

Impact of El Niño and malaria on birthweight in two areas of Tanzania with different malaria transmission patterns

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Background Malaria infection increases low birthweight especially in primigravidae. Malaria epidemics occur when weather conditions favour this vector borne disease. Forecasting using the El Niño Southern Oscillation (ENSO) may assist in anticipating epidemics and reducing the impact of a disease which is an important cause of low birthweight. The aim of the present study was to determine the impact of the malaria epidemic in East Africa during 1997–1998 on birthweights in two different areas of Tanzania and to explore ENSO's potential for forecasting low birthweight risk in pregnant women.

Method A retrospective analysis of birthweight differences between primigravidae and multigravidae in relation to malaria cases and rainfall for two different areas of Tanzania: Kagera, which experiences severe outbreaks of malaria, and Morogoro which is holoendemic. Birthweight and parity data and malaria admissions were collected over a 10-year period from two district hospitals in these locations.

Results The risk of delivering a low birthweight baby in the first pregnancy increases approximately 5 months following a malaria epidemic. An epidemic of marked reduced birthweight in primigravidae compared with multigravidae occurred, related to the ENSO of 1997–1998. In Kagera this birthweight difference and the risk of low birthweight were significantly lower compared with Morogoro, except after the ENSO when the two areas had similar differences. No significant interaction was noted between secundigravidae and any of the risk periods. The results indicate that the pressure of malaria is much greater on pregnant women, especially primigravidae, living in the Morogoro location.

Conclusions Surveillance of birthweight differences between primigravidae and multigravidae is a useful indicator of malaria exposure.

Keywords Malaria, El Niño, primigravidae, low birthweight, Tanzania

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Plasodium falciparum malaria is one of the major health problems in tropical and sub-tropical areas of the world. About two-fifths of the world's population live under constant threat of infection by the parasite. Every year 300–500 million people are infected and 1.5–3 million die. The vast majority of these are children and pregnant women. Malaria can cause many serious complications in pregnancy, such as anaemia, low birthweight, pre-term delivery, fetal and perinatal mortality, and maternal mortality. Several authors have shown an increase in parasite prevalence in pregnant women, in both peripheral and placental blood. This increase is significantly higher in the first pregnancy and results in an increased risk of low birthweight

(<2500 g) in primigravidae.¹⁻⁵ Malaria is the most important environmental factor which selectively increases low birthweight in first compared with later pregnancies.⁶ Women at the greatest risk of delivering low birthweight babies are those who have been pregnant during most of the rainy season and deliver towards the end of it, or at the beginning of the dry season.⁷ Most complications could be diminished if women received either effective chemoprophylaxis (i.e. regular suppressive doses), or intermittent preventive therapy (IPT) during pregnancy. Some sub-Saharan countries use weekly chloroquine chemoprophylaxis, but the spread of resistance has greatly reduced the protective effect of this drug. Two IPT doses of sulfadoxine-pyrimethamine (SP) given during the second and third trimester of pregnancy have been shown to significantly increase mean birthweight, especially in primigravidae.^{5,8} Recommendations for a policy change to SP occurred in May 1999 with the actual implementation occurring in August 2001. The more widespread use of intermittent SP therapy may have the added advantage of treating sub-clinical bacterial genital tract infections which could also improve birthweight outcomes.

There is a well-known connection in malarious areas between rainfall and malaria and recent evidence has demonstrated cycles of malaria associated with the El Niño Southern Oscillation (ENSO).^{9,10} The term ENSO refers to an unstable periodic climate system that originates in the Pacific and creates rainfall and temperature fluctuations worldwide including sub-Saharan Africa. In Tanzania there are two rainy seasons, the short rains occur sometime between mid-October and mid-December. They are shorter and less predictable than the long rains, which last from mid-March to mid-May. Between these there are drier periods with little rain and less malaria transmission, except in swampy areas with standing water. In December 1997 and for several subsequent months, when the ENSO appeared, unusually heavy rains occurred, and the rainy period was longer and more intense than previously. This ENSO was the strongest ever recorded. It also developed unusually quickly and had an enormous impact on weather globally with record flooding in Chile, extensive smog cloud over Indonesia and a quiet Atlantic hurricane season.¹¹ Tanzania experienced unusually heavy flooding in the central flatlands and the infrastructure collapsed in many parts of the country. Several authors have described the malaria catastrophe that followed in Kagera Region and neighbouring Uganda.¹²⁻¹⁴ A connection between malaria epidemics related to ENSO and their effect on reducing birthweight especially in first pregnancies has not previously been reported. In this paper we compare the consequences of ENSO on birthweight using data from two different malarious areas of Tanzania.

Methods

Study area 1

Kagera region is situated in the north-west corner of the country and is an area with endemic malaria and clearly defined seasonal changes in malaria prevalence. The GDP/capita in 1998 was US\$138, which makes Kagera one of the poorest regions in Tanzania (Bureau of Statistics, Ministry of Finance, 1999). Most women of reproductive age are subsistence farmers who

cultivate plantains (the staple food), maize, cassava, rice, and millet. Ndolage hospital is situated 60 km south of Bukoba Town, at an altitude of 1600 m above sea level. It is a mission hospital administered by the Evangelical Lutheran Church of Tanzania (ELCT). It has approximately 200 beds and an average of 1400 deliveries a year, contributing to approximately 45% of the deliveries in the catchment area of the hospital. The state-run antenatal clinics do not provide antimalarial prophylaxis, but those run by the churches sometimes do (chloroquine 300 mg base once weekly at the time of the study).

We collected retrospective hospital data for deliveries at Ndolage hospital for 1990-1999. Information from log books kept in different wards at the hospital was transcribed manually to data sheets and entered into an SPSS data file. Data concerning deliveries (birthweight, parity, twin birth, stillbirth, and delivery outcome) were collected. The data on blood smear examination for malaria parasites was obtained from the hospital laboratory record books. Malaria smears were routinely taken from all patients with malaria-like symptoms who visited the hospital, in- or out-patients. Quality control of malaria microscopy was not available, but the hospital technicians were experienced malaria microscopists. Information on use of malaria prophylaxis was obtained from individual patients during rounds made with the doctor in charge of the maternity ward. We also collected data on clinically diagnosed malaria cases admitted to the paediatric ward. Data on rain, humidity, and minimum and maximum temperature were available from the Bukoba Meteorology Station.

We considered that a malaria-related climatic effect on reducing birthweight would be greatest a number of months into the epidemic, as a longer duration of malaria exposure during pregnancy would increase the risk of birthweight reduction. We predicted that this birthweight effect would occur 3 months after the malaria peak and that it would last for 5 months. This approximation was made following an analysis of data from an earlier study in Kagera region.¹⁵ The rainy season was defined as rainfall >80 mm/month. In some years a well-defined seasonal rainfall pattern was observed even if monthly values did not fall below 80 mm. The malaria season was defined as an average of >150 positive malaria slides per month. This represented a weighted average estimate for all patients who visited the hospital, as an accurate denominator attendance estimate was not available. Seasonal trends were assessed (Figure 1). At the time of the study, treatment failures with chloroquine (25 mg/kg) were estimated at 50% at day 14.¹⁶

The El Niño rains in Kagera came with strong winds, which uprooted banana (plantain) plantations which is the staple food of this area which as a result was effected by famine. Immediately after El Niño rains, there was a prolonged draught whereby indigenous people could not readily grow green vegetables and beans.

Study area 2

Morogoro region is situated in central Tanzania and is an area with holoendemic malaria transmission with seasonal peaks. Apart from the Uluguru mountain ranges, most (80%) of the region is flat, with a risk of standing water following the rainy period. The GDP/capita in 1998 was US\$184, which was above the average for Tanzania (Bureau of Statistics, Ministry of Finance, 1999). Most women who give birth in the area are

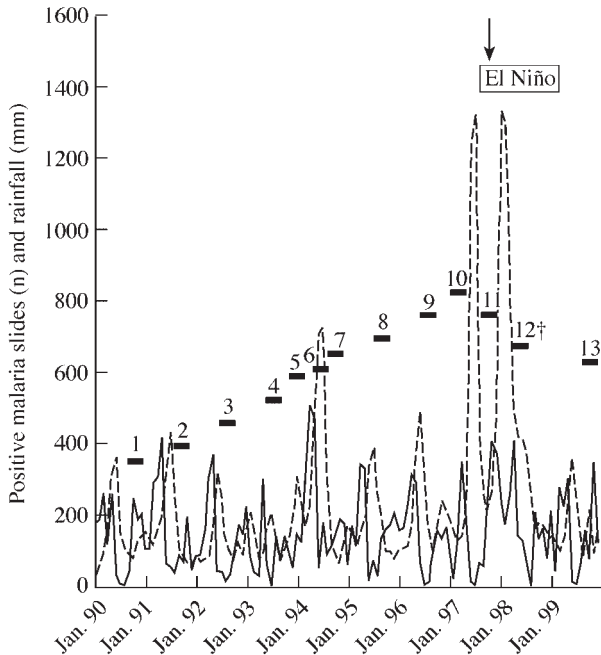


Figure 1 Rainfall, malaria, and estimated risk periods in Ndolage 1990–1999. Continuous line represents monthly rainfall and stippled line represents monthly positive malaria slides all ages. El Niño start is marked with an arrow. † indicates significance ($P = 0.001$)

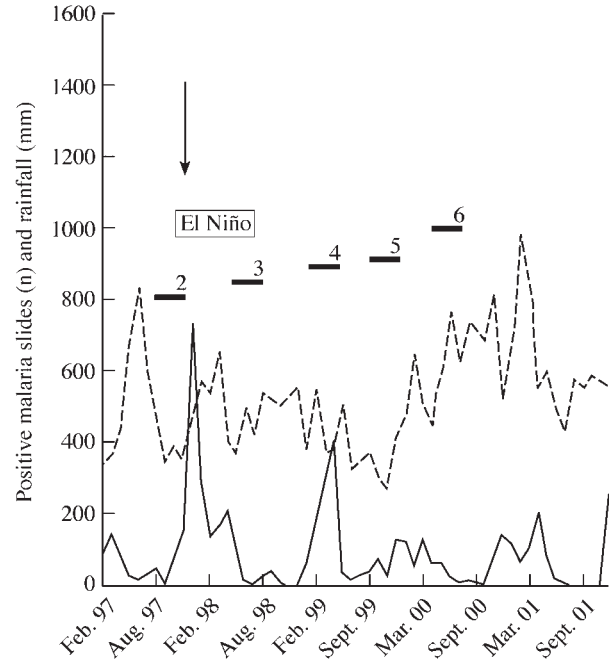


Figure 2 Rainfall, malaria, and estimated risk periods in Kilosa 1997–2001. Continuous line represents monthly rainfall and stippled line represents monthly positive malaria slides all ages. El Niño start is marked with an arrow.

subsistence farmers who cultivate maize (staple food), cassava, rice, and shogun. Kilosa hospital has 150 beds and 1200–1400 deliveries a year representing approximately 35% of deliveries in the catchment area. Data were available from Kilosa Hospital and the local meteorological station. Data on blood smear examination for malaria parasites was available from laboratory books for the period 1997–2001. The staff at the nine antenatal clinics were visited and the Doctor in Charge of Kilosa hospital. They informed us that malaria prophylaxis or IPT was not given routinely. Data on clinically diagnosed malaria cases from the paediatric ward were collected. The rainy season was as defined as in Ndolage, except that >450 positive malaria slides/month were used because of the higher weighted overall malaria positivity (Figure 2). At the time of the study clinical chloroquine treatment failures at day 14 were 72%.¹⁶

The data was entered into SPSS® (Statistical Package for the Social Sciences). A General Linear Model Univariate (SPSS®) was used for regression analysis, with analysis for one dependent variable (birthweight) by one or more factors (primigravidae, months, risk months, primigravidae risk months). The factor variables divided the population into groups. Using this General Linear Model procedure the null hypothesis was tested about the effects of other variables on the means of various groupings of a single dependent variable (birthweight). Interactions between factors (primigravidae risk months) were investigated as well as the effects of individual factors (primigravidae, months, risk months), all of which were fitted as fixed effects. We analysed birthweights on their original continuous scale to maintain statistical power, but where we use the term ‘low birthweight’, this is defined in the usual way as a newborn weight of <2500 g.¹⁷

These studies received ethical approval by the Ethical Committee at the National Institute for Medical Research in Tanzania, while permission to undertake the study was granted by the Evangelical Lutheran Church of Tanzania (Ndolage hospital) and the Medical Officer in charge of Kilosa hospital.

Results

Descriptive birthweight data for the two study areas are summarized in Table 1.

Kagera Region

The rains in Kagera region had a seasonal pattern (Figure 1 and Table 2). All the rainy periods were followed by malaria seasons, with two exceptions (October–December 1990 and September–December 1994). For two periods the short and the long rains merged into long rainy periods both lasting 9 months. The first was from September 1995–May 1996 and the average rainfall per month was low. The second lasted from October 1997–June 1998 and was the worst ENSO ever recorded.

Most rainy seasons were followed by an increased malaria incidence. The malaria seasons lasted for 2–4 months, with three exceptions. In April–August 1994 the malaria season lasted for 5 months. It was a recognized heavy malaria season with an average of 488 positive malaria slides per month. In April–September 1995 the season lasted for 6 months but was not impressive (250 slides/month). The heaviest malaria season, which was epidemic was during the ENSO (November 1997–August 1998). It lasted 10 months and had 631 positive malaria slides per month. June–September 1997 was another exceptional malaria epidemic, although short (4 months) and not preceded by high rainfall (820 positive malaria

Table 1 Descriptive data from the two study hospitals, (95% CI)

Area	Years	Sample size	Proportion of first pregnancies	Mean birthweight (g)		Birthweight difference PG and MG (g)	Prevalence low birthweight	
				PG ^a	MG ^b		PG	MG
Ndolage Hospital	1990–1999	11 903	34.8%	2859 (±13.7)	3071 (±11)	212 (±15)	14.8% (±1.1)	8.3% (±0.6)
Kilosa Hospital	1994–2001	9347	41.5%	2717 (±16.0)	3017 (±14)	300 (±22)	24.1% (±1.3)	10.1% (±0.8)

^a Primigravidae.^b Multigravidae.

slides/month). Between these rainy seasons there was a considerably smaller risk of malaria (Figure 1). The Figure shows that diagnosed clinical malaria in children in the paediatric wards and positive malaria slides for patients of all ages showed a good correspondence with rainfall pattern.

Data from the delivery ward in Ndolage hospital was collected for the years 1990–1999. There were 13 014 singleton live births during this period. Because of missing data in 8.6% of the births, the sample size with complete data was 11 895 (Table 1). The mean birthweight among primigravidae was 2859 g (95% CI: ±14) and among multigravidae 3071 g (95% CI: ±11). Mean birthweight difference between primigravidae and multigravidae for the 10-year period was 212 g (95% CI: ±15), with a variation of almost 100 g between the years. The proportion of primigravidae births in the hospital was 34.8%, which is above that expected in a rural area of a developing country.¹⁸ The prevalence low birthweight among primigravidae was 14.8% (95% CI: 1.1%) and among multigravidae 8.3% (95% CI: 0.6%). The risk period for the birthweight difference between primigravidae and multigravidae was calculated as commencing 3 months after the major malaria peak and lasting for 5 months. We identified only one period with a significant impact on birthweight difference and that was April–August 1998 (in connection with ENSO), when the difference was 367 g (95% CI: ±95 g). This is a greater difference by 155 g ($P = 0.001$) compared with the mean birthweight difference for the whole period (Table 2). Between September and January 1994, which was associated with a recognized heavy rainfall and malaria period the birthweight difference was marked (288 g [95% CI: ±84 g]), but was not significant (Table 2). Prolonging the risk period until September 1995 gave a similar difference (268 g [95% CI: ±50 g]), but one which reached statistical significance, $P = 0.023$ (not in Table).

Morogoro Region

Rain data for this region showed a seasonal pattern (Figure 2 and Table 3). The pattern was not as obvious as in the Kagera region. Often the short and long rains merged into a period that lasted approximately 4 months, with 400–600 mm rainfall. As in the Kagera region, October 1997–May 1998 was an exceptionally rainy season with 1884 mm.

Malaria data were available only from April 1995 to December 2001 for diagnosed malaria cases in the paediatric ward, and from January 1997 to December 2001 for positive malaria slides. All the rainy periods from April 1995 were followed by malaria seasons, although they were more difficult to define compared with those in the Kagera region (Figure 2). As in Kagera, malaria increased between May and August 1997 despite little preceding rain. ENSO (October 1997–May 1998) was followed by two malaria seasons that lasted for 3 and 7 months. During 2000–2001 there were normal short and long rains but the malaria season that started in February 2000 lasted more or less continuously until the end of the study period with some peaks. During all these periods there was a high incidence of malaria, 600–900 positive malaria slides per month. The Figure shows that diagnosed clinical malaria cases in the paediatric wards and positive malaria slides for patients of all ages showed a good correlation with rainfall patterns.

There were 9347 singleton live births at Kilosa hospital during 1994–2001. Missing data occurred for 4.1% of births and

Table 2 Description of rainfall, malaria season, and birthweight differences between primigravidae and multigravidae in Ndolage Hospital, Kagera Region

Risk Period number	Rainy period	Major rain peak	Rainfall (mm)	Malaria season	Major malaria peak	Positive malaria slides (n)	Malaria season (months)	Risk period (months) ^b	Total birthweight difference (g) ^c	P-value ^d
1	Jan 90–May 90	March 90	1015	April 90–June 90	May 90	860	3	Aug 90–Dec 90	122 (±74)	Not sign.
—	Oct 90–Dec 90	Oct 90	645	No malaria season	—	—	—	—	—	—
2	March 90–May 90	March 90	1021	April 91–Aug 91	June 91	1405	3	Sep 91–Jan 92	149 (±106)	Not sign.
3	Jan 92–May 92	April 92	1003	June 92–July 92	No peak	584	2	Sep 92–Jan 93	175 (±88)	Not sign.
4	Oct 92–Feb 93	Jan 93	736	Feb 93–March 93	No peak	664	3	May 93–Sep 93	205 (±81)	Not sign.
5	May 93	May 93	304	June 93–July 93	No peak	376	2	Sep 93–Jan 94	189 (±87)	Not sign.
6	Aug 93–Nov 93	Aug 93	461	Dec 93–Feb 94	Jan 94	704	3	April 94–Aug 94	204 (±76)	Not sign.
7	Jan 94–July 94	March 94	1847	April 94–Aug 94	June 94	2442	5	Sep 94–Jan 95	288 (±84)	Not sign.
-	Sep 94–Dec 94	Nov 94	628	No malaria season	—	—	—	—	—	—
8	Feb 95–May 95	April 95	965	April 95–Sep 95	June 95	1503	6	Sep 95–Jan 96	239 (±80)	Not sign.
9	Sep 95–May 96	March 96	1839	April 96–July 96	May 96	1405	4	Aug 96–Dec 96	158 (±86)	Not sign.
10	Sep 96–Jan 97	Sep 96	669	Oct 96–Jan 97	Nov 96	822	4	Feb 97–June 97	187 (±82)	Not sign.
11	March 97–May 97	April 97	674	June 97–Sep 97	June 97	3282	4	Sep 97–Jan 98	145 (±94)	Not sign.
12 ^a	Oct 97–June 98	Nov 97	2407	Nov 97–Aug 98	Jan 98	6313	10	April 98–Aug 98	367 (±95)	0.01
13	March 99–May 99	March 99	811	May 99–July 99	May 99	806	3	Aug 99–Dec 99	211 (±76)	Not sign.

^a El Niño 1997–1998 risk period.

^b Risk period defined as starting 3 months after first malaria peak and lasting 5 months.

^c Birthweight difference between primigravidae and multigravidae during risk period (±95% CI).

^d P-value for birthweight difference, refers to the **additional** birthweight difference, i.e. significance of interaction term risk period * primigravidae.

Table 3 Description of rainfall, malaria season, and birthweight differences between primigravidae and multigravidae in Kilosa Hospital, Morogoro Region

Risk Period number	Rainy period	First rain peak	Rain in mm	Malaria season	First malaria peak	Positive Malaria slides ^b	Malaria season in months	Risk period ^c	Birthweight difference ^c	P-value ^d
1	Feb 96–May 96	Feb 96	606	Feb 96–July 96	April 96	726 (diagnose malaria) ^e	6	July 96–Nov 96	382 (±99)	Not sign.
2	Feb 97–April 97	March 97	314	May 97–Aug 97	May 97	2639	3	Aug 97–Dec 97	319 (±92)	Not sign.
3 ^a	Oct 97–May 98	Dec 97	1,884	Jan 98–March 98	Jan 98	1779	3	April 98–Aug 98	237 (±92)	Not sign.
4 ^a	See period 3	See period 3	See period 3	June 98–Dec 98	June 98	3592	7	Oct 98–Feb 99	266 (±98)	Not sign.
5	Feb 99–April 99	March 99	892	May 99	May 99	511	1	Sep 99–Jan 00	339 (±106)	Not sign.
6	Dec 99–Jan 00 March 00	No peaks	256 132	Feb 00–Dec 01	Feb 00	14 574	23 ^f	May 00–Sep 00	304 (±81)	Not sign.
	Dec 00–Jan 01		266							
	March 01–May 01		399							
	Dec 01		263							

^a El Niño 1997–1998 risk period.

^b Risk period defined as starting 3 months after first malaria peak and lasting 5 months.

^c Birthweight difference between primigravidae and multigravidae during risk period (±95% CI).

^d P-value for birthweight difference refers to the **additional** birthweight difference.

^e Before 1997 no record of malaria slides, but malaria diagnosis in paediatric ward available.

^f Prolonged malaria season.

the sample size with complete data was 9337 (Table 1). The mean birthweight among primigravidae was 2717 g (95% CI: ±16) and among multigravidae 3017 g (95% CI: ±14). The mean birthweight difference between primigravidae and multigravidae for the 8-year period was 300 g (95% CI: ±22 g), with a variation of <50 g between years. The proportion of primigravidae born in the hospital was 41.5%. The prevalence of low birthweight among primigravidae was 24.1% (95% CI: ±1.3), and among multigravidae 10.1% (95% CI: ±0.8). The risk period for an increased difference in birthweight between primigravidae and multigravidae was calculated as for Ndolage hospital. No significant impact on birthweight difference for any of the calculated risk periods was observed, although the difference was uniformly high throughout the whole of the study period (Table 3).

There may also be increased risk of placental malaria in secundigravidae so the data were also analysed with secundigravidae as a separate class from multigravidae i.e. gravidae was split into three classes: primi, secundi, and multigravidae. Secundigravidae were intermediate between primigravidae and multigravidae in mean birthweight and frequency of low birthweight (data not shown). No significant interaction was noted between secundigravidae and any of the risk periods. In the specific case of risk period 12 in Ndolage, the additional effect on primigravidae became more significant (significance falling from $P = 0.01$ to $P < 0.0005$) while the additional effect on secundigravidae was small and non-significant. The latter result suggests that the additional impact on birthweight noted in this period was fairly specific to the primigravidae group of births.

Discussion

In the hillier Kagera region standing water after the rainy season became a problem during ENSO 1997–1998 with the consequence of an unusual long and intense malaria transmission season (10 months). During 1994 there was also unusually heavy rain and increased *P. falciparum* positivity with as a consequence a prolonged malaria season. The remainder of the study period showed a seasonal rainfall pattern with the malaria seasons lasting 2–4 months, except for 1995, when the season was longer but did not lead to much *P. falciparum* positivity. At Ndolage hospital there was evidence for seasonal malaria transmission regularly followed by a slight increase in low birthweight. This periodic pattern was broken between April–August 1998 when there was a clear trend towards higher birthweight differences between primigravidae and multigravidae and consequently increased risk of low birthweight in primigravidae. The difference was 367 g, which meant an additional 155 g difference compared with the mean of 215 g for the whole period. This increased difference was highly significant ($P = 0.001$). The prevalence of low birthweight in primigravidae was 22.2% (95% CI: ±6.8%), compared with 7.4% (95% CI: ±3.0) in multigravidae. The impact on birthweight difference was not significant for any other risk period. The intense malaria epidemic of June–September 1997 did not influence the birthweight difference or the risk of low birthweight, probably due to the very limited epidemic period. Although the El Niño in Kagera was followed by famine, the prevalence of low birthweight in multigravidae was not affected

during this period. The selective effect on primigravidae suggests malaria was the primary reason for the additional birthweight difference between primigravidae and multigravidae.

In Morogoro region the transmission was holoendemic, as the area is very flat, with a high risk of standing water even after moderate rainy seasons, thus providing breeding sites for mosquitoes. We identified periods when malaria diagnosis was increased and classified them as malaria seasons. There was persistent malaria transmission between the rainy seasons, probably due to the effects of standing water. Smith *et al.*¹⁹ have carried out a parasitological survey in two villages also situated in Morogoro region and their study indicated a very high prevalence of *P. falciparum* parasitaemia. The estimated mean annual inoculation rate was over 300 infectious bites per person per year with no seasonal fever pattern among children and adults. This constant malaria pressure was reflected in the very low mean birthweight among primigravidae in Kilosa hospital (2717 g, 95% CI: ± 16 g), more than 100 g lower compared with Ndolage and other hospitals in Tanzania.²⁰ The prevalence of low birthweight among primigravidae (24.1%) was high compared with Ndolage hospital (14.8%) and independent of season. In multigravidae this low birthweight difference between regions was much smaller. This data indicates that pregnant women in Kilosa live under a constant high pressure of malaria. During ENSO 1997–1998 there was a prolonged malaria season and from December 1999 to the end of the study period (December 2001) there was an escalating malaria season suggesting a malaria season out of control.²¹ Despite the immense impact of malaria, there was no further increase in the birthweight difference during these two periods. Malaria pressure may have reached a limit in terms of birthweight effects resulting in little further decrease in birthweight of primigravidae.

Primiparity is associated with low birthweight even in non-malarious areas, but this study from the Kagera and Morogoro regions of Tanzania confirms previous findings that the prevalence of low birthweight is substantially higher than expected in first compared with subsequent pregnancies in areas with endemic malaria transmission patterns.^{6,7,22} Earlier studies have focused on the impact of malaria on birthweight in areas with different malaria transmission patterns: perennial transmission;^{2,4,5,23} seasonal transmission;^{24,25} low or sporadic transmission;²⁶ and epidemic malaria amongst populations with little immunity.²⁷ These studies did not examine temporal changes in birthweight differences in relation to rainfall and malaria transmission. The results from Kagera region are consistent with the observations that many primigravidae become parasitaemic with *P. falciparum* malaria in early pregnancy and that consequently the effects of this would not be apparent until 4–6 months following the time of peak malaria transmission. The magnitude of the change in birthweight differences during the study period in Kagera region reduces the likelihood that these differences result only from confounding factors. Eclampsia, which is more common in first pregnancies, may show a seasonal pattern²⁸ and malaria has been associated with pre-eclampsia in Senegal.²⁹ Nevertheless, the incidence of these conditions is too low to account for the large changes in birthweight differences observed in this study. Other factors such as nutritional status

and increased physical workload could confound these results, but these factors usually affect multigravidae to a greater extent than primigravidae. In the Mwanza region of Tanzania, nulliparity and spleen enlargement were positively associated with low birthweight in primigravidae after allowing for other confounders.³⁰ In Kilosa hospital we found a significantly lower birthweight for all parities during the months between April and July. This pattern was closely linked to the seasonal lack of food before harvest. Bantje²⁵ collected data between 1972 and 1980 in Rufiji delta, Tanzania, and showed a consistent seasonal variation in infant birthweight. The difference was well correlated to increased physical workload and availability of food, but the birthweight data was not grouped by parity. In Morogoro, seasonal variation in birthweight distribution previously has been described, which was related to food availability, but this analysis also did not group data by parity.³¹

HIV infection in pregnant woman is associated with a significantly increased malaria prevalence. Simultaneous HIV infection in a pregnant woman worsens the effect of malaria and increases the risk of low birthweight in all parities.⁵ In Ndolage hospital we observed significant increases in birthweight in all parities through the 10-year study period. This was probably not due to an increase in living standards, since there are no indications of that, but more likely to a lower prevalence of HIV among pregnant women in this area (prevalence in Bukoba Town, Kagera region; 1993: 16.1%, 1996: 13.7%, and 1999: 7.0%).³²

This study has shown that the risk of delivering a low-birthweight baby in the first pregnancy increases approximately 5 months following a malaria epidemic. The analysis indicates that an epidemic which resulted in large birthweight differences between primigravidae and multigravidae occurred, related to ENSO's impact in 1997–1998. Birthweight and parity were collected from routine hospital data in two areas of Tanzania that are considered as having endemic malaria transmission patterns, but which in fact have very different malaria exposure risk in pregnancy. In Ndolage hospital, the birthweight difference and the risk of low birthweight was significantly lower compared with that in Kilosa hospital, except following the ENSO when the two areas showed similar differences. Famine in Kagera is unlikely to have contributed as eating habits in primigravidae are not considered to differ from multigravidae. This indicates that the pressure of malaria is much greater for pregnant women living in Morogoro.

There is a need to improve malaria control measures in pregnant women, especially during ENSO years if epidemics of lowered birthweight are to be prevented. This includes increasing monitoring and evaluation of birthweight indices, ensuring adequate drug supplies, improved access to intermittent preventive treatments, provision of effective first line therapy and, if feasible, intensifying vector control operations. In areas like Morogoro with such intense year-round transmission it is important to provide continuous anti-malarial protection to all pregnant women, which is not occurring at present. Current recommendations of the Tanzanian Ministry of Health follow those of the World Health Organisation in that they include the use of a single dose of sulfadoxine-pyrimethamine in the second trimester and a single dose in the third trimester. High coverage with this approach will be required to provide effective protection.

Comparison of malaria and birthweight data from regions with different levels of malaria transmission should allow a predictive model to be developed in relation to climatic factors

including the global impact of ENSO on the burden of low birthweight. The advances made in the past decade in the meteorological forecasting of the phases of the Southern Oscillation may help to predict areas at risk of malaria epidemics and facilitate improved more intense periods of malaria control in pregnancy.³³ Because the effect on low birthweight is mainly seen some weeks to a few months into an epidemic (i.e. after pregnant women have gone through the last trimester under very malarious conditions and suffered these adverse effects), monitoring of low birthweight indices may not identify a

malaria epidemic in its early phase. Its use should be combined with additional early warning systems.

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KEY MESSAGES

- Surveillance of birthweight differences between primigravidae and multigravidae is a useful indicator of malaria exposure in endemic areas of Africa.
- The risk of delivering a low birthweight baby in the first pregnancy increases approximately 5 months following a malaria epidemic.
- Birthweight differences between primigravidae and multigravidae occurred related to the El Niño Southern Oscillation of 1997–1998.
- It is important to provide regular antimalarial protection to all pregnant women.

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