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HYPERTENSION TRENDS AT SILOBELA DISTRICT HOSPITAL (SDH): AN APPLICATION OF THE BOX-JENKINS MODEL

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ABSTRACT

This paper employs monthly time series data on newly diagnosed Hypertension cases in Silobela District Hospital from January 2014 to December 2018; to forecast Hypertension cases over the period January 2019 to December 2020. Unit root tests indicate that the hypertension cases series is basically an I (0) series. The study applies the SARIMA (0,0,1)(0,1,1)$_{12}$ model, which has been selected based on the AIC. The residual correlogram of the applied model further shows that the model is stable and suitable for predicting hypertension cases at SDH. This model shows that hypertension cases will basically decline over the period January 2019 to December 2020. The main policy prescription emanating from this piece of work is three-fold and is envisioned to enhance hypertension prevention and control not only at SDH but also in other district hospitals in Zimbabwe.

1. INTRODUCTION

Hypertension, also known as High Blood Pressure (HBP) is one of the cardiovascular diseases that are gradually usurping the minds of public health workers globally (Suleman & Sarpong, 2011). An individual is hypertensive is he or she experiences a repeated elevated blood pressure exceeding 140 over 90 mmHg (a systolic pressure above 140 with a diastolic pressure above 90) (Kearney *et al*, 2005). What happens is that when the heart beats it contracts to pump blood and the pumped blood circulates throughout the body in blood vessels or arteries. As blood circulates through the blood system, it exerts pressure on the walls of the vessels or arteries and it is this pressure, however, strong or weak, that is reffered to as blood pressure. Blood Pressure (BP) is not constant all the time. It varies based on activities being carried out by an individual at a particular point in time or based on certain health conditions. But when this pressure is most of the time high in an individual, then the fellow is said to be suffering from HBP, or more formally, hypertension (Baeta, 2015). Hypertension occurs as a result of long duration of abnormal pressure in the main arteries (Cunha & Marks, 2011).

BP readings are measured in millimeters of mercury (mmHg) using an instrument called a sphygmomanometer which is made up of an inflatable rubber cuff, an air pump and a column of mercury, which reflects the blood pressure of an individual. BP readings are given in two numbers which appear like a fractional expression, for instance, 130 over 70 and is professionally written as 130/70 mmHg. 130 represents the Systolic BP (SBP) while 70 indicates the Diastolic BP (DBP). SBP is the pressure in the blood vessels or arteries during a heart beat and DBP is the pressure exerted by blood when the heart relaxes (Zareian, 2004; Cunha & Marks, 2011).

The SBP is high if it is 140 mmHg or above, whilst readings below 120 mmHg are deemed normal pressure. On the other side of the same coin, DBP is high if it is 90 mmHg and above, whilst readings below 80 mmHg are deemed normal pressure. Therefore, a person is reffered to as hypertensive if his or her blood pressure is consistently above the normal threshold of 140/90 mmHg. Readings ranging between 120/80 and 139/89 are reffered to as pre-hypertension, which implies that the individual is likely to develop HBP. There are two basic categories of hypertension, that is; primary (or essential hypertension) and secondary hypertension. Primary hypertension occurs when there is no obvious medical cause for the elevation of blood pressure and contributes approximately 90% to 95% of all hypertension cases. Secondary hypertension occurs as a result of a consequence of another disorder such as renal failure or reno-vascular disease or a side effect of medication and is evident in approximately 5% to 10% of hypertension cases (Cunha & Marks, 2011).

Knowing and forecasting the pattern of hypertension could help public health workers and government to organize educative programs for citizens on causes of hypertension and its associated problems (Suleman & Sarpong, 2011). In fact, to make use of limited resources, planning of healthcare interventions is important (Nguyen *et al*, 2014). In this regard, predictive modelling of hypertension can render valuable information for planning health interventions. This study, whose objectives are outlined below, is envisaged to enhance the management of hypertension at Silobela District Hospital (SDH) as well as in other similar district hospitals dotted around the country.

Objectives of the Study

i. To determine the months during which newly diagnosed hypertension cases mostly occur at SDH.
ii. To predict hypertension cases for the out-of sample period.
iii. To investigate the influence of past hypertension cases at SDH to the present time.

Relevance and Timeliness of the Study

Hypertension is the most common cause of morbidity and maternal mortality all over the world (Murray & Lopez, 1997; Tanuseputro *et al*, 2003; Wolf-Maier *et al*, 2003; Kearney *et al*, 2005; Lopez *et al*, 2006; Chataut *et al*, 2011; Middendorp *et al*, 2013; Tshimanga *et al*, 2014; Forouzanfar *et al*, 2017; Atibila *et al*, 2018; Monakali *et al*, 2018; Agyei-Baffour *et al*, 2018; Leung *et al*, 2019; Princewel *et al*, 2019), especially in developing countries (Lopez, 1993; He *et al*, 1995; He *et al*, 1999; Mancia *et al*, 2013; Dorobantu *et al*, 2014; Weber *et al*, 2014; Dorobantu *et al*, 2015; Dorobantu *et al*, 2018) and is the single most important risk factor for all other cardiovascular diseases (Bonow *et al*, 2002; Canto & Iskandrian, 2003; Graham *et al*, 2007), particularly coronary heart disease, cerebrovascular disease, peripheral artery disease and heart failure (Nadar *et al*, 2006) and is apparently the leading driver of cardiovascular disease deaths in Africa (Bosu *et al*, 2019).

In Zimbabwe, cardiovascular diseases, especially hypertension; account for approximately 9% of the total deaths (Ministry of Health and Child Care, 2016). More than a quarter of the world's population was hypertensive in the year 2000, a number totaling nearly one billion and the number is expected to increase to 1.56 billion people world wide by the year 2025 (Kearney *et al*, 2005). In Sub-Saharan Africa, the mortality among patients hospitalized for hypertension-related disorders is over 20% (M'Buyamba-Kabangu *et al*, 2009). In the case of Zimbabwe, where an epidemiological transition from communicable to non communicable diseases is taking place (Mungati *et al*, 2014; Chimberengwa & Naidoo, 2019), the burden of hypertension is sky-rocketing (Ministry of Health and Child Welfare, 2009), especially among women in urban areas (Mufunda *et al*, 2000), arguably due to Western diets and life style (Gelfand, 1981; Mutowo *et al*, 2015) and apparently accounts for approximately 25% of all out-patient visits for chronic conditions in Zimbabwe (Ministry of Health and Child Welfare, 2005). In fact, the Zimbabwe prevalence rate for hypertension is estimated to be approximately 27% (Ministry of Health and Child Care, 2016) and this is unacceptably high and calls for urgent evidence-based policy action.

Furthermore, hypertension is now a significant problem in groups previously thought to be at low risk such as rural populations, poor households and young people (Addo *et al*, 2006; Ofuya, 2007; Okeahialam *et al*, 2012; Awuah *et al*, 2014) and is actually a common cause of medical admission in African hospitals (Etyang & Gerard, 2013). In Zimbabwean rural communities (Chimberengwa & Naidoo, 2019) such as Silobela, hypertension is now becoming a serious public health problem. This study is in line with the National Health Strategy for Zimbabwe (2016 – 2020) which, among other things, seeks to reduce the incidence of Non-Communicable Diseases (NCDs) such as hypertension.

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2. LITERATURE REVIEW

Table 1: Related Literature on Modeling and Predicting Hypertension Cases

Author/Year	Country	Period	Method	Key Findings
Hajjar *et al* (2006)	United States	1997 – 2002	Survey	Hypertension control is still suboptimal in the United States and other countries
Esteghamati *et al* (2008)	Iran	2004 – 2005	Logistic regression model	The prevalence of hypertension is high in Iran
Parikh *et al* (2008)	United States	1998 – 2001	Weibull regression analysis	The hypertension risk prediction score can be used to estimate an individual's absolute risk for hypertension
Suleman & Sarpong (2011)	Ghana	2000 – 2010	ARIMA	The ARMA (1,1) and ARMA (3,2) models were the best models for predicting hypertension. There is a decreasing pattern in admission and outpatient cases in Navrongo
Owusu-Sekyere *et al* (2013)	Ghana	2012	Spatial model	Hypertension is emerging and increasing in Ghana
Baeta (2015)	Ghana	January 2010 – December 2014	VAR	Hypertension and heart disease will increase in Ghana for the year 2015
Teramukai *et al* (2016)	Japan	July 2005 – March 2007	Cox Proportional Hazard (CPH) model	The CPH model is a suitable hypertension prediction model
Kanegae *et al* (2018)	Japan	2010 – 2015	CPH model	When using new parameters of eating rate, uric acid, proteinuria and BMI by age, the CPH model performs better
Hamoen *et al* (2018)	Netherlands	April 2002 – January 2006	Logistic regression model	The logistic regression prediction model is good at monitoring

				the risk of developing HBP in children
Gheorghe-Fronea *et al* (2018)	Romania	2005 – 2016	SES; BLS	Prevalence of hypertension has increased in the last 11 years and will continue on an upward trend if no preventive strategies at population level will be implemented in the near future
Ye *et al* (2018)	China	January 2013 – December 2015	Machine Learning (XGBoost)	Machine Learning is a potential source of accurate 1 year risk prediction models for incident essential hypertension

From table 1 above, it is clear that there is no similar study that has been done for Zimbabwe and this endeavor is definitely the first of its kind. This study follows the intuition of previous studies such as Suleman & Sarpong (2011) who used Box-Jenkins ARIMA models to analyze hypertension cases in Ghana. Our approach, however, is slightly different form Suleman & Sarpong (2011) in the sense that we are going to apply the seasonal ARIMA instead of the generalized ARIMA model used by Suleman & Sarpong (2011).

3. METHODOLOGY

The Box – Jenkins models belong to Box & Jenkins (1970) and in this piece of work; it will be employed for analyzing newly diagnosed monthly hypertension cases for SDH. A generalized Box-Jenkins SARIMA model is as displayed in equation [1] below:

$$\phi_p(B)\emptyset_p(B^s)H_t = \theta_q(B)\Theta_q(B^s)\varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots. [1]$$

Where B is the backshift operator, $\phi_p, \emptyset_p, \theta_q\ and\ \Theta_q$ are polynomials of order p, P, q and Q respectively. ε_t is a white noise process and $H_t = \nabla_d \Delta_s^D Y_t$ is the differenced M series.

Data Issues

This study is based on newly diagnosed monthly hypertension cases [H] (adults (25 years old and above) and children (0-24 years old)- i.e., all age groups) at SDH, from January 2014 to December 2018. The out-of-sample forecast covers the period January 2019 to December 2020. All the data employed in this paper was obtained from the Outpatient Tally Sheets (T5) at SDH. The T5 form is the primary data source and the same information is recorded in the DHIS2 information system.

Diagnostic Tests and Model Evaluation
Stationarity Tests: Graphical Analysis

Figure 1: Graphical Analysis

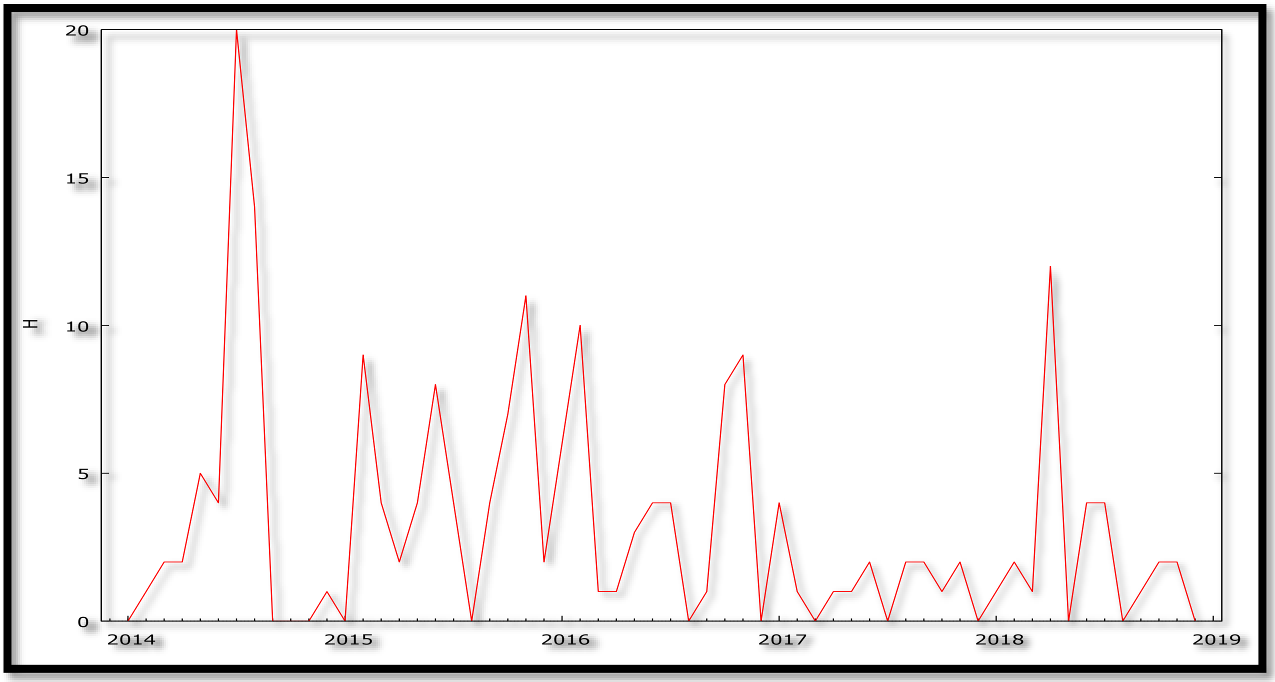


Figure 1 above basically shows that the H series does not follow any particular trend and for that reason, it is likely to be stationary in levels. The study will employ a formal stationarity test, that is, the famous Augmented Dickey-Fuller (ADF) test. We can also see that over the period under study, the peak of newly diagnosed hypertension cases was experienced in July 2014. Figure 1 suggests that for every month at SDH, there are at least two months where no patient is diagnosed with hypertension; for example, in 2014, there were no cases of hypertension in January, September, October and November; in 2015, there were no cases of hypertension in January and August; in 2016, there were zero cases of hypertension in August and December; in 2017, there were also zero cases of hypertension in March and July and finally in 2018, there were no cases of hypertension in May, August and December. It is therefore, not surprising to deduce that zero cases of hypertension cases at SDH have largely been associated with the months of August and December.

Unit Root Tests

Table 2: Unit root tests

	Augmented-Dickey-Fuller test		
	Test Statistic		
Variable	Constant	Constant + Trend	None
H	-5.840332***	-6.172576***	-1.962436**
*NB: ***, ** and * imply rejection of null hypothesis at 1%, 5% and 10% levels of significance, respectively.*			

The null hypothesis of non-stationarity is rejected under all the three circumstances and we conclude that H is an I (0) variable.

Model Evaluation (without a constant)

Table 3: Model Evaluation

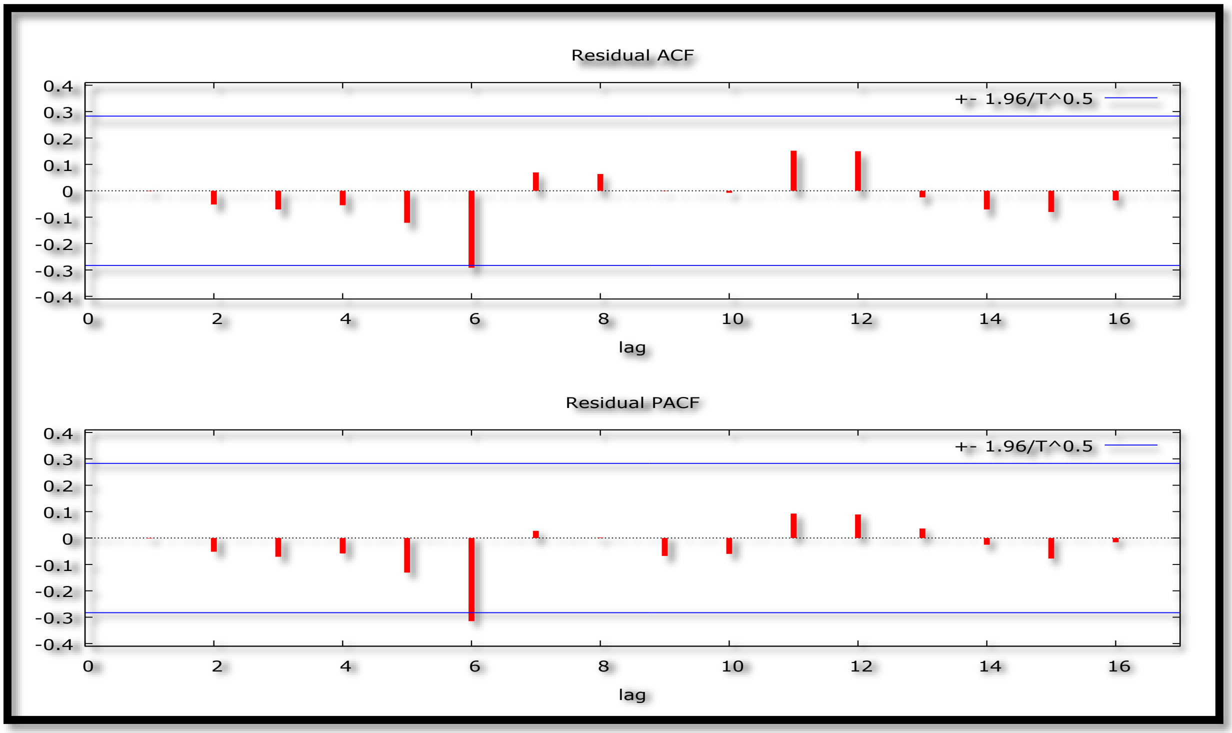
Model	AIC	ME	RMSE	MAE
SARIMA $(0,0,1)(0,1,1)_{12}$	**288.8576**	-0.55018	4.7232	3.2701
SARIMA $(1,0,1)(0,1,1)_{12}$	290.8566	-0.54796	4.7235	3.2705
SARIMA $(1,0,0)(0,1,1)_{12}$	289.6194	-0.5135	4.7749	3.3265
SARIMA $(0,0,2)(0,1,1)_{12}$	290.8561	-0.54715	4.7236	3.2707
SARIMA $(2,0,0)(0,1,1)_{12}$	290.6487	-0.58853	4.7052	3.2866
SARIMA $(2,0,2)(0,1,1)_{12}$	294.0001	-0.73549	4.6519	3.2752
SARIMA $(2,0,1)(0,1,1)_{12}$	292.0012	-0.73775	4.6516	3.2748
SARIMA $(1,0,2)(0,1,1)_{12}$	292.4785	-0.6828	4.6844	3.2492
SARIMA $(0,0,1)(1,1,1)_{12}$	290.9819	-0.52591	4.66	3.1133
SARIMA $(1,0,1)(1,1,1)_{12}$	292.1528	-0.5419	4.6602	3.1142
SARIMA $(0,0,2)(1,1,1)_{12}$	292.1525	-0.52368	4.6603	3.1144
SARIMA $(2,0,1)(1,1,1)_{12}$	293.2308	-0.71947	4.5962	3.1134
SARIMA $(1,0,2)(1,1,1)_{12}$	293.7545	-0.6673	4.6267	3.1064
SARIMA $(0,0,0)(0,1,2)_{12}$	289.7481	-0.50328	4.6296	3.012
SARIMA $(0,0,1)(1,1,2)_{12}$	291.6215	-0.51232	4.6335	3.0284
SARIMA $(1,0,0)(0,1,2)_{12}$	290.2757	-0.47786	4.6649	3.0228

From table xx above, the SARIMA (0,0,1)(0,1,1,) model is chosen as the optimal model since it has the lowest AIC value. Below, in figure xx, this model is analyzed, in order to check its stability.

Analysis of the Residuals of the SARIMA $(0, 0, 1)(0, 1, 1)_{12}$ Model

Residual Correlogram of the SARIMA $(0, 0, 1)(0, 1, 1)_{12}$ Model

Figure 2: Residual Correlogram

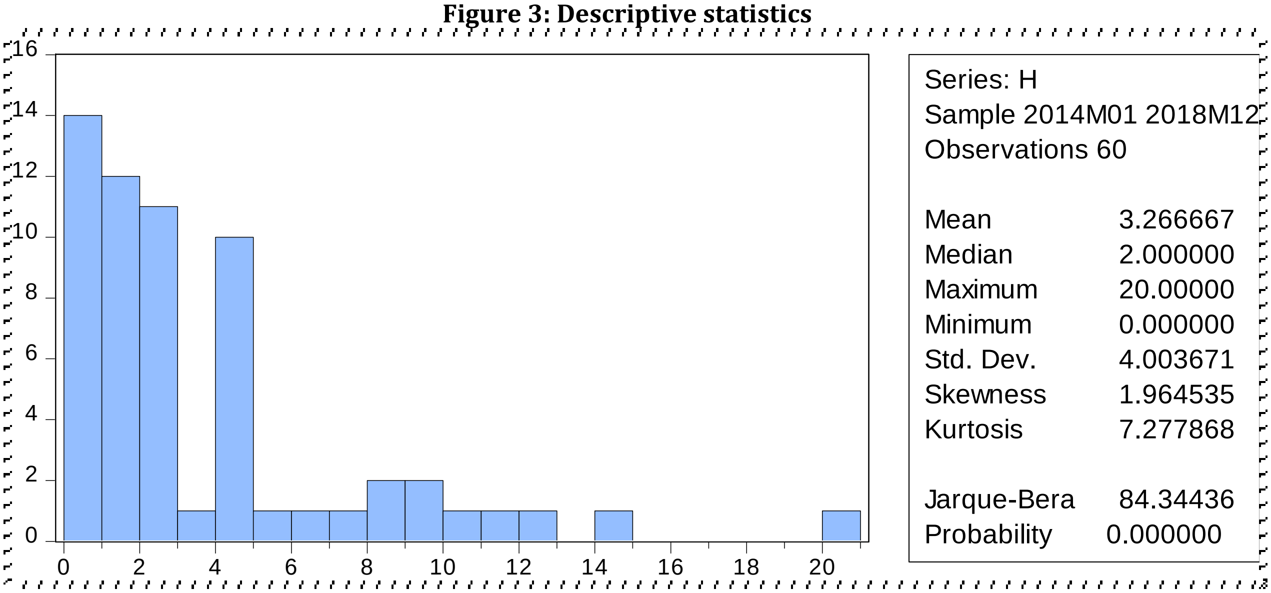


As we can see in figure xx above the autocorrelation coefficients at various lags are generally low, except for the sixth lags. Therefore, it is still logical for us to conclude that the selected model is stable and acceptable for forecasting hypertension cases at SDH.

4. FINDINGS OF THE STUDY

Descriptive Statistics

Figure 3: Descriptive statistics



As shown in figure xx above, the maximum number of newly diagnosed hypertension cases for SDH is 20 and this has been realized in July 2014. The minimum number of newly diagnosed hypertension cases for the period under study is as low as 0 for SDH. Over the period under study, we can see that on average, 3 people per month have been diagnosed with hypertension. Also important to note is that the data under consideration is not normally distributed but rather positively skewed as shown by the skewness statistic of approximately 1.96.

Results Presentation

Table 4: Main Results of the SARIMA (0, 0, 1)(0, 1, 1)$_{12}$ Model

The SARIMA (0, 1, 1)(0, 1, 1)$_{12}$ model can be presented as follows:

$$(1 - B^{12})H_t = (1 + 0.347556B)(1 - 0.452216B^{12})\varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Variable	Coefficient	Standard Error	z	p-value
θ_q	0.347556	0.128825	2.698	0.007***
Θ_q	-0.452216	0.194071	-2.33	0.0198**

*NB: ***, ** and * means significant at 1%, 5% and 10% level of significance, respectively.*

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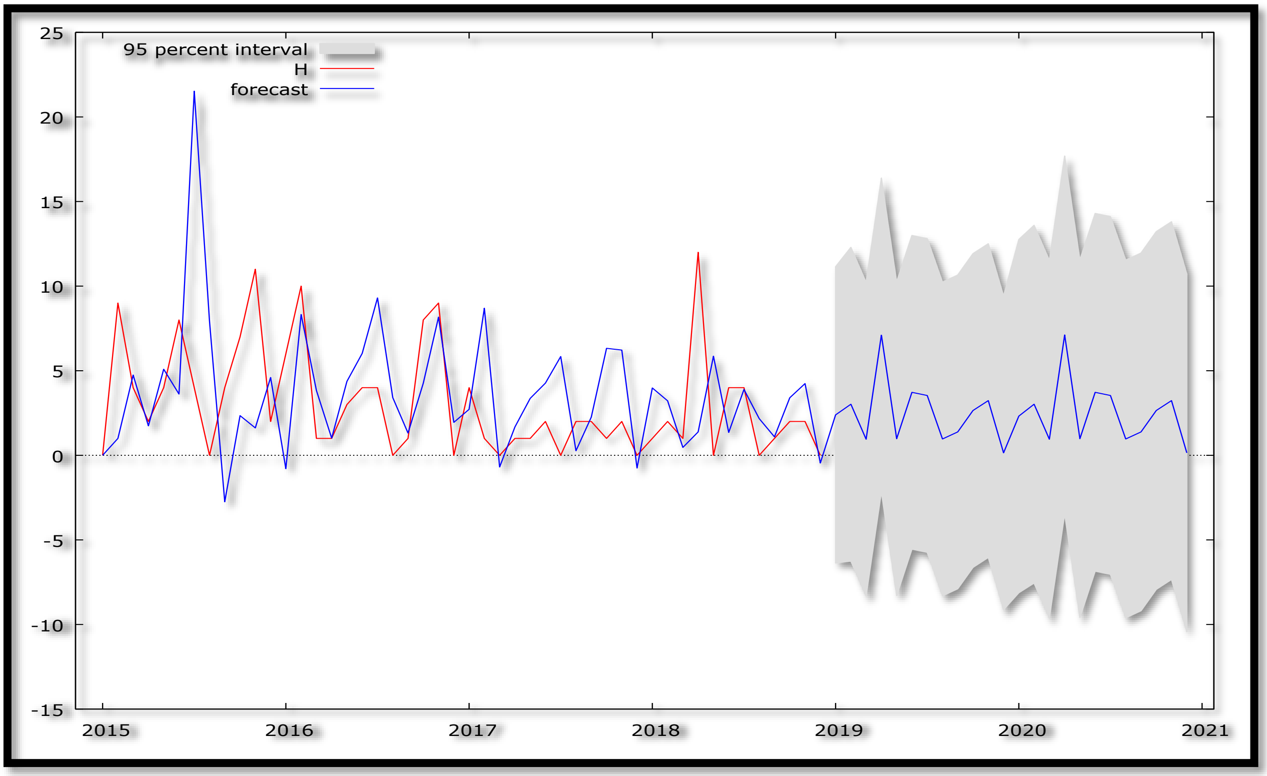
Forecast Graph

Figure 4: Forecast Graph



Out of Sample Forecasts

Table 5: Out-of-sample forecasts

Year: Month	Predicted H	Standard Error	95% Confidence Interval
2019:01	2.38825	4.47096	(-6.37467, 11.1512)
2019:02	3.02063	4.73329	(-6.25646, 12.2977)
2019:03	0.950548	4.73329	(-8.32654, 10.2276)
2019:04	7.11439	4.73329	(-2.16270, 16.3915)
2019:05	0.980518	4.73329	(-8.29657, 10.2576)
2019:06	3.72354	4.73329	(-5.55355, 13.0006)
2019:07	3.53678	4.73329	(-5.74031, 12.8139)
2019:08	0.964786	4.73329	(-8.31230, 10.2419)
2019:09	1.38210	4.73329	(-7.89498, 10.6592)
2019:10	2.64748	4.73329	(-6.62961, 11.9246)
2019:11	3.23268	4.73329	(-6.04440, 12.5098)
2019:12	0.145651	4.73329	(-9.13144, 9.42274)
2020:01	2.31655	5.32938	(-8.12884, 12.7619)
2020:02	3.02063	5.39693	(-7.55715, 13.5984)
2020:03	0.950548	5.39693	(-9.62723, 11.5283)
2020:04	7.11439	5.39693	(-3.46339, 17.6922)
2020:05	0.980518	5.39693	(-9.59726, 11.5583)
2020:06	3.72354	5.39693	(-6.85424, 14.3013)

2020:07	3.53678	5.39693	(-7.04100, 14.1146)
2020:08	0.964786	5.39693	(-9.61299, 11.5426)
2020:09	1.38210	5.39693	(-9.19568, 11.9599)
2020:10	2.64748	5.39693	(-7.93031, 13.2253)
2020:11	3.23268	5.39693	(-7.34510, 13.8105)
2020:12	0.145651	5.39693	(-10.4321, 10.7234)

Graphical Presentation of the Predicted Monthly SDH New Hypertension Cases

Figure 5: Graphical presentation of out-of-sample forecasts

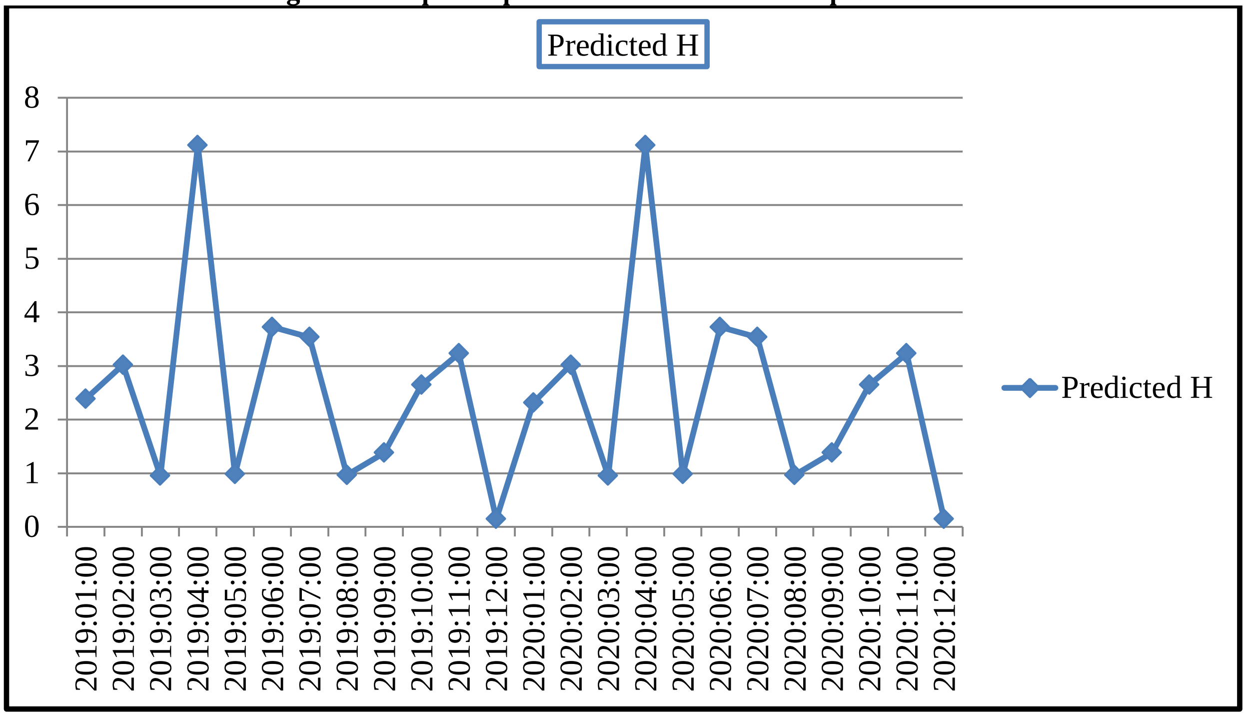


Table 4 shows the main results of the selected model for forecasting hypertension cases at SDH. Figure 4 and 5 as well as table 5 show the forecasted hypertension cases over the period January 2019 to December 2020. Equation [2] is the mathematical representation of the chosen predictive model. The results of this study basically show that hypertension cases are likely to decline over the out-of-sample period. This could be attributed to effective management of hypertension at SDH over the period under study and this should continue with the support of the government. Our study also confirms the argument made by Addo *et al* (2006); Ofuya (2007); Okeahialam *et al* (2012); and Awuah *et al* (2014) that hypertension is now becoming a threat to public health in rural communities. These results are also in line with Chimberengwa & Naidoo (2019) who argued that hypertension is also now evident in rural communities in Zimbabwe and Silobela is not an exception.

5. CONCLUSION & RECOMMENDATIONS

Hypertension used to be a disease that would only bother the urban dwellers; the rural folk, traditionally, had no problems with hypertension. In fact, in the case of Zimbabwe, the rural dwellers were at an advantage, precisely; due to their healthy diet and lifestyle as compared to the urban folk who have grabbed the Western diet and lifestyle. Today, hypertension is a serious problem in both rural and urban areas in Zimbabwe. This study is the first of its kind in Zimbabwe and uses the Box-Jenkins type models to investigate the patterns of hypertension at a rural community in Zimbabwe, that is, Silobela.

Policy makers should not wait until hypertension cases reach alarming levels for them to react. The study is the starting point to the analysis of cardiovascular diseases using time series models in Zimbabwe and boasts of three policy recommendations which are expected to enhance hypertension management at SDH

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as well as in other similar rural district hospitals in Zimbabwe:

i. The SDH management team should engage in public awareness programs in Silobela so that the community becomes knowledgeable on this detrimental disease. In this regard, members of the Silobela community need to be educated on the need for a healthy diet (e.g., reducing salt and fat intake, reducing or stopping alcohol intake, avoiding smoking) and lifestyle (e.g., regular exercise) and the need to adhere to antihypertensive medication. Adherence to treatment is important when taking antihypertensive drugs to prevent cardiovascular complications such as congestive cardiac failure, stroke and chronic kidney disease.
ii. There is need to reduce bottlenecks, (especially geographic access and continuity in respect to scheduled reviews) in the management of hypertension at SDH.
iii. The government of Zimbabwe should avail resources to ensure optimal control and treatment of hypertension in Silobela. It is important to note that figure 1 and 5 show that hypertension in Silobela is still at a controllable level and this is the right time for action. Policy makers should not wait until hypertension has become severe in Silobela; the scarce resources at SDH's disposal can be meaningfully used to make the desired change in terms of reducing the incidence of hypertension in the rural community of Silobela.

Further research should look into constructing various ARIMA models for various age groups; this can potentially bring out more information on the way forward in terms of hypertension management in Silobela. This study is envisioned to steer up a scholarly debate in the control and management of cardiovascular diseases, particularly hypertension; in Zimbabwean rural areas.

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