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On the Logistic Regression of Prevalence of Malaria Fever with Complications

P. E. Omaku[1], S. I. Jerome[2] and J. O. Braimah[3*]

Abstract

Logistic regression is used to evaluate the effect of Malaria complicated by Typhoid, Hypertension and HIV on covariates Age and sex. Three sets of models were fitted with regards to the complications. Results indicate that the effect of sex for all complications were not significant, when Malaria is complicated with Typhoid; age was significant for patients who are less than 19 years and above 50 years of age when p-values is 0.002 and 0.0000 respectively. The study also reveals that patients who are above 50 years of age are significant with p-value of 0.001 when Malaria is complicated with Hypertension. The work concludes that children and old adults are more vulnerable to this epidemic disease which has been a major cause of mortality worldwide.

1. Introduction

Malaria is a protozoan disease transmitted by the bite of infected female anopheles mosquitoes which bite mainly between dusk and dawn. It is the most important of all tropical diseases in terms of morbidity and mortality. More than two billion people (36% of world population) are exposed to the risk of contracting malaria (Greenwood *et al.*, 2008 and Snow *et al.*, 2005). Each year, malaria directly causes nearly one million deaths and about500 million clinical cases of which 2

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[3]Department of Mathematics and Statistics, Ambrose Alli University, Ekpoma, Nigeria
[1,2]Department of Mathematics and Statistics, Federal Polytechnic Nasarawa, Nigeria
E-mails: omakupete@gmail.com, ojbraimah2014@gmail.com

to 3million constitute severe and complicated malaria (Rowe, 2000, Hay *et al.*, 2004).

Malaria is a vector infectious disease caused by protozoan parasites of the genus plasmodium and is transmitted by an infected female Anopheles mosquito. Until the late 19th century, the contributory agent for malaria was largely unknown. The medieual Italian term, malaria, meaning "bad air," or commonly known as march fever was used to describe the flu-like symptoms, such as headaches, fevers, shivering, joint pain, vomiting, retinal damage, and convulsions of patients infected with malaria. It was not until 1880 that the true cause of malaria was discovered (Greenwood *et al.*, 2008).

Recent data suggest that there were around 627,000 deaths from malaria worldwide in 2012 (World Health Organization 2013, 2015 and 2017). These were deaths directly attributable to malaria (malaria also kills indirectly by reducing birth weight and debilitating children with repeated infections) and so would usually have been preceded by severe illness. With fewer than half of those who suffer severe malaria being able to reach a health facility, and assuming a case-fatality rate of 90% at home and 20% in hospital (Thwing, Eisele and Steketee, 2011), the global annual incidence of severe malaria can be estimated at approximately 2 million cases. In parts of the world where the transmission of P. falciparum is intense and stable, severe malaria is mainly a disease of children from the first few months of life to the age of about 5 years, becoming less common in older children and adults as specific acquired immunity gives increasing (although always incomplete) protection. About 90% of the world's severe and fatal malaria is estimated to affect young children in sub-Sahara Africa (Black, Cousens and Johnson, 2010). In areas of lower endemicity, severe malaria occurs in both adults and children. Non-immune travelers and migrant workers are vulnerable to severe malaria, irrespective of the endemicity of the area where their infection was acquired. Early large-scale intervention studies with insecticide-treated bed nets (ITN) suggested that malaria contributed to as much as half of all mortality in children aged between 1 month and 5 years (Alonso Lau and Jaber, 2008 and Nevill, Some and Mung'ala, 1996). A later systematic literature review concluded that for the year 2000, an estimated 545, 000 (uncertainty interval: 105,000–1,750,000) children under the age of 5 in sub- Saharan Africa were admitted to hospital for an episode of severe malaria (Roca-Feltrer, Carneiro and Armstrong, 2008).

In this paper, we obtain the prevalence of Malaria disease with complications for a wider gap of age categories and sex, diagnosed at the General Hospital Keffi, Nasarawa State, using Logistic Regression Model.

2. Materials and Method

The data used for this study is a secondary data collected from the record office of the Hospital. For the purpose of the study, a sample size of 252 patients were extracted from the register.
The model employed is the Logistic regression model, given as:

$$\frac{P}{1-P} = e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_n X_n} \tag{1}$$

with

$$Logit(Y) = \ln(\frac{P}{1-P}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \tag{2}$$

$$= \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_n X_n}}{1-e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_n X_n}} \tag{3}$$

where $\log\left(\frac{P}{1-P}\right)$ is the log odd ratio, $\beta_1, \cdots, \beta_n$ are the coefficient of the covariates under study β_0 is the intercept term, P is the probability of the event, and X's are a set of predictors. β_0 and β's are typically estimated by the maximum likelihood (ML) method, which is preferred over the weighted least squares approach. The ML method is designed to maximize the likelihood of reproducing the data given the parameter estimates (Biochem, 2014; Hosmer and Lemeshow, 2010; Jelf, 2012; and Lei and Koehly, 2000).

2.1 Odd Ratio

The odd ratio of an event is the number of those who experience the event divided by the number of those that do not experience the event. The probability of success is (P) and (1- P) is the probability of failure (Longjian, 2018; Nagelkerke, 1991; Phil and Yaqionq, 2013; and Peng and So, 2002).
Then the odd of success is the ratio:

$$\vartheta = \frac{P}{1-P} \tag{4}$$

The logit model is principally appropriate when the issue of interest is to describe the odds of success or another substantive outcome, or the odds of success faced by one group relative to another. Odds are defined as the ratio of probability of one outcome to another (Peng, So, Stage and John, 2002;
For the logit transformation, the quantity will be recognized as the antilog of the logit, exp Ω.

2.2 Variable Transformation

The variables were categorized appropriately as shown below:

$$\text{MT}=\begin{cases} 1 & if\ malaria\ is\ complicated\ with\ tyhoid \\ 0 & if\ maleria\ is\ not\ complicated\ with\ Tyhoid \end{cases}$$

MHYP= $\begin{cases} 1 \quad if\ malaria\ is\ complicated\ with\ Hypertension \\ 0\ if\ maleria\ is\ not\ complicated\ with\ Hypertension \end{cases}$

MHYP= $\begin{cases} 1 \quad if\ malaria\ is\ complicated\ with\ HIV \\ 0\ if\ maleria\ is\ not\ complicated\ with\ HIV \end{cases}$

SEX= $\begin{cases} 1\ if\ Sex\ is\ "male" \\ 0\ if\ se?D\ is\ "female \end{cases}$

CODEAGE1= $\begin{cases} 1 \quad if\ Age \leq 19years \\ 0 \quad if\ otherwise \end{cases}$

CODEAGE2= $\begin{cases} 1 \quad if \quad 20 \leq Age \leq 49 \\ 0 \quad if\ otherwise \end{cases}$

CODEAGE3= $\begin{cases} 1 \quad if \quad Age > 49 \\ 0 \quad if\ otherwise \end{cases}$

2.3 Models Formulation

The three models to be considered are:

Model I: $LOG\left(\frac{P_{MT}}{1-P_{MT}}\right) = \beta_0+\beta_1 SEX+\beta_2 \leq 19YRS+\beta_3\,(20-49YRS)+\beta_4 \geq 50YRS)$

Model II: $LOG(\frac{P_{MHY}}{1-P_{MHY}}) = \beta_0+\beta_1 SEX+\beta_2 \leq 19YRS+\beta_3(20-49YRS)+\beta_4 \geq 50YRS$

Model III: $LO??\left(\frac{P_{MHIV}}{1-P_{MHIV}}\right) = \beta_0+\ \beta_1 SEX+\beta_2 \leq 19YRS+\beta_3(20-49YRS)+\beta_4 \geq 5OYRS$

2.4 Test for Individual Significant

$H_0 : \beta = 0$ (Coefficient is not significant) Versus $H_1 : \beta \neq 0$ (coefficient is significant), for $\alpha = 0.05$

Decision Rule: reject H_0 if P-value $<\alpha$

Conclusion:

3. Data Analysis

The data consist of dependent variables; Malaria complicate by Typhoid (MT), Malaria complicated by HIV (MHIV) and Malaria complicated by Hypertension (MHYP) while the covariates considered are Sex, Age.

3.1 Results and Interpretation

Table 3.1: Table of coefficients, Test statistics and odd ratios for malaria complicated by typhoid Adjust by Sex and Age group

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1^a	**SEX**	-.183	.368	.248	1	.618	.833
	Age< 19Yrs	2.268	.750	9.143	1	.002	9.660
	20Yrs≤Age≤49Yrs	-.418	.678	.380	1	.538	.658
	Age>50Yrs	-3.215	.784	16.794	1	.000	.040
	Constant	.590	.665	.788	1	.375	1.805

$$LOG\left(\frac{P_{MT}}{1-P_{MT}}\right) = 0.590 - 0.183SEX + 2.268 \leq 19 - 0.418(20-49YRS) - 3.215 \geq 50YRS$$

The result from the analysis shows that sex is not significant while age less than 19 years and 50 years and above were found to be significant with p-values 0.002 and 0.000 respectively.

Model Interpretation

For a unit increase in covariate sex there is an impact of – 0.183 decrease in the log odd ratio of the prevalence of malaria complicated by typhoid. For a unit increase in covariate Age ≤19 yrs there is an impact of 2.268 increase in the log odd ratio of malaria complicated by typhoid, for a unit increase in covariate Age (20-49years) there is an impact of -0.418 decrease in the log odd ratio of malaria complicated by typhoid, for a unit increase in Age ≥50yeaears there is an impact of -3.215 decrease in the log odd ratio of malaria complicated by typhoid.

Interpretation of the Odd Ratios

From the odd ratios, male patient have the odd of having malaria complicated by typhoid 0.833 times of the female patients.
Patients age group ≤19years have the odd of suffering from malaria complicated by typhoid 9.660 times in comparison to patient of other age groups.
Patients of (20-49years) age group have the odd of suffering from malaria complicated by typhoid 0.658 times in comparison to patients of other age categories.
Again patients of ≥50years age group have the odd of suffering from malaria complicated by typhoid 0.040 times in comparison to patients of other age groups.

Table 3.2: Table of coefficients, test statistics and old ratios for patients with malaria complicated by Hypertension

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	**SEX**	.103	.348	.088	1	.766	1.109
	Age< 19Yrs	.137	.948	.021	1	.885	1.147
	20Yrs≤Age≤49Yrs	1.386	1.002	1.915	1	.166	4.000
	Age>50Yrs	3.383	1.022	10.951	1	.001	29.472
	Constant	-3.069	1.002	9.379	1	.002	.046

$$LOG\left(\frac{P_{MHY}}{1-P_{MHY}}\right) = -3.069 + 0.103SEX + 0.137(Age \leq 19yrs)$$
$$-1.386(20-49YRS) - 3.383AGE \geq 50\ YRS$$

The result from the analysis shows that age 50 years and above was found to be significant with p-value 0.001.

Model Interpretation

For a unit increase in covariate sex there is an impact of 0.103 increase in the log odd ratio. For a unit increase in covariate Age ≤19 yrs there is an impact of 0.137 increase in the log odd ratio of malaria complicated by hypertension, for a unit increase in covariate Age (20-49yrs) there is an impact of 1.383 increase in the log odd ratio of malaria complicated by hypertension, for a unit increase in Age ≥50yrs there is an impact of 3.383 increase in the log odd ratio of malaria complicated by hypertension.

Interpretation of the Odd Ratios

From the odd ratios, Male patient have the odd of having malaria complicated by hypertension 1.109 times to female patients, that is the Male and Female patients are approximately equally likely at odd.

Patients of ≤19yrs age group have the odd of suffering from malaria complicated by hypertension 1.147 times in comparison to patients from other age groups.

Patients of age group (20-49yrs) have the odd of suffering from malaria complicated by hypertension 4.00 times in comparison to patients in age group.

Again patients of ≥50yrs age group have the odd of suffering from malaria complicated by hypertension 29.472 times in comparison to patients in other age group.

Table 3.3: Table of coefficients, test statistics and odd ratios for patients with HIVcomplicated by malaria

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1^a	**SEX**	-.812	.447	3.292	1	.070	.444
	Age< 19Yrs	-1.427	1.414	1.019	1	.313	.240
	20Yrs≤Age≤49Yrs	2.198	1.406	2.443	1	.118	9.007
	Age>50Yrs	1.189	1.452	.670	1	.413	3.284
	Constant	-2.937	1.403	4.382	1	.036	.053

$$LOG\left(\frac{P_{MHIV}}{1-P_{MHIV}}\right) = -2.937 - 0.812SEX - 1.427(0-19YRS)$$
$$+2.198(20-49YRS) - 1.189(AGE \geq 50\ YRS)$$

The result from the analysis shows that all covariates were insignificant which suggests that patients of falling under these variables are equally likely to have the complication of Malaria with HIV.

Model Interpretation

Though not significant but may not be completely bad; for a unit increase in covariate sex there is an impact of -0.812 decrease in the log odd ratio. For a unit increase in covariate Age ≤19 years there is an impact of -1.427 decrease in the log odd ratio of malaria complicated by HIV, for a unit increase in covariate Age (20-49years) there is an impact of 2.198 increase in the log odd ratio of malaria complicated by HIV, for a unit increase in Age ≥50years there is an impact of 1.189 increase in the log odd ratio of malaria complicated by HIV.

Interpretation of the Odd Ratios

From the odd ratios, Male patient have the odd of having malaria complicated by HIV 0.444 times of the female patients that is the male patients are about 2 out of 5 time at odd in comparison with the female in having such complication. Patients of ≤19years age group have the odd of suffering from malaria complicated by HIV 0.240 times in comparison to patients from other age group. Patients of age group (20-49) years have the odd of suffering from malaria complicated by HIV 9.007 times in comparison to patients in other age group. Again, patients of ≥50years age group have the odd of suffering from malaria complicated by HIV 3.284 times in comparison to patients in other age group.

3.2 Findings

From the analysis carried out, it is observed that male patients were slightly more at odd of the prevalence of malaria with complications; Hypertension with odd ratio of 1.109 but less in odd when the prevalence of malaria is complicated with

Typhoid and HIV with odd ratios 0.833 and 0.444 respectively in comparison to their female counterparts. Results upon test suggest that the coefficients for covariate "sex" were not significant for the three (3) models.
Those of Age group $\leq$ 19years suffer the heat of malaria complicated by Typhoid with odd ratio 9.660 times to patients of other Age groups.
Those $\geq$ 50years are at odd of the prevalence of malaria 29.472 times to other age groups when malaria is complicated by Hypertension.
Patients of age group 20-49years are observe to be at odd of the prevalence of malaria complicated by HIV 9.007 times in comparison to other groups.

Conclusion

It was observed that male patients are more exposed to malaria complicated by hypertension, as their female counterparts are just a fragment higher with the prevalence of malaria complicated with typhoid, and about 2.5 times in the prevalence of malaria complicated with HIV than male patients. It was also observed that children and teenagers suffer malaria with typhoid more; Age group 20-49yrs suffer malaria complicated by HIV which happens to be an age group where individual (youths) have the urge to enjoy life more, with careless life style (sexually active) which are indicators to increase this complication with malaria. Those in Age group $\geq$50yrs were seen to suffer greatly from Malaria complicated with hypertension, which could be attributed to ageing factor.

References

[1] Alonso A., Lau J. and Jaber B. L. (2008). Biocompatible hemodialysis membranes for acute renal failure. The Cochrane Database of Systematic Reviews. CD005283.

[2] Biochem, M. Z. (2014). Understanding logistic regression analysis. J. Amer. Stat. **24** (1), 12-18.

[3] Black R. E., Cousens S. and Johnson H. L. (2010). Global, regional, and national causes of child mortality in 2008: a systematic analysis. Lancet. **375**, 1969-1987.

[4] Greenwood B. M., Fidock D. A., Kyle D. E., Kappe S. H., Alonso P. L. and Collins F. H. (2008)Malaria: progress, perils, and prospects for eradication. J. Clin Invest. **118** (12), 66-76.

[5] Hay S. I., Guerra C. A., Tatem A. J., Noor A. M. and Snow R. W. (2004). The global distribution and population at risk of malaria: past, present, and future. Lancet Infect. Dis. **4**, 32-36.

[6] Hosmer D. W. and Lemeshow S. (2010). Applied Logistic Regression, (2nd ed.). New York: John Wiley and Sons. **21**, 321-330.

[7] Jelf H. (2012). Introduction to Machine Learning - Logistics Regression in one Dimension. Biomtrica. 87-94.

[8] Lei P. W. and Koehly L. M. (2000). Linear Discriminant Analysis versus Logistic Regression: A comparison of Classification Errors. American Educational Research Association, New Orleans. **54**, 502-510.

[9] Longjian L. (2018). Basic concept of logistic regression in Heart Failure. Epidemiology and Research Methods, (2^{nd} Ed.). 7-19.

[10] Nagelkerke N. J. D. (1991). A Note on General Definition of the Coefficient of Determination. Biometrika. **78**, 691-692.

[11] Nevill C. G., Some E. S., Mung'ala V. O. (1996). Insecticide treated bed nets reduce mortality and severe morbidity from malaria among children on the Kenyan coast. Tropical Medicine and International Health. **1**, 139-146.

[12] Oommen T., Baise L. G., and Vogel R. M. (2011). Sampling Bias and Class Imbalance in Maximum-likelihood Logistic Regression. Mathematical Geoscience. **43**, 99-120.

[13] Phil R and Yaqionq W, (2013). Logistic regression for risk factor modelling in stuttering research Logistic Regression. Journal of Fluency Disorders. **38**, 88-101.

[14] Peng C. Y and So T. S. H. (2002). Modeling Strategies in Logistic Regression. Journal of Modern Applied Statistical Methods. **14**, 147-156.

[15] Peng C. Y., So T. S., Stage F. K. and John E. P. (2002). The Use and Interpretation of Logistic Regression in Higher Education. Research in Higher Education. **43**, 259-293.

[16] Roca-Feltrer A., Carneiro I. and Armstrong S. J. R. (2008). Estimates of the burden of malaria morbidity in Africa in children under the age of 5 years. Tropical Medicine and International Health. **13**, 771-783.

[17] Rowe A. K., Rowe S. Y., Snow R. W., Korenromp E. L., Schellenberg J. R. and Stein C. (2000). The burden of malaria mortality. Trans. R. Soc. Trop. Med. Hyg. **76**, 705-706.

[18] Snow R. W., Guerra C. A., Noor A. M., Myint H. Y. and Hay S. I. (2005). The global distribution of clinical episodes of Plasmodiumfalciparum malaria. Nature. **434**, 21-47.

[19] Thwing J, Eisele T. P. and Steketee R. W. (2011). Protective efficacy of malaria case management and intermittent preventive treatment for preventing malaria mortality in children: a systematic review for the Lives Saved Tool. BMC Public Health. **11** (Suppl 3), S14.

[20] World Health Organization (WHO) (2017). Disease Outbreak News. Fact Sheet. **156**.

[21] World Health Organization (WHO) (2015). Disease Outbreak News. Fact Sheet. **141**.

[22] World Health Organization (WHO) (2013). World Malaria Report 2013. World Health Organization, Geneva.