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Immunological and Virological Outcomes Among People Living with HIV1 and HIV2 subtypes on HIV1-antiretroviral Treatment in Njombe and Dar Es salaam region, Tanzania: A Hospital Based Retrospective Cross-Sectional Study

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Abstract:

Human immunodeficient Virus type one (HIV-1) and type two (HIV-2) are the two known global HIV types that result in HIV-1+2 dual infection. Despite the proof of HIV-2 and dual infection in Tanzania, the HIV-1 Antiretroviral Therapy (ART) regimen is the only drug used for treatment of both HIV types. This study aimed to determine the virological and immunological response to ART treatment based on the HIV subtypes among the HIV patients who are on HIV-1 ART regimen at the HIV Care and Treatment Center (HCTC) in Njombe and Dar es Salaam, Tanzania.

A retrospective cross-sectional study was conducted from January 2020 to December 2021 among 300 HIV patients who were on HIV-1 ART treatment from 2017 to 2021. HIV rapid tests were used to determine the prevalence of HIV subtypes, and FACS and M-PIMATMHIV-1/2 VL were used to determine CD4 T-Cells count and viral loads copies, respectively. Prevalence of HIV subtypes was estimated, and linear regression, an odds ratio (OR), 95% with confidence intervals (CIs), and a p-value ≤0.001 were used to determine the association between HIV subtypes and CD4 and viral load responses.

The study recruited 140 (46.7%) men and 160 (53.3%) women. Females had a higher proportion of HIV-1, HIV-2 and HIV1+2 dual infections compared to men. The median (IQR) CD4 count in HIV-1 was 252 (149-497) cells/ml with

viral load of 8.21 (3.3) log10 copies/ml compared to HIV-2 with 133 (86-321) cells/mL with viral load of l9.26 (3.4) log10 copies/ml and HIV 1+2 dual infection with CD4 count 210 (140-362) cells/mL with viral load of 8.7 (3.6) log10 copies/participants with HIV-1 subtype had higher CD4+ T cell counts and lower plasma RNA viral loads compared to individual with HIV-2 and or dual infections. This study shows poor immunological and virological outcomes for HIV-2 and dual infection HIV participants as indicated by low CD4 count and high viral load copies during the course of treatment. Therefore, new and safe ART regimens for HIV-2 and dual infections are needed.

Index Terms –
HIV-1, HIV-2, HIV 1+2 Dual Infection, Regimen, Antirétroviral therapy

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1.0.INTRODUCTION

The Human Immunodeficiency Virus (HIV) remains a leading cause of morbidity and mortality worldwide, especially in Sub-Saharan Africa. In 2018, UNAIDS estimated that there were nearly 40 million people living with HIV/ AIDS worldwide, whereby two - thirds come from sub-Saharan African countries [1]. Tanzania, with a general prevalence of 4.7%, has 1.7 million people living with HIV and reported 72, 000 new cases of HIV infections annually [2,3].

HIV-1 and HIV-2 are globally known HIV types that result in HIV1+2 dual infection for people infected with both types. HIV-1 is globally widespread compared to HIV-2, which is endemic in France, Europe, India in Asia, St. Francisco in the United States of America and Cape Verde, Gambia, Cote D'Ivoire, Guinea-Bissau and Angola in West Africa [4-7]. Current studies report the spread of HIV-2 to other parts of the world due to migrations, intermarriage and other social and economic factors [8]. In 2018, UNAIDS reported that out of 40 million people living with HIV, two million were infected with HIV-2, [9-11]. From I982 where the first case of HIV was discovered, Tanzania has been dominated by HIV-1. Like other areas, Tanzania consists of a few cases of HIV-2 and HIV 1+2 dual infection. The pre-study survey conducted in HIV Voluntary Counseling and Test (VCT) in Arusha, Dar es salaam and Kilimanjaro health facilities showed the existence of 5 to 10 HIV-2 and HIV1+2 dual infection positive results per annually [12]. Due to rare infections of HIV-2 and HIV 1+2 dual infections, there is an unawareness of clinicians and HIV implementers, including police makers, on specific management of the HIV-2 and HIV 1+2 dual for people living with HIV+2. Despite evidence of existing HIV-2 and HIV 1+2 dual infection, Tanzania has not yet initiated treatment for HIV-2-infected patients. Instead, both HIV- 2 and HIV- 1+2 HIV patients are treated with an HIV-1 ART regimen which is available [13]. The lack of HIV-2 and HIV 1+2 dual infection studies in Tanzania creates limited information about the impacts of the HIV-1 ART treatment regimen on the HIV -2 and HIV 1+2 dual infection, including drug resistance and treatment failure [14-17]

Therefore, this study aimed to determine the treatment outcomes and clinical characteristics of HIV patients with HIV-1, HIV-2 and HIV 1+2 dual Infections who are on an HIV-1 ART regimen at HIV Care and Treatment Centers (HCTC). Njombe and Dar es salaam region, Tanzania.

2.0. NEED OF THE STUDY.

In the global AIDS pandemic, HIV-1 infection is more common than HIV-2. Studies from HIV-2 endemic countries have revealed differences in the immunological and virological effects among PLHIV infected with HIV-1, HIV-2, or HIV-1/HIV-2 co-infections. Tanzania lacks information on the prevalence and immunological and virological effects of these HIV types, despite evidence of existing HIV-2 and HIV 1+2 dual infection brought about by HIV-2 migrants from the endemic area. Tanzania has not yet started treating patients who are HIV-2 positive. Instead, an HIV-1 ART regimen is used to treat both HIV- 2 and HIV- 1+2 patients [13]. The study's results provide information on the prevalence of HIV-1 and HIV-2 in the nation as well as immunologic and virological data, possibly for the first time. Also, the results will help the health policymakers to plan for initiation of the HIV-2 ART regimen for treatment of the hiv-2 and HIV 1+2 dual infections for purpose of improvement of their treatments.

3.0.RESEARCH METHODOLOGY

3.1Population and Sample

3.1.1,Study Area

Eight hospital facilities with HIV Care and Treatment Centers (HCTC) located in Dar es Salaam and Njombe regions, Tanzania served as study sites from January through December 2021. Dar es Salaam region with a population of 5 million people [18] and an HIV prevalence of 6.9% [19] is found in the eastern part of Tanzania, and was chosen because of its substantial likelihood of contracting, with HIV-1, HIV-2, or HIV1+2 dual infections from foreign migrants who come for residence, business, and other economic activities as it is among the east African business city. The choice of Njombe region with a population of 702,097 [18] has the highest HIV prevalence in Tanzania (14.8%) [19], which resulted from international trade activities and having the stopping center for large heavy truck cars that transport goods and commodities from Dar es Salaam Port to west and Southern African countries. Therefore, the probability of contracting HIV-1, HIV-2, or HIV-1+2 dual infections is high.

3.1.2.Study Design and Population

This was a hospital-based quantitative retrospective cross-sectional study that was conducted from January 2021 to December 2021 on HIV patients who were on ART treatment from 2016 to 2019. Eligible participants were HIV- patients 18 years old and above

and have at least four CD4 count measurements and Viral load test results from when they started on ART treatment. The study excludes those who were referred to other HCTC and those who did not sign informed consent.

3.1.3. Sample Size and Sampling Techniques

In this study, a multi-stage sampling strategy was employed. Using a precise formula for calculating sample size, a total sample of 300 HIV- patients who were on ART treatment from 2017 to 2019 and had at least four CD4 and viral load test results were randomly selected from their patients' files. A ratio of 1:1 was used to obtain 150 participants from each region of the study. A purposive sampling was used to select eight health facilities from the two districts in the selected regions.

3.2 Data and Sources of Data

Questionnaires were used to conduct an interview with participants and collection of data on the sociodemographic (age, marital status, level of education, employment, occupation). A 20 µl whole blood sample was drawn from the HIV patients and retained in an EDTI tube for determination of HIV subtypes, current levels of CD4 and viral load. 1.5µl blood samples were pipetted and placed at SD-Bioline™ (Allere Medical Company) as initial HIV rapid Test and their results were confirmed by Determine ™ (Trinity Plc. Ireland) HIV rapid test for determination of the HIV subtypes of the participant. For determination of the current CD4 count, the 1.5µl blood sample was pipetted and placed at CD4 test (FACS, Becton Dickinson and Company Australia) and for viral load, 1.5µl was pipetted and placed at viral test (M-PIMATMHIV-1/2VL). In addition, baseline and three CD4 and viral load laboratory results were taken from the patients' files from when participants started ART treatment. All findings were recorded in the laboratory extraction form for analysis

3.4, Statistical tools , Data Analysis and Interpretation

The Statistical Package for Social Sciences Software (SPSS) version 26.0 was used to enter and analyze the collected data. The prevalence, mean, mode, and median were summarized using a percentage with their respective dispersion. The chi-square test and continuing variables were used to examine differences between categorical groups, such as sex and age. An Odds ratio (OR), 95% confidence intervals (CIs), and p-value ≤0.001 were used to determine the association between HIV subtypes and CD4 and Viral Load. Logistic regression models and social demographic measures were done. Linear regression mixed models with auto-correlated errors were used for longitudinal data to correct for non-normality; plasma HIV RNA data were log-transformed (base 10), when levels were detectable, or set to 0, when levels were undetectable. The natural logarithms of the CD4+ T lymphocyte counts were used to normalize error terms.

3.5.Ethical Consideration

The ethical clearance and letter of permission to conduct the study were sought from KNCHREC and Regional Medical Officers (RMO) of the Dares Salaam and Njombe regions. Written informed consent was provided to those who agreed to participate. For purposes of maintaining confidentiality, the unique identification number was assigned to each participant in questionnaires and the laboratory extract form.

4.0. RESULTS AND DISCUSSION

4.1. Results of Descriptive Statics of Study Variables

4.1.1.Social Demographic of the Participants

Out of 300 HIV-patients who were recruited for the study, 150 (50%) were from Njombe, while another 150 (50%) were from Dar es Salaam. On sex based the study recruited participants, more female 160 (53.3%) compared to the 140 (46.7%) for both types of HIV subtypes . The mean age of the participants was 32.0 years, with standard deviation of 5 ± 0.24. For both HIV subtypes more participants had primary education 163 (54.3) and few of them 15 (5.0) had either college or university education. More participants were single 98 (32.7) followed by those who are married 92 (30.7) and divorced 62 (20.7) ***See Table 1 below:***

Table 1. Social demographic characteristics of the participant

Variables	HIV-1	HIV-2	HIV1/2	Total
N (%)	N (%)	N (%)	N (%)	n(%)
Age				
11-25 years	43 (20.8)	12 (27.3)	10 (20.4)	65 (21.7)
26-40 years	62 (30.0)	16 (36.4)	19 (38.8)	97 (32.3)
41-55 years	83 (40.1)	14 (31.8)	17 (34.7)	114 (38.0)
>55 years	19 (9.2)	2 (4.6)	3 (6.1)	24 (8.0)
Sex				
Male	97 (46.9)	19 (43.2)	24(49.0)	140 (46.7)
Female	110 (53.1)	25 (56.8)	25 (51.0)	160 (53.3)
Education level				
None	19 (9.2)	2 (4.6)	6 (12.2)	27 (9.0)
Primary	117 (56.5)	20 (45.5)	26 (53.1)	163 (54.3)
Secondary	61 (29.5)	19 (43.2)	15 (30.6)	95 (31.7)
College/University	10 (4.8)	3 (6.8)	2 (4.1)	15 (5.0)
Marital status				
Single	61 (29.5)	18 (40.9)	19 (38.8)	98 (32.7)
Married	68 (32.9)	8 (18.2)	16 (32.7)	92 (30.7)
Widow	29 (14.0)	7 (15.9)	6 (12.2)	42 (14.0)
Cohabited	5 (2.4)	1 (2.3)	0 (0)	6 (2.0)
Divorced	44 (21.3)	10 (22.7)	8 (16.3)	62 (20.7)
Income				
< 10,000	116 (56.0)	25 (56.8)	27 (55.1)	168 (56.0)
10,000-100,000	49 (23.7)	10 (22.7)	13 (26.5)	72 (24.0)
100000-500000	34 (16.4)	9 (20.5)	7 (14.3)	50 (16.7)
>500000	8 (3.9)	0 (0)	2 (4.10)	10 (3.3)
Occupation				
Employed	36 (17.4)	7 (15.9)	9 (18.4)	52 (17.3)
Self employed	123 (59.4)	21 (47.7)	26 (53.1)	170 (56.7)
Unemployed	48 (23.2)	16 (36.4)	14 (28.6)	78 (26.0)

4.1.2.Seroprevalence *of the HIV-1, HIV-2 and HIV-1+2 dual infections*

Out of the 300 samples that were examined, 207 (69%) had HIV-1 infection, 44 (15%) had HIV-2 infection, and 49 (16%) had HIV-1+2 infection (See figure 1). When the results stratified by the region, the prevalence of HIV-1 was higher in Dares Salaam 108 (72%), compared to Njombe 99 (66%) (p=0.26), the prevalence of HIV-2 was higher in Njombe 25(17%) compared to Dares Salaam 19(13 %), p=0.33 and the prevalence of HIV-1+2 was higher in Njombe region 26(17%) compared to Dar es Salaam 23(15%) p=0.64, however, the different was not significant **(see Figure 2**).

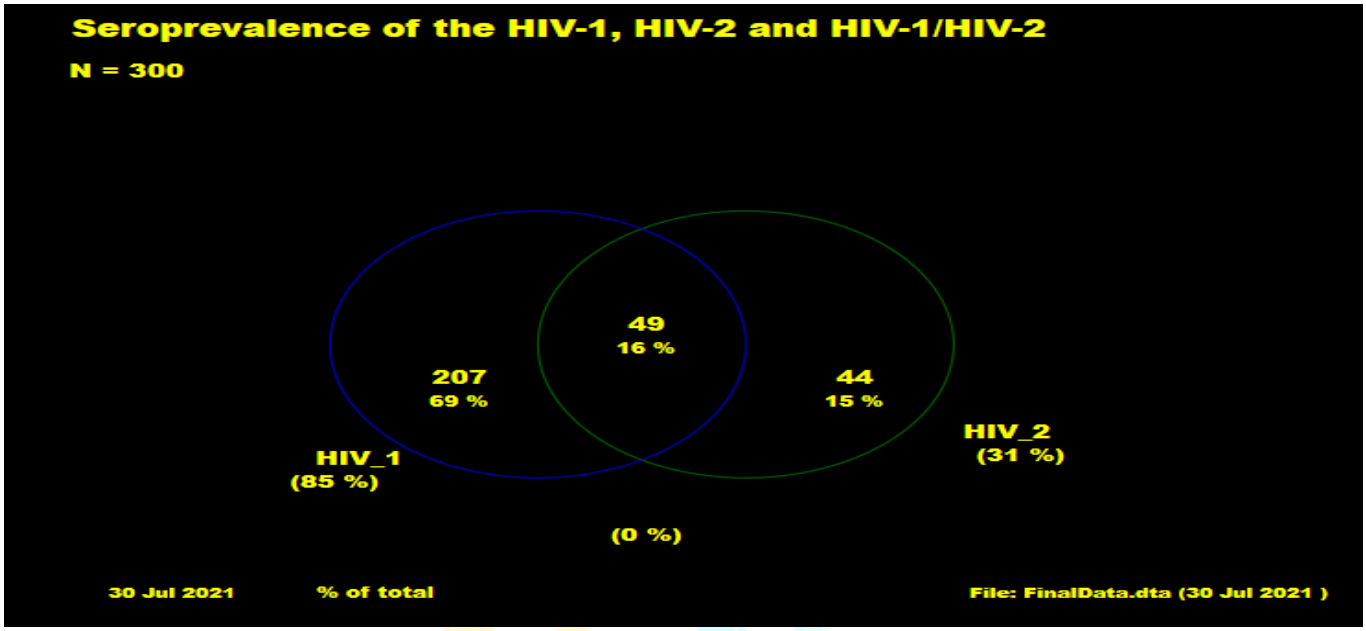

Figure 1: Overall Sero-Prevalence of the HIV-1, HIV-2 and HIV1+2 dual infections in Njombe and Dar-es-Salaam in Tanzania

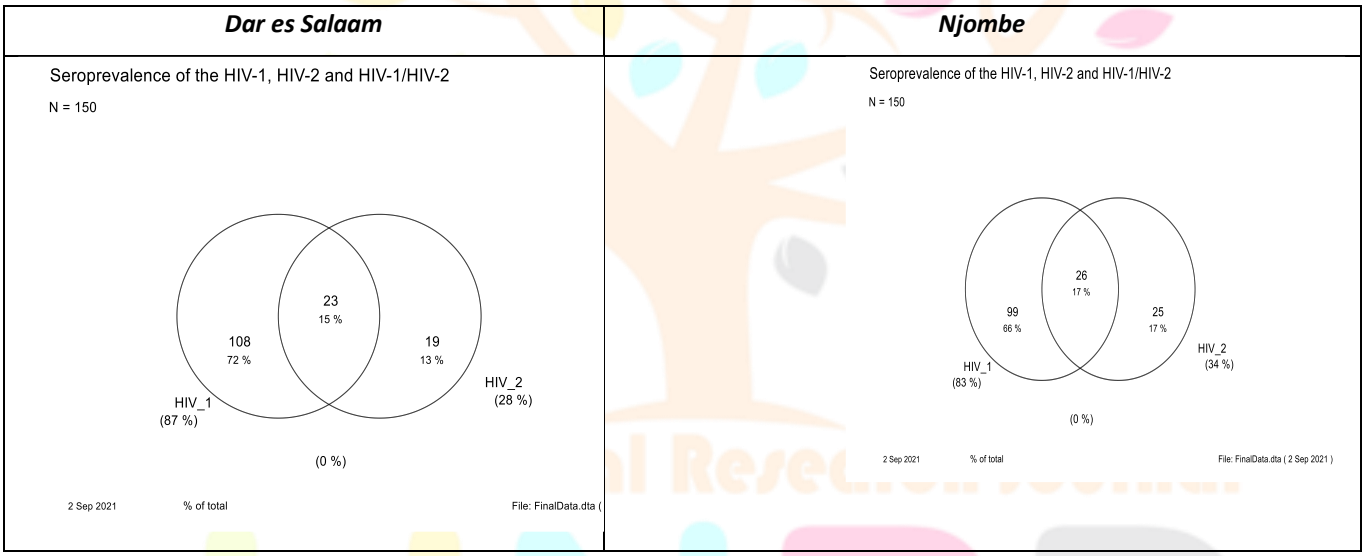

Figure 2: stratifying by region prevalence *in Njombe and Dares salaam regions in Tanzania*

4.1.3.Immunological and virological characteristics of study subjects infected with HIV-1, HIV-2 and HIV 1+2 dual infections.

The median (IQR) of the CD4+ T cell count at baseline among subjects with HIV-1 was 252 (149-497) cells/mL and the mean log10 plasma HIV RNA load was 8.21 (3.3) log10 copies/mL, compared with values of 133 (86-321) cells/mL and the mean log10 plasma HIV RNA load was 9.26 (3.4) log10 copies/mL among subjects with HIV-2 and lastly for those with HIV-1+2 dual infections it was 210 (140-362) cells/mL and the mean log10 plasma HIV RNA load was 8.7 (3.6) log10 copies/ml **(See Table 2)**

Table 2: Immunological and virological characteristics of study subjects infected with HIV-1, HIV-2 and HIV- 1/HIV-2 dual Infections

Characteristics	HIV-1	HIV-2	HIV12	P-value
CD4 cell count, cells/mL				
<350	133 (64.9)	36 (81.8)	36 (73.5)	0.07
>350	72 (35.1)	8 (18.2)	13 (26.5)	
Median (IQR)	252 (149-497)	133 (86-321)	210 (140-362)	0.02
Mean CD4 log_{10}	5.57 (1.2)	5.07 (0.9)	5.28 (0.9)	
VL, copies/mL				
<1000	72 (35.1)	10 (22.7)	16 (32.7)	0.28
>1000	133 (64.9)	34 (77.3)	33 (67.4)	
Median (IQR)	3650 (185-40000)	22010(6810-126205)	9784 (420-122111)	0.16
Mean VL log_{10}	8.21 (3.3)	9.26 (3.4)	8.7 (3.6)	

4.1.4.Immunological outcomes among the HIV Patients with HIV-1, HIV-2 and HIV- 1/HIV-2 dual Infection

Cross-sectional analysis of plasma RNA viral load vs. The CD4+ T cell count of patients with HIV-1, HIV-2 and HIV- 1+2 dual infections at baseline shows that subjects infected with HIV-1 presented with higher CD4+ T cell counts, and lower plasma RNA viral loads. Mean log10 plasma HIV RNA levels were greater in HIV-2–infected subjects than in HIV-1 infected subjects (9.26 (3.4) vs. 8.21 (3.3) log10 copies/mL, respectively. Among subjects with HIV-1 and subjects with HIV-2, lower CD4+ T cell counts were associated with higher levels of viral RNA. Persons infected with HIV-2 were found to have, on average, plasma RNA levels higher than those found in persons with HIV-1 who had similar CD4+ T cell counts. **(See figure 3)**

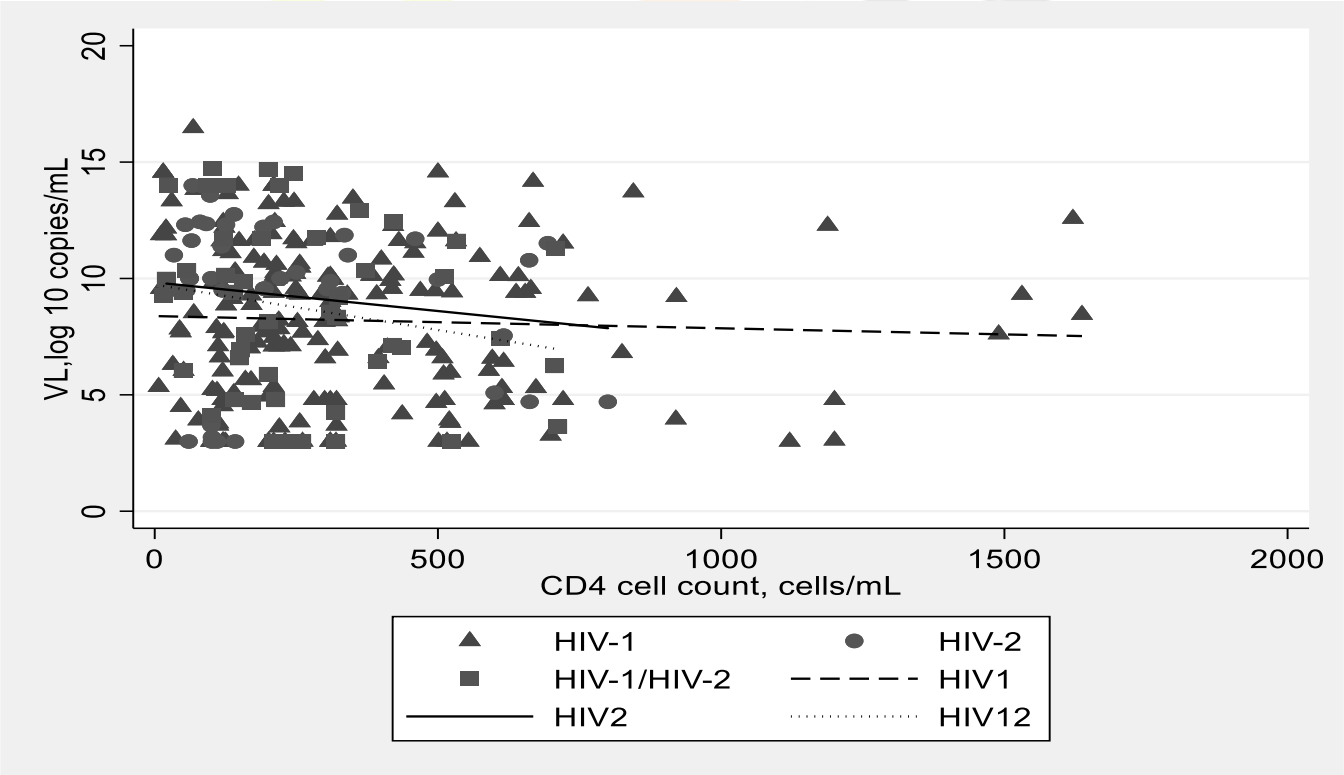

Figure 3. Correlation between plasma HIV RNA levels and CD4 count *in Njombe and Dares salaam region*

4.1.6.Pattern and rate of Change of CD4+ T- Cell and Viral load Copies over Time

The results showed the relationships between type of HIV infection (HIV-1, HIV-2 and HIV-12) and the rate of CD4+ T cells among the subjects who were seen on five occasions. From the base line to the fifth visit of the CD4 count, the results showed an increase in the CD4+ T cells among the HIV- 1 patients compared to the HIV -2 patients, which was shown to slowly increase. The lowest increase of the CD4+ T cell was shown for the HIV1+2 dual infection patient. The difference in CD4+ T cells can be explained by the slow response of the HIV- 1 ART regimen that HIV-2 and HIV 1+2 dual infection used **(See figure 4).**

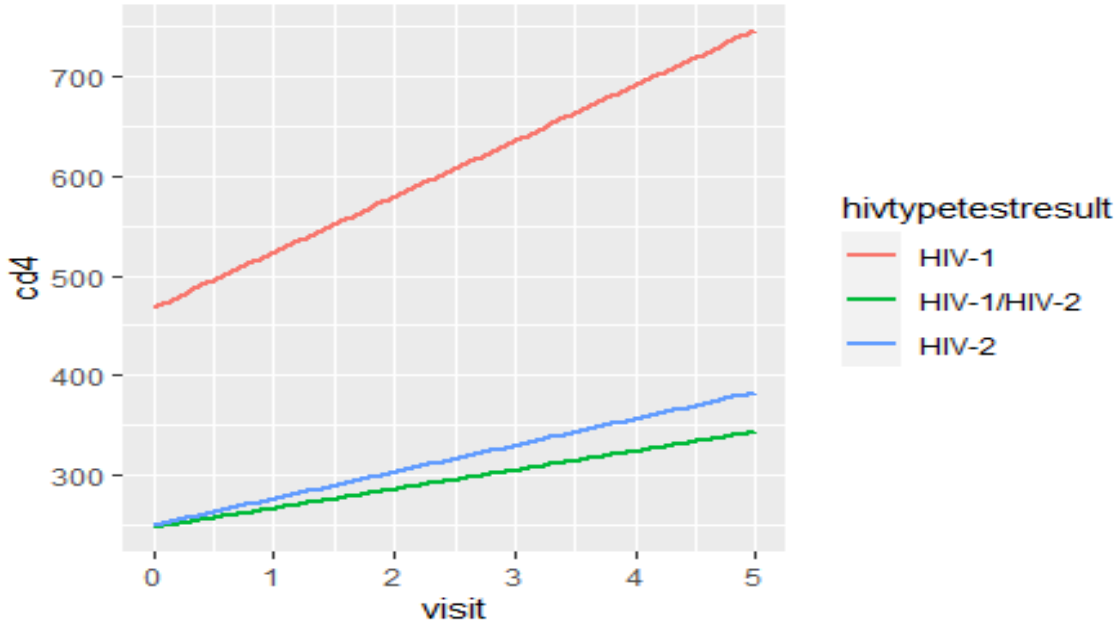

Figure 4: Pattern and rate of Change of CD4+ Cells over Time in *Njombe and Dares salaam region in Tanzania*

4.1.7. Pattern and rate of Change of Viral Load over Time

The results from the Linear regression mixed model showed the rate of decline in Viral Load over the first five tests post-seroconversion. It depends on the HIV subtype. The decline of the Viral Load was shown in the HIV -1 patients compared to the HIV-2 and HIV 1+2 dual infections. From the baseline to the fifth visits, the results showed high multiplication of the copies of Viral load to HIV-2 patients followed with HIV 1+2 dual infections increase of the viral load copies to HIV patients Infected with the HIV-2 and HIV 1+2 dual infection that can be explained by the slow response of the HIV- 1 ART regimen that HIV-2 and HIV 1+2 dual infection patients used for their treatment**. (See figure 5)**

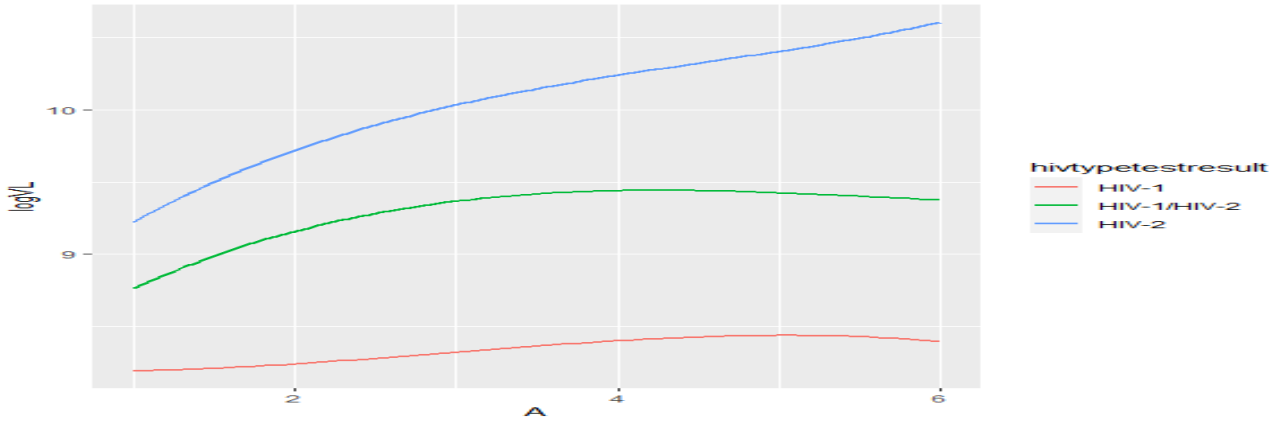

Figure 5: Pattern and rate of Change of VL over Time *based on HIV subtype in Njombe and Dares salaam region*

The table below presents estimates obtained from the model. The intercept shows that the mean Log VL at seroconversion among subjects with HIV-1 subtype was 8.01. Among subjects with the HIV-1 subtype, the mean VL increases by 0.1 per visit. It is 0.9 higher among patients with the HIV-1&2 subtype.

Table 6: The rate of decline in VL over the first five test post-seroconversion

logVL	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
hivtypetestresult						
HIV-2	1.705027	.5166475	3.30	0.001	.6924163	2.717637
HIV-1/HIV-2	.9225537	.4944698	1.87	0.062	-.0465893	1.891697
visit	.0908902	.0201274	4.52	0.000	.0514412	.1303393
_cons	8.014318	.22832	35.10	0.000	7.566819	8.461817

4.2**. Discussion**

The study observed the existence of the high prevalence both HIV-1, HIV-2 and HIV1&2 dual infections in Tanzania. The findings also shows poor immunological and virological response to HIV-1 ART for participants who had HIV-2 or HIV1&2 dual infection in Tanzania where only HIV-1 ART regimen are used for HIV treatments.

The observed slow responses in CD4 cell count increase and viral load decrease in HIV-2 and HIV-1&2 dual infection might be due to the use of HIV-1 treatment option without considering the specific HIV-2 treatment. May be this was a reason for poor treatment outcomes to HIV patients infected with HIV-2 and dual infection observed compared to those with HIV-1 [20-21]. The result observed is a consensus on the results of a study conducted by Thandiwe A et al. 2020 in Lusaka, Zambia 2020 that determined the seroprevalence, treatment outcomes and characteristics of HIV-1 and HIV-2 patients who were on an HIV-1 ART regimen with NNRTI combination [22]. Similarly, with a study that discovered the presence of HIV-2 (10.3%) and dual infection (12.2%) compared to HIV-1 (6,7%) that was not found prior to 2016[21]. The results from this study prove the existence of HIV-2 and dual infection in Tanzania. Thus, the adoption of the WHO HIV-2 and HIV 1+2 dual infection treatment regimen should be emphasized.

Also, this study observed differences in treatment outcomes and clinical impacts among the individual HIV patients infected with either HIV-1, HIV-2 or dual infections. The HIV-1 ART treatment regimen showed the effectiveness on treatment of the HIV patients infected with HIV-1 compared to those infected with either HIV-2 or dual infections. From the baseline when ART initiated the HIV patients to fifth visit of laboratory testes the study revealed low progress of increase of CD4 T cells count and higher multiplication of RNA viral copies HIV patients with HIV-2 and dual infections compared to those with HIV-1. In comparison with HIV-2 the lowest CD4+ T- cells count, highest viral load multiplication to HIV patients with HIV 1+2 dual infections. Similar results were observed in a cohort study conducted by Smith RA et al. 2019 in Senegal which revealed frequent of drug resistance and frequently occurrence of the opportunistic infection among the HIV -2 compared to HIV-1 poor [23]. Also, the study conducted by Thandiwe A et al. 2020 in Lusaka Zambia showed the persisting of the frequently OIs, drug resistance and low weight increase among the HIV-2 patients compared to those with HIV-1[21]. Evidence from the study implies that the HIV-1 ART regimen is the proper ART regimen for HIV-1 patients rather than HIV-2 and dual infections. Hence, the proper HIV treatment for HIV-2 and dual infection should be initiated to manage poor treatment outcomes of HIV-2 patients.

More than that, this study showed the statistical difference of CD4+ T cell counts between the HIV patients infected with HIV-1, HIV-2 and dual infection who were on an HIV1 ART treatment regimen (P=0.57). The mean number of CD4+ T cell counts were +72 cells/µl for HIV-1, 34.5 cells/µl for HIV-2 and 22.8 cells/µl for dual infection. The lower progress of CD4+ T cell counts in HIV patients with HIV-2 and dual infections predispose patients to drug resistance, occurrence of AIDS, and in the re-emerging of HIV Opportunistic Infections as a result of treatment failure. In Kenya researchers reported similar findings to our study whereby the median range for CD4+ T cell count increase were 210 cells/mm³ for HIV patients with HIV-1, 50 cells/mm³ for HIV patients with HIV-2 and 15.0 cells/mm³ for HIV patients with dual infections [19]. Another cohort study conducted in Ethiopia to compare the treatment outcome of the HIV 1- ART regimen reported 2-fold increase in the mean CD4+ T cell count to HIV patients with HIV -1 patients compared to those with HIV-2 and dual infections [20]. Another study reported mean CD4+ T cell count increase for 205 cells/mm for the HIV patients with HIV-1, 215 cells/mm³ and 96 cells/mm³ for the HIV patients with dual infections. [21]. These results emphasize the use of the HIV-2 regime for these, rather than the use of the HIV-1 ART regimen.

In RNA viral load multiplications, the study observed the statistical difference among the HIV patients infected with HIV-1, HIV-2 and dual infection. The mean viral load increase was log 0.9 for HIV patients with HIV-2 and log 1.7 for patients with HIV 1+2 dual infections and log 0.1 for patients with HIV-1. The highest increase of RNA viral load copies observed for HIV-2 and dual infections might be led to poor treatment outcomes and adverse events such as AIDS, HIV Opportunistic Infections and deaths. The observed results of RNA viral loads were similar to the results of a cohort study conducted by Alassan A. et al.(2018) in Bamako, Mali showed shown the higher prevalence of adverse events including death to the HIV patients infected with HIV-2 compared to HIV-1 due to RNA viral loads multiplication that caused by low increase of CD4 cell count between the HIV-2 AND HIV 1(139.93 vs 159.41 cells/mm3) [25]. Another study conducted in Guinea Bissau and Senegal in 2016 revealed that 40 per cent of the dually positive patients who started their HIV-1 ART regimen with the combinations of three nucleotide analogues of the reverse transcriptase have mean increase of the RNA viral of log 3.6 from the point of the initiation whereby those with HIV-2 have RNA viral of l0g 2.8 compared to those with HIV-1 with log 0.2. Over half of the HIV-1 individuals had a good immunological treatment outcome, which was different to those with HIV 2 and dual infection [26-28]. The result proves the HIV -1 ART regimen is not most effective for HIV patients who are infected with HIV-2 and dual infection due to slow virological and immunological responses which might lead to frequent occurrence of adverse events and poor treatment outcome.

5.0.Study limitation

The study was conducted within only two regions with high HIV prevalence and interaction in Tanzania which might not be the case in other regions in Tanzania. Also, the choice of variables included in the study was limited by the use of medical records. Therefore, some variables that may explain treatment outcomes according to HIV type were not collected. Despite these limitations, this study has brought to light interesting aspects that can help improve treatment options for HIV patients with HIV-2 and dual infections in order to provide better treatment outcomes for all HIV subtypes.

6.0.Conclusion and Recommendation

The study was able to identify the existence of HIV-2 and dual infection and poor treatment outcomes of the HIV patients infected with either HIV-2 or dual infection who were on an HIV-1 ART regimen. Decrease of the CD4+ T cell counts and increase of RNA viral load copies among the HIV-2 and dual infection proof the treatment failure of the HIV-1 ART regimen for the HIV patients infected with HIV-2 and their dual infections. Due to unique insights into the existence of existing HIV-2 and their dual infection there is a need for new and safe ART regimens for these HIV subtypes as recommended by WHO to improve the treatment outcomes and management. Lack of the awareness of HIV-2 and dual infections in HIV implementers resulted in a lack of evidence- based information regarding clinical impacts on HIV patients infected. Therefore, more research is needed to add information in order to support the intervention of management of HIV-2 and their dual infections.

.Disclosure

The authors declare no competing interests.

Authors' contributions

All the authors discussed the results and contributed to the critical review of the final manuscript. They have also read and approved the final manuscript.

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