Application of Multiple Correspondence Analysis for HIV/AIDS Disease Association and Distribution in Taraba State

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Abstract

The growing incidence of HIV/AIDS is still a serious public health issue that necessitates a detailed comprehension of its causes and dissemination. The goal of the study was to investigate the complex relationships that exist between several variables and the geographic distribution of HIV/AIDS patients in Taraba State, Nigeria. The Johns Hopkins Programme for International Education in Gynaecology and Obstetrics (JHPIEGO), an NGO active in Taraba State, provided the dataset, which includes 68,527 people living with HIV/AIDS in Taraba State. The variables include gender, age group, marital status, and status regarding tuberculosis. Multiple correspondence analysis (MCA) was employed in the study to investigate the spatial distribution of HIV/AIDS cases in Taraba State, Nigeria. According to the data, people who falls under "separated" category make up 27.05% of the population, while HIV/AIDS cases were concentrated in Gassol Local Government Area, housing 32.12% of the total. However, a sizable percentage (22.06%) have never had a tuberculosis test. Further examination of the data revealed that 30.91% of the population is single, while individuals aged between 10 and 19 account for 12.79%, placing them second. The information obtained is instrumental in crafting targeted and impactful interventions, as well as in the strategic allocation of resources to better support this vulnerable population. Notably, initiatives should focus on enhancing routine tuberculosis screening programs for individuals living with HIV/AIDS, raising awareness regarding marital status, and establishing effective monitoring systems to decrease the rates of MTCT transmission.

Keywords: *HIV/AIDS, Multiple Correspondence Analysis, Disease, Distribution, Association*

Introduction

Over time, HIV and AIDS prevalence in Nigeria has significantly increased, particularly in high-density areas. This public health emergency is mostly the result of the human immunodeficiency virus (HIV), which cause havoc to the immune system, particularly on the CD4 cells, which are essential for immunity. HIV weakens the immune system, making people more vulnerable to a variety of opportunistic infections and illnesses, from fungal infections and tuberculosis to serious bacterial infections and cancers (WHO, 2022). HIV is a sophisticated retrovirus belonging to the lentivirus family that is highly dangerous to human life and can be fatal if appropriate medical care is not received in a timely manner. Antiretroviral therapy (ART), which can prevent HIV replication, has been developed as a critical response to the virus's attack. For HIV-1 and HIV-2 patients, antiretroviral therapy (ART) is the only effective therapeutic option (De Vito *et al.*, 2023). Olakunde *et al*. (2017)

conducted a study that underscored the necessity of expanding the reach of mother-to-child transmission prevention programmes in Taraba State.

The prevalence of HIV/AIDS in Nigeria as at 2019 is distributed as follows: Akwa Ibom has the highest rate at 5.5%, closely followed by Benue at 5.3%. Other states with significantly lower prevalence rates are Rivers and Taraba, with 3.8% and 2.9%, respectively. Nigeria's states are all dealing with a significant HIV/AIDS epidemic. According to a study by Adeoye *et al*. (2021), Taraba State in northeastern Nigeria has the highest rate of HIV/AIDS prevalence. According to information gathered from the Nigerian HIV/AIDS Indicator and Impact Survey (NAIIS), there are roughly 1.9 million HIV/AIDS positive individuals registered in Nigeria (Ozozoyin, 2022). The high prevalences observed across the nation highlight the necessity of gaining a thorough understanding of how the disease is distributed among the states in order to pinpoint the major populations that are most impacted. In order to properly represent the link between the several variables of interest, multivariate statistical methods must be applied to the study of HIV/AIDS prevalence and distribution, which incorporates complicated intervening variables.

A flexible statistical technique called multiple correspondence analysis (MCA) is used to determine and simulate the link between multiple factors that have a major impact on the dependent variable (Greenacre, 2017). An expansion of principal component analysis, multiple correspondence analysis (MCA) examines the connections between qualitative variables. In order to ensure that the locations of the row and column points match their relationships in the table, this geometric method of visualising the rows and columns of a two-way contingency table as points in a low-dimensional space is used. Having a comprehensive image of the data that may be utilised for interpretation is the aim (Kamalja and Khangar, 2017). MCA presents the datasets in two dimensions and summarises them. Using a series of pairwise comparisons of the variables, the MCA can reveal connections that would not otherwise be visible (Tian *et al.*, 1993). The process makes use of the singular value decomposition (SVD) algorithm matrix with regard to certain values (Press *et al.*, 2007). The graphical representations facilitate the identification of linkages and enable straightforward, intuitive reasoning regarding the interrelationships between the variables in the researched categories (Panek, 2009).

Literature Review

Correspondence has been used in a number of researches to predict the distribution of numerous complex intervening factors. Dibal and Usman (2018) used correspondence analysis to investigate the distribution and correlations of common crimes committed in Yobe state. Their research indicates a correlation between crime categories and the potential hotspots (Local Government Areas) where they may occur.

Kim and Annunziato (2018) examined the relationships between gender, age, and physical and psychological symptoms in patients with cardiovascular disease using correspondence analysis (CA) biplots. The study found that patients in their 50s and 60s were more likely to develop psychological symptoms than patients in their male counterparts. These findings suggest that gender and age have a significant impact on the likelihood of exhibiting psychological symptoms.

Zhu *et al*. (2017) looked into the relationship between five chronic diseases—hypertension, hyperlipidemia, diabetes mellitus, heart disease, and obesity—and nine different formulations

of Traditional Chinese Medicine (TCM), using chi-square and correspondence analysis.. There were 2,660 individuals in the study, 600 of whom were gentle types. The study identifies important combinations between illness states and medication formulations that offer encouraging rates of recovery.

The main factors that contributed to vehicle-pedestrian crashes in rural Chennai, Tamilnadu, India were identified by Natarajan *et al*. (2020) using Multiple Correspondences Analysis (MCA). These factors included the type of collision, the reason for the accident, junction control, pedestrian age, lighting conditions, location, behaviour, crossings, and physical separation.

Methodology

This research is a quantitative research design using secondary data to examine the relationship and association between various categories of demographic indicators and TB Status. The secondary data was acquired from the Johns Hopkins Programme for International Education in Gynaecology and Obstetrics (JHPIEGO), a non-governmental organisation operating in Taraba State. The study employed multiple correspondence analysis to examine the relationships and associations among individuals living with HIV/AIDS in Taraba State. The information includes the gender (male, female), age group (0-9 ,10-19, 20-29 ,30-39, 40-49, 50-59, 60-69, 70+), marital status (Single, Married, Divorced, Widowed, or Separated), tuberculosis status (Completed TB Treatment, Currently on TB Treatment, Currently on TPT, No sign or symptom of TB, TB Positive Not on Drugs, TB Positive Not on Drugs), and local government region (which are Ardo Kola, Bali, Donga, Gashaka, Gassol, Ibi, Jalingo, Karim Lamido, Kurmi, Lau, Sardauna, Takum, Wukari, Yorro, and Zing) of individuals living with HIV/AIDS in Taraba State's local governments.

Study population

Secondary data was obtained from the non-governmental organisation, Johns Hopkins Programme for International Education in Gynaecology and Obstetrics (JHPIEGO), which is based in Taraba State, Nigeria. The study focuses on persons who are living with HIV/AIDS as at 2023 with a population of 68,527 individuals

Patterns of Inter dependence

An expansion of principal component analysis (PCA), the multiple correspondence analysis (MCA) enables the examination of the patterns and correlations among multiple categorical independent variables. By positioning each variable or unit of analysis as a point in a low-dimensional space, it is an extension of principal component analysis for analysing categorical variables to clearly expose patterns of correlations in large data sets using geometrical methods. use n observations to measure categorical variables. Once the various values for variable j are denoted by q_j, define a matrix G_j, which is equal to $n \times q_j$. An indication matrix is the matrix G. The total of q_j for matrix G is achieved by concatenating the $G_j's$.

Weighted Chi-square Distance (S)

To determine the relationship between (individuals in Taraba State) row i and column (variable categories p), the chi-Square test of independence (S) was employed. The following relation was used to get the weighted chi-square distances.

$$S = D_r^{-\frac{1}{2}}(p - rc^{\tau})D_c^{-\frac{1}{2}} \quad (1)$$

In doing so, the observed and expected values are compared. With $(I-1)(p-1)$ degree of freedom, the chi-square represents the relative frequency matrix. The chi-square distance (S), a gauge of the degree of correlation between the row and column variables, is obtained in this way. In this context, Standardised Residual $(S_{i,p})$ is also used.

Singular Value Decomposition (SVD)

The SVD restructures the high-dimensional variable data into a lower-dimensional data space without surrendering any information, based on the transformation of the correlated and uncorrelated variables. If k is the smallest number of dimensions to which the data may be reduced, its value can be obtained using the following expression:

$$K = min(I-1,\ p-1) \quad (2)$$

The matrix S is split up or factorised into three matrices, $U, V\ and\ E$, using singular value decomposition (Greenacre, 2017).

$$S = UD_{\alpha}V^{T}, where\ U^{T}U = V^{T}V = I \quad (3)$$

Contributions in Multiple Correspondence Analysis

The row j contribution to factor ι and the column j contribution to factor ι are ascertained, respectively:

$$t_{j,l} = \frac{f_{j,l}^2}{\lambda_e}\ and\ t_{j,l} = \frac{g_{j,l}^2}{\lambda_e} \quad (4)$$

The amount that a category contributes to the variability seen along a given dimension is reflected in its contribution to that dimension. After that, the MCA maps both factors and individuals, making it possible to create intricate visual maps with interpretable structuring.

Results and Discussions

Table 1 displays the test results for the percentage of people living with HIV/AIDS in Taraba State that were obtained using Chi-square analysis to determine the significance of the relationship between the variables.

Table 1: Results and Test Statistics for the Proportion of Person's Living With HIV/AIDS in Taraba State Using Chi-Square Test

Variables	Degrees of Freedom	Chi-Square Value	P-Value
LGA	14	30071	2.20E-16
Marital Status	4	78479	2.20E-16
TB Status At Last Visit	5	158377	2.20E-16
Age Group	7	65216	2.20E-16
Gender	1	9531.4	2.20E-16

Source: Taraba State *JHPIEGO (2023)*

Table 1 presents the test findings for the variables that were examined at the 0.05 level of significance, depending on their relative degrees of freedom. Based on the available data, it can be concluded that there is a substantial correlation between the demographic characteristics. In

Taraba State, the following variables have an impact on people living with HIV/AIDS: age group, gender, marital status, local government area, and tuberculosis status.

Table 2: Inertia Values for Top 33 Dimensions

	eigenvalue	Percentage of Variance	Cummulative Percentage of Variance
dim 1	0.439	6.645	6.645
dim 2	0.302	4.572	11.216
dim 3	0.527	3.895	15.111
dim 4	0.246	3.728	18.840
dim 5	0.238	3.612	22.451
dim 6	0.237	3.594	26.045
dim 7	0.220	3.331	29.377
dim 8	0.217	3.290	32.667
dim 9	0.214	3.236	35.903
dim 10	0.208	3.154	39.056
dim 11	0.206	3.122	42.178
dim 12	0.205	3.109	45.287
dim 13	0.203	3.080	48.367
dim 14	0.202	3.053	51.420
dim 15	0.201	3.050	54.469
dim 16	0.201	3.040	57.510
dim 17	0.200	3.031	60.541
dim 18	0.199	3.018	63.558
dim 19	0.199	3.012	66.571
dim 20	0.199	3.010	69.580
dim 21	0.195	2.950	72.530
dim 22	0.194	2.946	75.476
dim 23	0.194	2.935	78.411
dim 24	0.192	2.904	81.315
dim 25	0.185	2.799	84.113
dim 26	0.183	2.776	86.889
dim 27	0.174	2.639	89.528
dim 28	0.158	2.395	91.922
dim 29	0.156	2.363	94.285
dim 30	0.135	2.046	96.331
dim 31	0.106	1.604	97.934
dim 32	0.091	1.386	99.320
dim 33	0.045	0.680	100.000

Source: Taraba State *JHPIEGO (2023)*

According to Table 2, the variables with the highest values contribute the most to the importance of each dimension, with each dimension accounting for a different percentage of the overall variance. With the highest eigenvalue, Dimension 1 explains 6.645% of the variance in Taraba State's HIV/AIDS patient population. Significant diversity is captured by the first few dimensions, which makes them crucial to comprehending the intricate relationships between the variables and HIV/AIDS.

Table 3: Contribution of Key Variable Levels to the Factors

	Contibution 1	Contibution 2
Ardo Kola	0.5280	0.0400
Bali	0.1230	0.0680
Gassol	32.1120	0.5690
Ibi	0.6920	0.8590
Jalingo	1.4770	1.2310
Karim Lamido	0.1810	0.1200
Kurmi	0.6390	3.0340
Lau	0.0340	0.0670
Sarduana	0.4100	2.3000
Takum	0.0660	0.1630
Wukari	1.0540	1.0650
Yorro	0.2190	0.9020
Zing	0.0200	0.3390
Divorced	2.2580	0.8030
Married Separated	1.9650	11.1020
Separated	27.0500	0.0950
Single	1.3980	30.9130
Widowed	0.0002	2.5510
Completed TB Treatment	0.0270	0.0520
Currently on TB Treatment	0.0140	0.0002
Currently on TPT	0.5520	1.7300
No Sign or Symptoms of TB	5.1660	0.0180
Not Tested for TB	22.0530	0.2760
Presumtive TB	0.0760	0.0960
TB+ Not on Drugs	0.0150	0.0030
TB+ Not on TB Drugs	0.0250	0.0030
00 - 09	0.1110	10.9860
10 - 19.	0.1020	12.7900
20 - 29	0.6880	5.3440
30 - 39	0.0680	0.2300
40 - 49	0.3350	3.5670
50 - 59	0.0500	5.2640
60 - 69	0.0170	2.4970
70+	0.0010	0.5940
Male	0.0020	0.0100
Female	0.0040	0.0220

Source: Taraba State *JHPIEGO (2023)*

Table 3 shows that the main causes of HIV/AIDS prevalence in Taraba State are; those who have not had a TB test, people who are separated, and the Gassol Local Government Area, with respective percentages of 32.12%, 27.05%, and 22.06%. The fact that 30.913% of people in dimension 2 are classified as "singles" emphasises the significance of marital status in understanding HIV/AIDS dynamics. There is a significant correlation between age and the prevalence of HIV/AIDS, with age groups 10 to 19 contributing 12.79% and 00 to 09

contributing 10.99%. In Taraba State, the prevalence of HIV/AIDS is significantly influenced by marital status.

Table 4: Quality of Contribution to HIV/AIDS in Taraba State (squared cosine (cos^2))

	Cos^2_1	Cos^2_2
Ardo Kola	0.0120	0.0010
Bali	0.0030	0.0010
Donga	0.0100	0.0030
Gashaka	0.0010	0.0000
Gassol	0.7990	0.0100
Ibi	0.0160	0.0140
Jalingo	0.0390	0.0220
Karim Lamido	0.0040	0.0020
Kurmi	0.0150	0.0480
Lau	0.0010	0.0010
Sarduana	0.0100	0.0390
Takum	0.0020	0.0030
Wukari	0.0260	0.0180
Yorro	0.0050	0.0140
Zing	0.0005	0.0060
Divorced	0.0510	-0.0120
Married Separated	0.1050	0.4070
Separated	0.6450	0.0020
Single	0.0420	0.6410
Widowed	0,0000	0.0400
Completed TB Treatment	0.0010	0.0010
Currently on TB Treatment	0.0003	0.0000
Currently on TPT	0.0130	0.0280
No Sign or Symptoms of TB	0.3870	0.0010
Not Tested for TB	0.6120	0.0050
Presumtive TB	0.0020	0.0010
TB+ Not on Drugs	0.0003	0.0000
TB+ Not on TB Drugs	0.0010	0.0000
00 - 09	0.0030	0.1710
10 - 19.	0.0020	0.2000
20 - 29	0.0190	0.1010
30 - 39	0.0020	0.0050
40 - 49	0.0100	0.0700
50 - 59	0.0010	0.0880
60 - 69	0.0004	0.0390
70+	0.0000	0.0110
Male	0.0001	0.0005
Female	0.0001	0.0005

Source: Taraba State *JHPIEGO (2023)*

Table 4 shows that Taraba State's HIV/AIDS prevalence is well-represented and instructive in the Gassol Local Government Area. The area's features are crucial in determining how the

observed variability is shaped. Separated people and those who haven't had a tuberculosis test have a big part in the patterns that are shown. In addition, the squared cosine of Singles provides valuable insights into dimension 2, emphasising the significance of comprehending the dynamics of HIV/AIDS in Taraba State.

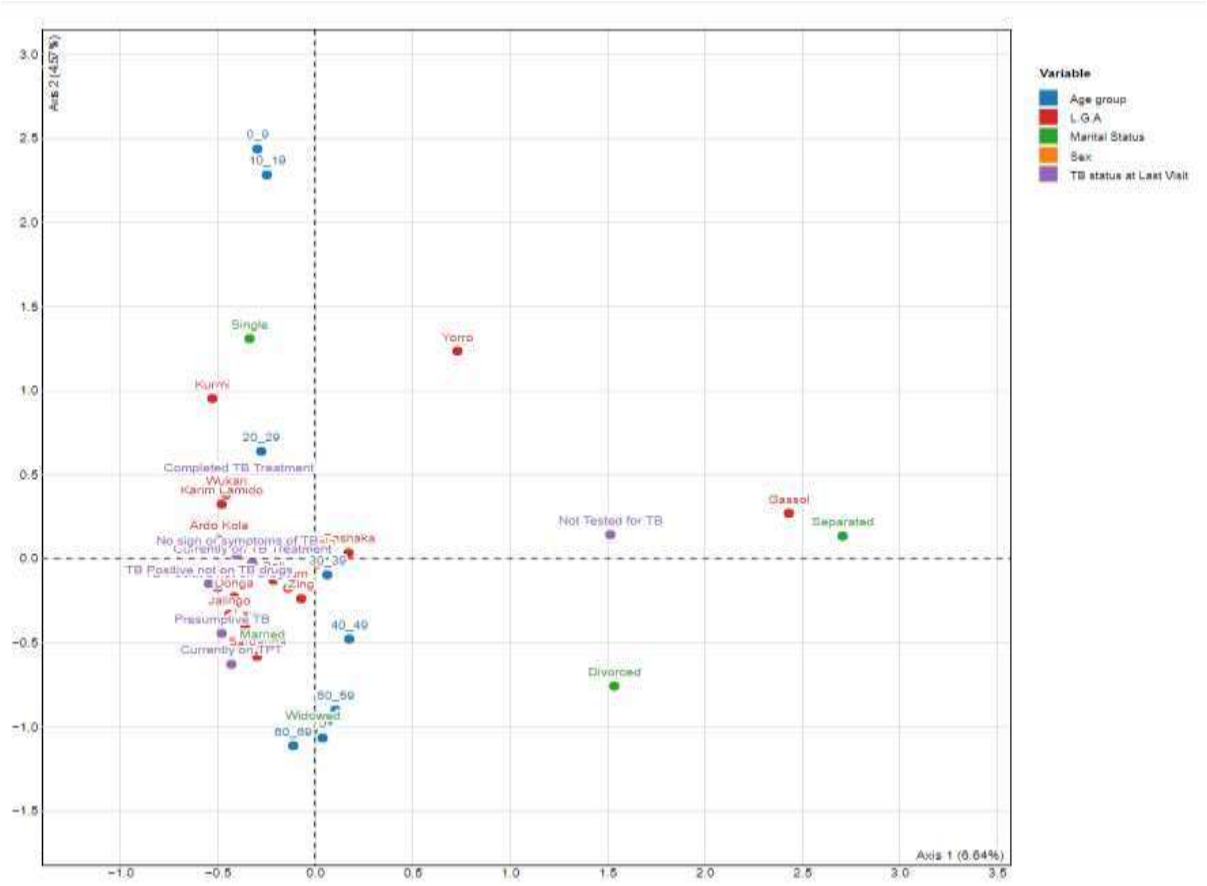

Figure. 1: Biplot of Multiple Correspondence analysis of L.G.A, Marital Status, TB Status and Age Group

Fig. 1 shows a clear relationship between; separated individuals, the Gassol local government, and those who have not had a TB test. These populations are at higher risk, which suggests that they have a significant influence on the HIV/AIDS transmission patterns in Taraba State.

Table 5: Significance of Key Categories on the First Plane

	Estimate	P-Value
Not Tested For TB	1.1320	0.0000
Separated	1.3130	0.0000
Divorced	0.5370	0.0000
Gassol	1.6570	0.0000
40 - 49	0.1620	1.08E-145
Yorro	0.5300	2.86E-74
30 - 39	0.0870	5.07E-37
50 - 59	0.1150	5.96E-20
Gashaka	0.1600	4.09E-11
Male	0.0078	4.41E-03
Female	-0.0078	4.41E-03
Currently on TB Treatment	-0.0850	6.31E-06
TB Positive Not On Drugs	-0.2020	1.74E-06
60 - 69	-0.0290	2.59E-07
Zing	-0.0010	9.36E-09
TB Positive Not On TB Drugs	-0.2320	8.91E-10
Completed TB Treatment	-0.1310	2.46E-10
Lau	-0.1910	5.41E-13
Takum	-0.0440	2.14E-25
Presumptive TB	-0.1890	8.90E-27
10 - 19.	-0.1180	1.58E-36
00 - 09	-0.1510	2.32E-39
Bali	-0.0950	8.84E-45
Karim Lamido	-0.2710	2.34E-62
Sarduana	-0.1500	5.83E-152
Donga	-0.2290	4.97E-155
Ardo Kola	-0.2800	1.79E-184
Currently On TPT	-0.1560	3.52E-196
Kurmi	-0.3030	1.87E-223
Ibi	-0.2790	2.16E-245
20 - 29	-0.1380	2.36E-285
No Sign Of TB	-0.1370	0.0000
Single	-0.7030	0.0000
Marrued	-0.6600	0.0000
Wukari	-0.2560	0.0000
Jalingo	-0.2450	0.0000

Source: Taraba State *JHPIEGO (2023)*

Table 5 sheds light on the "Significance of Key Categories on the First Plane," highlighting important factors affecting Taraba State's HIV/AIDS prevalence. The analysis identifies the disease-related variables that are statistically significant. Notably, those who have never had a TB test have a high positive estimate, highlighting the significance of TB testing in the treatment of HIV/AIDS. One notable contributing factor is marital status; those who are separated show higher estimations, indicating a possible association between relationship status and HIV/AIDS prevalence. The significance of the Local Government Areas (LGAs) varies, and Gassol LGA has a very high positive estimate, which suggests a higher prevalence.

On the other hand, LGAs with negative estimations, such as Kurmi, Ibi, and Ardo Kola, may have a lower prevalence.

The 40 – 49 age group shows a positive estimate, whereas the 60 – 69 age group shows a negative estimate. Age groupings also have a significant influence. According to gender-specific estimations, males are less likely to be affected, with men exhibiting a positive estimate. Certain TB statuses, such as being TB positive and not taking medications, or being on TB treatment at the moment, show negative estimations, suggesting possible preventive benefits against HIV/AIDS.

Table 6: Significance of Key Categories on Second Plane

	Estimate	P-Value
20 - 29	0.2340	0.0000
10 - 19.	1.1370	0.0000
00 - 09	1.2210	0.0000
Single	0.8140	0.0000
Kurmi	0.4620	0.0000
Wukari	0.1480	0.0000
Ibi	0.1880	0.0000
Yorro	0.6170	0.0000
Gossol	0.0870	0.0000
Not Tested For TB	0.1330	0.0000
Karim Lamido	0.1170	0.0000
Separated	0.1690	0.0000
No Signs Of Symptoms Of TB	0.0670	0.0000
Completed TB Treatment	0.3050	0.0000
Ardo Kola	0.0010	0.0000
Female	0.0130	0.0000
Male	-0.0130	0.0000
Lau	-0.2870	0.0000
Bali	-0.1320	0.0000
Presumptive TB	-0.1890	0.0000
Takum	-0.1580	0.0000
Donga	-0.1860	0.0000
30 - 39	-0.1700	0.0000
Zing	-0.1920	0.0000
70+	-0.7030	0.0000
Divorced	-0.3220	0.0000
60 - 69	-0.7280	0.0000
50 - 59	-0.6120	0.0000
40 - 49	-0.3800	0.0000
Currently On TPT	-0.2900	0.0000
Widowed	-0.4650	0.0000
Married	-0.1970	0.0000
Sarduana	-0.3800	0.0000
Jalingo	-0.2430	0.0000

Source: Taraba State *JHPIEGO (2023)*

Table 6: "Significance of Key Categories on the Second Plane" offers important information about the variables affecting Taraba State's HIV/AIDS prevalence. Interestingly, some age groups; 10 – 19 and 20 – 29 show notably favourable estimations, suggesting a considerable

influence on the disease's prevalence. One relevant element that comes to light is marital status, with single people showing a higher incidence. Some Local Government Areas (LGAs) that contribute significantly to the patterns that have been identified are Kurmi, Wukari, Ibi, and Yorro. Furthermore, TB status categories; not tested for tuberculosis, completed tuberculosis treatment, and presumed tuberculosis are linked to higher estimations, highlighting their significance in comprehending the dynamics of HIV/AIDS in the area. Furthermore, estimations based on gender point to a marginally higher frequency in women. The statistical significance of these correlations is supported by the continuously low p-values in every category.

Conclusion and Recommendation(s)

Vital information about the connections and relationships between several demographic characteristics, such as local government areas, married status, age group, gender, and TB status of people living with HIV/AIDS, is provided by the analysed HIV/AIDS data for Taraba State. The correlations and associations show which groups of people in Taraba State have a propensity to affect the disease's transmission as well as the most likely locations with high rates of HIV/AIDS prevalence. The findings provide important new information on the factors behind Taraba State's high rate of HIV/AIDS. With 32.12%, Gassol Local Government Area stands out as the main donor. This suggests that the traits linked to Gassol account for a significant amount of the total diversity in HIV/AIDS prevalence.

People who are labelled as "separated" had an impressive contribution of 27.05% after Gassol. This implies that there is a direct correlation between Taraba State's HIV/AIDS prevalence and the separated status. Additionally, a substantial portion of the observed variability, 22.06 %, is attributed to individuals who have not had a tuberculosis (TB) test. The second-most significant piece of information is captured by Dimension 2, which also identifies the main causes of the variation in HIV/AIDS prevalence that is seen. In dimension 2, those classified as "singles" are the most common donors, accounting for 30.913% of the total group. This significant representation suggests that factors related to the "singles" category account for a significant amount of the variation in HIV/AIDS prevalence.

This result emphasises how crucial marital status is to comprehending the dynamics of HIV/AIDS in Taraba State's population. The people who are in the age range of "10 - 19" come in second, contributing a significant 12.79% to dimension 2. This is a correlation between the incidence of HIV/AIDS in Taraba State and this particular age group. The identification of age-related trends adds to our understanding of the complex dynamics of HIV/AIDS.

In light of the above study, the findings provide valuable insights into the demographic factors associated with HIV/AIDS prevalence in Taraba State, Nigeria. To address the unique challenges faced by individuals living with HIV/AIDS in this region, it is recommended to scale up HIV/AIDS prevention and treatment interventions based on the identified demographic factors in Gassol Local Government Area (L.G.A.) and Jalingo L.G.A., and to enhance routine tuberculosis screening programs for individuals living with HIV/AIDS. These recommendations aim to guide healthcare practitioners, policymakers, and researchers in developing targeted and effective interventions, as well as facilitating resource allocation to better serve this vulnerable population.

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