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Statistical Analysis of Trends of Malaria Diagnosis and Patient Demographics: A Multivariate Study of Clinic Data in Ghana

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Abstract Multivariate analysis was applied to hospital data in this study. The underlying assumptions of MANOVA were verified with the data and were satisfied. The results from the post hoc test showed a positive and significant mean difference between children below the age of five years and patients between the ages of 5 and 19 years (MD=3.333, P<0.05). This means children below the age of five are more vulnerable and prone to hospitalization resulting from malaria infection than patients between the ages of 5 and 19 years. Similarly, there was a positive and significant mean difference (MD=12.933, P<0.05) between children below the age five years and pregnant women. This finding means that once again, children below the age of five are more vulnerable and prone to hospitalization resulting from malaria infection than pregnant women. Also, there was a positive mean difference between patients who were at least 20 years old and pregnant women (MD=10.100, P<0.05) when compared on the basis of hospitalization resulting from malaria infection. This indicated that patients who are at least 20 years old are hospitalized (due to malaria infection) more than pregnant women. With reference to the category of patients who were treated and discharged as a result of malaria infection, there was a positive and significant mean difference between patients who were between the ages of 5 and 19 years and patients who were at least 20 years old (MD=5.833, P<0.05). There was also a positive and significant mean difference between patients who were between the ages of 5 and 19 years and pregnant women (MD=8.833, P<0.05) based on the category of patients who were treated and discharged in relation to malaria infection. The results also showed that in terms of hospitalizations which were not related to malaria infection, children below the age of five were again found to be more vulnerable when compared to pregnant women (MD=5.600, P<0.05) and patients who are at least 20 years old (MD=5.125, P<0.05). The study advocated for reforms that grant free treatment to children below the age of five years since they were found to be the most vulnerable in contracting malaria and non-malaria related diseases and the most vulnerable to hospitalization.

Keywords Hospitalization, Multivariate Analysis, Statistical Analysis, Clinic data, Malaria

1. Introduction

Malaria remains a devastating public health menace in terms of morbidity and mortality in third world countries. It also remains the main cause of hospitalization and records the highest level of cases in outpatient department [1]. Prevalence of malaria intensity has been in its ascendency often resulting in maternal and infant morbidity and mortality. Pregnant women in sub-Sahara Africa often are in the records of pregnancy-associated malaria, and have been found to have lower immune system compared to non-pregnant women. In spite of the intervention of malaria prevention and control measures such as vector control with insecticide-treated nets (ITNs), indoor residual praying (IRS), intermittent preventive treatment of malaria in pregnancy (IPTp) and effective treatment, Artemisinin based combination therapy (ACT); malaria still remains a serious problem in Africa. Free or subsidized distribution of these control measures have increased from 30% to 100% across Africa and the distribution of bed net is now linked to antenatal care [2].

Approximately 80% of world infection due to malaria is associated with Africa. Out of this percentage, 89% of deaths were found to have occurred in Africa in the year 2008. Malaria prevalence his linked to poverty, ignorance and underdevelopment. In endemic areas of malaria infection, the most group associated with morbidity and mortality is young children, followed by pregnant women. Children under five years are estimated to be the most vulnerable with

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respect to malaria infection [3].

Malaria prevalence has been significantly attributed to Africa and Asia. About 51 percent of all malaria cases worldwide have been attributed to Africa with 42 percent being attributed to Asia. Children below the age of five years have been the most vulnerable group in all malaria patient categories. The malaria mortality of children below the age of five years have been estimated to be more than ten times the rate in industrialized nations [4, 5, 6, 7].

Thirteen children below the age of five years have been estimated to die every minute worldwide. Malaria mortality among children below the age of five has been attributed to several risk factors including poverty [8, 9, 10]. The malaria disease accounts for over 61% of hospital admissions as well as 25% rate of mortality of under-five children in Ghana. The disease remains a major threat to the survival of young children in Ghana and the rest of the sub Saharan Africa [11]. To this end; it is prudent to study more into hospital data to be abreast with the current trends in hospital diagnosis with respect to malaria infection in comparison with the various categories of patients including children under five years.

2. Review of Related Literature

Multivariate analysis procedure has been applied in diverse fields. It was used to study the factors that are linked with the risk of cancer in systemic lupus erythematous (SLE), in relation to a population of 16,409 participants. Cancer diagnosis was confirmed by checking with registry. The findings demonstrated smaller levels of SIR for overall cancer risk within black and white SLE patients. Cancer risk was found to have increased in SLE patients in comparison to the entire population. This was more prevalent with patients of white race and younger patients as well as those with lower SLE span [12].

Another study applied multivariate analysis to a data on pregnant women who visit antenatal clinics or who are hospitalized for non-obstetric connected ailment. Multivariate analysis of antenatal cohorts who domiciled in the district of Bastar known for stable malaria transmission was found to have a strong association with peripheral parasitaemia. Other explanatory variables which were found to be moderately associated were moderate anaemia, fever lasting for one week and lack of formal education. Also similar analysis showed that delivery unit's participants have strong association with peripheral and/or placenta parasitaemia. Admissions which were linked with malaria were more dominating among pregnant women in Bastar, a district known for high level of malaria prevalence [13].

Again, yet another study investigated the prevalence of malaria infection and prevailing risk factors in Sudan. The study interviewed selected sample of 836 pregnant women and examined them for malaria parasite. The multivariate analysis of the data concluded among many others that mothers who were below the age of 20 years as well as those with first and second pregnancies were independent predictors of malaria infection. Also, low-income and illiteracy were also identified as independent predictors. The study also found evidence of good correlation among pregnant women and their socioeconomic status as well as young age [2].

Multivariate study was conducted on a group of international travelers who had visited countries within a period of two years. The study examined the health status of the travelers after they reported back to their own countries. The results revealed that the prevalence of travel related diseases was higher among certain subgroups of travelers [14].

Yet another study sought to examine the YF vaccination coverage among French travelers who were suspected to be infected by YF virus while in Senegal. The study also sought to determine the factors that had association with vaccination coverage. The study collected responses from respondents on their attitude to YF vaccination before their travels. Multivariate analysis was employed in the determination of factors associated with coverage of vaccination. The study found that over 60% of travelers to Senegal failed to be YF vaccinated before embarking on trip. It was established that YF coverage was influenced by how much they knew about YF and perception of risk about YF in addition to the type of counseling they received before their trip [15].

3. Method

The study used retrospective hospital data from erstwhile Mpohor district clinic which is the only main clinic that serves all the sub districts (apart from CHIPPS compounds) in that particular district of Ghana. Patients from communities such as Manso, Edum Banso, Mpohor, and Ayiem among others patronize this clinic which in real terms happens to be the biggest health Centre in the district. Multivariate analysis was applied to the data in order to study into the various categories of patients who visit the health Centre. The categories included children less than five years, pregnant women, and people in the age range of 5 to 10 years; and those who are 20 years and above. The study analyzed into the categories of diagnosis resulting in hospitalization due to malaria, hospitalization due to others reason other than malaria, treatment and discharge due to malaria and treatment and discharge due to other illness not having to do with malaria. Pearson's' correlations among dependent variables was tested for meaningful pattern within a moderate range, to ascertain the appropriateness of MANOVA procedure. The Box's M p -value was examined for equality among covariance matrices. A one-way MANOVA was carried out to test the hypothesis that there would be one or more mean differences between patient levels and the diagnosis levels. The homogeneity of variance assumption was tested after performing series of Levene's F tests. A series of one-way ANOVAs (Tukey was performed for each dependent variable to examine their significance and effect sizes. The post hoc test (Tukey's test) was

employed to check the mean difference between significant categories.

4. Analysis

Table 1 shows the mean and standard deviations of the various categories. It can be seen that the standard deviations of each group is in a range of not more than four times each other, a situation which suggests homogeneity of variance. In general, pregnant women had the lowest mean with children under five having the highest mean across the categories. The general trend is that children under five are more prone to hospitalization and other diseases followed by people aged between 5 and 19. The trend also shows people aged 20 and above are more vulnerable to hospitalization due to malaria and other causes than pregnant patients.

Table 1 shows the Pearson Correlations, Means, and Standard Deviations Associated with Hospital Data. The Pearson Correlations between the dependent and independent variables were within acceptable range for MANOVA procedure (Meyer, Gampst, & Guarino, 2006).

The assumption of MANOVA is that the covariance matrices amongst the four dependent variables are the same across all 4 groups. The results from Table 2 show that the significance of the test is greater than 0.05 ($p > 0.05$) which satisfies the assumptions of MANOVA. The Box's Test of Equality of covariance matrices holds and suggests failure to reject the null hypothesis (p>0.05) since F-value is not statistically significant. Least significant difference (LSD) was used in the analysis of equality of variance test since it has the tendency of reducing the probability of make a type 1 error in event of statistically significant F-value MANOVA or ANOVA.

Table 1. Descriptive Statistics

Cases	Malaria Cases	Mean	Std. Deviation
Diagnosed (Hospitalized due to Malaria)	Under five	80.3333	3.32666
	Aged 5 to 19	77.5000	3.56371
	Aged 20 and above	74.3750	2.66927
	Pregnant	67.4000	9.83870
	Total	75.1600	6.63124
Diagnosed (Discharged due to Malaria)	Under five	84.1667	2.78687
	Aged 5 to 19	82.8333	1.47196
	Aged 20 and above	77.0000	2.13809
	Pregnant	74.0000	2.44949
	Total	79.5200	4.58367
Diagnosed (Other disease Hospitalized)	Under five	69.0000	5.76194
	Aged 5 to 19	65.6667	3.26599
	Aged 20 and above	63.8750	2.79987
	Pregnant	63.4000	2.07364
	Total	65.4400	4.12391
Diagnosed (other disease, not Hospitalized)	Under five	63.3333	8.59457
	Aged 5 to 19	57.6667	4.67618
	Aged 20 and above	60.6250	5.18066
	Pregnant	57.4000	4.39318
	Total	59.9200	6.05475

Table 2. Pearson Correlations, Means, Standard Deviations Associated with Hospital Data

		1	2	3	4	Mean	SD
1. diagnosedHM	Pearson Correlation	1				75.1600	6.63124
2. diagnozedDM	Pearson Correlation	.784	1			79.5200	4.58367
3. diagnozedORNMH	Pearson Correlation	.326	.426	1		65.4400	4.12391
4. diagnozedORNMNH	Pearson Correlation	.397	.266	.657	1	59.9200	6.05475

Note: N=300; correlations greater than 0.10 are statistically significant (p<.01).

Table 3 shows four different approaches of calculation the F-value for MANOVA. All these methods produced a significant F-value ($p < 0.05$). However, Pillai's Trace is most preferred method since it is the least sensitive to the violations of assumptions of covariance matrices. This method is used here since there is a possibility of violating the assumptions of covariance of matrices (i.e the Box's test is affected by sample size and normality assumptions).

Pillai's Trace helps to keep the research protected from violating the assumption of equality of covariance matrices. The table shows the independent variable (treatment). The value of Pillai's Trace is 1.091 but the actual F-value is 2.856 and significant at $p < 0.004$. Partial Eta Squared is equal to .364 and so about 36% of the variability in treatment across all four dependent variables in a canonical MANOVA derived estimate is being accounted for by the four group levels. We reject the null hypothesis that the treatment level is the same based on a MANOVA derived combined dependent variable by combining the four dependent variables together in a canonical variate.

Table 4 shows series of one-way ANOVA tests. This is done as a follow up using the first approach to doing MANOVA once we rejected the null hypothesis based on combined dependent variables for the MANOVA test. Here the individual dependent variables are studied separately using ANOVA. We accept the homogeneity of variance assumption to proceed with Levene's Test across all four dependent variables. The homogeneity assumption has been satisfied for all four dependent variables since none of the p values is less than 0.05. ANOVA is robust to violations of homogeneity test anyway.

Table 3. Box's Test of Equality of Covariance Matrices[a]

Box's M	56.551
F	1.154
df1	30
df2	944.980
Sig.	.261

Table 4. Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter
Intercept	Pillai's Trace	1.000	9393.126[b]	4.000	18.000	.000	1.000	37572.505
	Wilks' Lambda	.000	9393.126[b]	4.000	18.000	.000	1.000	37572.505
	Hotelling's Trace	2087.361	9393.126[b]	4.000	18.000	.000	1.000	37572.505
	Roy's Largest Root	2087.361	9393.126[b]	4.000	18.000	.000	1.000	37572.505
Category	Pillai's Trace	1.091	2.856	12.000	60.000	.004	.364	34.267
	Wilks' Lambda	.126	4.734	12.000	47.915	.000	.498	47.576
	Hotelling's Trace	5.292	7.350	12.000	50.000	.000	.638	88.199
	Roy's Largest Root	4.989	24.945[c]	4.000	20.000	.000	.833	99.778

The null hypothesis for Levene's test is for the groups being compared to have similar population variances. The table shows the results for four ANOVAs which shows "diagnosedHM" with F value of 6.289 and p-value p<0.05 and partial Eta squared value of .473. The table also shows "diagnozedDM" with F value of 26.404 and p-value p<0.05 and partial Eta squared value of .790. So we reject the null hypothesis. Somewhere along the four groups, there is at least one significant difference between them. Except for "diagnozedORNMH" and "diagnozedORNMNH", all the other dependent variables were statistically significant at some point which is now unknown. Since there are significant ANOVAs, a post hoc test was carried out to look at the individual mean differences on all dependent variables that were statistically significant.

The results from the post hoc test showed a positive and significant mean difference(MD=3.333, P<0.05) between children who were below the age of five years (who were hospitalized) and patients within the age bracket of 5 and 19 years (who were hospitalized). This means children below the age of five are more vulnerable and prone to hospitalization resulting from malaria infection than patients between the ages of 5 and 19 years. Similarly, there was a positive and a significant mean difference (MD=12.933, P<0.05) between children below the age of five years (who were hospitalized due to malaria infection) and pregnant women (who were hospitalized due to malaria infection). Again, there was a positive and significant mean difference (MD=10.100, P<0.05) between patients who were within the age bracket of 5 and 19 years and pregnant women (who were hospitalized due to malaria infection).Also, there was a positive mean difference (MD=6.975, P<0.05) between patients who were at least 20 years old (hospitalized due to malaria infection) and pregnant women who were hospitalized as a result of malaria infection.

There was significant and positive mean difference between children below the age of five years who were diagnosed and discharged due to malaria infection (MD=7.167, P<0.05) and patients who were at least 20 years old. Again, there was a positive and a significant mean difference between patients between the ages of 5 and 19 years who were diagnosed, treated and discharged due to malaria infection (MD=8.833, P<0.05) and pregnant women (MD=8.833, P<0.05).

The results also showed that in terms of hospitalizations which were not related to malaria infection, children below the age of five were again found to be more vulnerable when compared to pregnant women (MD=5.600, P<0.05) and patients who are at least 20 years old (MD=5.125, P<0.05).

Table 5. Levene's Test of Equality of Error Variances[a]

		Levene Statistic	df1	df2	Sig.
diagnosedHM	Based on Mean	3.014	3	21	.053
	Based on Median	.593	3	21	.626
	Based on Median and with adjusted df	.593	3	5.761	.643
	Based on trimmed mean	2.243	3	21	.113
diagnozedDM	Based on Mean	2.012	3	21	.143
	Based on Median	2.027	3	21	.141
	Based on Median and with adjusted df	2.027	3	15.598	.152
	Based on trimmed mean	2.130	3	21	.127
diagnozedORNMH	Based on Mean	1.828	3	21	.173
	Based on Median	.996	3	21	.414
	Based on Median and with adjusted df	.996	3	11.128	.430
	Based on trimmed mean	1.627	3	21	.213
diagnozedORNMNH	Based on Mean	2.760	3	21	.068
	Based on Median	2.653	3	21	.075
	Based on Median and with adjusted df	2.653	3	20.540	.076
	Based on trimmed mean	2.759	3	21	.068

Table 6. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter
Category	diagnosedHM	499.452	3	166.484	6.289	.003	.473	18.867
	diagnozedDM	398.573	3	132.858	26.404	.000	.790	79.212
	diagnozedORNMH	116.752	3	38.917	2.805	.065	.286	8.414
	diagnozedORNMNH	136.098	3	45.366	1.281	.307	.155	3.843

Table 7. Pairwise Comparisons

Dependent Variable	(I) Malaria Cases	(J) Malaria Cases	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
diagnosedHM	Under five	Aged 5 to 19	2.833	2.971	.351	-3.344	9.011
		Aged 20 and above	5.958	2.779	.044	.180	11.737
		Pregnant	12.933	3.115	.000	6.454	19.412
	Aged 5 to 19	Under five	-2.833	2.971	.351	-9.011	3.344
		Aged 20 and above	3.125	2.779	.273	-2.654	8.904
		Pregnant	10.100	3.115	.004	3.621	16.579
	Aged 20 and above	Under five	-5.958	2.779	.044	-11.737	-.180
		Aged 5 to 19	-3.125	2.779	.273	-8.904	2.654
		Pregnant	6.975	2.933	.027	.875	13.075
	Pregnant	Under five	-12.933	3.115	.000	-19.412	-6.454
		Aged 5 to 19	-10.100	3.115	.004	-16.579	-3.621
		Aged 20 and above	-6.975	2.933	.027	-13.075	-.875
diagnozedDM	Under five	Aged 5 to 19	1.333	1.295	.315	-1.360	4.027
		Aged 20 and above	7.167	1.211	.000	4.647	9.686
		Pregnant	10.167	1.358	.000	7.342	12.991
	Aged 5 to 19	Under five	-1.333	1.295	.315	-4.027	1.360
		Aged 20 and above	5.833	1.211	.000	3.314	8.353
		Pregnant	8.833	1.358	.000	6.009	11.658

Dependent Variable	(I) Malaria Cases	(J) Malaria Cases	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
	Aged 20 and above	Under five	-7.167	1.211	.000	-9.686	-4.647
		Aged 5 to 19	-5.833	1.211	.000	-8.353	-3.314
		Pregnant	3.000	1.279	.029	.341	5.659
	Pregnant	Under five	-10.167	1.358	.000	-12.991	-7.342
		Aged 5 to 19	-8.833	1.358	.000	-11.658	-6.009
		Aged 20 and above	-3.000	1.279	.029	-5.659	-.341
diagnozedORNMH	Under five	Aged 5 to 19	3.333	2.151	.136	-1.139	7.806
		Aged 20 and above	5.125	2.012	.019	.941	9.309
		Pregnant	5.600	2.256	.022	.909	10.291
	Aged 5 to 19	Under five	-3.333	2.151	.136	-7.806	1.139
		Aged 20 and above	1.792	2.012	.383	-2.392	5.975
		Pregnant	2.267	2.256	.326	-2.424	6.958
	Aged 20 and above	Under five	-5.125	2.012	.019	-9.309	-.941
		Aged 5 to 19	-1.792	2.012	.383	-5.975	2.392
		Pregnant	.475	2.124	.825	-3.941	4.891
	Pregnant	Under five	-5.600	2.256	.022	-10.291	-.909
		Aged 5 to 19	-2.267	2.256	.326	-6.958	2.424
		Aged 20 and above	-.475	2.124	.825	-4.891	3.941

5. Conclusions

Multivariate analysis was applied to hospital data in this study. The underlying assumptions were verified with the data and were satisfied. The results from the post hoc test showed a positive and significant mean difference between children below the age of five years and patients between the ages of 5 and 19 years (MD=3.333, P<0.05). This means children below the age of five are more vulnerable and prone to hospitalization resulting from malaria infection than patients between the ages of 5 and 19 years. Similarly, there was a positive and significant mean difference (MD=12.933, P<0.05) between children below the age five years and pregnant women. This finding means that once again, children below the age of five are more vulnerable and prone to hospitalization resulting from malaria infection than pregnant women. Also, there was a positive mean difference between patients who were at least 20 years old and pregnant women (MD=10.100, P<0.05) when compared on the basis of hospitalization. This indicated that patients who are at least 20 years old are hospitalized more than pregnant women. With reference to the category of patients who were treated and discharged as a result of malaria infection, there was a positive and significant mean difference between patients who are between the ages of 5 and 19 years and patients who are at least 20 years old (MD=5.833, P<0.05). There was also a positive and significant mean difference between patients who are between the ages of 5 and 19 years and pregnant women (MD=8.833, P<0.05) based on the category of patients who were treated and discharged in relation to malaria infection. The results also showed that in terms of hospitalizations which were not related to malaria infection, children below the age of five were again found to be more vulnerable when compared to pregnant women (MD=5.600, P<0.05) and patients who are at least 20 years old (MD=5.125, P<0.05). The study advocated for reforms that grant free treatment to children below the age of five years since they were found to be the most vulnerable in contracting malaria and non-malaria related diseases and the most vulnerable to hospitalization.

6. Recommendations

The study advocated for reforms to grant free treatment to children below the age of five years since they were found to be the most vulnerable in contracting malaria and non-malaria related diseases; the most vulnerable to hospitalization.

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