Assessing the impact of malaria interventions on morbidity through a community-based surveillance system

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Background	The ACCESS Programme aims at understanding and improving access to prompt and effective malaria treatment in rural Tanzania with a set of integrated interventions targeting both users and providers. The aim of this article is to evaluate the programme's impact on the community and health facility burden of malaria and to investigate the value of community-based reporting for routine malaria control programme monitoring.
Methods	This work was implemented within the Ifakara Demographic Surveillance System (DSS) between 2004 and 2008. At community level the DSS staff routinely collected data on reported history of fever and severe malaria (convulsions) based on a 2-week recall. In parallel, we collected in-patient and out-patient fever and malaria diagnoses data from the 15 health facilities in the area. Treatment-seeking surveys conducted in the study area and nationally representative data were used to validate our measure of community fever.
Results	Between 2005 and 2008, community-reported fever incidence rates in children under the age of 5 years declined by 34%, from 4.9 to 3.2 average cases per child per year, whereas convulsions, a marker of severe malaria morbidity in children, decreased by 46%, from 4263 to 2320 cases for every 100 000 children per year. The decrease in the community rates was paralleled by a decrease in the health facility fever rates, although the number of fever cases seen in health facilities did not change because of population growth. Our data showed very good internal and external consistency with independent local and national surveys.
Conclusions	There is an evidence of a substantial decline in the community burden of malaria morbidity between 2005 and 2008 in the Kilombero and Ulanga DSS areas in Tanzania, most likely as a result of malaria control efforts. The good internal and external consistency of the data shows that history of fever in the previous

2 weeks in children under the age of 5 years can be used as a morbidity monitoring tool.

Keywords   Malaria, morbidity, fever, seizures, programme evaluation

'Without high quality surveillance, the billion dollar malaria effort is flying blind'.[1]

Background

The massive increase in resources mobilized for malaria control calls for careful monitoring to ensure that money is spent effectively. Surveillance data are crucial at country level to know when targets are met and even more importantly to initiate mid-course corrections if progress is inadequate. Reliable evaluation data are also important as an evidence base to up-scale effective new interventions. The need for a comprehensive monitoring and evaluation plan has been recognized by donors and international technical agencies. This has led to the development of a comprehensive Monitoring and Evaluation (M&E) toolkit by the Global Fund to fight AIDS, TB and Malaria (GFATM) to assist countries in developing robust M&E systems.[2]

The GFATM's M&E toolkit is based on the widely applied input–output–outcome-impact framework and includes mortality and morbidity impact indicators. Mortality indicators are based on robust and validated methodologies.[3,4] They are widely used for the evaluation of malaria control efforts since the data can be obtained from nationally representative, cross-sectional retrospective surveys such as the Demographic Health Surveys (DHS)[5] and the Multiple Indicator Cluster Surveys (MICS).[6] However, mortality is multi-factorial and it is always difficult to tease apart the effect of malaria control from secular trends. The recommended morbidity indicators are parasite prevalence and anaemia prevalence. The Malaria Indicator Survey (MIS)[7] was especially designed to capture these two measures. Although the DHS, MICS and MIS also collect history of fever during the past 2 weeks, this measure is not widely used as a morbidity indicator and is not recommended in the M&E toolkit. Instead, it is used as a basis for operational indicators such as 'the percentage of children with fever in the previous 2 weeks who were treated with an antimalarial drug'. However, although parasite prevalence gives important information regarding the impact of control efforts on malaria transmission,[8] it is not directly a morbidity indicator. In high-endemicity areas, control efforts may first have an impact on fever and then only later on prevalence due to the reduction of multiplicity of infections that reduces clinical episodes.[9] Anaemia prevalence has been shown to be a reliable indicator of malaria morbidity but is also an indirect measure with multi-factorial causality.[10]

The ACCESS Programme was implemented in two Tanzanian districts with the aim of improving access to malaria treatment. The programme's interventions are based on an integrated approach, which targets both users and providers, and were accompanied by M&E activities.[11] Between 2004 and 2008, the ACCESS Programme's main intervention at user level was the implementation of social marketing campaigns for improved care seeking. At provider level, key activities in health facilities included strengthening routine supportive supervision and the implementation of a quality management scheme. In parallel, the Accredited Drug Dispensing Outlets (ADDO) programme was piloted in the study area from 2006 onwards to improve the availability of drugs and quality of care people obtain from the private retail sector.[12]

The ACCESS M&E plan included the measurement of output, outcome and impact indicators. Provider and user surveys conducted within the frame of the programme showed an improvement in access outputs and treatment outcomes,[13,14] although treatment with anti-malarials was already very high at baseline.[15] The proportion of recent fever cases treated with an anti-malarial increased from 86% to 96% between 2004 and 2008. This article is concerned with the programme's impact on morbidity and aims at assessing changes in the community and health facility burden of malaria between 2004 and 2008.[16] In this frame, we investigated the value of collecting history of fever in the previous 2 weeks at community level as a morbidity monitoring tool.

Methods

Study setting

The ACCESS Programme's monitoring and evaluation activities were embedded within the Kilombero and Ulanga DSS (Figure 1). It was established in 1996 and covers 25 villages (13 in Kilombero District and 12 in Ulanga District). The population in 2004 was almost 74 000 and it increased to just over 92 000 in 2008. There are six health facilities (one health centre and five dispensaries) in the Kilombero area and eight health facilities (one health centre and seven dispensaries) in Ulanga. Malaria transmission was intense and perennial with an entomological inoculation rate (EIR) of 350,[17] but has been declining over the past 10 years.[18] The area is characterized by a rainy season
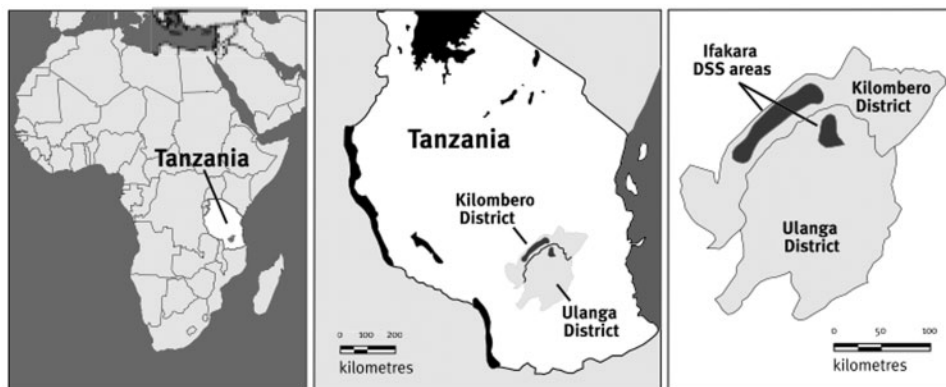
Figure 1 Location of the Ifakara DSS site [*source*: INDEPTH Monograph (20)]

from November to May, with rain levels consistently increasing month by month until April.[19] More details on the study area can be found elsewhere.[11,20]

Data collection and processing
We collected data at community and health facility level between 2004 and 2008 with three independent instruments. The community-based data included: (i) the collection of history of fever and convulsions in the previous 2 weeks with DSS-based surveys and; (ii) three cross-sectional treatment-seeking surveys in 2004, 2006 and 2008 to elicit information about people's actions in the event of fever. At health facility level, we collected Health Management and Information Systems (HMIS) data from all the dispensaries and health centres in the area.

History of fever and convulsions
We integrated the collection of community reported fever and convulsions cases within the routine DSS data collection activities between May 2004 and December 2008. Whereas fever (locally termed *homa*) is a proxy indicator for uncomplicated malaria, convulsions (*degedege*) are a sign of severe febrile illness, which includes cerebral malaria in children.[21,22] Both signs are not highly specific for malaria, but under the assumption that other causes remain stable, they provide useful markers of malaria morbidity. This is a reasonable assumption in our study areas, since there was no major intervention or event over the study period that could have led to the prevention of new fever cases. DSS field workers visited every household in the area at 4-month intervals (three rounds per year) to collect data on birth, death, in-migration and out-migration. Field workers collected information at village level by following a fixed schedule of household visits. Therefore, although each household was visited only every 4 months, data were effectively collected on a daily basis in each village. Given that each recorded case refers to fever in the past 2 weeks, each interviewed individual contributes 2 person-weeks of observation. We, therefore, constructed the following

approximated monthly fever and convulsions incidence rates for each of the 25 DSS villages, expressed in cases per 1000 person-weeks (c/1000 pw):

community fever rate
$$= \frac{\text{number of community reported fever cases per month}}{\text{total number of people interviewed per month} \times 2}$$

community convulsions rate
$$= \frac{\text{number of community reported fever convulsions per month}}{\text{total number of people interviewed per month} \times 2}$$

Unfortunately, due to logistical constraints, the data could only be collected on two-thirds of the DSS population. However, there was no indication that certain villages were consistently less visited than others and the distribution across ages was similar in every round and reflective of the DSS age distribution. It is, therefore, unlikely that the incomplete coverage is biasing our estimates.

Treatment-seeking surveys
In 2004, 2006 and 2008, a village stratified random sample of approximately 100 community-reported fever cases were followed up with treatment-seeking surveys. These surveys were conducted by the DSS field workers between May and August each year (second round of data collection). Patients who had not recovered were not interviewed and they were instead advised to seek care from a health facility. For the purpose of this analysis, we only analysed the data providing information on the proportion of fever cases brought to a health facility at some point during the illness. A detailed analysis of the treatment-seeking surveys is presented elsewhere.[14]

HMIS data from dispensaries and health centres
Health facility data were collected by specifically trained field workers who visited all the 14 facilities in the area (2 health centres and 12 dispensaries) on a 2-monthly basis between January 2004 and December 2008. The data collected included all in-patient and out-patient diagnoses disaggregated

by age group (children under the age of 5 years and all other patients) on a monthly basis. We created health facility catchment areas based on the villages in which facilities are located. Some catchment areas included more than one health facility or more than one village because: (i) some villages do not have a health facility but are located close to a village which does; and (ii) some villages have more than one health facility. By combining the data from the health facilities with the person time exposure data from the DSS database, we calculated the following monthly health facility fever and malaria incidence rates (c/1000pw) for each health facility catchment area:

Health facility fever rate

$$= \frac{\begin{array}{c}(\text{malaria} + \text{pneumonia} + \text{respiratory infections} + \text{measles} + \\ \text{typhoid} + \text{urinary tract infections) diagnoses per month}\end{array}}{\text{person-weeks exposed per month (DSS)}}$$

Health facility malaria rate

$$= \frac{\text{malaria diagnoses per month}}{\text{person-weeks exposed per month (DSS)}}$$

Mean imputation was carried out for the months where the data could not be obtained from health facilities: missing entries for a given month in a given health facility were replaced by the mean number of patients seen in the health facility in the year of observation. This method was considered appropriate since only 7.7% (153/1984) records were missing and data were seldom missing for more than one facility in the same month. This approach, therefore, did not have an effect on the seasonality of the rates.

Statistical analysis

We first estimated trends over time of the community fever and convulsions as well as the health facility fever and malaria rates. We then explored the validity of monitoring history of fever at community level by assessing the internal and external consistency of our data with surveys conducted in the study area and nationally representative surveys.

Trends over time

Random effects Poisson regression models were fitted to estimate changes in the community and health facility burden of malaria. The fever, convulsions and malaria cases N in village or catchment area i were assumed to have arisen from a Poisson distribution, as is most appropriate for count data. We thus assumed that the rate of incidence is constant for every individual and that the variance is equal to the mean. Hence, the following model was fitted:

$$\log \mu_i = \log(Y_i) + \alpha + \beta_1 \text{year}_i + \beta_2 \text{month } 2_i + \\ \cdots + \beta_{12} \text{ month } 12_i + u_i \quad \text{(Model 1)}$$

where μ_i is the expected value of the rate N_i/Y_i in village or catchment area i, Y_i are the person-weeks exposed per month and $\log(Y_i)$ is an offset term that

ensures that the rate is being modelled on the log scale. The coefficient α is the intercept term. Year is a continuous variable (from 2004 to 2008) and the $\exp(\beta_1)$ is the estimated incidence rate ratio (IRR) of changes over the years and months. Month is a categorical variable denoting month of the year (from 1 to 12), which ensures that the estimate of $\exp(\beta_1)$ is not confounded by monthly variations (seasonality). The random effect u_i explicitly allows for the clustering of rates in villages or catchment areas i and is assumed to follow a γ distribution $u_i \sim \gamma(1/\alpha, \alpha)$ which implies a mean 1 and variance α.

Internal consistency

To address the internal consistency of our data, we first correlated the health facility fever and community fever monthly rates to assess the temporal correlation between the two sources of data. We then fitted a Poisson regression to estimate the proportion of fever cases in the community that are brought to a health facility as well as changes in this proportion over time. These estimates were compared with independent information from the treatment-seeking surveys. For this purpose, cases and exposures were aggregated over villages and health facilities and the following models were fitted:

$$\log \mu = \log(Y) + \alpha + \beta_1 \text{year} + \beta_2 \text{month } 2 + \cdots \\ + \beta_{12} \text{month } 12 + \gamma_1 \text{ HF} \quad \text{(Model 2)}$$

$$\log \mu = \log(Y) + \alpha + \beta_1 \text{year} + \beta_2 \text{month } 2 + \cdots \\ + \beta_{12} \text{month } 12 + \gamma_1 \text{HF} + \gamma_2 \text{HF}^* \text{year} \quad \text{(Model 3)}$$

where HF indicates the type of case that is being modelled and takes the value of 1 if the cases are health facility-recorded cases and 0 if the cases are community reported. The coefficient $\exp(\gamma_1)$ in Model 2 is an estimate of the ratio of health facility rates to community rates and therefore provides an estimate of the proportion of fever cases in the community that are brought to a health facility. The coefficient $\exp(\gamma_2)$ of the interaction between type of case and year in Model 3 estimates the change over time of the proportion of fever cases brought to a health facility.

External consistency

To assess the external consistency of our data, we compared our estimates with data from the 2004/05 DHS[23] and 2007/08 MIS.[24] Both surveys were carried out on a nationally representative sample of the population between October and January. First, we compared the decrease in community fever from our surveys between 2004 and 2007 with the decrease in fever reported in the DHS and MIS. We then compared the decreases in fever rates with decreases in under-5 mortality in both settings. Under-5 mortality rates for our study area were obtained from the DSS for 2004 and 2007 and were expressed as the number

of cases per 1000 person-years (c/1000 py). Nation-wide estimates of under-5 mortality for 2004 and 2007 were derived by disaggregating the 2007/08 MIS estimate using the methodology described by Masanja *et al.*[25] and are expressed as a probability of dying between birth and the fifth birthday for every 1000 live births (5q0).

All data were double entered using Microsoft FoxPro and Microsoft Access (Microsoft Corp., Seattle, USA) and checked for coding errors and consistency. Intercooled Stata 10 (Stata Corp., College Station, TX, USA) was used for data management and analysis.

Ethics

The National Institute for Medical Research of the United Republic of Tanzania (NIMR/HQ/R.8a/Vol.IX/236, 16 September 2003) granted ethical clearance for the study.

Results

The number of fever cases reported in 2004 appeared to be unrealistically high at community level and un-realistically low at health facility level (Table 1 and Figure 2) compared with the values in subsequent years. A visual inspection of the rates suggests that more accurate reporting was achieved both at community level (Figure 2a and b) and in health facilities (Figure 2c and d) after a year of data collection. Fever rates at community level were much higher in the first year of data collection compared with subsequent years, suggesting over-reporting of cases when the questions on incidence of fever were asked for the first time. Conversely, fever rates at health facility level were much lower and less seasonally variable in the first year of data collection suggesting that many cases were not recorded. All the 2004 data were, therefore, excluded from any analysis.

The community fever and convulsions rates follow a clear seasonal pattern and have been decreasing over time. Seasonal peaks correspond with the middle of the rainy season (January–March) (Figure 2a and b). The rates averaged over the year show a constant decrease in community fever rates between 2005 and 2008 from 47.2 c/1000pw (16 350/34 6311) to 34.4 c/1000pw (11 567/33 6475) in all ages. This corresponds to a decrease from 2.5 to 1.8 average cases per person per year, i.e. an overall reduction of 28%. In children under the age of 5 fever rates decreased by 34% from 93.9 c/1000pw (5298/56403) to 61.6 c/1000pw (3419/55 490), which means a decrease from 4.9 cases to 3.2 cases per child per year. Convulsions are a much rarer event than fever and also decreased. Convulsion rates were 0.82 c/1000pw (284/346 427) in 2005 (4263 cases for every 100 000 children per year) and 0.45 c/1000pw (152/340.667) in 2008 (2320 cases for every 100 000 children per year)

Table 1 Community and health facility cases between 2004 and 2008

Level	Type of cases	Year	Cases	Person-weeks of observation
Community	Fever	2004	18 844	289 764
		2005	16 350	346 311
		2006	14 032	329 306
		2007	18 691	451 228
		2008	11 567	336 474
	Convulsions	2004	590	291 321
		2005	284	346 427
		2006	213	330 576
		2007	292	451 292
		2008	152	340 666
Health facility	Fever	2004	52 875	3 579 456
		2005	67 335	3 573 468
		2006	65 342	3 729 097
		2007	77 398	3 818 092
		2008	65 223	4 008 284
	Malaria	2004	35 011	3 579 456
		2005	45 931	3 573 468
		2006	44 562	3 729 097
		2007	55 788	3 818 092
		2008	42 358	4 008 284

which is equivalent to an overall reduction of 46% (Table 1).

The health facility rates exhibited much less seasonal variation and there was a less discernable pattern of change over time (Figure 2c and d). Between 2005 and 2007, there appeared to be a trend of increasing rates but this was followed by a low value in 2008 driven by a particularly low attendance in one of the health centres. In 2005, the median number of patients recorded per month was 523 (IQR = 339–658) in dispensaries and 856 (IQR = 693–1079) in health centres. These figures hardly changed in 2008 when the median number of patients recorded per month was still 523 (IQR = 347–410) in dispensaries and 840 (IQR = 745–1220) in health centres. Between 2005 and 2008, malaria diagnoses consistently accounted for 67.4% of all fever cases in all the months of data collection (Table 1, Figure 2c and d).

Trends over time

Fitting Model 1 on the community-reported rates shows a decrease in the incidence of both fever and convulsions. Overall community fever decreased by 10% per year [IRR = 0.90, 95% confidence interval (95% CI) = 0.87–0.89] between 2005 and 2008. Rates decreased more steeply in children under the age of
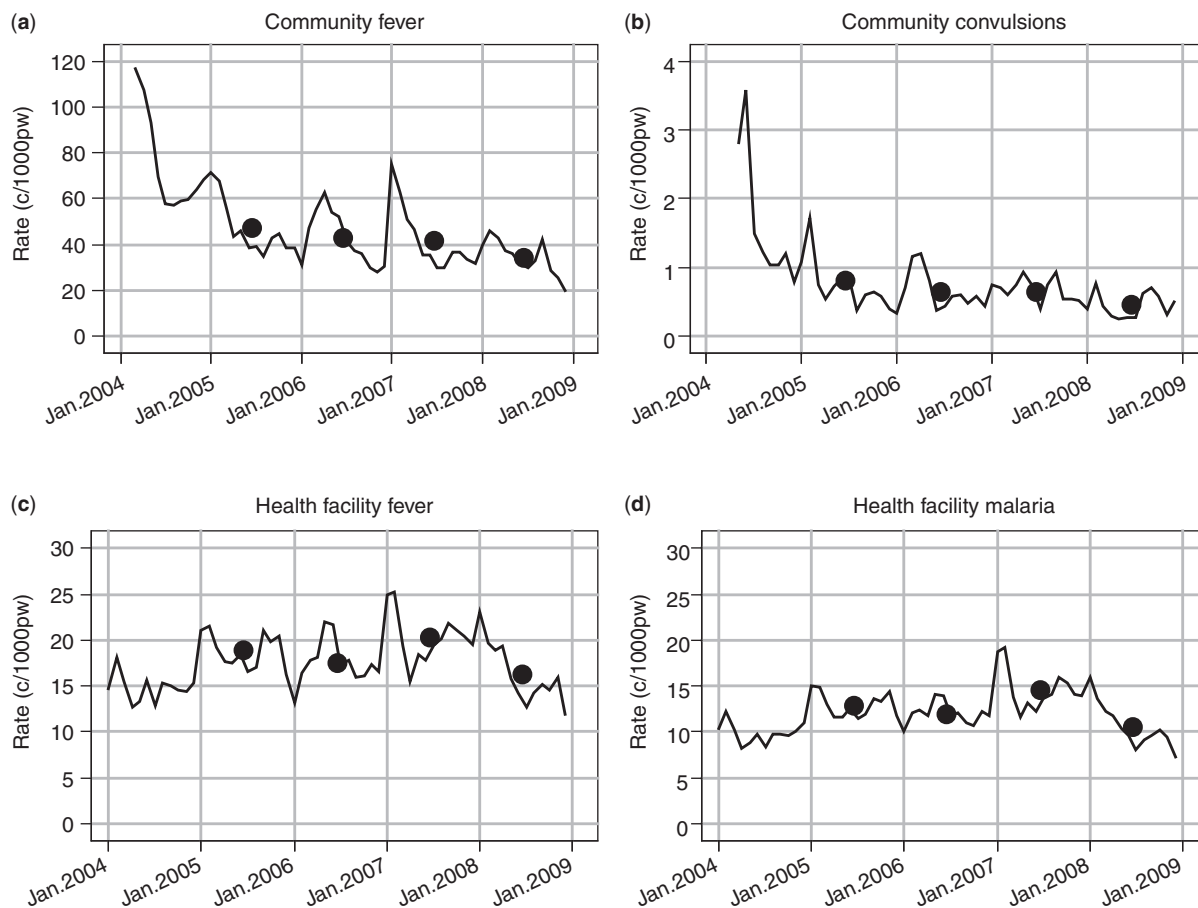
Figure 2 Community and health facility rates (*note*: *y*-axes differ across graphs)

5 at a rate of 13% per year (IRR = 0.87, 95% CI = 0.85–0.87) (Table 1 and Figure 2). The incidence of convulsions in children also decreased considerably over the study period at an estimated rate of 21% per year (IRR = 0.79, 95% CI = 0.74–0.92).

Model 1 was also used to estimate the extent to which the community fever cases were over reported in the first year of data collection (first round January–April 2004 but data were only collected from March onwards, second round May–August 2004 and third round September to December 2004). The extrapolation suggests an overall overestimation of 79.6% in the first round of collection (actual number of cases reported 9456 vs estimated 5265 for 83 434 person-weeks of observation); 43.7% in the second round of data collection (6432 vs 4469 cases for 95 718 person-weeks) and 39.7% in the third round (6048 vs 4329 cases for 99 087 person-weeks).

Health facility rates were also estimated to have decreased over the study period, but to a much lesser extent. The IRR of fever and malaria rates in adults over time were estimated at values very close to one (fever: IRR = 0.98, 95% CI = 0.98–0.98; malaria: IRR = 0.97, 95% CI = 0.97–0.98) suggesting an only

very slight decrease over time. A more appreciable decrease was estimated for rates in children; health facility fever rates were estimated to have decreased by 6% per year (IRR = 0.94, 95% CI = 0.94–0.95) and malaria rates by 7% per year (IRR = 0.93, 95% CI = 0.92–0.93) (Table 3).

Accounting for the seasonality of the data by including a categorical factor for the month of the year did not affect the estimated change over time. The log-likelihood ratio test for the inclusion of months of the year was highly significant in all the models estimating trends over time (Tables 2 and 3). However, the inclusion of this variable only affected slightly the size of the IRR estimating the changes over the years in the community rates. More specifically, the models fitted excluding months of the year overestimated the decrease over time, but only by 1% point (fever all ages: IRR = 0.90, 95% CI = 0.89–0.91; fever children < 5 years: IRR = 0.86, 95% CI = 0.85–0.88; convulsions: IRR = 0.78, 95% CI = 0.74–0.84). The exclusion of the variable did not affect the size of the IRRs for the health facility rates at all.

The inclusion of a random effect to account for the fact that different villages or catchment areas might have different rates did not affect the estimated

Table 2 IRRs (95% CI) from random effects Poisson regressions fitted on monthly community fever and convulsion rates (2005–08)

| | Fever | | Convulsions |
	All ages ($n = 1064$)	<5 years ($n = 1047$)	<5 years ($n = 1046$)
Year	0.90 (0.87–0.89)	0.87 (0.85–0.87)	0.79 (0.74–0.92)
Month[a]			
January	1	1	1
February	1.01 (0.97–1.05)	0.99 (0.91–1.07)	1.32 (0.90–1.94)
March	0.91 (0.88–0.95)	0.89 (0.82–0.97)	1.02 (0.70–1.50)
April	0.86 (0.82–0.90)	0.83 (0.75–0.91)	1.03 (0.66–1.61)
May	0.74 (0.70–0.78)	0.70 (0.63–0.77)	0.83 (0.52–1.34)
June	0.70 (0.66–0.72)	0.66 (0.61–0.72)	0.65 (0.43–0.97)
July	0.62 (0.59–0.65)	0.61 (0.58–0.68)	0.62 (0.41–0.94)
August	0.61 (0.57–0.65)	0.60 (0.54–0.68)	0.68 (0.39–1.20)
September	0.71 (0.67–0.74)	0.79 (0.72–0.87)	1.04 (0.67–1.62)
October	0.63 (0.60–0.65)	0.71 (0.66–0.77)	0.74 (0.49–1.11)
November	0.57 (0.54–0.60)	0.66 (0.61–0.72)	0.63 (0.41–0.97)
December	0.54 (0.50–0.57)	0.60 (0.53–0.68)	0.47 (0.24–0.89)
α[b]	0.07 (0.04–0.12)	0.04 (0.02–0.08)	0.20 (0.11–0.38)

[a]LLR test of inclusion—fever all ages: $\chi^2 = 2514.23$, $P < 0.001$; <5 years: $\chi^2 = 562.93$, $P < 0.001$; convulsions: $\chi^2 = 63.27$ $P < 0.001$.
[b]γ-Distributed random effects (95% CI) to account for between-village variance.

change over the years either. However, the variance α of the random effects was significantly different from zero in all the models fitted (Tables 2 and 3), suggesting that there is clustering between villages or catchment areas and that random effects should be included in the models to account for this.

Internal and external consistency of the data

The community fever rates correlate very well with fever rates from health facilities in children under the age of 5 years ($r = 0.81$, $P < 0.001$) but less so in all patients ($r = 0.67$, $P < 0.001$) (Figure 3).

Combining the fever rates at health facility and community level and comparing the results with the treatment seeking surveys shows reasonable but not all round internal consistency. According to the independent cross-sectional treatment seeking surveys, the proportion of fever cases brought to a health facility did not change significantly between 2006 and 2008 and was estimated ~68% in children and 65% in all ages [children from 67.3% (37/55) in 2006 to 69.2% (27/39) in 2008 OR = 1.05 95% CI = 0.67–1.63, all patients 61.2% (63/103) in 2006 to 69.7% (60/86) in 2008 OR = 1.21 95% CI = 0.89–1.64]. Model 2 estimated the proportion of fever cases brought to a health facility to be 72% (IRR = 0.72, 95% CI = 0.70–0.73) in children under the age of 5 years and 45% (IRR = 0.45, 95% CI = 0.45–0.46) in all patients between 2006 and 2008. According to Model 3, the

proportion of fever cases brought to a health facility increased by 8% per year (IRR = 1.08, 95% CI = 1.07–1.10) in children and by 9% per year in all patients (IRR = 1.09, 95% CI = 1.08–1.10) between 2006 and 2008. Hence, the estimated proportion of fever cases brought to a health facility was the same according to the treatment-seeking surveys and Model 2 in children (but not in adults); and Model 3 suggests a higher increase over time in proportion of fever cases brought to a health facility compared with the treatment seeking surveys.

There is very good external consistency between our data and data from the national DHS and MIS. These surveys report a decrease in the percentage of fever in the past 2 weeks from 25% for the period October 2004 to January 2005 to 18% for the period October 2007 to January 2008. This is equivalent to a 26% decrease in fever prevalence over the 3 years of observation. This was associated with an 8% decrease in mortality from 97.2 5q0 in 2004 to 89.5 5q0 in 2007 (ratio of fever to mortality decrease = 3.3). An extrapolation of our fever data (Model 1) estimated a fever incidence of 107.3 c/1000pw for the period October 2004 to January 2005 and 73.2 c/1000pw for the period October 2007 to January 2008. This is equivalent to a 32% decrease in fever, very close to the 26% decrease at national level. In the Kilombero and Ulanga DSS, this was associated with a 12% decrease in mortality from 25.3 c/1000py to 22.2 c/1000py (ratio of fever to mortality decrease = 2.6).

Table 3 IRRs (95% CI) from random effects Poisson regressions fitted on monthly health facility fever and malaria rates (2005–08, $n = 432$)

	Fever cases		Malaria diagnoses	
	All ages	<5 years	All ages	<5 years
Year	0.98 (0.98–0.98)	0.94 (0.94–0.95)	0.97 (0.97–0.98)	0.93 (0.92–0.93)
Month[a]				
January	1	1	1	1
February	1.00 (0.98–1.02)	0.99 (0.97–1.01)	0.99 (0.97–1.01)	0.97 (0.95–1.00)
March	0.91 (0.89–0.92)	0.92 (0.89–0.93)	0.86 (0.85–0.88)	0.87 (0.84–0.89)
April	0.86 (0.84–0.87)	0.94 (0.92–0.96)	0.77 (0.76–0.79)	0.85 (0.83–0.87)
May	0.89 (0.87–0.91)	0.87 (0.85–0.89)	0.81 (0.79–0.83)	0.79 (0.76–0.81)
June	0.87 (0.85–0.88)	0.85 (0.83–0.87)	0.79 (0.77–0.81)	0.78 (0.75–0.80)
July	0.80 (0.78–0.81)	0.77 (0.76–0.79)	0.74 (0.72–0.75)	0.72 (0.70–0.74)
August	0.84 (0.82–0.85)	0.81 (0.79–0.83)	0.78 (0.76–0.79)	0.76 (0.74–0.79)
September	0.90 (0.88–0.91)	0.89 (0.87–0.92)	0.83 (0.81–0.85)	0.84 (0.82–0.86)
October	0.87 (0.85–0.88)	0.90 (0.88–0.92)	0.82 (0.80–0.83)	0.85 (0.83–0.86)
November	0.90 (0.88–0.91)	0.88 (0.86–0.91)	0.83 (0.81–0.84)	0.83 (0.81–0.86)
December	0.78 (0.77–0.79)	0.76 (0.74–0.77)	0.74 (0.72–0.75)	0.73 (0.71–0.76)
α[b]	0.30 (0.12–0.72)	0.36 (0.15–0.86)	0.23 (0.10–0.57)	0.27 (0.11–0.65)

[a]LLR test of inclusion—fever all ages: $\chi^2 = 1440.82$, $P < 0.001$; <5 years: $\chi^2 = 1063.87$, $P < 0.001$; malaria diagnoses for all ages: $\chi^2 = 1730$, $P < 0.001$; <5 years: $\chi^2 = 1005.58$, $P < 0.001$.
[b]γ-Distributed random effects (95% CI) to account for between catchment area variance.
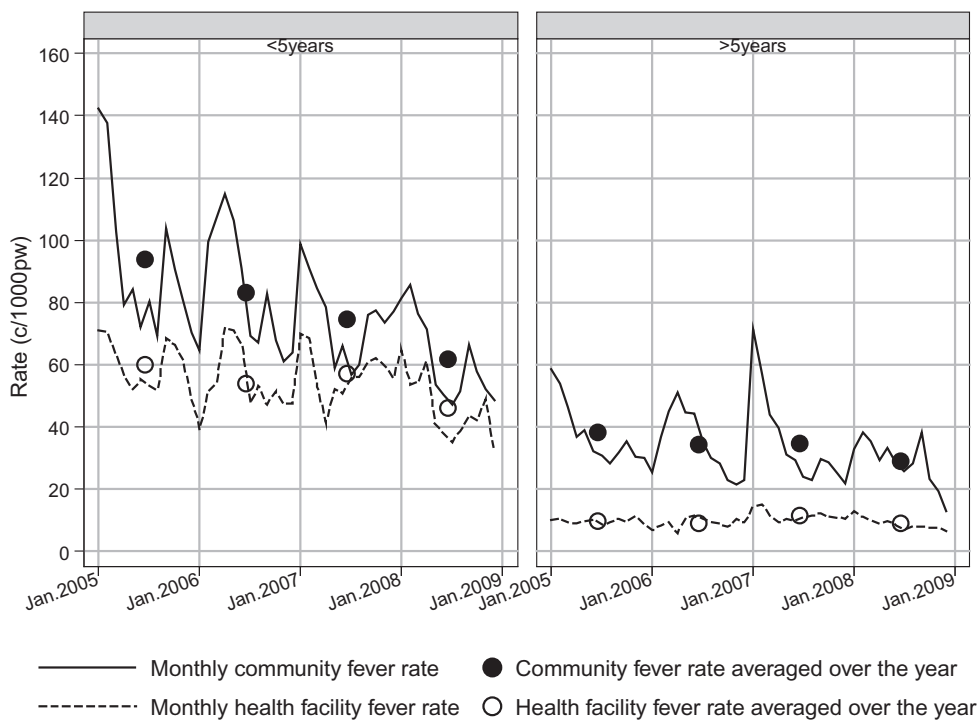

Figure 3 Community fever rates and health facility fever rates by age group between 2005 and 2008

Discussion

The data presented here document a decline in malaria morbidity between 2005 and 2008 in the highly malaria-endemic Kilombero and Ulanga DSS areas. Community-reported fever incidence rates declined by 10% per year in the overall population and by 13% per year in children under the age of 5 years. There is also an indication of a decrease in severe malaria morbidity as indicated by a 21% decrease in the incidence of reported convulsions in children. The decrease in the community burden of malaria in children is accompanied by decrease in the health facility fever and malaria rates in children (6 and 7% per year, respectively) but not as much in the overall population (2 and 3% per year). However, due to population growth, the average number of cases per month in health facilities remained constant, implying that there was no change in the health facility burden of fever and malaria.

Data from separate studies conducted in the study area provide evidence that the declines in community fever and convulsion rates are paralleled by a decline in malaria transmission. Data from two other projects documented a decrease in parasitaemia in children under the age of 5 years from 25% in 2004 to 10% in 2008.[26,27] Similarly, an older study reported an EIR of 349 infective bites per person per year (ib/p/y) between 2001 and 2003,[17] whereas by 2008 the EIR had declined to 81 ib/p/y.[18] In parallel, under-five mortality decreased from 24.5 c/1000py to 18.9 c/1000py between 2004 and 2008.[28] These data give us confidence that the decrease we observed in fever rates is to a large extent malaria related, although we could not assess independently the proportion of true malaria cases among all the fever episodes.

The increased treatment coverage is very likely to have contributed to the decrease in morbidity. The first line treatment for malaria in Tanzania was sulphadoxine pyrimethamine (SP) until 2006 when it was replaced by the artemisinin combination therapy (ACT) artemether–lumefantrine (ALu). The long half-life of SP[29] and its prophylactic effect have been clearly documented.[30] The treatment of any potential malaria case with SP not only clears parasites in true cases of malaria but also provides chemoprophylaxis for up to 4 weeks in those who were and those who were not infected, which in turn reduces the parasite burden in individuals and the infectious reservoir in the community. This has led to the hypothesis that widespread presumptive treatment with the drug contributes to a decrease in transmission, based on the observation that malaria started decreasing in Kenya before the widespread use of insecticide-treated nets (ITNs).[31] ACTs do not have a prophylactic effect, but do have gametocidal properties[32–34] and hence it has been suggested that ACTs can have an impact on transmission.[35] In our study area, malaria treatment has reached very high levels with an increase in the proportion of fever cases treated with an anti-malarial from 86% in 2004 to 96% in 2008. SP was used to treat 30–40% of all identified cases between 2004 and 2008, whereas ALu was used in a 40% of cases in 2008. Hence, it is reasonable to ascribe part of the observed decrease in malaria-related fevers to improved treatment.

The increased vector control in the area over the same period also explains in part the decrease in malaria transmission and morbidity rates. A very high mosquito ITN coverage has been achieved in the study area following the nation-wide up-scaling[17,36] of the KINET scheme for the promotion and subsidisation of nets.[37] However, much of the increase in ITN coverage happened before our assessment and ITN coverage remained largely unchanged between 2005 and 2008, with over 90% of household ownership. This does not rule out continued effect over time since recent modelling work suggests that sustaining coverage with ITN at such levels may lead to constant decreases in transmission, even if coverage does not increase (Prof. T. Smith, personal communication, Swiss Tropical and Public Health Institute, Basel). Furthermore, most nets were untreated in 2005[17] whereas by 2008 nearly half of the nets were treated.[18] A recent study concluded that the addition of long-lasting insecticide treatment of bednets in the area was able to reduce the intensity of malaria transmission 4.6-fold.[18] Increased IPTp may also have played a role in decreasing morbidity, especially in children.[38] According to regional data the proportion of women who received two doses of SP during their pregnancy increased from 23% in 2004 to 44% in 2007.[23,24]

The good internal and external consistency of our data shows that reported history of fever in the previous 2 weeks can be used to monitor the community burden of malaria in children under the age of 5 years reliably in highly malaria endemic areas. Our data are internally consistent since, we were able to show that: (i) community fever rates were very highly correlated health facility fever rates in children under the age of 5 years; and (ii) estimates of health facility attendance for fever (i.e. the proportion of fever cases in the community brought to a health facility) resulting from the ratio of health facility to community rates are similar to those obtained from an independent treatment-seeking survey. In addition, our data showed good external consistency with national surveys. Although a slightly lower decrease in incidence of fever was observed at national level compared to our study site between 2004 and 2007 (25% vs 32%), the ratio of fever incidence decrease to under-five mortality decrease was comparable in both settings (3.3 vs 2.5). This finding is of high interest to malaria control programmes because it offers for the first time a validated community-based measure of malaria morbidity that can be used for monitoring. It follows that fever recall data collected by representative household surveys such as the DHS, MICS and MIS

can be analysed to monitor morbidity trends and impact.

However, there is an important caveat associated with the use of fever recall as a morbidity monitoring tool. Our experience shows that cases are substantially over-reported when the question: 'Have you had fever in the past 2 weeks?' is asked for the first time, and this is consistent with findings from other studies.[39,40] A possible explanation is that respondents do not only report episodes which occurred in the past 2 weeks but also previous ones. According to our data, respondents are better able to limit reporting to episodes that occurred strictly within the requested time interval after three rounds. Therefore, fever rates based on a 2-week recall in cross-sectional household surveys such as the DHS, MICS and MIS are likely to be over-estimated. Fortunately, consistency checks between our data and the 2007/08 Tanzania MIS and the 2004/05 DHS suggested that over-reporting is consistent between surveys and therefore does not jeopardise the comparability of data collected in the frame of different surveys and these estimates can still be used to assess changes over time. However, it implies that such data should not be used, for example, to derive the number of fever-related commodities required in a given population (typically anti-malarial drugs and diagnostic tests) as estimates are likely to be too high.

Unfortunately, we were not able to validate the use of history of convulsions in the past 2 weeks in the frame of this study. It can be argued that the incidence of convulsions is the only marker of severe malarial disease that can be monitored at community level. There is evidence from a hospital study conducted in the Kilifi District Hospital in Kenya[41] that ~50% of convulsions in malaria endemic settings can be attributed to malaria. However, we cannot exclude the possibility that estimates of incidence of convulsions based on reported data are biased. Our estimates were about 10 times higher than those reported in Kilifi (from 4300 to 2300 cases for every 100 000 children per year between 2005 and 2008 compared with 235 cases per 100 000 per year in 2006 in Kenya). On one hand, it is recognized that hospital estimates of incidence are lower than what would be expected at community level in most of sub-Saharan Africa where many cases are managed at home.[42] The authors themselves caution that many children with convulsions may have died without reaching the hospital, and that a few may have been treated successfully in peripheral health facilities. On the other hand, it is likely that our estimates are too high because of the same recall bias that was seen for simple fever estimates: a rare and dramatic event such as a convulsion in a small child might have led to recall beyond the 2 weeks that we were asking for.

Our data confirm that 'caution is required when using health facility-based data to evaluate the health impact of malaria control efforts in Africa'.[16] The main concern with health facility records is obviously their quality. Our experience shows that in the absence of constant supervision records were often not filled in properly. Acceptable reporting was only achieved after 1 year of repeated visits and we had to discard the data from the first year of data collection. Furthermore, health facility staff mostly rely on presumptive diagnosis of malaria in malaria endemic countries.[40] The data we presented here show that the proportion of fever cases diagnosed did not change throughout the year. Both during the months of high transmission and during the months of low transmission, ~two-thirds of fever cases were systematically diagnosed as malaria. Rapid diagnostic tests (RDT) for malaria were introduced in 3 out of the 14 health facilities in the area in late 2007. Although a decrease in malaria diagnoses was observed in those facilities (Robert Tillya, manuscript in preparation), this effect was diluted in our study when the data were aggregated over all the facilities.

Beyond data quality issues, relying exclusively on health facility data can lead to biases. First, such data do not take population growth into account. Our results clearly show that population growth can affect results, since despite decreases in health facility fever and malaria rates there was no impact on the absolute number of cases seen in health facilities which ultimately represents the burden of malaria at health facility level. Second, health facility users are not necessarily representative of the population at large when the proportion of cases brought to a health facility is low, which is often the case in resource-limited countries.[42] In our study, the decline in community fevers was matched by a decline in health facility fevers in children under the age of 5, the majority of whom attended a health facility (72%), but not in the overall population for whom health facility attendance was much lower (estimated between 45% and 57%).

Conclusions

The community burden of malaria morbidity declined between 2005 and 2008 in the Kilombero and Ulanga DSS, most likely as a result of malaria control efforts. Meanwhile, the health facility burden remained unchanged due to population growth. The good internal and external consistency of our data strengthens our conclusions and shows that history of fever in the previous 2 weeks can be used as a community-based morbidity-monitoring tool.

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KEY MESSAGES

- Between 2005 and 2008, the incidence of reported fever in children under the age of 5 years declined by 34%, from 4.9 to 3.2 average cases per child per year in the Kilombero and Ulanga DSS areas in Tanzania.

- This decrease is associated with improved treatment seeking as well as high coverage with ITNs.

- The good internal and external consistency of the data collected within the frame of this study shows that history of fever in the previous 2 weeks in children under the age of 5 years can be used as a morbidity-monitoring tool.

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