Research Journal of Mathematics and Statistics 7(2): 20-26, 2015
ISSN: 2042-2024, e-ISSN: 2040-7505

Submitted: October 29, 2014 Accepted: January 19, 2015 Published: May 25, 2015

# Models for Characterising Hypertensive and Non-Hypertensive Diabetic Patients: A Case Study of Komfoanokye Teaching Hospital-Kumasi, Ghana

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**Abstract:** This research study sought to model and predicts hypertensive status of diabetic patients. To this end, data on 260 diabetic patients at the Komfo Anokye Teaching Hospital's Diabetic Centre in Ghana were collected using data extraction form.The majority (144) of the 260 diabetic patients representing about 55% were also hypertensive as against 116 (45%) who were not hypertensive. Frequency analysis also revealed female dominance as far as the two diagnoses (Diabetes with hypertension and diabetes without hypertension) were concerned. However, the percentage of females in diabetes with hypertension (77%) was greater than the percentage of females in diabetes without hypertension (67%). The minimum age of hypertensive diabetic patients was 30 years as against 11 years for those diagnosed as non-hypertensive diabetic. A logistic regression model was developed for assessing the risk associated with diabetic patients with hypertension. The analysis revealed that people who were suffering from the two medical conditions (diabetes with hypertension and diabetes without hypertension) differ when it comes to age, Body Mass Index (BMI), drinking (alcohol consumption) and gender. The odds ratios associated with the significant predictor variables are 1.396, 1.110, 1.718 and 0.532, respectively. However, there was no statistical significant difference between hypertensive diabetic patients and the non-hypertensive diabetic patients in terms of Blood Glucose Level (BGL), exercise and smoking using 0.10 level of significance. Finally, it was concluded that ageing and extra weight gained, drinking (alcohol consumption) and gender (i.e., being a female) are risk factors for developing hypertension in addition to diabetes. The model was good for prediction and has overall correct classification of 66.5%.

**Keywords:** Diabetes, Ghana, hypertension, model, logistic regression analysis

## INTRODUCTION

The study sought to model and predicts hypertensive diabetic and non-hypertensive diabetic patients. Diabetes is a medical condition whereby the body is unable to physiologically regulate Blood Glucose Level (BGL), resulting in too much glucose (a sugar) in the blood. Hypertension on the other hand means High Blood Pressure (HBP). It is a medical condition that occurs when the pressure inside arteries is too high.

While some clinical indicators such as blood Haemoglobin (Hb), BP and BGL of a healthy person may not be the same when the person is not healthy and may constitute the main determinants of presence or absence of a particular disease in the person, one cannot ignore the effects of some risk factors (e.g., age, sex, weight, height, etc.) which expose people to be less or more prone to the acquisition of some diseases, including diabetes and hypertension. Most recent studies have found obesity which is measured by Body Mass Index (BMI) as a risk factor for developing hypertension (No Author, 1994). People sometime by their lifestyles prepare fertile grounds for diseases to thrive. Some of these are excessive drinking of alcohol, smoking, eating habit, lack of regular exercise etc.

Researchers continue to find risk factors for the various cardiovascular diseases but a key question that still requires more answers is why some people develop only diabetes and others are living with both diabetes and hypertension. Hypertension is an extremely common comorbidity of diabetes, affecting between 20 and 60% of people with diabetes (Wingard and Barrett-Connor, 1995).

The objective of the study therefore was to explore the application of Logistic Regression to expose variables that can predict and classify a hypertensive diabetic patient and a non-hypertensive diabetic patient. The study was to model a hypertensive diabetic patient and a non-hypertensive diabetic patient.

In 2002, a report in American Family Physician, a peer-reviewed journal, stated that hypertension and diabetes mellitus are common diseases in the United States and that patients with diabetes have a much higher rate of hypertension than would be expected in the general population (Harris *et al*., 1994). Moreover,

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hypertension is twice as common in persons with diabetes as it is in others (Epstein and Sowers, 1994). Similar study titled 'The treatment of Hypertension in Adult Patients with Diabetes reviewed that hypertension is an extremely common comorbidity of diabetes, affecting 20-60% of people with diabetes. The prevalence of hypertension in the diabetic population is 1.5-3 times higher than that of non-diabetic age-matched groups (Wingard and Barrett-Connor, 1995).

National High Blood Pressure Education Program Working Group report on hypertension in diabetes published in 1994 stated that "Obesity may be a common link between the two disorders".

A study conducted to determine the prevalence of hypertension in newly diagnosed type 2 diabetic patients and its association with risk factors for cardiovascular and diabetic complications. A cross-sectional study was employed to select newly diagnosed type 2 diabetic patients ($n$ = 3648, mean age 52 years, 59% male) recruited for the UK Prospective Diabetes Study (UKPDS). Some of the measurements taken were blood pressure, body mass index and waist-hip ratio (Turner *et al*., 1993). In the end, the results were that hypertensive patients had a greater mean body mass index (30.1 versus 28.0 kg/m2, p<0.0001) than the normotensive patients. They also had higher fasting plasma triglyceride (1.94 versus 1.69 mmol/l, p<0.0001) and insulin (15.0 versus 12.8 mU/L, p<0.0001) levels but these associations disappeared or weakened when obesity was taken into account (Turner *et al*., 1993).The conclusion was that hypertension is common in newly diagnosed type 2 diabetes and is associated with obesity.

The most recent guidelines from the American Diabetes Association (ADA) and National Kidney Foundation (NKF) recommend that blood pressure be decreased to less than 130/80 mm Hg, with an optimal target of below 120/80 mm Hg, especially in patients with proteinuria or renal insufficiency (American Diabetes Association, 2002). The study pointed out that strategies to attain this goal include lifestyle modifications and pharmacologic therapy.

In the Dietary Approaches to Stop Hypertension trial, lifestyle modifications such as exercise and a diet low in salt and high in potassium have clearly been shown to decrease blood pressure (Moore *et al*., 2001).

## MATERIALS AND METHODS

**The research design:** The study was carried out at the Diabetic Centre of KomfoAnokye Teaching Hospital in Kumasi in Ashanti Region, Ghana. The hospital was established in 1955 and became a Teaching Hospital in 1975, for the training of medical students from Kwame Nkrumah University of Science and Technology (KNUST), School of Medical Sciences (SMS), Kumasi in Ashanti Region, Ghana.

The Diabetic Centre which is a specialist centre was however set up in 2000 to treat and manage diabetic patients. The centre is therefore a referral centre where diabetic patients are referred.

The target population was the population diagnosed with diabetes in Ghana. The study population was the population diagnosed with diabetes at Komfo Anokye Teaching Hospital-Kumasi. Cluster sampling was adopted to select the clients to be part of the study. The various clinic days in June, 2014 were considered as clusters because of the heterogeneous nature of the clients with respect to their hypertensive status, gender and background. Information from the clients' folders from the selected clusters was recorded. Because of inadequate information in the clients' folders for this purpose, the clients were contacted to respond to some additional questions.

The procedure was that, after interviewing the client, his or her folder would be traced and the rest of the information captured from the folder. A well-designed data extraction form was used to collect the needed information from the clients and their folders. As a result, the nature of the research design was conclusive. The extracted information was subjected to vigorous quantitative analysis. The research tested specific hypotheses and examined the strength of the model.

Descriptive research design was employed. A clear statement of the problem, a prior formulation of specific hypotheses and detailed information needs were stated. Also, the needed information was collected from the sample of the population elements only once and this made the study a cross-sectional. The study employed single cross-sectional design. This means that only one sample of respondents from the study population was involved in the study. In all, 260 diabetic patients were involved in the study.

The analyses of the data were divided into two: the first part was purely descriptive analysis using Statistical Product and Service Solution (SPSS: IBM version 20). The second part which was largely inferential analysis was focused onlogistic regression and analysis; parameter estimation and testing, derivation of odds ratios, predicted probabilities (on the link as well as on the odds ratios), testing of model adequacy and, classification analysis. The second part of the analysis was carried out using Statistical Analysis System (SAS).

**Measured variables:**

**Classification variables:** The information were obtained from the diabetic patients using the following measured variables. Classification variables such as gender of the patients: (Male or Female), the age of the patients (Below 25yrs, 25- 35, 36-59 and, 60 and above). With regards to the age, the actual ages of the patients were also recorded.

Marital status of the patients were also sought (Single, Married, Divorced Widowed and Other). The educational level of the patients (None, First cycle, Second cycle, Tertiary and Other). Again, the occupation of the patients was sought (Student, Civil Servant, and Retired, Farming, Trading, Industry, Unemployed and Other).

**Lifestyles and risk variables:** Quite a number of lifestyle and risk variables were measured. Majority of these variables were dichotomous ('Yes' or 'No' responses). These include the smoking status, alcoholism, salt usage and exercise with reference to their past. In addition to the above, the weights and heights of the patients were also measured. The weights and the heights were subsequently used to derive the patients' Body Mass Index (BMI).

**Patients' clinical indicators and family clinical history:** The following clinical indicators of the patients and their family clinical history were also recorded. Among them are the blood pressure (systolic and diastolic) and the blood glucose level. The hypertensive status of the diabetic patients (diabetes with hypertension or diabetes without hypertension) was also recorded.

The study also sought to know from those who reported diabetes with hypertension, which of the conditions (hypertension and diabetes) they developed first, the number of years the second condition was developed after the first condition.

**The model specification (binary logistic regression):** The binary logistic regression is a probability model similar to a linear regression model but is suited to models where the dependent variable is dichotomous. And, it is different from discriminate function analysis in that logistic regression is capable of taking on board categorical independent variables in addition to continuous independent variables (Liao, 1994). Binary logistic regression is therefore the appropriate tool to identify predictor variables to predict the presence or absence of a hypertension given that the person has diabetes. The relationship between the categorical response variable with the set of predictors is possible through the use of link function. The appropriate link function is the log of the odds $(\frac{p}{1-\mathrm{p}})$, where $p$ is the proportion of individuals who are both diabetic and hypertensive. This proportion $p$ is defined as:

$$p = \frac{e^{\beta x}}{1 + e^{\beta x}} \tag{1}$$

The non-linear link function called *log it* allows the mean to be linearly dependent on the set of independent variables as follow:

$$\mathrm{Log}\,(\frac{p}{1-\mathrm{p}}) = \beta X + \varepsilon \tag{2}$$

where,

$\mathrm{Log}(\frac{p}{1-\mathrm{p}})$ = The log of the odd ratio

$X$ = The so-called *model* or *design* matrix

This matrix is made of the full set of individual independent variables namely, age, gender, systolic BP, diastolic BP, BMI, smoking, alcohol consumption, exercise and BGL. The matrix, $\beta$, is the solution vector of predictors with appropriate dimension and $\varepsilon$ is the vector of residuals. The $\beta$ vector is estimated by maximum likelihood method. Individual elements of $\hat{\beta}$, of the vector of estimates are tested using the Wald statistics $(\hat{\beta}/SE_{\hat{\beta}})^2$.For the model goodness of fit, the likelihood ratio chi-squaretest gives the overall assessment of how well the selected model fits the data with respect to the selected set of variables (McCulloch and Searle, 2001).

## RESULTS

**Characteristics of the patients sampled:** The majority (144) of the 260 diabetic patients representing about 55% were also hypertensive as against 116 (45%) who were not hypertensive. Frequency analysis also revealed female dominance as far as the two diagnoses (Diabetes with hypertension and diabetes without hypertension) were concerned. However, the percentage of females in diabetes with hypertension (77%) was greater than the percentage of females in diabetes without hypertension (67%).

The minimum age of hypertensive diabetic patients was 30 years as against 11 years for those diagnosed as non-hypertensive diabetic. The mean age of the hypertensive diabetic patients was 55.5 years as against that of non-hypertensive diabetic patients, 46.5 years.

From Table 1, the mean BMI of the hypertensive diabetic clients (26.84) kg/m$^2$ is higher than that of the non-hypertensive diabetic clients (23.84) kg/m$^2$. Obviously, we were not expecting both the systolic BP and diastolic BP of the two different conditions to be the same. The mean BGL of the hypertensive diabetic clients (13.660) mmHg is not much different from that of the non-hypertensive diabetic clients (14.333) mmHg.

Smoking and drinking of alcohol have been identified as lifestyles that can increase ones chance to develop cardiovascular diseases such as diabetes and hypertension. The percentage of the hypertensive diabetic clients who said they were smokers was 13.9 as against 12.9 of the non-hypertensive diabetic clients.

On the issue of drinking alcohol, 56.3% hypertensive diabetic patients used to take alcoholic beverages as compared with 49.1% non-hypertensive diabetic patients.

Table 1: Comparative analysis of descriptive statistics of the diagnoses

| Variable | Diabetes with Mean/Proportion | Hypertension Standard error | Diabetes without Mean/Proportion | Hypertension Standard Error |
|---|---|---|---|---|
| Age (yrs) | 55.50 | 0.8590 | 46.50 | 1.4060 |
| Weight (kg) | 70.70 | 1.1944 | 63.60 | 1.2054 |
| Height (metres) | 1.630 | 0.0069 | 1.630 | 0.0073 |
| BMI | 26.84 | 0.4664 | 23.84 | 0.4350 |
| Systolic BP | 132.0 | 1.7430 | 132.0 | 1.4440 |
| Diastolic BP | 80.00 | 1.2920 | 80.00 | 1.0500 |
| BGL | 14.30 | 0.3814 | 14.30 | 0.5191 |
| Smoking | 0.139 | 0.0288 | 0.129 | 0.0311 |
| Drinking | 0.563 | 0.0413 | 0.491 | 0.0464 |
| Exercise | 0.472 | 0.0416 | 0.517 | 0.0464 |

Table 2: Test for global null hypothesis

| Test | Chi-Square | DF | P-value |
|---|---|---|---|
| Likelihood ratio | 64.0733 | 8 | <0.0001*** |
| Score | 50.1088 | 8 | <0.0001*** |
| Wald | 36.1863 | 8 | <0.0001*** |

Table 3: Analysis of Effects of the Individual variables in the model

| Effect | DF | Chi-square | P-value |
|---|---|---|---|
| Age | 1 | 12.03190 | 0.0005*** |
| AgeSq | 1 | 8.5386 | 0.0035*** |
| BMI | 1 | 10.6862 | 0.0011*** |
| BGL | 1 | 0.074900 | 0.7844 |
| Gender | 1 | 2.91390 | 0.0878* |
| Smoking | 1 | 0.01330 | 0.9083 |
| Alcohol | 1 | 3.11470 | 0.0776* |
| Exercise | 1 | 0.06840 | 0.7936 |

Out of 144 hypertensive diabetic clients interviewed, 48 of them representing about 47.2% claimed they used to exercise regularly while 60 out of 116, representing about 51.7% non-hypertensive diabetic patients also claimed they used to exercise regularly.

With regards to the level of salt usage, about 29.9% of the 144 hypertensive diabetic patients add extra salt when served with food compare to 26.7% of the 116 non-hypertensive diabetic patients who also indicated that they add extra salt to the food.

**Binary logistic regression model specification:** We modeled diagnosis (diabetes with hypertension and diabetes without hypertension), a dependent dichotomous variable, using a binary logistic model. The probability that "diabetes with hypertension" = 1 is being modeled. All the analyses assume the criteria of $\propto = 0.10$ level of significance.

Table 2 is the test for the global null hypothesis, a test for the model fit. The likelihood ratio chi-square of 64.0733 with a $p$-value of 0.0001 indicates that the model as a whole fits significantly better than an empty model. The Score and Wald tests are asymptotically equivalent tests of the same hypothesis tested by the likelihood ratio test. It is therefore not surprising that these tests also indicate that the model is statistically significant.

The analysis of effects table (Table 3) shows the hypothesis tests for each of the variables in the model separately. The chi-square test statistics and associated $p$-values shown in the table indicate that age, age square, BMI, gender and alcohol consumption significantly improve the model fit as their $p$-values are less than the selected level of significance ($\propto = 0.10$).

For age, age square, BMI and BGL, the analysis of maximum likelihood estimate's table (Table 4) duplicates the test of the coefficients shown in the Table 3. However, for class variables (e.g., gender),

Table 4 gives the multiple degree of freedom test for the overall effect of the variable. It shows the coefficients (labeled estimate), standard errors, the Wald chi-square statistic and associated $p$-values. The coefficients for age, age square, BMI, are statistically significant, as are the terms for gender=1 and alcohol consumption = 1.

The logistic regression coefficients give the change in the log odds of the outcome for a one unit increase in the predictor variable:

- For every unit change in age, the log odds of developing hypertension in addition to diabetes increases by 0.3337.
- For a unit increase in BMI, the log odds of developing hypertension in addition to diabetes increases by 0.1043.
- The coefficients for the categorical variable have a slightly different interpretation. The results show that a male diabetic patient has less log odds of 0.6320 of developing hypertension compare with a female diabetic patient. It means that males who are diabetic have less chance of developing hypertension compared with their females counterpart. This explains why the coefficient is negative from Table 4.
- Similarly, the results show that a diabetic patient who use to drink alcohol (alcohol = 1), versus a diabetic patient who was not into alcohol (alcohol = 2), increases the log odds of developing hypertension by 0.5412.

Table 5 gives the coefficients as odds ratios. Odds ratio which is the exponent of the coefficient, can be interpreted as the multiplicative change in the odds for a one unit change in the predictor variable. Table 5 shows that for a one unit increase in age, the odds of

Table 4: Analysis of maximum likelihood estimates

| Parameter | D.F | Estimate | Standard error | Wald Chi-square | P-value |
|---|---|---|---|---|---|
| Intercept | 1 | -12.7966 | 2.8016 | 20.8632 | 0.0001*** |
| Age | 1 | 0.33370 | 0.0962 | 12.0319 | 0.0005*** |
| AgeSq | 1 | -0.0026 | 0.0009 | 8.5386 | 0.0035*** |
| BMI | 1 | 0.10430 | 0.0319 | 0.6862 | 0.0011*** |
| BGL | 1 | 0.00830 | 0.0303 | 0.0749 | 0.7844 |
| Gender 1 | 1 | -0.6320 | 0.3702 | 2.9139 | 0.0878* |
| Gender 2 | 0 | 0 | - | - | - |
| Smoking 1 | 1 | -0.0495 | 0.4300 | 0.0133 | 0.9083 |
| Smoking 2 | 0 | 0 | - | - | - |
| Alcohol 1 | 1 | 0.5412 | 0.3067 | 3.1147 | 0.0776* |
| Alcohol 2 | 0 | 0 | - | - | - |
| Exercise 1 | 1 | 0.0781 | 0.2985 | 0.0684 | 0.7936 |
| Exercise 2 | 0 | 0 | - | - | - |

Table 5: Odds ratio estimates

| Effect | | Point estimate | 95% Wald confidence limits | |
|---|---|---|---|---|
| Age | | 1.396 | 1.156 | 1.686 |
| AgeSq | | 0.997 | 0.996 | 0.999 |
| BMI | | 1.110 | 1.043 | 1.181 |
| BGL | | 1.008 | 0.950 | 1.070 |
| Gender | 1 vs 2 | 0.532 | 0.257 | 1.098 |
| Smoking | 1 vs 2 | 0.952 | 0.410 | 2.211 |
| Alcohol | 1 vs 2 | 1.718 | 0.942 | 3.134 |
| Exercise | 1 vs 2 | 1.081 | 0.602 | 1.941 |

Table 6: The logistic regression classification table

| | | Predicted | | |
|---|---|---|---|---|
| | | Diagnosis | | |
| Observed | | Diabetes without hypertension | Diabetes with hypertension | Percentage correct |
| Diagnosis | Diabetes without hypertension | 64 | 52 | 55.2% |
| Overall | Diabetes with Hypertension | 35 | 109 | 75.7% |
| Percentage correct | | 64.6% | 67.7% | 66.5% |

hypertensive diabetic (versus non-hypertensive diabetic) increase by a factor of 1.396.

The classification table (Table 6) provides us with an indication of how well the model is able to predict the correct category (diabetes with hypertension or diabetes without hypertension). We can compare this with the percentage of correct classification (55.4%) obtained earlier, with none of the predictor variables entered into the model to see how much improvement there is when the predictor variables are included in the model.

From Table 6, the model correctly classified 66.5% of cases overall (sometimes referred to as the percentage accuracy in classification in Principal Component Analysis), an improvement over the 55.4% obtained earlier. From the table, we were able to correctly classified 75.7% of people diagnosed as hypertensive diabetic and 55.2% of those diagnosed as non-hypertensive diabetic. The two percentages can be further classified as sensitivity of the model (for that of diabetes with hypertension) and the specificity of the model (for that of diabetes without hypertension) since the former has the characteristic of interest. The positive predictive value is 67.7%, indicating that, of the people predicted to be diagnosed as hypertensive diabetic, our model accurately picked 67.7% of them. On the other hand, the negative predictive value is 64.6%, indicating that of the people predicted to be diagnosed as non-hypertensive, our model accurately picked 64.6% of them.

## DISCUSSION

The majority (144) of the 260 diabetic patients representing about 55% were also hypertensive as against 116 (45%) who were not hypertensive. Frequency analysis also revealed female dominance as far as the two diagnoses (Diabetes with hypertension and diabetes without hypertension) were concerned. However, the percentage of females in diabetes with hypertension (77%) was greater than the percentage of females in diabetes without hypertension (67%).

The dominance of hypertensive patients in the diabetic family is supported by the 2002 report in American Family Physician, a peer-reviewed journal, which stated that hypertension and diabetes mellitus are common diseases in the United States and that patients with diabetes have a much higher rate of hypertension than would be expected in the general population (Harris *et al*., 1994). Moreover, hypertension is twice as common in persons with diabetes as it is in others (Epstein and Sowers, 1992). Similar study titled 'The Treatment of Hypertension in Adult Patients with Diabetes reviewed that hypertension is an extremely common comorbidity of diabetes, affecting 20-60% of people with diabetes. The prevalence of hypertension in the diabetic population is 1.5-3 times higher than that of non-diabetic age-matched groups (Wingard and Barrett-Connor, 1994).

From Table 1, the mean BMI of the hypertensive diabetic clients (26.84) kg/m$^2$ is higher than that of the non-hypertensive diabetic clients (23.84) kg/m$^2$. Our logistic regression model clearly found BMI significant in predicting who is hypertensive diabetic and it completely agrees with the National High Blood Pressure Education Program Working Groupreport in 1994 which stated that "obesity may be a common link between the two disorders".

In fact, our finding was also in line with a study conducted to determine the prevalence of hypertension in newly diagnosed type 2 diabetic patients and its association with risk factors for cardiovascular and diabetic complications. A cross-sectional study was employed to select newly diagnosed type 2 diabetic patients ($n$ = 3648, mean age 52 years, 59% male) recruited for the UK Prospective Diabetes Study (UKPDS). Some of the measurements taken were blood pressure, body mass index and waist-hip ratio. In the end, the results were that hypertensive patients had a greater mean body mass index (30.1 versus 28.0 kg/m2, p<0.0001) than the normotensive patients. They also had higher fasting plasma triglyceride (1.94 versus 1.69 mmol/l, p<0.0001) and insulin (15.0 versus 12.8 mU/l, p<0.0001) levels but these associations disappeared or weakened when obesity was taken into account (Turner *et al*., 1993).The conclusion was that hypertension is common in newly diagnosed type 2 diabetes and is associated with obesity.

The most recent guidelines from the American Diabetes Association (ADA) and National Kidney Foundation (NKF) recommend that blood pressure be decreased to less than 130/80 mm Hg, with an optimal target of below 120/80 mm Hg, especially in patients with proteinuria or renal insufficiency (American Diabetes Association, 2002). The study pointed out that strategies to attain this goal include lifestyle modifications and pharmacologic therapy. Indeed, our study found lifestyle characteristic such as alcohol consumption as a significant variable to predict who is a hypertensive diabetic patient.

Unfortunately, we could not establish in our study that exercise as a lifestyle characteristic can predict hypertensive status of a diabetic patient. In the Dietary Approaches to Stop Hypertension trial, lifestyle modifications such as exercise and a diet low in salt and high in potassium have clearly been shown to decrease blood pressure (Moore *et al*., 2001).

The minimum age of hypertensive diabetic patients was 30 years as against 11 years for those diagnosed as non-hypertensive diabetic. The mean age of the hypertensive diabetic patients was 55.5 years as against that of non-hypertensive diabetic patients, 46.5 years. The logistic regression model found age a significant predictor of a diabetic hypertensive patient.

## CONCLUSION

The binary logistic regression analysis suggested that people who are suffering from the two medical conditions differ when it comes to age, BMI, drinking (alcohol consumption) and gender. However, there was no statistical significant difference between hypertensive diabetic patients and the non-hypertensive in terms of BGL, exercise and smoking using 0.10 level of significance.

Finally, we conclude that ageing and extra weight gained,drinking (alcohol consumption) and gendercould be risk factors for developing hypertension in addition to diabetes.The model was good for prediction and has overall correct classification of 66.5%.

## ACKNOWLEDGMENT

We would like to acknowledge Prof. Kaku Sagary Nokoe, Biometrician, and University for Development Studies and Prof. B. K. Gordor of Mathematics and Statistics Department, University of Cape Coast for their rich directives and supervision which contributed immensely to the success of this project.

We are also grateful to Dr. F. Micah and Dr. AgyenimBoateng all of KomfoAnokye Teaching Hospital Diabetic Centre and Mr. N. O. Frimpong (Head of Biostatistics Unit, KomfoAnokye Teaching Hospital) for their support and guidance.

We thank the entire Biostatistics Unit staff-KomfoAnokye Teaching Hospital, especially, Kwaku Kwarteng, Yaw Owusu, Emmanuel Appiah-Kubi and Kwamina Johnson for their support and encouragement.

Finally, our sincere thanks goes to the staff of Research Unit, KomfoAnokye Teaching Hospital and the Committee on Human Research, Publications and Ethics, School of Medical Sciences, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana for granting us the ethical clearance for the study.

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