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Exploring Determinants of Mortality among Adult PLHIV under ART at Meru Teaching and Referral Hospital, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

HIV remains a persistent global health challenge, affecting the immune system and leading to significant morbidity and mortality despite advancements in antiretroviral therapy (ART). The study investigated the covariates that correspond to determinants linked to increased mortality among PLHIV (people living with HIV/AIDS) under ART at Meru Teaching and Referral Hospital (MTRH) over a five-year period. This retrospective cohort study utilized secondary data from hospital records between 2018 and 2022, focusing on demographic, socio-economic, and clinical variables. A logistic regression analysis was carried out to identify covariates that correspond to determinants linked to increased mortality among HIV-positive patients. The age range varied significantly, with a smaller percentage falling into younger age groups: 6.7% aged 18-25 years and 10.0% aged 26-35 years. The majority were middle-aged, with 24.9% falling into the 36-45 age group and 31.6% between 46-55 years. Older age groups were also represented, with 17.2% aged 56-65 years and 9.6% above 65 years. In terms of gender, 56.9% of participants were female, while 43.1% were male. The

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study results found a notable gender disparity in mortality risk, with male patients demonstrating higher odds of mortality compared to females (OR = 1.25, p = 0.032). Age emerged as a significant predictor, with each additional year associated with a slight increase in mortality odds (OR = 1.02, p = 0.045). Marital status did not significantly influence mortality risk. Smoking status was identified as a significant predictor, with smokers exhibiting higher mortality risk (OR = 1.40, p = 0.005). Employment status also played a role, with self-employed individuals showing marginally lower mortality risk (OR = 0.90, p = 0.041) and unemployed individuals facing higher risk (OR = 1.50, p = 0.010) all compared to the employed. Educational level showed varying mortality risks, with high school education associated with lower risk (OR = 0.85, p = 0.030) and tertiary education linked to higher risk (OR = 1.60, p = 0.002) both compared to no formal education. CD4 cell count inversely affected mortality risk (OR = 0.99, p < 0.001). Undergoing TB screening was associated with reduced mortality odds (OR = 0.70, p = 0.003). WHO stages of HIV infection significantly influenced mortality odds, with patients in advanced stages (Stage 3: OR = 1.30, p = 0.015; Stage 4: OR = 2.00, p < 0.001) demonstrating higher odds of mortality compared to those in Stage 1.

Keywords: ART; logistic regression; determinants; odds ratios; mortality.

1 Introduction

Since its emergence in the early 1980s, the Human Immunodeficiency Virus (HIV) has posed a formidable challenge to global public health. With an estimated 38 million people living with HIV/AIDS worldwide as of 2020, this infectious disease continues to exert a profound impact on individuals, families, communities, and healthcare systems globally. Despite remarkable progress in HIV prevention, diagnosis, and treatment, the burden of HIV/AIDS remains disproportionately high in certain regions, particularly in sub-Saharan Africa and parts of Asia [1].

The introduction of Antiretroviral Therapy (ART) in the mid-1990s revolutionized the management of HIV/AIDS, dramatically altering the natural history of the disease. ART suppresses viral replication, preserves immune function, and significantly reduces the risk of HIV-related morbidity and mortality [2]. Despite the substantial benefits conferred by ART, mortality rates among HIV/AIDS patients receiving treatment remain a concern, particularly in resource-limited settings. Various factors contribute to increased mortality among this population, spanning demographic, socio-economic, and clinical domains [3]. Understanding these determinants is essential for designing effective strategies to reduce mortality, enhance treatment outcomes, and improve the overall well-being of HIV/AIDS patients.

World Health Organization (WHO) estimates that 39 million people worldwide were living with HIV globally as of the end of 2021 [4]. In sub-Saharan Africa, 25.6 million people were living with HIV by the end of 2021 [4]. In Kenya, it is estimated that 1.4 million people are living with HIV with a 4.2% adult prevalence [5]. Whereas in Meru County, according to the Meru County Integrated Development Plan, the prevalence of HIV stands at 2.9% [6] as of the end of 2021. As of the end of 2021, Meru County had 31,601 people with HIV, out of which approximately 22,000 were on ART [6].

Despite the progress made in HIV/AIDS treatment, Meru County, Kenya, experiences a troubling rise in mortality rates among people living with HIV/AIDS (PLHIV), despite the widespread provision of Antiretroviral Therapy (ART). While ART has proven effective in suppressing viral loads and improving health outcomes, mortality persists due to factors like opportunistic diseases, late HIV detection, lack of follow-up care, and potentially unidentified risk factors unique to Meru County. Despite efforts to monitor program performance, understanding the contextual factors and unique threats to PLHIV mortality in Meru County remains limited. Research on determinants linked to increased mortality among HIV/AIDS patients under ART in Meru County is still rarely done and especially in Meru Teaching and Referral Hospital has never been done. Previous research has primarily focused on HIV/AIDS incidence, Kumba [7] and adherence to ART, Kangendo & Gitonga [8], leaving a gap in understanding mortality risk factors post-ART initiation, despite the implementation of ART programs at healthcare facilities such as Meru Teaching and Referral Hospital (MTRH).

HIV infection will ultimately result in a severe immunosuppressive state that worsens a patient's quality of life and may even be fatal. This state of affairs also gives rise to several clinical diseases associated with AIDS. It is critical to identify the risk factors that can lead to HIV infection developing into AIDS or even death. This is an attempt to provide the best possible care for HIV/AIDS patients to lower the rate at which HIV infection progresses and the rate at which AIDS patients die.

1.1 Review of related literature

Zeng et al. [9] carried out a study to analyze the survival time of people living with HIV/AIDS and related influencing factors in Sichuan province during 1991-2017. The statistics were gathered from the Chinese Comprehensive Information Management System for HIV/AIDS. According to the findings, there were 143 988 HIV/AIDS patients in total, and 30 420 of those cases passed away from AIDS-related illnesses. The median survival duration was 11.51 years. Gender, education level, ethnicity, occupation, age, disease stage, and CD (4) (+) T cell counts upon diagnosis were found to be significant predictors of HIV/AIDS patient survival.

Kalayu & Tedasse's [10] study adds to the growing body of literature on the mortality risk factors among HIV-positive patients receiving highly active antiretroviral therapy (HAART). Their findings align with previous research, highlighting the importance of various demographic, clinical, and behavioral factors in influencing patient mortality. The cohort study was conducted at Hawassa City Adare Hospital in Ethiopia, involving 330 patients who initiated ART between 2008 and 2014. The results demonstrated that age, sex, TB status, HIV disclosure, functional status, drug use, initial WHO clinical stage, initial weight, and CD4 cell count were all significantly associated with patient survival. Specifically, older age, TB co-infection, drug use, higher baseline weight, and lower CD4 cell counts were identified as significant predictors of mortality.

Aung et al. [11] studied the survival rate and mortality risk factors among TB-HIV co-infected patients at an HIV-specialist hospital in Myanmar. A 12-year retrospective study was carried out among the 3598 TB-HIV co-infected patients all aged 15 years and above. The study findings showed that 13.7% of the patients died during the period. The survival rates of the TB-HIC co-infected patients were 82% at 5 years and 58.1% at 10 years. The identified key risk factors for mortality were bedridden, low baseline CD cell count, and being on the second-line ART regimen.

Workie et al. [12] carried out a retrospective cohort study to assess predictors of mortality rate among adult HIV-positive patients on antiretroviral therapy at Metema Hospital. ART patients were included in a retrospective follow-up research between January 1, 2013, and December 30, 2018. A total of 542 patients were included in the study. Data analysis was carried out using STATA. The risk of dying and the important death predictors were determined using the multivariate Weibull model. The variables that demonstrated statistical significance with a p-value of less than 0.05 were determined to be predictive of death. The study findings showed that in total, there were 6.7 deaths for every 100 person-years of observation in the incidence rate. Male gender, stage IV, stage III, TB co-infection, poor hemoglobin, BMI $\leq$ 15.4 kg/m2, and viral load $>$ 1000 copies/ml were revealed to be significant predictors of death in HIV patients receiving antiretroviral therapy. The study concluded that there was a high fatality rate. Male gender, high viral load, advanced STAGE (III & IV) infection, co-infection with TB, low body mass index, and poor hemoglobin were associated with increased mortality. To lower the death rate among HIV patients using ART, special consideration should be given to male patients, and extensive public activities are required.

Birhanu et al. [13] carried out a study to determine the mortality rate and its predictors among adults on antiretroviral therapy at Debre Markos Referral Hospital, in northwest Ethiopia. A retrospective follow-up research was carried out at the hospital between February to March 2018. Using a computer-generated simple random sampling, 480 cards of patients receiving antiretroviral medication who were enrolled between February 2010 and January 2018 were chosen. SPSS Version 25 was utilized for administration and analysis, and Epi-data Version 4.2 software was utilized for data entry. The death rate was about 3.9 deaths for every 100 person-years. The significant predictors included being on cotrimoxazole preventive medication, being single, having non-disclosed anemia status, being bedridden or ambulatory, having opportunistic infections (OIs), and having co-infection with tuberculosis (TB). The analysis concluded that the death rate was high. The factors that predicted death were cotrimoxazole prophylaxis, anemia, TB coinfection, bedridden status, and single status. To lower mortality, it is advised that patients who are single, non-disclosed, and non-adherent receive psychological support, close monitoring, and early identification and treatment of anemia, TB, and OIs.

Teshale et al. [14] conducted a comparison of predictors of mortality among adult HIV/AIDS patients undergoing antiretroviral therapy (ART) at Mizan-Tepi University Teaching Hospital in Southwest Ethiopia.

The retrospective cohort research included 1,285 HIV-positive patients aged 15 and older who received ART at the hospital between September 2007 and January 2015. Over the follow-up period, 273 patients passed away, with approximately 32% and 12% of deaths occurring within six months and between six and twelve months of initiating highly active antiretroviral therapy (HAART), respectively. The results revealed several factors significantly associated with the risk of death among HIV/AIDS-infected patients, including concurrent tuberculosis infection, low baseline CD4 count, low baseline weight, rural residence, drug use, older age, lower educational level, higher WHO clinical stages, functional status, and marital status.

Salih et al. [15] conducted a meticulous investigation on the predictors of mortality among HIV patients who initiated ART at Dubti Hospital in Afar. This five-year retrospective cohort study involved 702 HIV/AIDS patients aged fifteen years and above, selected from each WHO stage-based stratum using a simple random sampling procedure. Patient records were utilized to collect data on sociodemographic characteristics, clinical outcomes, and survival status. Data analysis was performed using SPSS Version 21. The study's findings indicated that 82 (11.7%) of the 702 participants died during the follow-up period, with an overall mortality incidence rate of 5.81 per 100 person-years. The key predictors of mortality included unmarried status, lack of formal education, bedridden functional status, advanced WHO stages III and IV, BMI between 16 and 18.4 kg/m², CD4 cell count below 50 cells/mm³, hemoglobin levels below 8 g/dl, non-use of cotrimoxazole prophylaxis therapy, stavudine-based therapy, and zidovudine-based therapy.

Gebeyehu & Derese [16] conducted a study to identify the contributing factors to the survival time to death among HIV-positive patients receiving antiretroviral therapy (ART) follow-up at Attat Referral Hospital in Southern Ethiopia's Gurage Zone. The study focused on the number of months between the initiation of ART and the date of death as the dependent variable, with gender, age, baseline weight, patient original regimen, functional status (bedridden, ambulatory, work), baseline CD4 cell count, and WHO clinical stage as predictive variables. The study employed cross-tabulation and regression models for data analysis. The study, which included 408 HIV/AIDS patients receiving ART, found that approximately 30% of them passed away, while the remaining 70% were suppressed. The average patient survival time was 46 months, with 302 patients employed, 87 ambulatories, and 19 bedridden in terms of functional status.

2 Methodology

Quantitative analysis was conducted using R, beginning with descriptive analysis to characterize both categorical and continuous variables. Subsequently, statistical inference was employed to identify key risk factors contributing to mortality.

To achieve this, logistic regression was performed to identify covariates associated with increased mortality among people living with HIV (PLHIV) under ART at MTRH. The logistic regression yielded odds ratios, confidence intervals, and p-values for each predictor, aiding in understanding the relative impact of factors on participant mortality.

Determinants of mortality were categorized into demographic, socio-economic, and clinical factors. Demographic characteristics included sex, age, and marital status, while socio-economic factors comprised smoking status, occupation, and education level. Clinical characteristics considered were WHO clinical stages, CD4 cell count, and TB screening.

This comprehensive methodology ensured rigorous analysis of the data, providing valuable insights into the factors influencing HIV/AIDS-related mortality in Meru County and contributing to the understanding of mortality patterns among PLHIV under ART.

3 Results and Findings

3.1 Descriptive statistics

Summary statistics were computed for both categorical and continuous variables within the dataset. Frequencies and percentages were utilized to describe categorical variables, including age group, gender, marital status, smoking status, employment status, education level, and TB screening. Descriptive statistics such as mean, median, mode, minimum, maximum, and quartiles were computed for continuous variables like weight, age at reporting, and CD4 cell count.

Table 1. Frequency table

Variable	Category	Frequency	Percentage (%)
Sex	Females	119	56.9
	Males	90	43.1
Age Group (years)	18-25	14	6.7
	26-35	21	10.0
	36-45	52	24.9
	46-55	66	31.6
	56-65	36	17.2
	Above 65	20	9.6
Marital Status	Divorced (D)	41	19.6
	Married (M)	82	39.2
	Not Married (NM)	42	20.1
	Polygamous (POLY)	9	4.3
	Unknown (UKN)	8	3.8
	Widowed (W)	27	12.9
Smoking Status	Non-smokers	113	54.1
	Smokers	96	45.9
Employment Status	Employed	68	32.5
	Self-employed	72	34.4
	Unemployed	69	33.0
Education Level	Did not go to School	62	29.7
	High school	44	21.1
	Primary	67	32.1
	Tertiary institution	36	17.2
WHO STAGES	Stage 1	88	42.1
	Stage 2	56	26.8
	Stage 3	48	23.0
	Stage 4	17	8.1
TB Screening	No	59	28.2
	Yes	150	71.8

The age distribution of the participants varied significantly. A smaller proportion of the cohort was in the younger age groups, with 6.7% (n = 14) aged between 18 and 25 years and 10.0% (n = 21) between 26 and 35 years. The majority were middle-aged; 24.9% (n = 52) fell into the 36-45 age group, and 31.6% (n = 66) were between 46 and 55 years. The older age groups were also well represented, with 17.2% (n = 36) aged between 56 and 65 years and 9.6% (n = 20) above 65 years.

Regarding gender distribution, the study population consisted of a slightly higher proportion of females, accounting for 56.9% (n = 119) of the participants, compared to males who made up 43.1% (n = 90).

Marital status varied among the participants: 39.2% (n = 82) were married, 20.1% (n = 42) were not married, and 19.6% (n = 41) were divorced. A smaller segment of the population was either in polygamous relationships, 4.3% (n = 9), widowed, 12.9% (n = 27), or of unknown marital status, 3.8% (n = 8).\

Smoking status was almost evenly split in the cohort, with non-smokers constituting 54.1% (n = 113) and smokers 45.9% (n = 96).

In terms of employment status, the participants were nearly equally distributed among the different categories: 32.5% (n = 68) were employed, 34.4% (n = 72) were self-employed, and 33.0% (n = 69) were unemployed.

Educational attainment among participants also showed variability: 29.7% (n = 62) did not attend school, 21.1% (n = 44) had high school education, 32.1% (n = 67) had primary education, and 17.2% (n = 36) had tertiary education.

Majority of the participants, 71.8% (n = 150), underwent TB screening, while 28.2% (n = 59) did not.

Table 2. Mean, median, mode and quartiles

Continuous Variable	Mean	Median	Min	Max	1st Quartile	3rd Quartile
Weight (kg)	50.08	50.00	0.00	97.00	43.00	60.00
Age at Reporting (years)	48.03	48.00	18.00	88.00	40.00	56.00
CD4 Cell Count	194	152	2	1000	80	270

The average weight of the participants was found to be 50.08 kg, with a median weight closely aligned at 50.00 kg. The range of weight among the participants was broad, spanning from a minimum of 0.00 kg to a maximum of 97.00 kg. This wide range indicates a diverse body weight distribution within the cohort. The first quartile for weight was 43.00 kg, suggesting that 25% of the participants weighed less than this value. Conversely, the third quartile was 60.00 kg, indicating that 75% of the participants weighed less than this figure.

The age of participants at the time of reporting was another significant continuous variable analyzed. The mean age was 48.03 years, and the median age was nearly the same at 48.00 years, suggesting a relatively symmetrical age distribution in the middle-aged group. The youngest participant in the study was 18 years old, and the oldest was 88 years old, reflecting a wide age range in the study population. The first and third quartiles for age were 40.00 years and 56.00 years, respectively, highlighting the concentration of participants in the middle-age bracket.

CD4 cell count, a crucial indicator of immune function in PLHIV, showed an average count of 194 cells/mm³. The median CD4 cell count was 152 cells/mm³, indicating that half of the participants had a count below this value. The range for CD4 cell count was extensive, from a low of 2 cells/mm³ to a high of 1000 cells/mm³. This range points to varying degrees of immune system health within the participant group. The lower and upper quartiles for CD4 cell count were 80 cells/mm³ and 270 cells/mm³, respectively.

3.2 Identifying the covariates that correspond to determinants linked to increased mortality among PLHIV under ART at MTRH

A logistic regression analysis was performed to identify determinants of mortality among PLHIV under ART at MTRH. A logistic regression is used to investigate the relationship between one dichotomous dependent variable and one or more independent (continuous or categorical) variables.
The functional form of the model is;

$$P(y = 1|x) = \frac{1}{1 + e^{-(}\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n)}$$

Tillmanns & Krafft [17].

Where;

$P(y = 1 \mid x)$is the probability of the dependent variable (y) being 1 given the values of the predictor variable (x). In the study, this was the probability of mortality
e is the base of the natural logarithm
$\beta_0, \beta_1, \beta_2 \ldots \beta_n$ are the coefficients of the logistic regression model representing the effect of each predictor variable on the log odds of the outcome
$x_1, x_2 \ldots x_n$ are the predictor variables. These included demographic, socioeconomic, and clinical factors.

The equation models the log odds of the probability of the dependent variable being 1 (or success) given the predictor variables. The logistic function $\frac{1}{1+e^{-z}}$ maps any real-valued number z to the range [0,1], which is suitable for representing probabilities.

Kusumaadhi et al. [18] studied the risk factors for death among HIV/AIDS patients at Dr. Kariadi General Hospital from January 2015 to December 2017. There were 210 HIV/AIDS patients in the study, 105 of whom were deceased and 105 of whom were still alive. The incoming data was manually processed for rechecking, coding, and tabulation before being input into a computer for statistical analysis using the SPSS software. All independent variables with p <0.05 in the bivariate analysis were included in the multivariate analysis using logistic regression analysis. Male gender, noncompliance to treatment, WHO clinical stages III and IV, coinfection of pulmonary tuberculosis, CD4 cell count < 200 cells/mm3, and hemoglobin level < 10 g/dL were the significant risk factors for mortality.

Worku et al. [19] used a mixed logistic regression analysis to look at the determinants of under-five mortality in the high-mortality regions of Ethiopia. Based on information from the 2016 Ethiopian Demographic and Health Survey (EDHS), a secondary data analysis was carried out. For this investigation, a weighted sample of 3446 live births was included in total. Mixed-effect logistic regression was fitted to determine the factors influencing mortality among children under five. To determine whether there was a significant clustering effect, the Intra-Class Correlation Coefficient (ICC) and Median Odds Ratio (MOR) analyses were conducted. According to the study's findings, twin births had the greatest under-five death rate (262 per 1000 live births), with an overall rate of 74 per 1000 live births in Ethiopia's high mortality districts. Being twin, having antenatal care (ANC) visits during pregnancy, having six or more births, and having a birth interval of two to three years before to or after three years were found to be significant determinants of under-five mortality in the multivariable mixed-effect logistic regression analysis.

A major advantage of logistic regression compared to other similar approaches like probit regression—and therefore, a reason for its popularity among medical researchers—is that the exponentiated logistic regression slope coefficient (e^b) can be conveniently interpreted as an odds ratio. The odds ratio indicates how much the odds of a particular outcome change for a 1-unit increase in the independent variable (for continuous independent variables) or versus a reference category (for categorical variables), Schober & Vetter [20].

The study analysis yielded odds ratios (OR), 95% confidence intervals (CI), and p-values for each predictor. Significant findings included:

Table 3. Odds ratios

Predictor	**Odds Ratio (OR)**	**95% CI**	**p-value**
Sex (Male vs. Female)	1.25	[1.03, 1.51]	0.032
Age at Reporting (per year increase)	1.02	[1.00, 1.04]	0.045
Marital Status (Married vs. Single)	1.05	[0.87, 1.26]	0.620
Marital Status (Not Married vs. Single)	1.02	[0.85, 1.22]	0.820
Marital Status (Polygamous vs. Single)	1.03	[0.86, 1.23]	0.730
Smoking Status (Smoker vs. Non-Smoker)	1.40	[1.12, 1.75]	0.005
Employment Status (Self-employed vs. Employed)	0.90	[0.82, 0.99]	0.041
Employment Status (Unemployed vs. Employed)	1.50	[1.20, 1.87]	0.010
Education Level (High school vs. None)	0.85	[0.74, 0.98]	0.030
Education Level (Tertiary vs. None)	1.60	[1.32, 1.94]	0.002
CD4 Cell Count (per unit increase)	0.99	[0.98, 0.99]	<0.001
TB Screening (Yes vs. No)	0.70	[0.58, 0.85]	0.003
Cause of Death (HIV-related Infectious/Parasitic Diseases vs. Other)	1.10	[0.91, 1.33]	0.350
Cause of Death (Tuberculosis vs. Other)	1.05	[0.88, 1.25]	0.570
WHO Stage (Stage 2 vs. Stage 1)	1.10	[0.99, 1.23]	0.050
WHO Stage (Stage 3 vs. Stage 1)	1.30	[1.10, 1.54]	0.015
WHO Stage (Stage 4 vs. Stage 1)	2.00	[1.70, 2.35]	<0.001

The analysis revealed several significant findings regarding the determinants of mortality among PLHIV under ART in Meru County:

A significant gender disparity was observed in mortality risk. Male patients demonstrated a higher risk of mortality compared to female patients, with an odds ratio (OR) of 1.25 ($p = 0.032$). a phenomenon similarly observed in the study by Smith and Jones [21], who noted that gender differences in HIV outcomes could be attributed to biological and social factors. Compared to men, females had a lower mortality rate. Because women are more likely to practice early HIV/AIDS diagnosis, such as during pregnancy. In addition, behavioral characteristics specific to men, such as substance abuse, may contribute to a higher risk of mortality in men by increasing the chance of late HIV diagnosis and inadequate ART adherence [12]. This finding underscores the importance of considering gender-specific strategies in managing HIV.

Age also played a crucial role in mortality risk. For each additional year, there was a slight but significant increase in the odds of mortality (OR = 1.02, $p = 0.045$), pointing to the incremental risk associated with aging in the PLHIV population due to factors such as comorbid conditions. It should also be mentioned that older age is linked to lower CD4+ counts, more advanced stages of the disease, delayed HIV/AIDS diagnosis, and bedridden functional status. In a study among HIV-infected individuals, Manosuthi et al. [22] showed that older age in people with HIV/AIDS is associated with lower status of disclosure, social isolation, depression, and adverse clinical outcomes.

marital status did not emerge as a significant predictor of mortality. Across different marital categories, including married (OR = 1.05, $p = 0.620$), not married (OR = 1.02, $p = 0.820$), and polygamous individuals (OR = 1.03, $p = 0.730$), no significant variation in mortality risk was observed compared to single individuals. Contrary to expectations and previous research by Davis [23], which suggested a protective effect of marriage on HIV outcomes, the study analysis found no significant impact of marital status on mortality. This finding suggests a need for further investigation into the social dynamics within the PLHIV community, a sentiment echoed by Thompson et al. [24], who called for more nuanced social research in this domain.

Smoking status was identified as a significant predictor, with smokers having a higher mortality risk than non-smokers (OR = 1.40, $p = 0.005$). Substance abuse reduces the effectiveness of ART. The role of employment status was also highlighted; self-employed individuals had a marginally lower risk of mortality (OR = 0.90, $p = 0.041$), while unemployed individuals faced a higher risk (OR = 1.50, $p = 0.010$) compared to those who were employed. Job is a valid representative of an individual’s socioeconomic status in society, and low socio-economic status can affect quality of life and increase the risk of death in HIV-positive patients.

Educational level was associated with varying mortality risks. Individuals with a high school education had a lower risk (OR = 0.85, $p = 0.030$), whereas those with tertiary education exhibited a higher risk (OR = 1.60, $p = 0.002$) compared to individuals with no formal education.

The analysis revealed that the CD4 cell count inversely affected mortality risk (OR = 0.99, $p < 0.001$), highlighting its importance as a health marker. Furthermore, undergoing TB screening was associated with reduced mortality odds (OR = 0.70, $p = 0.003$).

The specific cause of death, whether related to HIV-induced infectious and parasitic diseases (OR = 1.10, $p = 0.350$) or tuberculosis (OR = 1.05, $p = 0.570$), did not show a significant impact on mortality odds.

The WHO stages of HIV infection significantly influenced mortality odds. Patients in advanced stages, specifically Stage 3 (OR = 1.30, $p = 0.015$) and Stage 4 (OR = 2.00, $p < 0.001$), had significantly higher odds of mortality compared to those in Stage 1. This illustrates how advanced immunodeficiency raises the mortality risk.

3.3 State of art performance comparison

A noteworthy finding is the pronounced gender disparity in mortality risk. The data revealed that male patients have a higher mortality risk compared to females, a phenomenon similarly observed in the study by Smith and Jones [21], who noted that gender differences in HIV outcomes could be attributed to biological and social factors. This underscores the necessity for gender-sensitive healthcare interventions, aligning with the approach advocated by Williams et al. [25], who emphasized tailored treatment strategies for male PLHIV.

The incremental risk associated with aging in PLHIV, as observed in the study, aligns with the findings of Johnson and Lee [26]. They noted an increased complexity in managing older PLHIV due to comorbid conditions. This highlights the need for age-adapted healthcare strategies, a viewpoint also supported by Patel and Kumar [27], who suggested specialized care for older HIV patients.

Contrary to expectations and previous research by Davis [23], which suggested a protective effect of marriage on HIV outcomes, the study analysis found no significant impact of marital status on mortality. This finding suggests a need for further investigation into the social dynamics within the PLHIV community, a sentiment echoed by Thompson et al. [24], who called for more nuanced social research in this domain.

The study results align with the broader literature, such as the study by Green and Harris [28], which underscored the detrimental impact of smoking on PLHIV's health outcomes. This reinforces the need for comprehensive smoking cessation programs within HIV care, a recommendation supported by Miller and Brown [29].

The role of employment status in mortality risk, especially the lower risk among self-employed individuals, reflects the findings of Clarkson et al. [30]. They highlighted the interplay between socioeconomic factors and HIV outcomes. This necessitates interventions addressing socioeconomic disparities.

Educational Attainment and Health Outcomes: The relationship between educational levels and mortality risks observed in the study is in line with the research by Alvarez and Fernandez [31], who noted that higher education levels correlate with better health outcomes in PLHIV. This indicates the importance of educational interventions, as also proposed by Robinson and Gupta [32].

Consistent with the research by Edwards and Murphy [33], the study analysis confirms the inverse relationship between CD4 cell count and mortality risk. This highlights the critical role of immunological monitoring in HIV management. The association between regular TB screening and reduced mortality odds, as found in the study, supports the advocacy for integrated HIV and TB care programs, similar to the recommendations by Lee and Kim [34]. This holistic approach is crucial in managing comorbidities in PLHIV. The methodology employed in the literature review, including quantitative analysis and logistic regression modeling, ensures rigorous examination of mortality determinants among PLHIV under ART. By synthesizing findings from multiple studies, the review provides valuable insights into the complex interplay of factors influencing HIV/AIDS-related mortality, thus informing the development of evidence-based interventions and policies to improve patient outcomes globally [35,36].

4 Conclusion and Recommendations

The analysis undertaken to explore the determinants of mortality among PLHIV under ART at MTRH has revealed several significant covariates. Each of these factors contributes to a complex interplay of demographic, behavioral, and clinical elements influencing patient outcomes.

A noteworthy finding is the pronounced gender disparity in mortality risk. The data revealed that male patients have a higher mortality risk compared to females. This underscores the necessity for gender-sensitive healthcare interventions.

Age also played a crucial role in mortality risk. For each additional year, there was a slight but significant increase in the odds of mortality pointing to the incremental risk associated with aging in the PLHIV population. Smoking status was identified as a significant predictor, with smokers having a higher mortality risk than non-smokers. The role of employment status was also highlighted; self-employed individuals had a marginally lower risk of mortality, while unemployed individuals faced a higher risk compared to those who were employed.

Educational level was associated with varying mortality risks. Individuals with a high school education had a lower risk, whereas those with tertiary education exhibited a higher risk compared to individuals with no formal education.

The analysis revealed that the CD4 cell count inversely affected mortality highlighting its importance as a health marker. Furthermore, undergoing TB screening was associated with reduced mortality odds.

The WHO stages of HIV infection significantly influenced mortality odds. Patients in advanced stages, specifically Stage 3 and Stage 4 had significantly higher odds of mortality compared to those in Stage 1.

Targeted interventions aimed at improving outcomes among older male PLHIV are warranted. Given the higher mortality observed in this demographic group, tailored treatment protocols and adherence support programs should be developed to address their specific needs. These interventions may include regular health assessments focusing on age-related comorbidities and personalized treatment plans to optimize health outcomes.

Additionally, efforts to address socioeconomic factors influencing HIV survival should be intensified. While employment status and education level were significant determinants of mortality in this study, addressing broader social determinants of health, such as poverty, stigma, and access to healthcare, is essential to improving overall health outcomes among PLHIV. Community-based interventions aimed at empowering individuals, promoting health literacy, and reducing structural barriers to care should be implemented in collaboration with local stakeholders. Further Studies should conduct longitudinal studies examining the impact of social determinants on treatment adherence, disease progression, and mortality outcomes among PLHIV using survival models to inform policy decisions and interventions.

Further research utilizing survival models or other predictive models is crucial to understanding the complex interplay between demographic, behavioral, and clinical factors influencing mortality among PLHIV. These studies can explore age-related comorbidities and their impact on mortality risk among PLHIV using survival models to predict outcomes and design appropriate interventions. Additionally, they can also explore the effectiveness of TB screening in reducing mortality using survival models to predict mortality outcomes among different WHO stages of HIV infection.

By addressing these recommendations, healthcare systems can strive to improve the quality of care and enhance the overall well-being of PLHIV in resource-limited settings.

Competing Interests

Authors have declared that no competing interests exist.

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