice as likely to have a blood test for malaria compared with those in 2005, and this was particularly prominent in the private sector where almost all patients were offered a blood test in 2013. Considering that dissatisfaction with the public sector is common and studies in Southeast Asia have shown that a large proportion of individuals seek treatment in the private sector, improvement of both sectors is vital to ensuring public health benefits.

Our findings also demonstrate that individuals diagnosed with malaria in 2013 were 3-fold more likely to receive the recommended treatment regimen. Importantly, both the public and private sectors implemented the policy change to ACT, with reductions in prescriptions of non-ACT antimalarials apparent in both sectors. This included an 8-fold decline in chloroquine prescriptions. Furthermore, better prescribing practices were also observed for primaquine, which is encouraged as a single dose for reducing the transmission potential of Plasmodium vivax. But this was countered by individuals reporting having lived in the area longer which would facilitate greater asymptomatic infections. In 2013, the only significant risk factor for recent febrile illness was being non-Papuan (Supplemental Table 1). Whereas in 2005 lowland Papuans, children less than 5 years old, and those from lower SES household were all at greater risk. The changes in treatment-seeking behavior therefore likely reflect a complex shift in population dynamics coupled with the impact of better treatment regimens and healthcare provision.

The observed changes in treatment seeking had important implications for the household costs incurred by malaria. While the mean cost for each febrile episode decreased from US$53.5 to US$41.9, reported monthly income in households increased from 60% with less than US$500 in 2005 to 49% with less than US$560 in 2013. Furthermore, in 2005, households more frequently reported multiple household members with fevers in the past month and those household members reported repeat visits as compared with 2013. Considering the decrease in symptomatic individuals who were parasite positive, it is likely that many of these changes in treatment-seeking behavior are a result of effective treatment.

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The study has a number of limitations. First, a degree of recall bias is likely due to the time between the fever episode and the survey, although this bias would be expected to be similar for both surveys. The 8-year gap between surveys increases confounding from other changes besides the policy change including demographic dynamics, such as smaller households, greater representation of females, and duration residing in the study area. Public health and malaria control activities aimed at changing behavior remained similar over this time period. Because of differences in the phrasing of the questionnaires, we were unable to explore how the use of bed nets had changed over time. As with the previous survey, many older male household members were not present at the time of the interviews and temporary migrants were excluded.

In conclusion, the policy change in March 2006 to a unified treatment of malaria with DHP has had a significant impact on treatment-seeking behavior, resulting in more patients...
attending healthcare facilities where better case management was being provided. These changes have had a significant impact on the burden of malaria with less patients reporting febrile illness; however, increases were seen in asymptomatic infections. Further reduction in malaria and its ultimate elimination will require implementing more effective radical cure of *P. vivax* and the implementation of active case detection or presumptive interventions.

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