Infect Dis Trop Med 2023;9: e1153

Nutritional status and immune recovery of HIV-positive patients receiving antiretroviral therapy in Fako Division, Southwest Region, Cameroon

R.V. Nyingchu[1,2], D.A. Tangoh[1], T.O. Apinjoh[3]., N.S. Bassah[1], S.T. Ndipingwi[1], G.B. Wepnje[2], B.L. Tangunyi[1], A.N. Jelil[1], E.A. Achidi[2]

[1]Faculty of Health Sciences, University of Buea, Buea, Cameroon
[2]Faculty of Science, University of Buea, Buea, Cameroon
[3]National Higher Polytechnic Institute, University of Bamenda, Bamenda, Cameroon

ABSTRACT:

Objective: Over the last 15 years, there has been a decline in Human Immunodeficiency Virus (HIV) infection and HIV/AIDS mortality in West and Central Africa, due to the success of antiretroviral medication. However, as HIV patients live longer, the risk of metabolic diseases mediated by adverse drug effects increases. This can be mitigated by ensuring a correct diet routine. This study assessed the effects of nutritional status on the immune recovery of HIV/AIDS patients in the Southwest Region of Cameroon. The main aim of this study is to assess the influence of the nutritional status of patients on Highly Active Antiretroviral Therapy (HAART) on their immune recovery.

Subjects and Methods: Sociodemographic and socioeconomic information were collected using questionnaires, and anthropometric measurements were made to obtain information for calculating Body Mass Index (BMI). Whole anticoagulated blood was obtained to measure CD4 cell count, haemoglobin concentration, and HIV Viral Load (VL). Statistical analysis was performed using SPSS 22, and significant levels were set at 0.05. Chi-square was used to compare proportions. Univariate and multivariate analyses were used to look for the association between variables.

Results: The majority or patients (47.2%, 238/610) had a normal BMI, while 39 (6.5%), 173 (28.9%), and 104 (17.4%) showed undernutrition, overweight, and obesity, respectively. Consumption of vegetables was associated with CD4 count status (χ^2 = 10.034; p = 0.007) and lowered viral load. Smoking increased the risk of having a viral load higher than 75 HIV RNA copies/ml by 18 times (CI 1.86-180.32, p = 0.013).

Conclusions: About half of the people living with HIV/AIDS (PLWHA) under HAART in this study were either obese or under-nourished based on anthropometric indicators. Nevertheless, consuming fruits and vegetables and non-consumption of alcohol were important factors that promoted immune recovery in this population.

Keywords: *Nutrition, Obesity, HIV/AIDS, Body Mass Index, Anaemia, CD4 cell count, Viral load, Cameroon.*

Abbreviations: AIDS: Acquired Immune deficiency syndrome; ANOVA: Analysis of Variances; BMI: Body mass Index; CD4: Cluster of Differentiation-4; CDC: Cameroon Development Corporation; CI : Confidence Interval; FHS: Faculty of Health Sciences; HAART: Highly Active Antiretroviral Therapy; HB: Haemoglobin; HIV: Human Immunodeficiency Virus; MS: Metabolic Syndrome; NIH: National Institute of Health; PLWHA: People Living with HIV/AIDS; RNA: Ribonucleic Acid; SPSS: Statistical Package for Social Sciences; VL: Viral Load; WHO: World Health Organisation.

Corresponding Author: Delphine A. Tangoh, Ph.D; e-mail: anye.tangoh@gmail.com

INTRODUCTION

Between 2006 and 2020, the global prevalence of Human Immunodeficiency Virus (HIV) infection remained almost the same at a rate of 0.7%, while AIDS-related mortality dropped from 1.5 million to 580.000 deaths per year for the same period[1]. The prevalence of the infection in West and Central Africa remains high (1.3%), causing up to 110.000 deaths per year[1]. In Cameroon, the prevalence of HIV infection and deaths in adults dropped from 4.7% and 30,000 in 2006 to 3% and 14,000 in 2020[1]. The introduction of Highly Active Antiretroviral Therapy (HAART) drugs has thus significantly improved the prognosis and quality of life of HIV/AIDS patients[2,3]. However, antiretroviral drug side effects, such as metabolic syndrome (MS), a severe chronic condition characterized by hyperlipidemia, lipodystrophy, and impaired glucose metabolism[4], have become commonplace and require attention. Poor nutritional status has been reported to contribute to HIV/AIDS morbidity and mortality, as well as the inefficacy of HAART treatment[5]. HAART efficacy has been shown to be increased by providing dietary support to patients to lengthen their survival time and improve their quality of life[6]. Malnutrition encompasses undernutrition (wasting, stunting, and underweight), insufficient vitamins and minerals, being overweight, obesity, and diet-related non-communicable diseases[7]. Long-term malnutrition leads to changes in cellular metabolism, reduced function, and, finally, the loss of body tissues[8,9].

Infection activates both specific and non-specific host defensive systems, which are regulated by micro- and macronutrient nutritional status[10]. Immune changes, which are intimately linked to the nutritional condition, significantly increase vulnerability to infectious agents and can also decrease nutritional status, resulting in a vicious cycle[11]. People living with HIV have a higher daily calorie and micronutrient demand than HIV-negative peers; moreover, coinfection and chronic diarrhea related to HIV enteropathy play a crucial role in HIV-associated malnutrition[12]. In patients on HAART, a higher baseline BMI has been associated with a lower mortality rate, while a low baseline BMI has been associated with early mortality in resource-limited settings[6].

Other health challenges, such as overt liver and kidney disease, Diabetes mellitus, and chronic inflammatory conditions, also affect the nutritional and immune status of PLWHA[3,4].

The main aim of HIV treatment is immune recovery characterized by increased CD4 cell count, increased haemoglobin, and viral suppression, amongst other indicators[13,14]. Certain diet modifications and supplements have been shown to aid in immune recovery in those HAART[15,16].

This study sought to investigate the effect of nutritional status on the immune recovery of HIV/AIDS patients on antiretroviral treatment in the Southwest Region of Cameroon.

SUBJECTS AND METHODS

Study Design and Population

A cross-sectional study was carried out in three HIV treatment centers in Fako Division of Southwest Region of Cameroon from May 2019 to November 2020. The centers included Cameroon Development Corporation (CDC) Central Clinic Tiko, CDC Clinic Bota, and Buea Regional Hospital. All adult HIV/AIDS patients on HAART reporting for routine check-ups were eligible for enrolment. In-patients, pregnant women, those with liver and kidney disease, and individuals below 21 years were excluded.

Study Area

Fako Division is located in the Southwest Region of Cameroon and is on latitude 4.167 and longitude 9.167, and the capital town is Limbe. The inhabitants are civil servants, farmers, traders and workers of the CDC. There are several HIV/AIDS treatment Centers that cater to the needs of PLWHA in this Division.

Ethical Considerations

Ethical clearance (2019/0250/UB/SG/IRB/FHS) was obtained from the Institutional Review Board of the Faculty of Health Sciences, University of Buea, and administrative authorization was obtained from the Director of the Regional Hospital, Buea, and Cameroon Development Corporation (CDC) Health Services. Only individuals who volunteered to participate by signing a written informed consent were enrolled. Patient identity was coded, and physical data were secured in a locked drawer, while electronic information was stored in a device that was password-protected.

Data Collection

A structured questionnaire was used to document information on the demographic and socioeconomic status of all participants. The weight was measured with a mechanical balance (Yongkang Zhezhong, Wuzhou, China). The height was measured with a stadiometer, and the hip and waist circumference were measured with an inelastic measuring tape. The Body Mass Index (BMI) was calculated by dividing the weight (in Kg) by the height squared in meters and nutritional status classified as underweight (BMI $\leq$ 18.5 kg/m^2), normal (18.5 > BMI $\leq$ 24.9 kg/m^2), overweight (25 > BMI $\leq$ 29.9 kg/m^2) and obese (BMI $\geq$ 30 kg/m^2) as previously described[17].

Blood Sample Collection and Analysis

Venous blood (3-5 ml) was collected from each patient by venipuncture and transported to the Infectious Dis-

ease Laboratory (FHS, University of Buea) to determine viral load, CD4 count and HB levels. The CD4 cell count was determined by flow cytometry (BD FACSPresto™ Near-Patient CD4 Counter, Auckland, New Zealand). Haemoglobin (HB) was measured using a haemoglobinometer (Sejoy®101, Zhejiang, China) and anaemia was defined as Hb ≤ 13 g/dL in men and ≤ 12 g/dL in women[18]. CD4 count was classified as low (< 200), or adequate (≥ 200) cells/ml[19]. Results of viral load were copied from the patient's results that were obtained within the past month. In previous literature, viral load was classified as optimal viral suppression (HIV RNA < 75 copies/mL), persistently low-level viremia (HIV RNA < 200 copies/mL) and virologic failure (HIV RNA > 200 copies/mL)[20]. However, in this study, only two categories were considered; viral suppression (HIV RNA < 75 copies/mL) and viral non-suppression (HIV RNA > 75 copies/mL).

Statistical Analysis

Data analysis was performed using the Statistical Package for Social Sciences (SPSS, IBM Corp., Armonk, NY, USA) version 22. Descriptive statistics were conducted, and variables were presented using mean, frequency, and proportions. Independent predictors of adult malnutrition, such as socio-demographic and clinical characteristics, were determined using bivariate and multivariate binary logistic regression. The Chi-Square test was used to compare proportions, and risk was assessed using Odd Ratios (OR). The level of significance was set at $p \leq 0.05$.

RESULTS

Characteristics of Study Population

A total of 610 participants were enrolled in the study and their socio-demographic characteristics are presented in Table 1. The ages ranged from 21 to 83 years (mean = 44.4 ± 10.8). Most of the participants were female (73.4%), had attained a primary level of education (52.9%), and earned below XAF 100,000.00 (US$ 159.07) per month on average (86.6%).

Clinical and Behavioral Characteristics Among HIV-Positive Patients

The clinical and behavioral characteristics of participants (Table 2) revealed that all of the 610 participants were on HAART. The median CD4+ cell count was 328 cells/mL (range: 96-510), with the majority of patients (82.6%) having ≥200 CD4+ cells/mL of blood. Most had a viral load of <75 copies of HIV RNA (54.8%), were involved in physical activities (60.2%), and reportedly consumed animal products, vegetables, fruits, and starch-rich foods at least once a week. Anaemia was prevalent in 35.8% of participants.

Nutritional Status of HIV-Positive Patients

The mean ± SD BMI of the participants was 25.1 ± 5.5 kg/m^2. Two hundred and eighty-three participants (47.2%) had a normal BMI and 39 (6.5%) had under-

Table 1. Sociodemographic characteristics of HIV-positive adults (N = 610).

Characteristics	n	%	(95% CI)
gender			
Male	162	26.6	(23.2-30.2)
Female	448	73.4	(69.8-76.8)
Age group (years)			
<30	53	8.7	(6.7-11.2)
30-39	122	20.0	(17.0-23.4)
40-49	254	41.6	(37.8-45.6)
≥50	181	29.7	(26.2-33.4)
Level of education*			
No education	40	6.6	(4.9-8.8)
Primary	321	52.9	(48.9-56.8)
Secondary	187	30.8	(27.3-34.6)
Tertiary	59	9.7	(7.6-12.3)
Employment status*			
Unemployed	304	50.1	(46.1-54.0)
Employed	303	49.9	(45.9-53.9)
Average monthly income (XAF)**			
<100,000 (US $ 159.07)	478	86.6	(83.5-89.2)
≥100,000 (US $ 159.07)	74	13.4	(10.8-16.5)

*N = 607; **N = 522.

Table 2. Clinical and behavioral characteristics of HIV-positive adults.

Characteristics	n	%	(95% CI)
CD4 cell count (N = 155)			
<200	27	17.4	(12.3-24.2)
≥200	128	82.6	(75.8-87.7)
Viral load (N = 126)			
Unhealthy (>75 copies)	57	45.2	(36.8-53.9)
Healthy (<75 copies)	69	54.8	(46.1-63.2)
Anaemic status (N = 606)			
Anaemic	217	35.8	(32.1-39.7)
Non-anaemic	389	64.2	(60.3-67.9)
Difficulty in eating (N = 603)			
Yes	86	14.3	(11.7-17.3)
No	512	85.7	(82.7-88.3)
Type of physical activity (N = 610)			
Light activity	310	50.8	(46.9-54.8)
Heavy activity	57	9.3	(7.3-11.9)
No activity	243	39.8	(36.0-77.8)
Smoking (N = 592)			
Yes	23	3.9	(2.6-5.8)
No	569	96.1	(94.2-97.4)
Alcohol consumption (N = 596)			
Yes	316	53.0	(49.0-57.0)
No	280	47.0	(43.0-50.9)
Consumption of animal products (N = 603)			
Once daily	405	67.2	(63.3-70.8)
Once weekly	176	29.2	(25.7-32.9)
Hardly	22	3.6	(2.4-5.5)
Consumption of vegetables (N = 604)			
Once daily	344	56.9	(53.0-60.8)
Once weekly	245	40.6	(36.7-44.5)
Hardly	15	2.5	(1.5-4.5)
Consumption of fruits (N = 604)			
Once daily	344	56.9	(53.0-60.8)
Once weekly	245	40.6	(36.7-44.5)
Hardly	15	2.5	(1.5-4.5)
Consumption of starch-rich food (N = 602)			
Once daily	584	97.0	(95.3-98.1)
Once weekly	12	2.0	(1.1-3.4)
Hardly	6	1.0	(0.5-2.2)

nutrition, which was severe in 7 (17.9%), moderate in 5 (12.8%), and mild in 27 (69.2%). One hundred and seventy-three (28.9%) were overweight, and 104 (17.4%) were obese; thus, 52.8% of all respondents were classified as malnourished (Figure 1).

Risk Factors Associated with Anaemia

Of all the factors considered as risk factors of anaemia, only smoking showed a relationship ($\chi^2 = 3.218$, $p = 0.073$), though not statistically significant. Using bivariate analysis, those smoking had more than twice fewer chances of being anaemic compared to nonsmokers, though not significant [AOR = 0.4 (CI = 0.13-1.2), $p = 0.101$]. Meanwhile, the type of food consumed, or the participants' physical activity had no association with their anaemic status (Table 3).

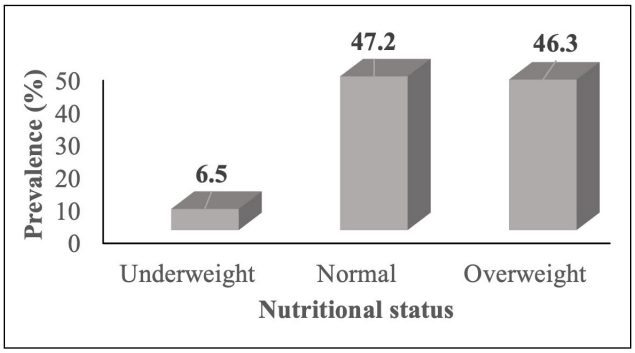

Figure 1. Nutritional status of HIV-positive adults enrolled in the study.

Table 3. Risk factors associated with anaemia.

Variable	Category	Anaemic % (n)	χ^2, *p*-value	OR	95% CI	*p*-value
Difficulty in eating	Yes	40.7 (35)	1.236; 0.266	1.2	0.84-1.86	NA
	No	34.5 (177)		Ref		
Physical activity	Light activity	34.6 (107)	1.979; 0.372	0. 8	0.59-1.19	NA
	Heavy activity	29.8 (17)		0.7	0.36-1.25	
	No activity	38.8 (93)		Ref		
Smoking status	Yes	17.4 (4)	3.218; 0.073	0.4	0.14-1.14	0.101
	No	35.6 (201)		Ref		
Alcohol consumption	Yes	32.1 (101)	2.218; 0.136	0.9	0.75-1.04	0.132
	No	37.9 (105)		Ref		
Consumption of animal products	Once daily	34.5 (139)	0.292; 0.864	0.9	0.38-2.245	NA
	Once weekly	36.8 (64)		1.0	0.4-2.56	
	Hardly	36.4 (8)		Ref		
Consumption of vegetables	Once daily	36.5 (124)	0.708; 0.702	0.9	0.29-2.48	NA
	Once weekly	33.5 (82)		0.7	0.26-2.19	
	Hardly	40.0 (6)		Ref		
Consumption of fruits	Once daily	36.5 (124)	0.708; 0.702	0.9	0.29-2.48	
	Once weekly	33.5 (82)		0.7	0.26-2.19	
	Hardly	40.0 (6)		Ref		
Consumption of starch-rich food	Once daily	35.5 (206)	0.016; 0.992	1.1	0.2-6.04	NA
	Once weekly	36.4 (4)		1.1	0.14-9.29	
	Hardly	33.3 (2)		Ref		

Risk Factors Associated with Low CD4 Cell Counts Status

Consumption of vegetables (once daily, once weekly, hardly) was associated with CD4+ cell count status (χ^2 = 10.034; p = 0.007) with patients who hardly consumed vegetables having significantly lower CD4+ cell counts. In the multivariate analysis, those who reportedly ate vegetables once a day were 10 times less likely to have low CD4+ cell count as compared to those who hardly eat vegetables (OR = 0.1, CI = 0.1-2.2). The other variables did not show any association with CD4+ cell count (Table 4).

Table 4. Risk factors associated with anaemia.

Variable	Category	CD4 <200 cells/µl of blood % (n)	χ^2, *p*-value	OR	95% CI	*p*-value
Difficulty in eating	Yes	17.6 (3)	0.006; 0.939	1.0	0.32-3.38	NA
	No	16.9 (23)		Ref		
Physical activity	Light activity	12.7 (10)	2.696; 0.260	0.5	0.2-1.16	NA
	Heavy activity	18.2 (2)		0.7	0.14-3.8	
	No activity	23.1 (15)		Ref		
Smoking status	Yes	0.0 (0)	0.879; 0.348	-		NA
	No	18.1 (25)				
Alcohol consumption	Yes	20.5 (15)	1.048; 0.306	1.2	0.85-1.78	NA
	No	14.1 (10)		Ref		
Consumption of animal products	Once daily	14.3 (15)	1.925; 0.382	0.4	0.07-2.34	NA
	Once weekly	22.0 (9)		0.7	0.11-4.24	
	Hardly	28.6 (2)		Ref		
Consumption of vegetables	Once daily	10.6 (11)	10.034; 0.007	0.1	0.01-2.02	0.141
	Once weekly	29.8 (14)		0.4	0.02-7.27	0.554
	Hardly	50.0 (1)		Ref		
Consumption of fruits	Once daily	10.6 (11)	10.034; 0.007	0.1	0.01-2.02	
	Once weekly	29.8 (14)		0.4	0.02-7.27	
	Hardly	50.0 (1)		Ref		
Consumption of starch-rich food	Once daily	17.8 (26)	1.502; 0.472			NA
	Once weekly	0.0 (0)				
	Hardly	0.0 (0)				

Factors Associated with Viral Load

Physical activity was associated with viral load (p = 0.049). Using multivariate analysis, participants who undertook light physical activities (walking and jogging) and heavy physical activities (running, playing football, and handball) were found to be twice and 5 times less likely to have VL above 75 HIV RNA copies/ml of blood respectively, though not statistically significant (CI = 0.05-1.18, p = 0.079).

Smoking was related to viral load (p = 0.020), and those who smoked were 18 times more likely to have VL greater than 75 HIV RNA copies/ml (CI. 0.97-62.93, p = 0.013). However, those who took alcohol were 1.5 times less likely to have high VL, (p = 0.008). The consumption of fruits and vegetables was related to viral load as shown by bivariate analysis (p = 0.008), with those consuming vegetables more often having lower odds of having viral loads above 75 HIV RNA copies/ml (Table 5).

Correlating BMI with Haemoglobin Levels, CD4 Count and Viral Load

Further analysis to determine the association between BMI and clinical characteristics is shown in Table 6. Following a correlation analysis, viral load showed a negative correlation with BMI (r = -0.318; p < 0.001), while haemoglobin levels showed a positive correlation with BMI (r = 0.098; p = 0.017).

Relationship Between BMI and CD4+ Cell Count, Haemoglobin and Viral Load

Those who had a lower BMI (undernutrition) had lower mean haemoglobin levels (p = 0.011) when compared to those who had normal nutrition and the overweight/obese. Meanwhile, there was a non-significant increase in CD4+ cell count and a reduction in viral load with increased BMI when analyzed by ANOVA (Table 7).

DISCUSSION

The main aim of this study was to estimate the prevalence of malnutrition and its association with immune recovery (assessed by haemoglobin levels, CD4 count and viral load) in PLWHA who are on antiretroviral drugs. The prevalence of undernutrition in this study area was 6.5% (39/612), while 28.9% were overweight and 17.4% obese, giving an overall malnutrition prevalence of 52.8%.

The rate of undernutrition in this study (8.5%) is close to that reported in the Central Region of Cameroon[21]. However, this is lower than the 14.1% reported nationwide[22] and the 11.6% reported in the East Region[23]. The differences in these rates could be due to sample size differences, as well as to the nutritional habits of the patients in the different regions in Cameroon affected by food security. This suggests that undernutrition remains a threat to PLWHA in Cameroon and needs to be addressed. It has been reported[24] that malnourished women have a higher mortality rate than those with nor-

Table 5. Risk factors associated with viral load status.

Variable	Category	Viral load with >75 copies % (n)	χ^2, p-value	OR	95% CI	p-value
Difficulty in eating	Yes	47.6 (10)	0.081; 0.776	1.1	0.51-2.44	NA
	No	44.2 (46)		Ref		
Physical activity	Light activity	43.0 (34)	6.024; 0.049	0.5	0.2-1.11	0.342
	Heavy activity	25.0 (4)		0.2	0.05-0.81	0.079
	No activity	61.3 (19)		Ref		
Smoking status	Yes	85.7 (6)	5.401; 0.020	7.8	0.97-62.93	0.013
	No	40.9 (47)		Ref		
Alcohol consumption	Yes	35.5 (22)	3.954; 0.047	0.7	0.47-1.01	0.008
	No	53.2 (33)		Ref		
Consumption of animal products	Once daily	37.3 (31)	5.612; 0.060	0.3	0.02-3.42	0.914
	Once weekly	59.0 (23)		0.7	0.06-8.61	0.626
	Hardly	66.7 (2)		Ref		
Consumption of vegetables	Once daily	34.6 (28)	9.754; 0.008	0.3	0.02-3.04	0.241
	Once weekly	63.4 (26)		0.9	0.07-10.38	0.765
	Hardly	66.7 (2)		Ref		
Consumption of fruits	Once daily	34.6 (28)	9.754; 0.008	0.3	0.02-3.04	NA
	Once weekly	63.4 (26)		0.9	0.07-10.38	
	Hardly	66.7 (2)		Ref		
Consumption of starch-rich food	Once daily	45.0 (54)	0.183; 0.912	1.6	0.14-18.53	NA
	Once weekly	50.0 (1)		2.0	0.05-78.24	
	Hardly	33.3 (1)		Ref		

Table 6. Correlation between nutritional status (BMI), CD4 cell count, viral load and haemoglobin levels.

Nutritional status	Clinical characteristics	Correlation (r)	*p*-value*
BMI	CD4 cell count	0.117	0.155
	Viral load	-0.318	<0.001
	Haemoglobin	0.098	0.017

Table 7. Comparison between the means of CD4 count, haemoglobin and viral load with nutritional status.

	Undernutrition	Normal	Overweight/obese	Significance	
CD4	298.0 ± 78.4	302.4 ± 92.3	309.1± 91.1	F = 0.139,	*p* = 0.871
Hb	10.6 ± 2.6	11.5 ± 2.1	11.7 ± 2.1	F = 4.557,	*p* = 0.011
Viral Load	99,091.7 ± 129,209.5	81,469.1 ± 200,084.6	23,999.8 ± 107,363.4	F = 2.066,	*p* = 0.131

mal nutritional status, thus malnutrition in HIV-infected individuals on HAART should be taken seriously.

The main aim of HIV treatment is to enable patients to live a comfortable life. There are several markers of improvement in health for PLWHA. We assessed the effects of sociodemographic variables on haemoglobin levels, CD4 count and viral load. Smoking has been associated[25] with increased red blood cells in order to counter the effects of carbon monoxide in the bloodstream. However, it has been reported[26] that smoking is a risk factor for iron deficiency anaemia. Those who smoke had lower odds of being anaemic, though not significant.

Vegetables contain antioxidants and some other bioactive molecules that reduce inflammation[27], and those who ate more vegetables and/or fruit showed better CD4 counts[15,16]; moreover, immune markers were found[28] in patients with cardiovascular diseases. Our study showed that those who engaged in heavy physical activity had lower odds of high viral load. Other studies[29] have shown that increased physical activity also increases the cardiometabolic markers, the functional capacity of the patients, and reduced viral load by decreasing depression levels in PLWHA[30]. Smoking has also been associated[31,32] with increased viral load, which was also reflected in this study. Viral loads have been also found to be lower in those who ate more fruit and vegetables, as has also been previously reported[15].

The viral load had a negative correlation with BMI; meanwhile, haemoglobin levels showed a positive correlation with BMI. Harding et al[33] had a similar trend. Lower haemoglobin is a major risk factor for mortality in PLWHA, and haemoglobin levels should be assayed routinely, and the anaemia treated. Other studies[34,35] on HIV-negative individuals also show that HB was positively correlated to BMI.

CONCLUSIONS

Most of the PLWHA (52.8%) in this study had abnormal nutritional status, as evaluated by anthropometric indicators. However, the incidence of both obesity and undernutrition is a cause for concern as these negatively impact the health of patients. Eating vegetables, smoking, and doing physical exercise are factors identified to influence immune recovery. PLWHA are therefore encouraged to eat more vegetables, abstain from smoking and engage in physical exercise.

Acknowledgments:
We wish to acknowledge the administration and staff of the following health facilities: CDC Central Clinics Tiko and Bota, and The Regional Hospital Buea for collaborating in this study by providing preparing the patients and providing space for sample collection.

Ethics Approval:
Ethical clearance (2019/0250/UB/SG/IRB/FHS) was obtained from the Institutional Review Board of the Faculty of Health Sciences, University of Buea, and administrative authorization was obtained from the Director of the Regional Hospital, Buea, and Cameroon Development Corporation (CDC) Health Services.

Informed Consent:
Only individuals who volunteered to participate by signing a written informed consent were enrolled.

Funding:
This study received funding from a grant to Dr. Anye Delphine Tangoh as a Post-Doctoral career development fellowship (Ref: 2517/FCRM/D/DR/08-18) by the Central African Network for Tuberculosis, AIDS and Malaria (CANTAM) team. Sincere gratitude goes to the entire team of the funding body

Authors' contributions: Robert Vuchuh Nyingchu participated in the conception and design of the study, acquisition of data, analysis, and interpretation of data; drafting the Article, and revising it. Delphine Anye Tangoh participated in the conception and design of the study, acquisition of data, analysis, and interpretation of data; drafting of the Article, and revising it. Tobias Obejun Apinjoh participated in revising the article and final approval. Nahyeni Shiella Bassah participated in data acquisition and revising the Article. Sirri Teneng Ndipingwi participated in data acquisition, sample anal-

ysis, and drafting of the article. Godlove Bunda Wepnji analyzed the data and revised the article. Beatrice Loh Tangunyi participated in data acquisition. Abdel Njouendou Jelil made a critical revision of the Article, and Eric Akum Achidi supervised the work and approved the final version of the Article to be published.

ORCID ID:
Robert V. Nyingchu: 0000-0003-1606-516X
Delphine A. Tangoh: 0000-0002-1851-7222
Tobias O. Apinjoh: 0000-0001-9889-7271
Nahyeni S. Bassah: 0000-0002-4217-2391
Sirri T. Ndipingwi: 0000-0002-4630-2341
Godlove B. Wepnji: 0000-0001-8335-6624
Beatrice L. Tangunyi: 0000-0002-9735-5419
Abdel N. Jelil: 0000-0002-6336-6160
Eric A. Achidi: 0000-0001-5587-6243

Conflict of Interest:
None of the authors have any conflict of interest as they do not belong to the funding body.

Availability of Data and Materials :
The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

References

1. IN DANGER: UNAIDS Global AIDS Update 2022. Geneva: Joint United Nations Programme on HIV/AIDS; 2022. Licence: CC BY-NC-SA 3.0 IGO.
2. Costa JO, Ceccato MDGB, Silveira MR, Bonolo PF, Reis EA, Acurcio F de A. Effectiveness of antiretroviral therapy in the single-tablet regimen era. Rev Saúde Pública 2018; 52: 87.
3. Jiang X, Zhao Y, Jike KC, Xu JL, Yu G, Yu HL, Wang J, Zhao DC, Liao Q, Gan XM, Liu ZF. Survival time and related factors of antiretroviral therapy among HIV/AIDS patients in Liangshan Prefecture, during 2005-2015. Zhonghua yu Fang yi xue za zhi 2020; 54: 1237-1242.
4. Jevtović DJ, Dragović G, Salemović D, Ranin J, Djurković-Djaković O. The metabolic syndrome, an epidemic among HIV-infected patients on HAART. Biomed Pharmacother 2009; 63: 337-342.
5. Song Y, Qiu J, Hou W, Wang D, Yang Y. Micronutrient Supplementation Combined with HAART on Nutritional Status and Immune Function of AIDS Patients. Acta Microscopica 2020; 29: 2526-2532
6. Jiang J, Qin X, Liu H, Meng S, Abdullah AS, Huang J, Qin C, Liu Y, Huang Y, Qin F, and Huang J. An optimal BMI range associated with a lower risk of mortality among HIV-infected adults initiating antiretroviral therapy in Guangxi, China. Scientific reports 2019; 9: 7816.
7. Fact sheets - Malnutrition Accessed February 18, 2023. Available at: https://www.who.int/news-room/fact-sheets/detail/malnutrition.
8. Emery PW. Metabolic changes in malnutrition. Eye 2005; 19: 1029-1034.
9. Martins VJ, Toledo F, TMM G, LP F. M. do CP, Martins, PA, Clemente, APG, Sawaya, AL. Long-Lasting Effects of Undernutrition. Int. J. Environ. Res. Public Health 2011; 8: 1817-1846.
10. Duggal S, Chugh TD, Duggal AK. HIV and Malnutrition: Effects on Immune System. Clin Dev Immunol 2012; 12: 1-8.
11. Pereira PCM. Interaction between infection, nutrition and immunity in tropical medicine. J Venom Anim Toxins Trop Dis 2003; 9: 163-173.
12. Rose AM, Hall CS, Martinez-alier N. Aetiology and management of malnutrition in HIV-positive children. Arch Dis Child 2014; 99: 546-551.
13. Liu J, Wang L, Hou Y, Zhao Y, Dou Z, Ma Y, Zhang D, Wu Y, Zhao D, Liu Z, Zhang F. Immune restoration in HIV-1-infected patients after 12 years of antiretroviral therapy: a real-world observational study. Emerg. Microbes Infect 2020; 1: 2550-2561.
14. Shah GH, Maluantesa L, Etheredge GD, Waterfield KC, Ikhile O, Beni R, Engetele E, Mulenga A. HIV Viral Suppression among People Living with HIV on Antiretroviral Therapy in Haut-Katanga and Kinshasa Provinces of Democratic Republic of Congo. In Healthcare 2021; 1: 69
15. Hendricks KM, Mwamburi DM, Newby P, Wanke CA. Dietary patterns and health and nutrition outcomes in men living with HIV infection. Am J Clin Nutr 2008; 88: 1584-1592.
16. Kalantari N, Taghynejad M, Gholamalizadeh M, Torkaman M, Doaei S, Oraz N. Food group intake and Cd4 cell counts in Hiv infected patients. Acta Medica Mediterranea 2017; 33: 151-155.
17. Nuttall FQ. Body Mass Index: Obesity, BMI, and Health: A Critical Review. Nutr Today 2015; 50: 117-128.
18. Cappellini MD, Motta I. Anemia in Clinical Practice-Definition and Classification: Does Hemoglobin Change With Aging? Semin Hematol 2015; 52: 261-269.
19. Vajpayee M, Kaushik S, Sreenivas V, Wig N, Seth P. CDC staging based on absolute CD4 count and CD4 percentage in an HIV-1-infected Indian population: treatment implications. Clin Exp Immunol 2005; 141: 485-490.
20. Hess KL, Hall HI. HIV Viral Suppression, 37 States and the District of Columbia. J Community Health 2018; 43: 338-347.
21. Perpetue FFD, Charles KT, Anatole PC. Nutritional Assessment of HIV/AIDS patients in Centre Region of Cameroon: A pilot study. J Food Sci Nutr Res 2021; 4: 77-93.
22. Billong SG, Fokam J, Bissek A, Onambele G, Guegang C, Temgoua E, Abessouguie I, Mballa A, Nfetam J. Nutritional Profile in Households of HIV-Infected Patients receiving Antiretroviral Therapy in the 10 Regions of Cameroon: Toward the Implementation of Specific Food Interventional Programs. Revue de Médecine et de Pharmacie 2012; 2: 185-196.
23. Abba A, Fokam J, Kamgaing RS, Yimga JF, Ka'e AC, Nka AD, Tchouaket MC, Chenwi CA, Semengue EN, Ndjolo A, Sosso SM. Correlation between the immuno-virological response and the nutritional profile of treatment-experienced HIV-infected patients in the East region of Cameroon. PLoS One 2021; 16: e0229550.
24. Sharma A, Hoover DR, Shi Q, Gustafson D, Plankey MW, Hershow RC, Tien PC, Golub ET, Anastos K. Relationship between body mass index and mortality in HIV-infected HAART users in the women's interagency HIV study. PLoS One 2015; 10: e0143740.
25. Leifert JA. Anaemia and cigarette smoking. Int J Lab Hematol 2008; 30: 177-184.
26. Vivek A, Kaushik RM, Kaushik R. Tobacco smoking-related risk for iron deficiency anemia: A case-control study. J Addict Dis 2022: 1-9.
27. Hosseini B, Berthon BS, Saedisomeolia A, Starkey MR, Collison A, Wark PA, Wood LG. Effects of fruit and vegetable consumption on inflammatory biomarkers and immune cell populations: a systematic literature review and meta-analysis. Am. J. Clin. Nutr 2018; 108: 136-155.
28. Peluso I, Raguzzini A, Catasta G, Cammisotto V, Perrone A, Tomino C, Toti E, Serafini M. Effects of high consumption of vegetables on clinical, immunological, and antioxidant markers in subjects at risk of cardiovascular diseases. Oxid. Med. Cell. Longev 2018; 2018: e5417165
29. Bopp CM, Phillips KD, Fulk LJ, Dudgeon WD, Sowell R, Hand GA. Physical activity and immunity in HIV-infected individuals. AIDS Care 2004; 16: 387-393.

30. Blashill AJ, Mayer KH, Crane H, Magidson JF, Grasso C, Mathews WC, Saag MS, Safren SA. Physical activity and health outcomes among HIV-infected men who have sex with men: a longitudinal mediational analysis. Ann Behav Med 2013; 46: 149-156.
31. Cropsey KL, Willig JH, Mugavero MJ, Crane HM, McCullumsmith C, Lawrence S, Raper JL, Mathews WC, Boswell S, Kitahata MM, Schumacher JE. Cigarette smokers are less likely to have undetectable viral loads: results from four HIV clinics. J. Addict. Med 2016; 10: 13.
32. Pollack TM, Duong HT, Pham TT, Do CD, Colby D. Cigarette smoking is associated with high HIV viral load among adults presenting for antiretroviral therapy in Vietnam. PLoS One 2017; 12: e0173534.
33. Harding BN, Whitney BM, Nance RM, Ruderman SA, Crane HM, Burkholder G, Moore RD, Mathews WC, Eron JJ, Hunt PW, Volberding P. Anemia risk factors among people living with HIV across the United States in the current treatment era: a clinical cohort study. BMC Infect Dis 2020; 20: 1-8.
34. Lee BJ, Kim JY. Identification of Hemoglobin Levels Based on Anthropometric Indices in Elderly Koreans. PloS One 2016; 11: e0165622.
35. Kamruzzaman M. Is BMI associated with anemia and hemoglobin level of women and children in Bangladesh: A study with multiple statistical approaches. PloS One 2021; 16: e0259116.