Analysis of Malaria Incidence using Quasi-Poisson Regression Model: Evidence from Obuasi Municipality, Ghana

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Abstract
Death and economic losses associated with malaria have become a global phenomenon that need urgent attention. To obtain a better understanding of incidence of the disease, a quasi-Poisson regression model has been applied in this study to determine the incidence of malaria in Obuasi Municipality, Ghana. Our results show that the incidence of malaria is more prevalent among individuals within the ages of 20 to 34 years and those above 50 years, as compared to children under 5 years of age. In addition, the study reveals that most incidence of malaria were reported in the last quarter of every year between 2007 and 2010.
Keywords: Obuasi Municipality, malaria, risk factors, quasi-Poisson regression model

1. Introduction

Malaria has been a protracted life-threatening parasitic disease transmitted by female anopheles mosquitoes. This disease has contributed to human mortality in the world, particularly among children. Malaria threatens 2.4 billion (40%) of the world's population living in the poorest countries and more than one million deaths are attributable to the disease annually (World Health Organization 2000). Most of these deaths occur among children in high-transmission areas, and account for approximately one in five of all childhood deaths in Africa (Mufunda *et al.* 2007). World Malaria Report 2013 estimated that in 2012 there were 627,000 malaria deaths worldwide, 90% occurring in sub-Saharan Africa and 77% in children under 5 years of age (World Health Organization 2014). However, the true burden of malaria is difficult to estimate as many people are treated at home and no proper post-mortem diagnosis is made in the case of death (Mufunda *et al.* 2007). Since there is no post-mortem diagnosis, many malaria cases go unreported.

Malaria continues to be a major threat to health, occurring in 109 countries worldwide (Malaria RB 2014). Various institutions have been established to overcome this problem. The Global Strategy has come up with three components: malaria control; malaria elimination; and research into new tools and approaches (Malaria RB 2014). Of the 35 countries responsible for the majority of total deaths worldwide, six are in Africa, accounting for 50% global deaths and 47% malaria cases. A large number of these 35 countries have high transmission of *P. falciparum* malaria and are located in sub-Saharan Africa (Malaria RB 2014). Malaria is more prevalent in Africa south of the Sahara, and among very young children and pregnant women.

In areas of stable endemic malaria transmission in sub-Saharan western Africa, it has been estimated that in the year 1995 about 1 million deaths were directly attributable to malaria infection (Snow *et al.* 1999). Of these deaths, about 75% were children below the age of 5 years. Accordingly, a World Bank Report of 1993 noted that malaria accounts for an estimated 35 million disability-adjusted life years per year lost in Africa due to ill-health and premature death (Jamison *et al.* 1993). Greenwood and Pickering (1993) also argued that malaria was the main cause of death among early European visitors to The Gambia. Successful efforts have been achieved through interventions and research aimed towards malaria elimination. Chiyaka *et al.* (2013) reported that between 1945 and 2010, 79 countries worldwide achieved malaria elimination and 75 remained malaria free, leading to the reduction of the global geographical spread of the disease.

Generally, there has been considerable research pertaining to malaria incidence and risk factors. For example, Greenwood *et al.* (1987) measured mortality and morbidity from malaria among 3,000 children under the age of 7 years in a rural area of The Gambia using a post-mortem questionnaire technique. From their study, malaria was identified as the probable cause of 4% of infant deaths and 25% of deaths in children aged 1 to 4 years in rural areas of The Gambia. Koram *et al.* (1995) studied socio-economic risk factors for malaria in peri-urban area of The Gambia. Their study showed that malaria was associated with poor quality housing and crowding and with travel to rural areas, where the level of malaria transmission was higher than in urban centres. No association was found between the risk of malaria and the overall education level of parents or guardians of the sampled children.

Stresman (2010) looked beyond temperature and precipitation, and studied ecological risk factors that modify malaria transmission. The research by Stresman (2010) revealed that temperature and water for breeding habitats were important primary ecological factors that impact the distribution of malaria vectors and the rate at which mosquito and parasite develop. Mendez *et al.* (2000) studied risk factors associated with malaria infection in an urban setting, and their study revealed that malaria infection was prevalent in areas of the city with the highest incidence of the disease. Their study also assessed the association between some characteristics of the population and the risk of malaria infection. The prevalence of malaria infection was 4.4% among the 1,380 people studied and it decreased with age, knowledge of disease and preventive measures directed to the elimination of breeding sites. In addition, the infection was positively associated with exposure to the forest.

Kudom and Mensah (2010) studied the potential role of the educational system in addressing the effect of inadequate knowledge of mosquitoes on the use of insecticide-treated nets in Ghana. They contended that since 2001, there had been a tremendous increase in the number of households protected by Insecticide Treated Nets (ITNs) and Internal Residual Spraying (IRS) in Ghana. However, they could not find any evidence of a reduction in malaria cases as expected, but rather reported deaths were found to have increased since 2007. Their study was meant to get a better understanding of insights of malaria, knowledge on mosquitoes and the significance attached to ITNs among secondary and tertiary students in the Cape Coast, Ghana. They employed structured questionnaires which were administered randomly to collect data on demographic characteristics of students, knowledge of mosquitoes and ITNs and attitude towards the use of ITN in seven public high schools and four tertiary institutions in Cape Coast metropolis.

The study by Bai *et al.* (2013) reviewed climate change and mosquito-borne diseases in China. The objective of their study was to summarize what is known about the influence of climate change on the incidence and prevalence of malaria, dengue fever and Japanese encephalitis in China, and to offer important information and trend for adaptation policy making. Fifty-five (55) papers met the inclusion criteria for their study. Analysis of the results thereof indicated that the variability in temperature, precipitation, wind and extreme weather events is linked to transmission of mosquito-borne diseases in some regions of China. However, the findings of their study were inconsistent across geographical locations and this requires strengthening current evidence for timely development of adaptive options.

Yewhalaw *et al.* (2013) undertook a study on the effect of dams and seasons on malaria incidence and anopheles abundance in Ethiopia using a longitudinal cohort study conducted over a period of two years. The aim of their study was to determine *P. falciparum* malaria incidence among children under 10 years of age living near a mega hydropower dam in Ethiopia. A total of 2,080 children from 16 villages situated at different distances from a hydropower dam were followed-up from the year 2008 to 2010 using active detection of cases based on weekly house-to-house visits. This cohort of children comprised 951 girls and 1,059 boys, with a median age of 5 years. Malaria vectors were concurrently surveyed in all the 16 villages. Frailty models were used to explore associations between time-to-malaria and potential risk factors, whereas, mixed-effects Poisson regression models were used to assess the consequence of different covariates on anopheline abundance. Overall, 548 (26.9%) children experienced at least one clinical malaria episode during the follow-up period with mean incidence rate of 14.3 cases per 1,000 child-months at risk (95% CI: 12.16 - 16.36). *P. falciparum* malaria incidence showed no statistically significant association with distance from the dam reservoir (p = 0.32), although it varied significantly between seasons (p < 0.01). The malaria vector, *Anopheles arabiensis*, was however, more abundant in villages nearer to the dam reservoir. The researchers concluded that *P. falciparum* malaria incidence dynamics were more influenced by seasonal drivers than by the dam reservoir itself.

Malaria is a serious threat, not only for autochthonous or indigenous inhabitants, but also for non-immune individuals travelling or working in malaria-endemic areas. The study undertaken by Texier *et al.* 2013, quotes from the 2011 international travel and health book that approximately 125 million international travellers visit malaria-endemic countries annually, after which more than 10,000 cases of malaria are reported upon returning to their home countries. The objective of their study was, *inter alia*, to identify, at a country scale (Ivory Coast), the environmental factors that are associated with clinical malaria among non-immune travellers, opening the way for a remote sensing-based counselling for malaria risk prevention among travellers using a sample of 87 cohorts, including 4,531 French soldiers who travelled to Ivory Coast during approximately four months, between September 2002 and December 2006. Due to the fact that malaria is insect-vector transmitted, the environment was found to be a key determinant of the spread of infection (Texier *et al.* 2013). Geo-climatic factors, such as temperature, moisture and water quality, determine the presence of Anopheles breeding sites, vector densities, adult mosquito survival rate, longevity and vector capacity. The association between environmental factors and malaria incidence in autochthonous population have been shown in several studies (Kleinschmidt *et al.* 2001; Guthmann *et al.* 2002; Hakre *et al.* 2004; Danis-Lozano *et al.* 2007; Gomez-Elipe *et al.* 2007; Berrang-Ford *et al.* 2009; Oliveira-Ferreira *et al.* 2010); Zacarias & Andersson 2010; Girod *et al.* 2011; Mathanga *et al.* 2012), yet the association between the incidence of clinical malaria cases among non-immune travellers and environmental factors is yet to be evaluated. However, (Texier *et al.* 2013) analysed the association between the incidence of clinical malaria and other factors (including individual, collective and environmental factors evaluated by remote sensing methods) in a random effect mixed Poisson regression model to take into account the sampling design. The results of their study showed that 140 clinical malaria cases were recorded during 572,363 person-days of survey, corresponding to an incidence density of 7.4 clinical malaria episodes per 1,000 person-months under survey. The risk of clinical malaria was significantly associated with the cumulative time spent in areas with NDVI > 0.35 (RR = 2,42), a mean temperature higher than 27°C (RR = 2,4), a longer period of dryness during the preceding month (RR = 0,275) and the cumulative time spent in urban areas (RR = 0,52). The present results suggest that remotely-sensed environmental data could be used as good predictors of the risk of clinical malaria among vulnerable individuals travelling through African endemic areas.

Kang *et al.* (2013) investigated the causal effect of malaria on stunting. The aim of their study was to estimate the causal effect between malaria episodes and stunted growth by applying a combination of Mendelian randomization using the sickle cell trait, and matching on a cohort of children in the Ashanti Region, Ghana. They established that the risk of stunting increases by 0.32 (P-value: 0.004, 95% CI: 0.09, 1.0) for every malaria episode. The risk estimate based on Mendelian randomization substantially differs from the multiple regression estimate of 0.02 (P-value: 0.02, 95% CI: 0.003, 0.03). In addition, based on the sensitivity analysis, their results were reasonably insensitive to unmeasured confounders. Again, the results from their study revealed a causal relationship between malaria and stunting in young children in an area of high endemicity, and demonstrated the usefulness of the sickle cell trait as an instrument for the analysis of conditions that might be causally related to malaria.

Ahmed *et al.* (2013) researched into the epidemiology of symptomatic *P. falciparum* malaria in a specific area of Bangladesh subsequent to the introduction of a national malaria control program. They carried out surveillance for symptomatic malaria due to *P. falciparum* in two demographically defined unions of the Chittagong Hill Districts in Bangladesh, bordering western Myanmar, between October 2009 and May 2012. The relationship between socio-demographics and temporal and climate factors with symptomatic *P. falciparum* infection over two years of surveillance data, was assessed. Risk factors for infection were determined using a multivariate regression model. The results showed 472 cases of symptomatic *P. falciparum* malaria cases which were identified among 23,372 residents during the study era. More than 85% of cases occurred during the rainy season from May to October, and were highly crowded geographically within these two unions with more than 80% of infections occurring in areas that contain approximately one-third of the total population. Risk factors statistically associated with infection in a multivariate logistic regression model were living in the areas of high incidence, were young in age, and their occupation included jhum cultivation and/or daily labour. Use of long lasting insecticide-treated bed nets was high (89.3%), but not associated with decreased incidence of infection. The researchers concluded that *P. falciparum* malaria continues to be hypoendemic in the Chittagong Hill Districts of Bangladesh, is highly seasonal, and is much more common in certain geographically limited hot spots and among certain occupations.

In Ghana, malaria caused about 8,200 illness daily and 3,000,000 yearly with 3,000 deaths in the year 2010 (National Malaria Control Programme Annual Report 2010). The most vulnerable groups remain children under five years of age and pregnant women (Asante & Asenso-Okyere 2003). Moreover, 25% of children who die before their fifth birthday are killed by the disease, which also claims the lives of many pregnant women. Diagnosis of malaria in children is difficult without laboratory support because the symptoms and signs of malaria overlap with those of other febrile illnesses such as pneumonia (Olaleye *et al.* 1998). Malaria is caused by the plasmodium parasites which are transmitted by female anopheles mosquito. Despite consistent efforts to reduce malaria episodes that include chemical spraying, use of treated mosquito bed nets, clearing bushes, cleaning drains and subsidized treatments, prevalence rates and malaria incidence, remain high. It is probable that the efforts to reduce malaria do not specifically take into account the risk factors likely to aggravate malaria disease. According to Bøgh *et al.* (2007), understanding local variability in malaria transmission risk is critically important when designing intervention or vaccine trials. This study therefore endeavours to analyse the incidence of malaria episodes using quasi-Poisson regression model.

The rest of the paper is organized as follows: Section 2 describes the concept of methods employed in the research and the data source. The empirical analysis and results are presented in Section 3. Section 4 provides the concluding remarks.

2. Data and Methods

The malaria data used in this study was obtained from the Out Patients Department (OPD) compiled by the data management section of the Obuasi Government Hospital in Ghana, which provides health services to all people within the Obuasi Municipality. The Municipality is one of the 27 districts of the Ashanti Region of Ghana and was created as part of the Government effort to decentralise governance. The vegetation is largely degraded and semi-deciduous forest with Gold mining as the major occupation of the natives.

The data covers all the reported cases for the period of January 2007 to December 2010. The data also establishes cases for males and females, as well as age categories (i.e. from infants to the aged). Since malaria cases are considered as count data, a quasi-Poisson regression model was specified to determine the risk factors for malaria infections. The covariates considered include gender, age as well as quarterly time period of reported malaria incidence cases between 2007 and 2010.

2.1 Specification of the Model and Estimation

2.1.1 Generalized Linear Models

The basic count data regression models can be represented and understood using the Generalized Linear Models (GLMs) framework (Nelder & Weddeburn 1992).

GLMs describe the dependence of a scalar variable $y_i(i=1,...,n)$ on a vector of regressors x_i. The conditional distribution $y_i \mid x_i$ is a linear exponential family with a probability function:

$$f(y;\lambda,\phi) = \exp \frac{y\lambda - b(\lambda)}{\phi} + c(y,\phi) \qquad (1)$$

where:

λ is the canonical parameter that depends on the regressors via a linear predictor;

ϕ is a dispersion parameter that is often known;

$b(.)$ and $c(.)$ are known and determine which member of the family is used, for example, normal, binomial or Poisson distributions.

2.1.2 Overdispersion

Most count models are often overdispersed. Overdispersion is a situation where the variance exceeds the mean. A typical example is the Poisson regression model whose assumption of the mean being equal to the variance is very restrictive and often violated, and hence overdispersed. Models such as Negative binomial, quasi-Poisson, etc., relax the assumption of overdispersion in fitting a model for count data.

2.1.3 Quasi-Poisson regression model

An alternative way of dealing with overdispersion is to use the mean regression function $E[y_i \mid x_i] = \mu_i = b'(y_i)$ and the variance function $VAR[y_i \mid x_i] = \phi.b''(\lambda_i)$ from Poisson GLM, but leaving the dispersion parameter ϕ unrestricted. Thus, ϕ is not assumed to be fixed at 1, but it is estimated from the data. This strategy leads to the same coefficients as the standard Poisson model, with the exception of inferences that are adjusted for overdispersion. Consequently, both models (quasi-Poisson and sandwich-adjusted Poisson) adopt the estimation function view of the Poisson model and do not correspond to fully specified likelihoods. As a result, a quasi-Poisson regression model shall be used to expound the incidence of malaria using quarterly data between 2007 and 2010, and gender and age groups as covariates.

3. Empirical Results and Discussion

Tables 1: Descriptive Statistics of the Variables (2007-2010)

Variable	Frequency	Percentages
Time Trend		
2007	5206	12.7
2008	4547	11.2
2009	10697	26.3
2010	20269	49.7
Season		
Quarter 1	8671	21.3
Quarter 2	9642	23.6
Quarter 3	10486	25.7
Quarter 4	11920	29.2
Age group (years)		
Less than 5	9117	22.3
5 – 9	3768	9.2
10 – 14	3456	8.4
15 – 19	5187	12.7
20 – 34	8567	21.0
35 – 49	6179	15.1
50 and above	4445	10.9
Gender		
Female	23460	57.6
Male	17259	42.3

The incidence of malaria according to the selected background characteristics is shown in Table 1. Within the four-year year study period, a total of 40,719 malaria cases were documented at the hospital, and it can be seen that there is an increasing trend of malaria incidence wherein the fourth year (2010) has about 4 times the incidence in the starting year (2007). This means that, the incidence of malaria in the year 2010 increased four folds compared to 2007. The proportion of malaria incidence was found to be high within the fourth quarter of every year. This highly reported cases of malaria in the fourth quarter, i.e. October to December, can be attributed to the rainy season which is known for promoting mosquito breeding in areas where water gets stagnant, and also in areas where there are unclean and chocked gutters.

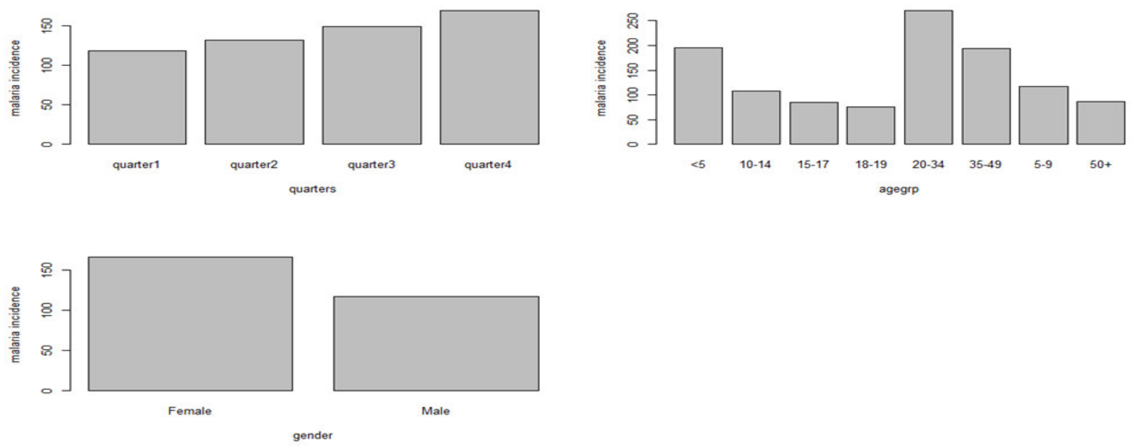

Figure 1: Incidence of malaria with respect to covariates (quarters, age groups and gender) in 2007-2010

With respect to the various age groups, the proportion of malaria incidence was found to be high among infants and children under 5 years of age as well as among adults aged 20 to 34 years. Moreover, this high proportion of malaria incidence is also found to be high among females than males (see Figure1).

3.1 Quasi-Poisson Model Specification

To analyse the incidence of malaria, the study fitted a quasi-Poisson regression model to the data available. The aim was to analyse the incidence of malaria with respect to age, gender and season (quarters of a year) within which the cases were recorded (2007 and 2010). The model was selected based on likelihood ratio chi-square test, Quasi Akaike information criterion and the residual deviance.

Table 2: Parameter Estimates for Quasi-Poisson Regression Model

Variable	Coefficient	Standard error	P-value	Confidence Interval (L25.5% - U97.5%)		Odds ratio
Constant	5.2551	0.1546	0.0000	4.9435	5.5501	191.5483
Gender						
Female	Reference	-----	-----	-----	-----	-----
Male	-0.3521	0.0979	0.0039	-0.5452	-0.1612	0.7032
Age group(years)						
<5	Reference	-----	-----	-----	-----	-----
5-9	-0.5089	0.1893	0.0077	-0.8867	-0.1426	0.6012
10-14	-0.5953	0.1945	0.0045	-0.9848	-0.2199	0.5514
15-19	-0.8286	0.2103	0.0001	-1.2536	-0.4259	0.4367
20-34	0.3242	0.1522	0.0342	0.02767	0.6255	1.3829
35-49	-0.0138	0.1646	0.9332	-0.3372	0.3093	0.9863
50+	-0.3521	0.0979	0.0002	-1.2442	-0.4189	0.7032
Season						
Quarter 1	Reference	-----	-----	-----	-----	-----
Quarter 2	0.1079	0.1455	0.4589	-0.1770	0.3943	1.1137
Quarter 3	0.2293	0.1415	0.1065	-0.0470	0.5086	1.2577
Quarter 4	0.3587	0.1377	0.0097	0.0907	0.6311	1.4314
Likelihood ratio chi-square test 0.0000						

Table 2 summarizes the maximum likelihood estimates of the parameters in the model. The coefficients for all the variables are estimated relative to a reference group. To evaluate the final model, a likelihood ratio test was performed to test the difference between the null model, i.e. model without any predictor and the fitted model.

Based on the p-value of the likelihood chi-square test, we rejected the null hypothesis that the fitted model is significantly not different from the null model. Thus, the selected model fits the data better, compared to the model without any predictor.

From the results of the estimated model presented in Table 2, we observe that malaria incidence is less common among males than females. The estimate was found to be 0.3521 less than females. Gender difference in malaria incidence is indeed significant in the sense that norms and values influence division of labour, leisure patterns and sleeping arrangements, and eventually leads to different patterns of exposures to mosquitos.

When the consequence of age and prevalence of malaria was measured, we found that the incidence of malaria was significantly low among the 10 to 14 year olds as well as 50 year olds and above, compared to children under 5 years. Nevertheless, it was significantly high amongst the 15 to 19 year age group compared to children under 5 years. The reason for children under 5 years of age being mostly affected is probably because they have not yet developed the defensive immunity against most severe forms of the disease.

With respect to the four quarters considered, it was found that the incidence of malaria is significantly high in quarter four (i.e. October to December), with 0.3857 more than in quarter one. This finding shows that transmission also depends on climatic conditions such as rainfall patterns, temperature and humidity - all of which may affect the survival of mosquitos. In many places, transmission is seasonal with the peak during and just after the rainy season, hence accounting for the high incident rate in the last quarter.

4. Conclusion

Malaria has been a long life-threatening parasitic disease transmitted by female anopheles mosquitoes. This paper seeks to analyse the incidence of malaria at Obuasi Government Hospital in Ghana using a quasi-Poisson regression model. Regarding the four-year period, a total of 40,717 malaria cases were reported at the hospital. Again, within the four-year period, there was an increasing trend of malaria incidence with the current year (2010) being about 4 times the starting year (2007). This means that, the incidence of malaria in the year 2010 increased nearly 4 times compared to 2007. From the estimated quasi-Poisson regression model, the proportion of malaria incidence was found to be high within the third and fourth quarters of every year. This highly reported cases of malaria in the last two quarters (i.e. July to December), can be attributed to the rainy season which promotes mosquito breeding.

With respect to the various age groups, the proportion of malaria incidence was found to be high among infants and children under 5 years of age as well as adults aged 20 to 34 years. Moreover, this high proportion of malaria incidence was also more common among the female group than the male group. The findings of this research confirm those of Asante and Asenso-Okyere (2003), who established that 25% of children who die before their fifth birthday are killed by the malaria disease, which also claim the lives of many pregnant women. The high incidence cases reported during the last quarter also confirm the work done by Stresman (2010) whose study looked beyond temperature and precipitation - ecological risk factors that modify malaria transmission. It was revealed that temperature and water for breeding habitats are important primary ecological factors that impact the distribution of malaria vectors and the rate at which mosquito and parasite develop, hence more cases in the last quarter.

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