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Full Length Research Article

MODELLING COINFECTION DYNAMICS OF HIV&AIDS, TUBERCULOSIS AND HEPATITIS C VIRUS

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ABSTRACT
HIV and coinfection (i.e. Tuberculosis and Hepatitis C) adversely affects the lives of individuals in both the biological and psychosocial aspects. This study focuses on modelling coinfection dynamics of HIV&AIDS and some selected opportunistic infections, there-by determining their long-run and causal relationship. The study focuses on six (6) states in the North West Geo-Political Region of Nigeria, these states under study includes; Kaduna, Sokoto, Katsina, Kano, Zamfara and Kebbi. The Johansen Multivariate Cointegration approach was applied to establish the long-run relationship among variables and Granger Causality test was also applied to determine whether variables move in either unidirectional or bidirectional. The results for the cointegration test showed that there is a long-run relationship between HIV/AIDS, Tuberculosis and Hepatitis C in Kaduna, Katsina and Kebbi States. While, Granger causality test indicates that, no bidirectional Granger causality is found in the sample period, only unidirectional causality. The test showed that in the short-run HIV/AIDS Granger causes Tuberculosis in Kaduna, Katsina, Zamfara and Kebbi, while, HIV/AIDS Granger causes Hepatitis C in only Kaduna and Sokoto.

Keywords: Human Immunodeficiency Virus, Tuberculosis, Hepatitis, Coinfection, Cointegration, Granger Causality

1. INTRODUCTION

In recent times, the level of interdependency among two or more variables have been studied by various researchers and professionals. Hence, this interdependency is termed cointegration. Determining the long-run relationship better known as cointegration between two or more diseases for instance, HIV/AIDS and coinfections, is currently a vast topic to explore (Engle and Granger, 1987). Infections such as tuberculosis and hepatitis C are no more independent as thought over the years. About 53,000 HIV related deaths in 2018; with 1.5% prevalence rate among people within the age 15 to 59years (Avert, 2019). By implication, if proper steps are not taken to ensure that the 90:90:90 strategy set-up by USAID (i.e. end AIDS epidemic by 2030) then, the working force which account for the large number of persons with the HIV virus will drastically reduce which in turn will affect the economy negatively. Presently, the HIV prevalence rate stand at 1.4% in Nigeria (USAID, 2019 and NAIIS, 2018). The North West Zone accounts for 0.6% HIV prevalent rate, which Kaduna State has the highest rate of 1.1% in the region, Kano and Kebbi States both have 0.6%, the third highest is Zamfara State with 0.5% followed by Sokoto State with 0.4%, While, Katsina and Jigawa States both have a prevalent rate of 0.3% which is the least in the zone (NAIIS, 2018).

Tuberculosis is an air-borne bacterial disease caused by tubercle bacilli termed as *Mycobacterium tuberculosis.* This disease is absolutely transferred from someone that is infected to an uninfected person through the spread of infectious droplets. A person with TB stays infected for a long period of time and maybe he/she might stay latent infected throughout their life when the person is not well treated. It is important to note that, TB is the major principal causes of death amongst people living with HIV/AIDS worldwide and Nigeria is currently among the top ten TB nation (USAID, 2019). Both HIV and HCV are viral infections which is blood borne and are often transmitted together, particularly amongst people who inject drugs (PWID) (Alter, 2006; Vickerman *et al.,* 2013). It is important to note that both infections can interrelate that is, HIV causes deterioration of the body immune system which in-turn can lead to clearance rates of HCV and other opportunistic infection as well as reducing chances for treatment success (Kim and Chung, 2009).

HCV co-infection prevalence rate was 31.6 percent and the number of co-infection patients are significantly more probable to be older, black, and injection drug users (IDU). In multivariate analysis, the period of survival from the time of diagnosis of AIDS was significantly reduced for HIV and HCV coinfected patients with a hazard ratio of 1.84. That is, HCV coinfection is common in persons infected with HIV (Katie et al., 2004).

In the globe today, HIV and co-infection treatments are gradually gaining ground and the adoption of new drugs and with the fast growing discoveries concerning drug resistant TB as well as handling persons who are multiple co-infected has significantly transformed the co-infection dynamics of HIV, TB and HCV. Consequently, over one-third of 39.5 million people with HIV are co-infected with TB and above 50% of these group without TB are projected to be infected with TB (USAID, 2019). TB disease prevalence rate stand at 4% in Nigeria WHO (2019), with the practical data challenges in the recent assessment techniques in Nigeria.

Thus, it is the objective of this study to consider other modelling methodology for HIV/AIDS and some selected opportunistic infections (i.e. TB and HCV) so as to help investigate the extent of co-infection dynamics in Nigeria HIV epidemic scenario using the North West part of the country in conducting. The following sections attempts to examine comprehensively the descriptive statistics and conceptions of time series analysis as carried out in this study. To apply the cointegration approach, it is vital to identify whether the time series is stationary. Stationarity of the data can be achieved by applying differencing method if the data sets under consideration are non-stationary. The Augmented

Dickey-Fuller (ADP) test is then applied to confirm stationarity of the data (i.e. whether unit root exist or not). Also, the study aims at investigating whether there is a long-run relationship among the study variables employing the Johansen cointegration system framework for testing cointegration, the study will also apply the Granger causality test to investigate the direction of the study variables and lastly, the study will propose some recommendations based on the key findings from this study.

2. MATERIALS AND METHODS

2.1. Data Source and Description

This study depends largely on the nature of data available on HIV/AIDS, Tuberculosis and Hepatitis C in North West Region of Nigeria; thus, secondary data is applied in this study. The health sector response includes all the activities of the State Ministry of Health, and the State Health Board. The data under review takes into account yearly observations from the period of 1991 – 2019 in North West zone of Nigeria, and were obtained from National Agency for the Control of AIDS (NACA) through AIDS Healthcare Foundation in Nigeria. The data modelled in this study are patients undergoing treatment in selected facilities across the geopolitical zone. This study takes into account six (6) North West States namely; Kaduna, Sokoto, Katsina, Kano, Zamfara and Kebbi. This study present each states with their respective prevalence rate on HIV/AIDS as well as the co-infected diseases as highlighted in this study, the yearly series ranges from 1991 to 2019 amounting to 29 observations. This study seeks to evaluate the relationship between Human Immuno-deficiency Virus (HIV)/AIDS and opportunistic infections like Tuberculosis (TB) and Hepatitis C virus (HCV) in North West Zone of Nigeria. Specifically, the following objectives are of essence to this research:

i. To ascertain the magnitude HIV/AIDS causes Tuberculosis and Hepatitis C in North West Zone of Nigeria.
ii. Is there a long-run relationship existing amongst HIV/AIDS and coinfections (Tuberculosis and Hepatitis C).

To examine the causal relationship amongst HIV/AIDS and coinfections (Tuberculosis and Hepatitis C).

2.2. Augmented Dickey-Fuller (Unit Root) Test

In investigating for unit root, the ADF test is applied, the analytical process for this test is the same as for the Dickey-Fuller test, and the only difference is that it is applied to the model. The null – hypothesis for an ADF test: $H_o: \gamma = 0 \; vs \; H_1: \gamma < 0$. That is, the null hypothesis signifies unit root presence while, the alternative hypothesis implies no unit root presence in the dataset. The ADF test is centered on t-statistic and probability method. The DF tabulated critical values are selected at significance level of 1%, 5% and 10%, respectively. In investigating the presence of unit root, the calculated t-statistic with its corresponding probability values, which is indicated as statistic ADF test, is compared to the critical values. Accordingly, if the probability value of the test statistic value is greater than the level of significance, the null hypothesis cannot be rejected which implies that the series is non-stationary series.

2.3. Johansen Cointegration Test

If in a long-run, two variables shares in a conjoint stochastic movement then, one can conclude that both variables are cointegrated. The Johansen cointegration test states that the method can only be applied on data sets that are integrated of the same order. A Vector Autoregressive based cointegration analysis techniques by Johansen (1991) is given below:

Consider a vector autoregressive (VAR) model of order p:

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p \qquad (1)$$

Where Y_t is the k – vector of non-stationary $I(1)$ variables, X_t is the d – vector of deterministic variables and ε_t is a vector of innovations. We may rewrite this $VAR(p)$ as:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + BX_t + \varepsilon_t \qquad (2)$$

Where, $\Pi = \sum_{i=1}^{p} A_i - I, \Gamma_i = -\sum_{j=i+1}^{p} A_j$

The Granger's theorem states that if the coefficient matrix Π has reduced rank $r < k$, then there exist $k \times \mathrm{r}$ matrices $\alpha \; and \; \beta$ each with rank r such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is $I(0)$. r is the number of cointegration relations and each column of β is the cointegration vector. Johansen cointegration test computes two statistics: trace statistic and maximum eigenvalues statistic. The trace statistic for the null hypothesis of r cointegration relations in computed as:

$$LR_{\boldsymbol{tr}}(r|k) = -T \sum_{i=r+1}^{k} \log(1 - \lambda_i) \qquad (3)$$

While, the maximum eigenvalue test statistic is computed as:

$$LR_{max}(r|r+1) = -Tlog(1 - \lambda_{r+1}) = LR_{\boldsymbol{tr}}(r|k) - LR_{\boldsymbol{tr}}(r+1|k) \qquad (4)$$

Where λ_i is the i-th largest eigenvalue of the Π matrix in (w), $r = 0,1,2, \ldots, k-1$.

2.4. Granger Causality Test

Cointegration shows presence of a long run relationship amongst variables. Note that, even if the variables are not cointegrated in the long run, it is very possible they may be interrelated in the short-run. Hence, to properly comprehend the short-run inter-dependence between variables, Granger causality tests might be suitable to explain these relationship dynamics. This test rely on a standard F-test to investigate whether variations in one variable cause changes in another variable.

Let us start with a simple VAR model:

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_k y_{t-k} + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \cdots + \alpha_k x_{t-k} + \mathrm{e_t} \qquad (5)$$

If all α coefficients on lagged values of X are significant in this equation, then "X Granger causes Y". If X Granger causes Y and not vice-versa, it is called unidirectional causality. But, when the causality is vice versa, then it is refers to as bidirectional (Brooks, 2008).

The hypotheses for the test is stated as follows:

$\mathrm{H_0}: \alpha_1 = \alpha_2 = \cdots = \alpha_k = 0$ ("X does not Granger causes Y")

$\mathrm{H_1}: \alpha_1 \neq \alpha_2 \neq \cdots \neq \alpha_k \neq 0$, for at least one of α_i coefficients ("X does Granger cause Y"). Though, if causality exist in one or both ways among two variables, it does not necessary mean that they are both cointegrated (Granger, 1988).

3. RESULTS

3.1. Data Sources and Description

HIV/AIDS, TB and Hepatitis C modelled in this study were obtained from National Agency for Control of AIDS (NACA) through AIDS Healthcare Foundation in Nigeria. The descriptive statistics of HIV/AIDS, Tuberculosis and Hepatitis C are presented in table 1, 2 and 3 below.

Table 1: Descriptive Statistics of HIV/AIDS in North West Zone (1991 - 2019)

	KADUNA	SOKOTO	KATSINA	KANO	ZAMFARA	KEBBI
Mean	8.870370	3.848148	2.329630	7.418519	4.500000	6.600000
Median	9.500000	3.900000	2.200000	7.500000	4.500000	6.300000
Maximum	16.80000	7.800000	4.300000	10.80000	8.200000	11.50000
Minimum	1.600000	1.100000	0.400000	3.100000	1.200000	2.300000
Std. Dev.	4.517897	1.995258	1.014440	1.966065	1.990168	2.586652
Jarque-Bera	1.157637	2.203504	0.226131	0.187253	1.367894	0.158277
Probability	0.560560	0.332288	0.893092	0.910623	0.504621	0.923912
Sum	239.5000	103.9000	62.90000	200.3000	121.5000	178.2000
Sum Sq. Dev.	530.6963	103.5074	26.75630	100.5007	102.9800	173.9600
Observations	28	28	28	28	28	28

Source: National Agency for the Control of AIDS (NACA) & AIDS Healthcare Foundation (AHF), Nigeria

It is observed from Table 1 that in North West Nigeria, Kaduna State have the highest HIV/AIDS prevalent rate for the period under study, it rate ranges from 1.60 to 16.8 with an average of 8.87 and standard deviation of 4.52. This study also shows that, Kano State follows with an average of 7.42 in a range of 3.1 to 10.8, followed by Kebbi, Zamfara and Sokoto with average of values of 6.60, 4.50 and 3.85, respectively. While, Katsina is the least state in North West Nigeria with HIV/AIDS prevalent rate, ranging from 0.40 to 4.3 with an average of 2.33.

The Jarque-Bera measures whether the series is normally distributed or not. The Jarque-Bera test statistics obtained for the series of all the state are not statistically significant at 0.05 level of significance (i.e. p-values > 0.05), this result indicates that the null hypothesis of normal distribution for HIV/AIDS prevalence is rejected, signifying that the time series data set for all the states in-terms of HIV/AIDS may exhibit nonlinearity and possibility of structural break/changes/or shifts (i.e. the rate does not show a particular pattern or trend).

Table 2: Descriptive Statistics of Tuberculosis in North West Zone (1991 - 2019)

	KADUNA	SOKOTO	KATSINA	KANO	ZAMFARA	KEBBI
Mean	8.303704	5.437037	4.066667	8.418519	6.592593	8.911111
Median	8.400000	5.400000	3.800000	8.100000	6.400000	9.500000
Maximum	16.20000	9.400000	8.400000	12.10000	10.20000	12.10000
Minimum	1.400000	1.300000	1.600000	5.200000	3.200000	6.100000
Std. Dev.	4.418709	2.926293	1.598798	2.002313	1.760884	1.745397
Jarque-Bera	1.738304	2.936561	3.793556	1.589876	0.333489	1.496589
Probability	0.419307	0.230321	0.150051	0.451609	0.846416	0.473173
Sum	224.2000	146.8000	109.8000	227.3000	178.0000	240.6000
Sum Sq. Dev.	507.6496	222.6430	66.46000	104.2407	80.61852	79.20667
Observations	28	28	28	28	28	28

Source: National Agency for the Control of AIDS (NACA) & AIDS Healthcare Foundation (AHF), Nigeria

Based on Table 2 above, it shows that in North West Nigeria, Kebbi State have the highest TB cases for the period under study, it rate ranges from 6.10 to 12.10 with an average of 8.91 and standard deviation of 1.74. This study also shows that, Kano State follows with an average of 8.41 in a range of 5.2 to 12.1, followed by Kaduna, Zamfara and Sokoto with average of values of 8.30, 6.59 and 5.43, respectively. While, Katsina has the least TB cases within the North West geopolitical zone, ranging from 1.60 to 8.4 with an average of 4.07.

The results of other statistics are also evident from Table 2 above. The Jarque-Bera test statistics obtained for the series of all the state are not statistically significant at 0.05 level of significance (i.e. p-values > 0.05), this result indicates that the null hypothesis of normal distribution for TB cases is rejected, signifying that the time series data set for all the states in-terms of TB cases also exhibit nonlinearity and possibility of structural break/changes/or shifts (i.e. the rate does not show a particular pattern or trend).

Table 3: Descriptive Statistics of Hepatitis in North West Zone (1991 - 2019)

	KADUNA	SOKOTO	KATSINA	KANO	ZAMFARA	KEBBI
Mean	7.125926	5.755556	3.355556	8.640741	6.840741	8.811111
Median	5.300000	5.700000	3.200000	9.300000	6.900000	9.200000
Maximum	16.30000	9.800000	5.300000	11.50000	9.500000	11.20000
Minimum	1.200000	1.300000	1.200000	4.500000	4.200000	6.200000
Std. Dev.	5.023452	2.681322	0.960101	2.071651	1.342861	1.226732
Jarque-Bera	3.495507	1.603303	0.319117	1.234913	0.732407	0.960474
Probability	0.174165	0.448588	0.852520	0.539314	0.693362	0.618637
Sum	192.4000	155.4000	90.60000	233.3000	184.7000	237.9000
Sum Sq. Dev.	656.1119	186.9267	23.96667	111.5852	46.88519	39.12667
Observations	28	28	28	28	28	28

Source: National Agency for the Control of AIDS (NACA) & AIDS Healthcare Foundation (AHF), Nigeria

Table 3 shows clearly Hepatitis C rate in the six (6) states of the geopolitical zone from 1991 to 2019, it shows an increasing trend of the virus. It can be seen that in North West Nigeria, Kebbi State also takes the lead of the up-ward trend of this infection, figures ranges from 6.2 to 11.2 with an average of 8.81 and standard deviation of 1.23. This study also shows that, Kano State follows with an average of 8.64 within the range of 4.50 to 11.50; this up-ward trend is followed by Kaduna, Zamfara and Sokoto with average values of 7.13, 6.84 and 5.76, respectively. While, Katsina has the lowest cases in the zone, ranging from 1.20 to 5.30 with an average of 3.36.

The Jarque-Bera test statistics obtained for the series of all the state are not statistically significant at 0.05 level of significance (i.e. p-values > 0.05), this result indicates that the null hypothesis of normal distribution for Hepatitis C cases is rejected, signifying that the time series data set for all the states in-terms of Hepatitis C cases do not follow a particular trend.

3.2. Testing for Unit Root and Stationarity of HIV/AIDS, Tuberculosis and Hepatitis in North West Zone (1991 – 2019)

The stationarity/or unit root test is conducted using, Augmented Dickey Fuller (ADF). The statistic tests the null hypothesis that the data series has a unit root with the alternative that the data series is stationary. The presence of unit root or the data set been non-stationary implies that, the data will not be appropriate for time series analysis, the data will be differenced until the data attain stationarity.

The results obtained for the six selected states of the zone are presented in Table 4, 5 and 6 below:

Table 4: Unit Root and Stationarity Test for the HIV/AIDS Series

State	ADF values	P-value	Hypothesis (H_0)	Decision	Remarks
Kaduna	-2.8076	0.0715	Unit Root	accept H_0	Not Stationary
Kebbi	-2.1172	0.2399	Unit Root	accept H_0	Not Stationary
Kano	-3.0771	0.0409	Unit Root	reject H_0	Stationary
Zamfara	-1.1943	0.6612	Unit Root	accept H_0	Not Stationary
Katsina	-2.8366	0.0670	Unit Root	accept H_0	Not Stationary
Sokoto	-1.5712	0.4826	Unit Root	accept H_0	Not Stationary

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05

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Table 4 above presents ADF test for the HIV disease in the six states of investigation. The ADF statistic values for Kaduna, Kebbi, Zamfara, Katsina and Sokoto with *p*-values of 0.0715, 0.2399, 0.6612, 0.0670 and 0.4826, respectively, which are greater than 0.05 level of significance, we do not reject the null hypothesis of having a unit root series and therefore, conclude that that the HIV data series of the state mentioned, has unit root/or are not stationary and each respective data has to be differenced so as to achieve stationarity before applying the cointegration test. While, for Kano State, the p-value is less than 0.05 level of significance, implying that the data is stationary.

Table 5: Unit Root and Stationarity Test for the Tuberculosis Series

State	T-Statistic	P-value	Hypothesis (H_0)	Decision	Remarks
Kaduna	-1.9515	0.3050	Unit Root	accept H_0	Not Stationary
Kebbi	-3.4796	0.0170	Unit Root	reject H_0	Stationary
Kano	-3.0844	0.0403	Unit Root	reject H_0	Stationary
Zamfara	-4.3459	0.0022	Unit Root	reject H_0	Stationary
Katsina	-3.4733	0.0172	Unit Root	reject H_0	Stationary
Sokoto	-2.4163	0.1472	Unit Root	accept H_0	Not Stationary

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05

Table 5 above presents ADF test for the Tuberculosis disease in the six states of investigation. The ADF statistic values of Kaduna and Sokoto with *p*-values of 0.3050 and 0.1472 respectively, which are greater than 0.05 level of significance, we do not reject the null hypothesis of having a unit root series and therefore conclude that the data series of both states are considered non-stationary, they are indeed having unit roots. In conclusion, it is clear from Table 5 above that Kebbi, Kano, Zamfara and Katsina time series data set are all stationary and can be used without differencing since their respective p-values are less than 0.05 level of significance.

Table 6: Unit Root and Stationarity Test for the Hepatitis C Series

State	T-Statistic	P-value	Hypothesis (H_0)	Decision	Remarks
Kaduna	-0.2821	0.9724	Unit Root	accept H_0	Not Stationary
Kebbi	-2.5719	0.1114	Unit Root	accept H_0	Not Stationary
Kano	-4.8890	0.0010	Unit Root	reject H_0	Stationary
Zamfara	-2.0652	0.2593	Unit Root	accept H_0	Not Stationary
Katsina	-3.1191	0.0375	Unit Root	reject H_0	Stationary
Sokoto	-2.2997	0.1795	Unit Root	accept H_0	Not Stationary

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05

Table 6 above presents ADF test for the Hepatitis C disease in the six states of investigation. The result as shown in Table 6, indicate that both Kano and Katsina with p-values of 0.0010 and 0.0375 respectively are less than 0.05 level of significance, implying that their data sets are stationary. While, the ADF statistic values of the remaining states with *p*-values of 0.9724, 0.1114, 0.2593 and 0.1795 for Kaduna, Kebbi, Zamfara and Sokoto, respectively are all greater than 0.05 level of significance by implication, we do not reject the null hypothesis of having a unit root series and therefore conclude that the Hepatitis C data series of the four states are considered non-stationary. Thus, it is necessary to difference the datasets of the four state before further test can be applied as shown in this study.

3.3. First Differenced and Unit Root Test on Data Series

After majority of the data series were found to be non-stationary through the ADF test, the series is transformed by carrying-out first differencing and the results are presented in 7, 8 and 9 below:

Table 7: Unit Root and Stationarity of First Differenced HIV/AIDS Series

State	T-Statistic	P-value	Hypothesis (H_0)	Decision	Remarks
Kaduna	-4.6256	0.0013	Unit Root	reject H_0	Stationary
Kebbi	-3.9861	0.0062	Unit Root	reject H_0	Stationary
Zamfara	-4.8347	0.0008	Unit Root	reject H_0	Stationary
Katsina	-6.1977	0.0000	Unit Root	reject H_0	Stationary
Sokoto	-5.1752	0.0003	Unit Root	reject H_0	Stationary

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05

Table 8: Unit Root and Stationarity of First Differenced Tuberculosis Series

State	T-Statistic	P-value	Hypothesis (H_0)	Decision	Remarks
Kaduna	-7.5149	0.0000	Unit Root	reject H_0	Stationary
Sokoto	-6.4502	0.0000	Unit Root	reject H_0	Stationary

Level of Significance: 0.05 or 5%, **Decision Rule:** Reject H_o, if P-value < 0.05

Table 9: Unit Root and Stationarity of First Differenced Hepatitis C Series

State	T-Statistic	P-value	Hypothesis (H_0)	Decision	Remarks
Kaduna	-9.0765	0.0000	Unit Root	reject H_0	Stationary
Kebbi	-4.4622	0.0019	Unit Root	reject H_0	Stationary
Zamfara	-3.4165	0.0234	Unit Root	reject H_0	Stationary
Sokoto	-6.0936	0.0000	Unit Root	reject H_0	Stationary

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05

The results displayed above for each of the cases as represented in Table 7, 8 and 9 showed that all the series were integrated of order one (i.e. $I(1)$). By implication, the assumption for applying the cointegration test is satisfied and the series are suitable for analysis applying the cointegration method.

3.4. Johansen Multivariate Cointegration Test Results

Since, the order of integration have been identified and also, the integration process is of order 1, $I(1)$ (i.e. first difference) then, the unit root test carried-out indicates that a long-run effect might exist amongst the variables under study. To investigate this fact, we applied the Johansen Multivariate Cointegration technique as proposed in this research. Hence, the cointegration test results are presented for each state below.

3.4.1. Johansen Test for Cointegration (HIV/AIDS, Tuberculosis and Hepatitis C) in Kaduna State

Table 10.0: Johansen Multivariate Cointegration Test (Trace)

Hypothesis		Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
H_0	H_1				
$r = 0$	$r > 0$	0.585100	30.03667	29.79707	0.0469
$r \leq 1$	$r > 1$	0.237756	8.043712	15.49471	0.4608
$r \leq 2$	$r > 2$	0.049018	1.256495	3.841466	0.2623

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Trace test indicates one cointegrating equation at 5% level

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Table 10.1: Johansen Multivariate Cointegration Test (Maximum Eigenvalue)

Hypothesis		Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
H_0	H_1				
$r = 0$	$r > 0$	0.585100	21.99296	21.13162	0.0378
$r \leq 1$	$r > 1$	0.237756	6.787217	14.26460	0.5146
$r \leq 2$	$r > 2$	0.049018	1.256495	3.841466	0.2623

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Max-eigenvalue test indicate one cointegrating equation 5% level

From the Johansen Multivariate Cointegration technique in Table 10.0 and 10.1 above both indicate one cointegrating equation, the normalized cointegrating equation is obtained which shows the long run relationship between HIV/AIDS and coinfections in Kaduna State. The Table 10.2 below contains the coefficients of the first normalized cointegrating equation. The results from Table 10.0 and 10.1 both indicate cointegration between HIV/AIDS and co-infections at 5% significance level. That is, in Kaduna State the causes of Hepatitis C and Tuberculosis might be linked to HIV/AIDS.

Table 10.2: Normalized Cointegrating Coefficients

HIV/AIDS	Hepatitis C	Tuberculosis
1	0.4620	0.8432
Standard Errors	0.1699	0.1739

The normalized coefficients in Table 10.2, shows that HIV/AIDS has a positive relationship with coinfections in Kaduna State. That is, the causes of Hepatitis C and Tuberculosis are mostly associated with people living with HIV/AIDS in the State. Furthermore, based on the result obtained from this study, it can be deduced that for the period under review 46.2% and 84.3% cases of Hepatitis C and Tuberculosis, respectively are linked to HIV/AIDS.

3.4.2. Johansen Test for Cointegration (HIV/AIDS, Tuberculosis and Hepatitis C) in Sokoto State

Table 11.0: Johansen Multivariate Cointegration Test (Trace)

Hypothesis		Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
H_0	H_1				
$r = 0$	$r > 0$	0.426083	21.92891	29.79707	0.3024
$r \leq 1$	$r > 1$	0.218807	8.047127	15.49471	0.4604
$r \leq 2$	$r > 2$	0.072212	1.873803	3.841466	0.1710

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Trace indicates no cointegrating equation at 5% level

Table 11.1: Johansen Multivariate Cointegration Test (Maximum Eigenvalue)

Hypothesis		Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
H_0	H_1				
$r = 0$	$r > 0$	0.426083	13.88178	21.13162	0.3748
$r \leq 1$	$r > 1$	0.218807	6.173323	14.26460	0.5911
$r \leq 2$	$r > 2$	0.072212	1.873803	3.841466	0.1710

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Max-eigenvalue indicates no cointegrating equation at 5% level

Table 11.0 and 11.1 above indicates that no cointegrating equation in both the trace and maximum eigenvalue. By implication, there is no long-run relationship between HIV/AIDS and coinfections in Sokoto State at 5% significance level. That is, both Tuberculosis and Hepatitis C may not necessary be linked to HIV/AIDS in the State. Furthermore, it is very possible both coinfections may share common stochastic trend in the short-run.

Table 11.2: Normalized Cointegrating Coefficients

HIV/AIDS	Tuberculosis	Hepatitis C
1	-10.9403	10.5767
Standard Errors	2.8571	3.3246

The normalized coefficients in Table 11.2 shows that HIV/AIDS has an inverse relationship with Tuberculosis but shows a direct relationship with Hepatitis C. That is, the cause of Tuberculosis might not necessary be linked to HIV/AIDS as that of Hepatitis C which coefficient indicate a positive relationship signifying that, Hepatitis C virus even though not having a long-run relationship with HIV/AIDS but showed that 10.6% cases are associated with HIV/AIDS in Sokoto State for the time period been considered for this study.

3.4.3. Johansen Test for Cointegration (HIV/AIDS, Tuberculosis and Hepatitis C) in Katsina State

Table 12.0: Johansen Multivariate Cointegration Test (Trace)

Hypothesis		Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
H_0	H_1				
$r = 0$	$r > 0$	0.541110	31.73953	29.79707	0.0295
$r \leq 1$	$r > 1$	0.349406	12.26590	15.49471	0.1446
$r \leq 2$	$r > 2$	0.058956	1.519143	3.841466	0.2177

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Trace test indicates one cointegrating equation at 5% level

Table 12.1: Johansen Multivariate Cointegration Test (Maximum Eigenvalue)

Hypothesis		Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
H_0	H_1				
$r = 0$	$r > 0$	0.541110	19.47364	21.13162	0.0839
$r \leq 1$	$r > 1$	0.349406	10.74675	14.26460	0.1674
$r \leq 2$	$r > 2$	0.058956	1.519143	3.841466	0.2177

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Max-eigenvalue indicates no cointegrating equation at 5% level

The results from Table 12.0 indicate one (1) cointegrating equation between HIV and coinfections at 5% significance level in Katsina State. Based on this result, we can conclude that there is a long-run relationship between HIV/AIDS and coinfections in Katsina State

Table 12.2: Normalized Cointegrating Coefficients

HIV/AIDS	Tuberculosis	Hepatitis C
1	0.2415	-1.5159
Standard Errors	0.1165	0.1862

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The normalized coefficients in Table 12.2 shows that HIV/AIDS has an inverse relationship with Hepatitis C but shows a direct relationship with Tuberculosis. That is, the cause of Hepatitis C may not directly be linked to HIV/AIDS but the same result indicates that about 24.2% of Tuberculosis cases is associated with HIV/AIDS in Katsina State during the period under review.

3.4.4. Johansen Test for Cointegration (HIV/AIDS, Tuberculosis and Hepatitis C) in Kano State

Table 13.0: Johansen Multivariate Cointegration Test (Trace)

Hypothesis H_0	H_1	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
$r = 0$	$r > 0$	0.393239	21.55733	29.79707	0.3238
$r \leq 1$	$r > 1$	0.244236	9.066836	15.49471	0.3592
$r \leq 2$	$r > 2$	0.079325	2.066193	3.841466	0.1506

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Trace test indicates no cointegrating equation at 5% level

Table 13.1: Johansen Multivariate Cointegration Test (Maximum Eigenvalue)

Hypothesis H_0	H_1	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
$r = 0$	$r > 0$	0.393239	12.49049	21.13162	0.5001
$r \leq 1$	$r > 1$	0.244236	7.000643	14.26460	0.4891
$r \leq 2$	$r > 2$	0.079325	2.066193	3.841466	0.1506

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Max-eigenvalue indicates no cointegrating equation at 5% level

The results from Table 13.0 and 13.1 indicate no cointegrating equation between HIV/AIDS and coinfections at 5% significance level. This implies that, there is no long-run relationship existing between HIV/AIDS and coinfections in Kano State.

Table 13.2: Normalized Cointegrating Coefficients

HIV/AIDS	Tuberculosis	Hepatitis C
1	-1.9262	1.7280
Standard Errors	0.6184	0.6110

The normalized coefficients in Table 13.2 shows that HIV/AIDS has an inverse relationship with Tuberculosis but shows a direct relationship with Hepatitis C. That is, the cause of Tuberculosis cases is not directly linked to HIV/AIDS. While, the result shows that Hepatitis C and HIV/AIDS shares a direct relationship also, the result indicate that about 1.73% cases of Hepatitis C is associated with HIV/AIDS in Kano State.

3.4.5. Johansen Test for Cointegration (HIV/AIDS, Tuberculosis and Hepatitis C) in Zamfara State

Table 14.0: Johansen Multivariate Cointegration Test (Trace)

Hypothesis H_0	H_1	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
$r = 0$	$r > 0$	0.386367	23.20838	29.79707	0.2360
$r \leq 1$	$r > 1$	0.354157	10.99941	15.49471	0.2115
$r \leq 2$	$r > 2$	0.002774	0.069457	3.841466	0.7921

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Trace test indicates no cointegrating equation at 5% level

Table 14.1: Johansen Multivariate Cointegration Test (Maximum Eigenvalue)

Hypothesis H_0	H_1	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
$r = 0$	$r > 0$	0.386367	12.20897	21.13162	0.5272
$r \leq 1$	$r > 1$	0.354157	10.92995	14.26460	0.1577
$r \leq 2$	$r > 2$	0.002774	0.069457	3.841466	0.7921

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Max-eigenvalue indicates no cointegrating equation at 5% level

The results from Table 14.0 and 14.1 indicate no cointegrating equation between HIV/AIDS and coinfections in the State at 5% significance level. That is, there is no long-run relationship between HIV/AIDS and coinfections in Zamfara State.

Table 14.2: Normalized Cointegrating Coefficients

HIV/AIDS	Tuberculosis	Hepatitis C
1	-3.1426	0.0098
Standard Errors	0.7202	0.8908

The normalized coefficients in Table 14.2 shows that HIV/AIDS has an inverse relationship with Tuberculosis but shows a direct relationship with Hepatitis C. That is, the cause of Tuberculosis cases is not directly linked to HIV/AIDS but also, the result showed that about 0.98% cases of Hepatitis C is associated with HIV/AIDS in Zamfara State for the period under study.

3.4.6. Johansen Test for Cointegration (HIV/AIDS, Tuberculosis and Hepatitis C) in Kebbi State

Table 15.0: Johansen Multivariate Cointegration Test (Trace)

Hypothesis H_0	H_1	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
$r = 0$	$r > 0$	0.489919	28.87941	29.79707	0.0435
$r \leq 1$	$r > 1$	0.338426	12.04976	15.49471	0.0546
$r \leq 2$	$r > 2$	0.066540	1.721431	3.841466	0.0895

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Trace test indicates one cointegrating equation at 5% level

Table 15.1: Johansen Multivariate Cointegration Test (Maximum Eigenvalue)

Hypothesis H_0	H_1	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.*
$r = 0$	$r > 0$	0.489919	16.82965	21.13162	0.0402
$r \leq 1$	$r > 1$	0.338426	10.32833	14.26460	0.0613
$r \leq 2$	$r > 2$	0.066540	1.721431	3.841466	0.1995

Level of Significance: 0.05, **Decision Rule:** Reject H_o, if P-value < 0.05, Max-eigenvalue test indicates one cointegrating equation at 5% level

The results from Table 15.0 and 15.1 indicate two (2) cointegrating equation between HIV and coinfections at 5% significance level. This result shows that, there is a long-run relationship that exist between HIV/AIDS, Tuberculosis and Hepatitis in Kebbi State.

Table 15.2: Normalized Cointegrating Coefficients

HIV/AIDS	Tuberculosis	Hepatitis C
1	22.9499	0.7269
Standard Errors	5.9911	7.6557

The normalized coefficients in Table 15.2 shows that HIV/AIDS has a direct relationship with both Tuberculosis and Hepatitis C. That is, the causes of both Tuberculosis and Hepatitis are linked to HIV/AIDS. Based on this result, it can be seen that about 22.95% and 72.7% cases of Tuberculosis and Hepatitis, respectively is associated with HIV/AIDS in Kebbi State from 1991 to 2019.

3.5. Granger Causality Analysis

The cointegration test performed revealed that a long-run effect exist between Tuberculosis, Hepatitis C and HIV in Kaduna, Katsina and Kebbi States. Nevertheless, it is very paramount to also investigate the short run relationship/effect between all three cases/ or variables been study by applying the Granger causality test. As the result might be ambiguous if more than two (2) variables are involve; performing a pairwise causality test will help give the result more clarity. One key attribute for applying the causality check is for the datasets involve to be stationary, but in cases were stationarity is not achieved then, the first differenced dataset is used. Below, is the Granger causality test result as shown in Table 16.

Table 16: Granger Causality Test among HIV, Tuberculosis and Hepatitis C

State	Null hypothesis	Observations	F-statistic	P-value
Kaduna	HIV/AIDS does not Granger Cause Hepatitis C	29	4.2331	0.0442
	Hepatitis C does not Granger Cause HIV/AIDS		0.1871	0.8308
	Tuberculosis does not Granger Cause HIV/AIDS	29	0.7142	0.5017
	HIV/AIDS does not Granger Cause Tuberculosis		4.6822	0.0215
Sokoto	HIV/AIDS does not Granger Cause Hepatitis C	29	4.3986	0.0261
	Hepatitis C does not Granger Cause HIV/AIDS		0.7575	0.4818
	Tuberculosis does not Granger Cause HIV/AIDS	29	0.6159	0.5501
	HIV/AIDS does not Granger Cause Tuberculosis		1.2574	0.3059
Katsina	HIV/AIDS does not Granger Cause Hepatitis C	29	0.1364	0.8733
	Hepatitis C does not Granger Cause HIV/AIDS		0.0617	0.9404
	Tuberculosis does not Granger Cause HIV/AIDS	29	1.0397	0.3719
	HIV/AIDS does not Granger Cause Tuberculosis		4.4938	0.0175
Kano	HIV/AIDS does not Granger Cause Hepatitis C	29	0.5778	0.5702
	Hepatitis C does not Granger Cause HIV/AIDS		0.8572	0.4393
	Tuberculosis does not Granger Cause HIV/AIDS	29	0.3894	0.6825
	HIV/AIDS does not Granger Cause Tuberculosis		0.0502	0.9511
Zamfara	HIV/AIDS does not Granger Cause Hepatitis C	29	1.6669	0.2140
	Hepatitis C does not Granger Cause HIV/AIDS		2.7054	0.0912
	Tuberculosis does not Granger Cause HIV/AIDS	29	1.6877	0.5142
	HIV/AIDS does not Granger Cause Tuberculosis		4.4878	0.0248
Kebbi	HIV/AIDS does not Granger Cause Hepatitis C	29	3.6306	0.0425
	Hepatitis C does not Granger Cause HIV/AIDS		1.0585	0.7694
	Tuberculosis does not Granger Cause HIV/AIDS	29	1.7272	0.2033
	HIV/AIDS does not Granger Cause Tuberculosis		3.4669	0.0457

*Denotes rejection of the hypothesis at 0.05 level

The Granger causality tests revealed that HIV/AIDS Granger causes both Tuberculosis and Hepatitis C virus in Kaduna State, while, HIV/AIDS Granger causes Hepatitis C in Sokoto State. Also, HIV/AIDS Granger causes Tuberculosis in three other States namely, Katsina, Zamfara and Kebbi. The results obtained from conducting this test revealed that only unidirectional causality is established in the sample period. By implication, short run effects exist more among the studied diseases than in the long-run. This result supports the fact that both diseases (i.e. TB and HCV) are the most opportunistic infection of HIV/AIDS in Nigeria. Furthermore, the cointegration detected by the Johansen cointegration test between the HIV and other two diseases is supported with the Granger causality test. Consequently, the prior values of HIV/AIDS can be used to forecast the infection of the Tuberculosis and Hepatitis C virus.

4. DISCUSSION

The study shows that in North West Nigeria, Kaduna State have the highest HIV/AIDS prevalent rate for the period under review with rate that ranges from 1.60 to 16.8 with an average of 8.87 and standard deviation of 4.52. Kebbi State has the highest TB cases for the period under study, it rate ranges from 6.10 to 12.10 with an average of 8.91 and standard deviation of 1.74. Also, our results clearly shows an increasing trend of the Hepatitis C virus with Kebbi State also taking the lead of the up-ward trend of this rate, figures ranges from 6.2 to 11.2 with an average of 8.81 and standard deviation of 1.23. From the Johansen Multivariate Cointegration test, the result shows that there is a long-run relationship between HIV/AIDS and coinfections in Kaduna State. That is, in Kaduna State the causes of Hepatitis C and Tuberculosis might be linked to HIV/AIDS. Furthermore, based on the result obtained from this study, it can be seen that 46.2% and 84.3% cases of Hepatitis C and Tuberculosis, respectively are linked to HIV/AIDS. The result shows that, there is no long-run relationship between HIV/AIDS and coinfections in Sokoto State. That is, both Tuberculosis and Hepatitis C may not necessary be linked to HIV/AIDS in the State. Furthermore, it is very possible both coinfections may share common stochastic trend in the short-run. Hepatitis C virus even though not having a long-run relationship with HIV/AIDS but showed that 10.6% cases are associated with HIV/AIDS in Sokoto State for the period under review.Based on our findings, we can conclude that there is a long-run relationship between HIV/AIDS and coinfections in Katsina State. The result also indicates that HIV/AIDS has an inverse relationship with Hepatitis C but shows a direct relationship with Tuberculosis. That is, the cause of Hepatitis C may not directly be linked to HIV/AIDS but the same result indicates that about 24.2% of Tuberculosis cases is associated with HIV/AIDS in Katsina State. In Kano State, HIV/AIDS and coinfections shows no cointegrating equation. This implies that, there is no long-run relationship existing between HIV/AIDS and coinfections. Also, our findings shows that HIV/AIDS has an inverse relationship with Tuberculosis but shows a direct relationship with Hepatitis C. This implies that the cause of Tuberculosis cases is not directly linked to HIV/AIDS. While, the result shows that Hepatitis C and HIV/AIDS shares a direct relationship indicating that about 1.73% cases of Hepatitis C is associated with HIV/AIDS in Kano State. Furthermore, the results also indicate no cointegrating equation between HIV/AIDS and coinfections in Zamfara State that is, there is no long-run relationship between HIV/AIDS and coinfections in the State. But, the result showed that about 0.98% cases of Hepatitis C is associated with HIV/AIDS in Zamfara State for the period under review. While, our results shows that, there is a long-run relationship that exist between HIV/AIDS, Tuberculosis and Hepatitis in Kebbi State. And also, it can be seen that about 22.95% and 72.7% cases of Tuberculosis and Hepatitis, respectively is associated with HIV/AIDS in Kebbi State. Finally, the Granger causality test shows that, HIV/AIDS Granger causes both Tuberculosis and Hepatitis C virus in Kaduna State, while, HIV/AIDS Granger causes Hepatitis C in Sokoto State. Also, HIV/AIDS Granger causes Tuberculosis in three other States namely, Katsina, Zamfara and Kebbi. The results obtained from conducting this test revealed that only unidirectional causality is established in the sample period. By implication, short run effects exist more among the studied diseases than in the long-run.

5. Conclusion and Recommendations

5.1. Conclusion

This study uses a multivariate time series approach, that is Johansen Multivariate Cointegration and Granger Causality in determining both the long and short run relationship that exist among HIV/AIDS, Tuberculosis and Hepatitis C virus in six (6) selected states of high HIV/AIDS prevalence rates as shown by (NAIIS, 2018) report in the North West Zone in Nigeria. The data employed in this study as an annual data of HIV/AIDS and some selected coinfections (i.e. Tuberculosis and Hepatitis C) from 1991 to 2019 obtained from National Agency for the Control of AIDS (NACA) and AIDS Healthcare Foundation (AHF) in Nigeria. The North West States selected for this study include Kaduna, Sokoto, Katsina, Kano, Zamfara and Kebbi. Based on the analysis carried-out, it shows that Kaduna State has the highest HIV/AIDS prevalent rate for the period under study with a mean value of 8.87 followed by Kano State with a mean value of 7.41. Before applying the Cointegration and Granger causality test, the Augmented Dicky Fuller (ADF) test was used to determine the presence of unit root in the datasets used for this study; the ADF test shows that for HIV/AIDS series, only Kano State was stationary, while, the other five (5) states became stationary at first difference. For Tuberculosis series, Kebbi, Kano, Zamfara and Katsina were stationary, while, Kaduna and Sokoto became stationary after first difference. Finally, investigating for unit root in the Hepatitis C series, only Kano and Katsina were stationary, while, Kaduna, Kebbi, Zamfara and Sokoto became stationary after first difference. The results on cointegration revealed that only Kaduna, Katsina and Kebbi States showed that there is a long-run relationship between HIV/AIDS, Tuberculosis and Hepatitis C virus. While, the Granger causality test showed that only unidirectional causality exist in the data sets. Furthermore, HIV/AIDS Granger causes both Tuberculosis and Hepatitis C virus in Kaduna State, while, HIV/AIDS Granger causes Hepatitis C in Sokoto State. Also, HIV/AIDS Granger causes Tuberculosis in three other States namely, Katsina, Zamfara and Kebbi. Lastly, the study revealed that there were more short-term relationship between the analyzed diseases than in the long-run.

5.2. Recommendations

Despite the recent survey conducted in Nigeria, showing that the country has a low HIV prevalence rate of 1.4% USAID (2019) and NAIIS (2018), the number of people living with HIV/AIDS is still high and most importantly, opportunistic infection is on the rise each day.

In accordance with this study, we have recommended the following:

i. Thus, it is crucial to support surveillance structure aiming at the population workforce as well as the other age groups. Frequent and strategic prevention movement/campaigns should be organized.
ii. The monitoring structure of HIV/AIDS in North West zone and the country at large needs to be improved and well-structured so as to enhance proper and diverse assessment of the epidemic.
iii. Since, the findings of this study revealed that both long and short run relationship exist between HIV/AIDS and coinfections in North West Nigeria then, it is very vital to carry-out proper sensitization at all level of settlements to ensure that people have proper understanding about these coinfections. Also, sexually transmitted infection programming should be properly design as well as ensuring that HIV/AIDS and sexual and reproductive health services should be properly integrated into the program and the promotion of gender equity is of essence in the zone.
iv. If the country must achieve the USAID 90:90:90 strategy on ending HIV/AIDS by 2030 then, it is paramount that programmes should be design to encourage citizens to knows their status that is, promoting HIV counselling and testing as this will help ascertain early case detection and timely linkage to healthcare for early treatment.

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