



Research article

Serum vitamin E deficiency among people living with HIV and undergoing antiretroviral therapy at Ho Teaching Hospital, Ghana

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ABSTRACT

Vitamin E is a potent antioxidant that helps to counteract oxidative stress in the body. Oxidative stress is known to greatly affect people living with HIV (PLWH) through the stimulation of HIV replication and apoptosis of CD4+ T cells. There is however, a paucity of scientific data on the serum levels of vitamin E among PLWH in Ghana, and hence, there is a need to assess its level because of the pivotal role it plays in cell longevity determination and the immune system enhancement of such persons. This study aims to assess the serum levels of vitamin E among PLWH undergoing highly active antiretroviral therapy at Ho Teaching Hospital, Ghana. In a cross-sectional study, serum vitamin E levels of 103 randomly selected PLWH aged 24–88 years who attended an antiretroviral therapy clinic at the Ho Teaching Hospital, Ghana, were measured by following standard protocols. A 24-hour dietary recall and food frequency questionnaire were employed to assess dietary intake. The results show that a high level of serum vitamin E deficiency (82.5%) was observed among the participants. Majority (91.3%) of the participants had normal serum zinc status. Participants' serum vitamin E levels did not show significant correlation with their dietary intakes (correlation coefficient (ρ) = -0.094, p-value = 0.35). The prevalence of vitamin E deficiency among underweight, normal weight, overweight, and obese participants was 91.7%, 75.4%, 86.5%, and 91.7% respectively with no significant difference among these groups. There was no significant correlation between serum vitamin E levels and HIV infection duration (ρ = 0.010, p-value = 0.405) and HAART duration (ρ = 0.001, p-value = 0.313). The low serum vitamin E levels found in this study suggests that the participants could potentially be at an increased risk of developing oxidative stress and its effects.

1. Introduction

Vitamin E is a fat-soluble vitamin which primarily functions as an antioxidant. It is thus unique among other vitamins, which act as co-factors or have specific metabolic functions. Coupled with other nutrients and factors, it helps to prevent or reduce oxidative stress by breaking the oxidative chain reactions and by acting as a scavenger of free radicals [1].

According to studies, individuals with human immunodeficiency (HIV) virus infection experience oxidative stress because the virus and antiretroviral therapy (ART) are both known to produce free radicals that cause oxidative stress [2, 3, 4]. To counter these reactive species, serum vitamin E, one of the body's antioxidant defence machinery, could be depleted especially if dietary sources are not replenished [5, 6]. Adequate

consumption of the vitamin however prevents or attenuates its depletion [5]. It has also been reported that infections and drug side effects could reduce food intake, digestion, absorption, and metabolism of nutrients; especially micronutrients including vitamin E [7, 8, 9, 10].

Low levels of vitamin E could also enhance a state of oxidative stress, which may promote a pro-inflammatory state that could result in an endothelial dysfunction and subsequent cardiovascular diseases and cancers [11, 12]. Presence of oxidative stress and a proinflammatory state could compromise the immune function and promote progression of HIV infection into acquired immune deficiency syndrome (AIDS) which could lead to worsening of the quality of life the patients and mortality. Studies on the nutritional status of PLWH which analysed vitamin E levels are limited. In a Baltimore cohort among HIV seropositive men, no

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apparent relationship was found between the risk of progression to AIDS or mortality and low vitamin E levels; although participants in the highest quartile of vitamin E levels at enrolment displayed a reduced risk of progression to AIDS compared with the rest of the cohort [13]. In another prospective study, Graham et al. [14] assessed the serum levels of vitamin E among women living with HIV in Kenya. They concluded that higher vitamin E levels pre-infection are associated with higher mortality among the participants. These two results, as conflicting as they seem, reflects a persisting knowledge gap with regard to the role of vitamin E in HIV infection and disease progression. By enhancing immune response, vitamin E has been shown to confer protection against various infectious diseases in animal and human models. The proposed mechanisms involved with these include: firstly, the decrease of prostaglandin E₂ (PGE₂) production by the inhibition of cyclooxygenase (COX₂) activity mediated via reducing nitric oxide production; secondly, the enhancement of effective immune synapse formation in naive T cells and the initiation of T cell activation signals and, lastly, the modulation of Th1/Th2 balance [41].

There is paucity of scientific data on the serum levels of vitamin E among PLWH, especially in Ghana. This study assessed the serum vitamin E levels of PLWH who were undergoing antiretroviral therapy at Ho Teaching Hospital, Ghana. The findings from the research will make significant contributions towards existing knowledge on the role of vitamin E in HIV infections and form the basis for further investigations towards an improvement in HIV treatment, nutrition and health promotion among PLWH.

2. Materials and methods

2.1. Study design and participants

This is a hospital-based cross-sectional study carried out at the antiretroviral therapy (ART) clinic of the Ho Teaching Hospital (HTH) (formally the Volta Regional Hospital) in Ho, Ghana. The HTH is the fifth public Teaching Hospital in Ghana. Before its upgrade, the HTH was a 240-bed capacity government regional hospital that takes referrals from lower-level health units in the Volta region. Specialist services provided by the hospital include obstetrics and gynaecology, internal medicine, paediatrics, dental care, ear, nose and throat, radiology, imaging, nutrition and dietetics and physiotherapy. The ART unit was started in 2006 initially to manage HIV cases, but at present runs both the ART and tuberculosis (TB) clinics. The study population consisted both adult males and females who have been diagnosed with HIV and are attendants of the Ho Teaching Hospital ART clinic.

All consecutive ambulatory, non-smoking, non-acutely ill, HIV positive individuals, 18 years and above, diagnosed six months or more before data collection, were considered for the study. To be eligible for inclusion, participants should have been on antiretroviral therapy continuously for at least three months aside giving consent. The participants were not on any antioxidant vitamin therapy before the study and also did not have liver dysfunction, and/or intractable diarrhoea. One hundred and three participants, who were randomly sampled from a pool of eligible people, were recruited into the study.

Ethical clearance for the conduct of the study was obtained from the Committee on Human Research, Publications and Ethics (CHRPE), School of Medical Sciences – Kwame Nkrumah University of Science and Technology (SMS – KNUST) with reference number CHRPE AP/170/17. Permission to carry out the study at the HTH was given by the management of the hospital. Informed consent was obtained from the participants of the study.

2.2. Data collection

Demographic information was collected by using a pretested structured questionnaire. Anthropometric data that comprised height and

weight were taken. Venous blood samples were also collected for the various biochemical analyses by an experienced phlebotomist. Secondary data that provided information on participants' past and present medical histories that includes date of HIV diagnosis, date of initiation of HAART, drug history that includes antiretroviral drug combination, were obtained from study participants' medical records from the ART unit of the hospital.

2.3. Anthropometry

All measurements were taken by the principal investigator with assistance from two trained staff nurses, two dietitians, a nutritionist, and a resident doctor. The height and weight of the patients were measured using standardised protocols [15]. Both measures were taken using a Seca® stadiometer and digital scale (Seca, UK), respectively. Height was measured with subjects standing barefoot, arms hanging loosely, heads erect, and looking straight ahead, whereas heels, buttocks, and upper part of the back touched the scale. The readings were taken twice and recorded in centimetre (cm) and the average was calculated and recorded to the nearest 0.1 m. Weight was measured to the nearest 0.1 kg with the subject lightly dressed. Instruments used for the measurement were the same for all subjects. There was regular calibration of the weighing scale to prevent systematic errors.

2.4. Biochemistry

Venous blood was collected from the antecubital vein of the participants early in the morning after 8–12 h overnight fast. Collected blood was centrifuged and serum separated from blood cells after 4–6 h of collection and then frozen at below -20 °C. A set of samples were also transported under standard conditions to the Molecular Medicine Laboratory SMS, KNUST where serum vitamin E was analysed.

2.5. Serum zinc

Serum zinc was analysed at the clinical chemistry laboratory of the study centre by using Zinc test kit (colorimetric) (Biobase Bioindustry (Shandong) Co., Ltd, China) according to the manufacturer's instruction with reference (9.2–19.9) µmol/L. Sixty microlitres (60 µL) of serum samples derived from the participants' blood were pipetted into test tubes. About 1000 µL of reagent 1 was added and the mixture was incubated in a water bath at 37 °C for 5 min. Two hundred and fifty microlitres (250 µL) of reagent 2 was added to the test tube and mixed thoroughly, and thereafter, incubated in a water bath for 5 min. Absorbance was read immediately at 570 nm.

2.6. Serum vitamin E

Serum vitamin E was analysed using enzyme-linked immunosorbent assay (ELISA) sandwich method from (Biobase Biotech Ltd, Shandong, China) and an Inqaba Biotech Micro Plate Reader Elisa Plate Analyser, Inqaba Biotechnical Industries (Pty) Ltd, Pretoria, South Africa) according to the manufacturer's instructions. A microelisa strip plate provided in the kit was pre-coated with an antibody specific to vitamin E Standards. A Horseradish Peroxidase (HRP) - conjugated specific for vitamin E was added to each Microelisa strip plate well and incubated. All the free components were washed away. The 3, 3', 5, 5'-Tetramethylbenzidine (TMB) substrate solution was added to each well. Only those wells that contain vitamin E and HRP- conjugated vitamin E antibody appeared blue in colour, which then turned yellow after the addition of the stop solution. The spectrophotometric optical density (OD) was measured at a wavelength of 450 nm. The OD value is proportional to the concentration of vitamin E. The concentration of vitamin E in the samples was calculated in comparison with the OD of the samples to the curve.

2.7. Dietary assessment

Dietary information was collected using a 24-hour dietary recall and a food frequency questionnaire, adopting standardised methodology. For the 24-hour recall, participants were asked to recall all foods that included snacks consumed before 24 h of the data collection. The recall started backwards, from the recent food consumed to the last consumption, with their respective quantities. Handy measures were used to help respondents easily recall and estimate the portion of the various consumed foods. Major mealtimes i.e., breakfast, lunch, and supper, were captured, and then those meals taken in-between the major meals were also captured. The food frequency questionnaire was used to assess the number of times the participants consumed fruits and vegetables, plant oils, and fish oils over the past six months before data collection. Participants were asked whether they consumed the various food items on the food frequency questionnaire daily, once to thrice-weekly, monthly, occasionally, or if they never consumed them. The interviews were carried out by a registered nutritionist who recorded all responses in the questionnaire.

2.8. Data processing

Measured weight and height values were used to compute each participant's body mass index (BMI) as weight divided by the square of the height ($\text{Weight}/(\text{Height})^2$) in kg/m^2 . The WHO classification of BMI [16] was used to classify subjects in various weight statuses. Vitamin E deficiency was defined as serum levels $<12 \mu\text{mol}/\text{L}$ [17]. Serum zinc levels were classified using Johns Hopkins Medical Laboratories reference values, and those within the ranges from 0.0 – 9.2 ($\mu\text{mol}/\text{L}$) were classified as low, whereas those from 9.2 – 19.9 ($\mu\text{mol}/\text{L}$) were classified as adequate. The Ghana Foods and their Weights, (Dietetics Department, University of Ghana, Legon) was used to convert the quantities of the various food items recorded in the 24-hour recall and food frequency questionnaire into grams and their nutrient contents were analysed using Esha Food Processor® Nutrition Analysis Software, (Esha, Oregon, USA). Nutrient intakes were assessed using dietary reference intakes (DRIs) recommended by the Institute of Medicine (IOM) of the U.S. National Academy of Sciences [18]. A minimum caloric intake was determined using the median energy requirement for the population after the estimation of individual caloric requirements of participants using the Mifflin St Jeor formula. Median macronutrients intakes were compared with Acceptable Macronutrient Distribution Ranges (AMDR). Median carbohydrates, fats, and proteins were compared with the IOM of the U.S. National Academy of Sciences recommendation of 45%–65%, 20%–35%, and 20%–35% of caloric intake, respectively. Vitamins A, C, E, and D, and zinc were compared with recommended daily allowances (RDAs) [18].

In this study, duration of the HIV infection was determined by calculating the date from which HIV infection diagnosis was confirmed till the day blood sample collection was made. Likewise, HAART duration was calculated by using the date of initiation of HAART till the day of blood sample collection.

2.9. Statistical analysis

Data entry and analyses were done using the IBM® Statistical Package for Social Sciences (SPSS) version 22. Normality tests were carried on all continuous variables. The Chi-Square (χ^2) test of independence were performed on one categorical dichotomous, nominal, or ordinal variable, and between two categorical variables, respectively. The Spearman's correlation was also performed for association between nonparametric variables. The Wilcoxon signed rank test as used to compare various nutrients intakes of participants to recommended allowances. A p-value less than 0.05 was considered statistically significant for all analyses. Continuous variables that were normally distributed were presented as mean and standard deviation and those that were not, were reported as median (minimum and maximum). Categorical variables were presented

as frequencies, proportions, and percentages. Results were presented in tables, pie charts, and graphs, and possible interpretations of findings were made.

3. Results

The socio-demographic background of the study participants are presented in Table 1. A total of one hundred and three (103) participants took part in the study. Out of this number, (77) 74.80% were females and 26 (25.20%) were males. Most of the participants (74.80%) have just basic level education and majority (81.60%) of them was self-employed.

Table 2 shows the serum zinc and vitamin E statuses of participants. Serum zinc analysis of participants indicates that a greater proportion had normal levels. Low serum vitamin E levels was recorded among most of the participants. This translated into vitamin E deficiency in the majority (82.5%) of the study subjects.

Table 3 below shows BMI status of the participants. Overall, more than half (55.30%) of the participants had normal BMI, whereas 11.7% of them were either underweight or obese based on the BMI classifications.

When caloric intake is compared with their median requirements, females consumed 1552.0 kcal (384.0–4688.0 kcal/day) which is lesser than their median daily requirements of 1700.0kcal/day (1300.0–2000.0 kcal/day), whereas the males consumed 1956.5kcal/day (764.0–4314.0kcal/day) slightly above their median daily requirements; even though both differences show no statistical significance as contained in Table 4.

Vitamin A was not shown to be either above or below the recommended daily allowance. Vitamin C consumption were also low compared to recommended intakes although only that of males were statistically significant. Vitamins D and E intakes were low compared to the recommended intakes for both males and females. The measured values for zinc levels are not shown to be significantly different from the recommended.

There was no correlation between vitamin E intake and serum vitamin E level ($r^2 = -0.001$, $p = 0.99$) based on the result.

Figure 1 presents the frequency of consumption of vitamins A, C, and E rich foods and zinc-rich foods. The participants did not usually consume selected foods rich in the nutrients daily. Majority of the participants, 82.5%, 61.17%, and 67.96% only occasionally consumed vitamin C, vitamin E, and zinc-rich foods, respectively. Vitamin A-rich foods were consumed by 59.2% of the participants at least once a week.

Table 5 shows correlation analyses between serum levels of vitamin E and zinc against the duration of HIV infection and duration on HAART. Serum levels of vitamin E was neither significantly correlated with HAART duration, nor with HIV infection duration of participants. Although there were significant effects of HIV infection and HAART duration on serum levels of zinc of the participants, only 4.8% and 5.3% of the variability of serum zinc levels of the participants could be accounted for by HIV infection and HAART duration, respectively.

4. Discussion

This study assessed the intake and serum levels of vitamin E among people living with HIV (PLWH) and undergoing antiretroviral therapy at Ho Teaching Hospital in Ho, Ghana. Findings from our study revealed a high-level of vitamin E deficiency among the PLWH population. The results furthermore showed a general low dietary intake of vitamin E and other antioxidant micronutrients; vitamins A and C, and zinc, among the participants. The low dietary intake of vitamin E among the participants is further confirmed by the fact that the majority of them only consumed vitamin E rich foods occasionally.

Low dietary vitamin E intake and serum levels have been documented in earlier studies [19, 20, 21, 22]. In one of such studies which was conducted in Ghana [19], about 73% of HIV negative and 88% of HIV positive individuals were found to be deficient in vitamin E. Both low

Table 1. Basic characteristics of study participants stratified by gender.

Characteristic	Male (%)	Female (%)	Total (%)
Age categories (years)			
Less than 30	5 (19.2)	7 (9.1)	12 (11.6)
between 30 and 40	2 (7.7)	13 (16.9)	15 (14.6)
between 40 and 50	6 (23.1)	28 (36.4)	34 (33.0)
between 50 and 60	9 (34.6)	21 (27.3)	30 (29.1)
60 and above	4 (15.4)	8 (10.4)	12 (11.6)
Marital status			
Married	14 (53.8)	32 (41.6)	46 (44.7)
Not married	12 (46.6)	45 (58.4)	57 (55.3)
Educational background			
No formal education	2 (7.7)	6 (7.8)	8 (7.8)
Basic	17 (65.4)	60 (77.9)	77 (74.8)
Secondary	5 (19.2)	8 (10.4)	13 (12.6)
Tertiary	2 (7.7)	3 (3.9)	5 (4.9)
Occupation			
Civil servant	5 (19.2)	4 (5.2)	9 (8.7)
Self-employed	15 (57.7)	69 (89.6)	84 (81.6)
Unemployed	2 (7.7)	4 (5.2)	6 (5.8)
Others	4 (15.4)	0 (0.0)	4 (3.9)
Ethnicity			
Ewe	24 (92.3)	73 (94.8)	97 (94.2)
Akan	1 (3.8)	3 (3.9)	4 (3.9)
Other	1 (3.8)	1 (1.3)	2 (1.9)
Duration of HIV infection (years)			
Less than 5	17 (65.4)	44 (57.4)	61 (59.2)
Between 5 and 10	8 (30.8)	30 (39.0)	38 (36.9)
10 and above	1 (3.8)	3 (3.9)	4 (3.9)
Duration on HAART (years)			
Less than 5	18 (69.2)	46 (59.7)	64 (62.1)
Between 5 and 10	7 (26.9)	29 (37.7)	36 (35.0)
10 and above	1 (3.9)	2 (2.6)	3 (2.9)

Data are presented as absolute values with corresponding percentages in parentheses.

dietary intake and serum levels of vitamin E have been described by Stephensen et al. [20] among young adults living with HIV.

Although the consumption of dietary vitamin E was also below the recommended daily allowance, this study could not link it to the high-level of deficiency found in the study population, as there was no statistically significant correlation with the serum levels. Studies [23, 24, 25, 26] have revealed that dietary α -tocopherol intake do not correlate very highly with circulating α -tocopherol concentrations which seemingly supports this study's results. A more controlled experiment is required to specifically assess the existence of this relationship.

Table 2. Serum vitamin E and serum zinc status of participants.

	Number of participants	Percentage
Serum vitamin E		
Less than 12 $\mu\text{mol/L}$	85	82.5
Above 12 $\mu\text{mol/L}$	18	17.5
Total	103	100.0
Serum zinc		
0–9.2 ($\mu\text{mol/L}$)	9	8.7
9.2–19.9 ($\mu\text{mol/L}$)	94	91.3
Total	103	100.0

Data are presented as absolute values (n) with corresponding percentages in parentheses. [‡] Serum zinc data -based on Johns Hopkins Medical Laboratories reference values (9.2–19.9 $\mu\text{mol/L}$).

Vitamin E is the most significant lipid-soluble antioxidant in the cell that functions as a powerful peroxy radical scavenger. From its position in the lipid portions of the cell membrane, it protects unsaturated phospholipids of the membrane from oxidative degeneration as a result of ROS and other free radicals using a chain-breaking antioxidant action and also exerts this antioxidant action on plasma lipoproteins [1]. Peroxy radicals ($\text{ROO}\bullet$) after being generated react many times faster with vitamin E (Vit E-OH) compared with polyunsaturated fatty acids (PUFA or RH); hence, vitamin E protects lipoproteins and membranes from the chain reaction of lipid peroxidation. Hydroperoxide (ROOH) and the tocopheroxyl radical (Vit E – O) are made as the peroxy radical reacts with the hydroxyl group of tocopherols. The tocopheroxyl radical reacts with a hydrogen donor, such as vitamin C, where it oxidises the latter and returns vitamin E to its reduced state.

As an antioxidant, serum vitamin E levels may reduce because of HIV- and HAART -induced oxidative activity, where more of this vitamin will be used up to prevent oxidative stress. Data from this study, however, could not show any significant effects of HIV infection and HAART duration on serum vitamin E levels. This is different from the serum zinc levels that were shown to be affected by both the duration of HIV infection and HAART use. The duration of antiretroviral therapy has been shown to be correlated with some dysfunctions in HIV infection in previous studies [27, 28]. Most of these studies, however, did not specifically assess these associations between specific microelements such as vitamin E and zinc. The effects of HAART on oxidative stress still remain a controversial subject [29]. Well-controlled longitudinal studies are therefore, vital in resolving these conflicting reports.

Clinical indicators of vitamin E deficiency vary substantially and may take 5–10 years to develop. They mostly target certain organ systems such as the vascular, neuromuscular, and reproductive systems. Main symptoms include loss of deep tendon reflexes, impaired vibratory and position sensation, changes in balance and coordination, muscle weakness, and visual disturbances [30]. Apart from causing neurologic disorder, vitamin E deficiency also causes muscle deterioration and this may lead to death [23]. In HIV infection, vitamin E deficiency has been associated with heightened wasting levels, increased viral load, and oxidative stress [31]. As most of the participants had normal BMI in addition to others who were obese, this study did not support the association of vitamin E deficiency with wasting. Low serum vitamin E levels found in this study suggests that the participants could potentially be at an increased risk of developing oxidative stress; but its effects have not been established in this study, and therefore, should be investigated in future studies.

The deficiency of vitamin E is seldom observed in adults, but is more frequent in children; apparently because of limited stores and also because children are in the growth phase [23]. The population under consideration is, however, unique from the general population because of the HIV infection and the dependence on ART, and hence, the high proportion of them recording low serum levels of vitamin E is worrying. Considering the fact that vitamin E deficiency effects take time to present with symptoms, more research is required to understand the gaps unearthed in our study.

Zinc remains a vital mineral for human health because of its role as a co-factor for over 2000 transcription factors and 300 enzymes and as an essential mediator of cellular signalling [32, 33]. Although not an antioxidant, zinc functions in protecting cells against oxidative stress. It is thus considered a pro antioxidant as it protects cells against detrimental effects of oxygen radicals generated during immune activation [34]. This study revealed that serum zinc levels of majority of the participants fell within the normal range (Table 3). The results however, contradicts earlier studies that found zinc deficiency to be prevalent among HIV-infected people [35, 36, 37, 38, 39]. Adequate dietary intakes of zinc were found among participants and this could explain the amount of serum levels among them. Furthermore, the seemingly 'good' serum zinc levels recorded could also be credited to the adequate protein intake of the participants (Table 4.8) as proteins, especially animal source proteins

Table 3. Body mass index distribution among participants.

	Underweight (n = 12)	Normal (n = 57)	Overweight (n = 22)	Obese (n = 12)	p – value
% Vitamin E deficient	91.7	75.4	86.4	91.7	0.22
% Vitamin E sufficient	8.3	24.6	13.6	8.3	

Data is presented as percentages; n is the total number of participants in each category. P-value generated from a chi square test. P-value is significant at $p < 0.05$. Each column sums up to 100%.

Table 4. Pattern of nutrients intake by participants by gender.

	Males			Females		
	Nutrient intake Median (min – max)	AMDR	P-value	Nutrient intake Median (min – max)	AMDR	P-value
Calories	1956.5 (764.0–4314.0)	1900.0 (1400.0–2400.0)	0.47	1552.0 (384–4688)	1700.0 (1300.0–2000.0)	0.62
Macronutrients						
Carbohydrate(g)	332.0 (130.0–777.0)	260.0 (240.0–290.0)	0.02	240.0 (76.9–836.0)	225.0 (200.0–250.0)	0.04
Fat(g)	33.40 (4.52–129.0)	70.0 (65.0–76.0)	0.02	37.9 (3.5–94.4)	60.5 (56.0–65.0)	<0.001
Protein(g)	70.25 (14.5–127.0)	60.0 (49.0–72.0)	0.15	46.1 (7.7–156)	50.2 (42.0–62.0)	0.80
Micronutrients						
Zinc (mg)	9.4 (2.78–26.2)	11.00	0.40	8.4 (1.7–28.1)	8.0	0.30
Vitamin A (µg)	307.0 (15.5–3306)	900.00	0.29	287.0 (0–3350)	700.0	0.61
Vitamin C (mg)	43.9 (0–255)	90.00	0.01	57.70 (0.00–334.0)	75.0	0.38
Vitamin D (µg)	0.0 (0–89.2)	15.00	<0.001	0.0 (0–72.7)	15.0	<0.001
Vitamin E (mg)	0.0 (0.00–6.97)	15.00	<0.001	0.0 (0.0–8.5)	15.0	<0.001

Data are presented as median with minimum and maximum values in parenthesis. AMDR – Acceptable Macro/Micro-nutrient Distribution Ranges/Values for adults (WHO, 2004). Carbohydrate, 50–60%; Fat, 30–35%; and Protein, 10–15% of total calorie for macronutrients. P-values were generated from Wilcoxon signed-rank test and were statistically significant at $p < 0.05$. Significant p-values are in bold.

are good zinc sources according to Mahan and Raymond [40]. Our analysis however, did not find a significant association between dietary zinc intakes and serum levels. In a similar observation [35], an association between zinc intake and plasma zinc levels was not found when an assessment of plasma zinc status of HIV- infected individuals who either had hyperglycaemia or normoglycaemia was done. Findings from this present study, are however contrary to what Baum et al. [37] reported in their study when they assessed the serum zinc status of HIV infected people who used illicit drugs. They demonstrated that there was a dose effect of dietary zinc intake on plasma zinc status. Zinc supplementation

at nutritional levels has been shown to delay immunological failure and reduce diarrhoea over time in patients with poor viral control [36]. Notwithstanding the findings about zinc in this study, there are concerns that excess serum zinc enhances HIV replication and consequently increases viral load and reduces survival. Caution should therefore be taken, taking into consideration the dietary intakes of the individuals when implementing supplementation programmes.

This study found that participants' fat intakes were low. This finding corroborates well with those reported by Juma et al. [42] in Kenya where they documented low energy and fat intake for nearly half of the

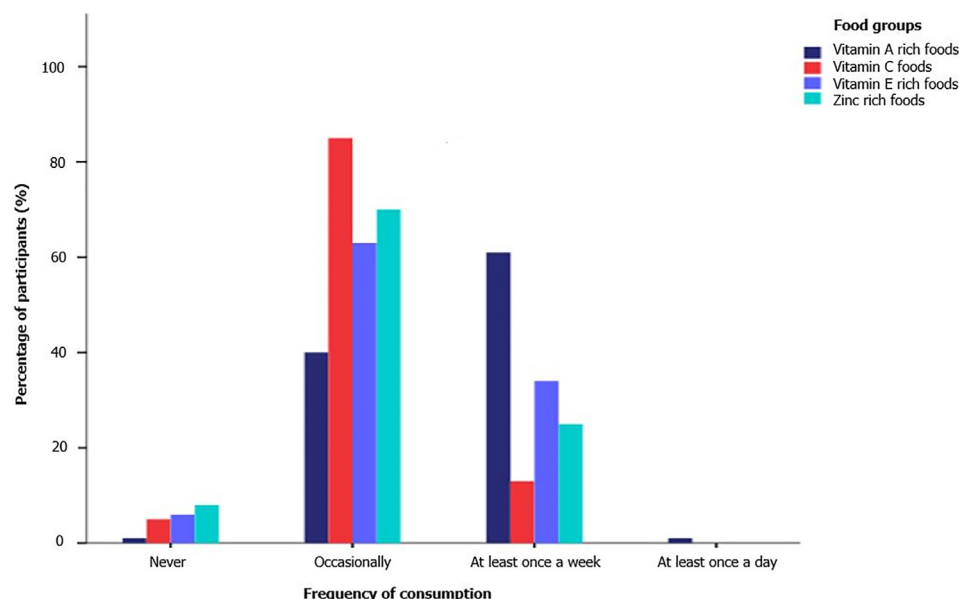
**Figure 1.** Participant consumption pattern of selected vitamins A, C, and E, and zinc-rich food.

Table 5. Correlation between duration of HAART and HIV infection and serum zinc and vitamin E of participants.

	HAART duration (years)		Duration of HIV infection (years)	
	r ²	P-value	r ²	P-value
Serum zinc (μmol/L)	0.053	0.02*	0.048	0.03*
Serum vitamin E (μmol/L)	0.001	0.31	0.010	0.41

Data are presented as r² (p-value). r²-coefficient of determination. *P-value is significant at p < 0.05.

population (120 HIV infected individuals) studied. It however contrasts Hendricks et al.[43] who found high intakes among 321 HIV infected adults in the United States and Klassen and Goff [44] who reported higher than recommended saturated fat intakes among their cohort in the UK. Energy requirements among PLWH have been shown to vary greatly, with obese people possessing less metabolically active tissues hence, lower energy per kilogram weight requirements. High intakes of saturated fats are associated with increased risk of developing cardiovascular diseases and contribute to abnormalities in lipid metabolism during HAART.

5. Limitations

This study has its own limitations. Data on HIV viral load and CD4+ T-cell count were not collected. These data are potential confounding factors that could affect the results. Future studies should include these variables as confounders. All dietary assessment methods have their limitations and related criticisms. The 24-hour dietary recall and the food frequency questionnaire employed in this study depends fully on the respondent's memory and as such recalls could be biased which could lead to underreporting or overreporting of the types, amounts, and frequencies of food intake.

6. Conclusion

Data from this study showed a high level of serum Vitamin E deficiency among the PLWH in this study. It also showed a low dietary intake of vitamin E and other antioxidant micronutrients; vitamins A and C, and zinc among the participants. As the symptoms of vitamin E deficiency are usually sub clinical and take time to develop, and also because the antioxidant effect of this vitamin is important for PLWH, more research is required to further understand the dynamics of vitamin E intake, serum levels, and clinical effects on the PLWH.

Declarations

Author contribution statement

Daniel Edem Kpewou: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Faustina O. Mensah: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Collins A. Appiah: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Huseini Wiisibie Alidu: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Vitus Sambo Badii: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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