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Original Research

# Obesity Defining Criteria, and Association with Cardiovascular Disease Risk Factors Among People Living with HIV in Jos, Nigeria.

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## Abstract

**Background:** Obesity is linked to non-communicable conditions. We looked at obesity using four definable criteria and their relationship to biochemical and inflammatory indicators of cardiovascular diseases (CVDs) in people living with HIV (PLHIV).

**Methodology:** This cross-sectional study involved 140 randomly selected HIV-infected patients attending HIV clinics at the Jos University Teaching Hospital and Faith Alive Foundation in Jos, Nigeria. Anthropometric measurements such as height, weight, waist circumference, and hip circumference were taken to identify those with obesity. Fasting plasma glucose, lipid profile, High-sensitivity CRP (hsCRP), and HIV-related markers were evaluated.

**Result:** The mean (SD) age of the participants was 42.5 (8.8) years, and the majority (71.4%) were females. The prevalence of Obesity based on Body-Mass-Index (BMI), International Diabetes Federation (IDF), Adult Treatment Panel (ATP), and Waist-Hip-Ratio (WHR) criteria were 18.6%, 50.7% 34.3%, and 45.7% respectively. Obesity concordance among the criteria for obesity was highest between IDF and ATP (Kappa= 0.673, $p<0.001$); and least between BMI vs WHR (Kappa= 0.124, $p<0.073$). Only 9.3% had obesity by all 4 criteria. BMI was independently associated with hypertension but not glycaemic status nor dyslipidaemia while Obesity by WHR was significantly associated with hypertension and dyslipidaemia, after adjusting for age and sex. There was no significant association between Obesity by all the criteria and HIV-related parameters such as duration of HIV infection, Antiretroviral (ARV) use, and CD4 counts ($p>0.05$).

**Conclusion:** Our study urges a unified assessment of obesity and a more prominent use of parameters of central obesity, for assessing cardiovascular risk in PLHIV.

**Keywords:** HIV; Obesity; Cardiovascular Disease Risk; Dyslipidaemia.

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## Introduction

Obesity is a worldwide public health problem due to its link to several diseases, resulting in morbidity and mortality. Obesity is linked to adverse alterations in metabolic and cardiovascular parameters, such as insulin resistance, dyslipidaemia, blood pressure, and markers of systemic inflammation, therefore, it is associated with non-communicable diseases such as diabetes mellitus, cardiovascular disease, asthma, and arthritis, liver disorders, certain cancers among others [1, 2].

Fundamentally, obesity occurs due to an imbalance in the calories consumed and calories expended. This often manifests as an increased intake of energy-packed foods high in fat and sugars on one hand and an increase in physical inactivity and a sedentary lifestyle on the other [3]. However, besides nutritional factors and physical activity, other factors including genetics, hormonal and metabolic factors particularly in women have been fingered in the aetiology of obesity.[4]

The prevalence of obesity is on the increase. The World Obesity Federation estimates that 770 million adults worldwide were estimated to be obese by 2020 and expected to rise to more than one billion by 2030 with 6.6% of the global load expected to come from sub-Saharan Africa (SSA) [5,6].

The concept of epidemiological transition has been suggested to explain the increasing prevalence of obesity in sub-Saharan Africa (SSA) due to a tendency towards urbanization and Western lifestyle [7,8].This is a divergence from the generally accepted picture of the region being plagued by infectious diseases and starvation, which causes underweight. Until recently, the HIV epidemic, whose epicenter is in SSA, was thought of as a "wasting disease" marked by undernutrition and weight loss. Nonetheless, the introduction and ongoing use of antiretroviral medications (ARVs) has improved the outlook for the condition and increased the life expectancy of People Living with HIV (PLHIV). This however has created a problem of rising incidence of non-communicable diseases especially cardiovascular diseases (CVDs) in PLHIV [1,9].

Obesity as one of the prevalent risk factors for CVDs in PLHIV is significantly linked to other factors such as insulin resistance, impaired glycaemia, dyslipidaemia, and hypertension in a constellation of metabolic syndrome [1, 5]. Obesity is also associated with increased low-grade inflammation [5].These accompanying features have been implicated in an atherosclerotic process that underlies CVDs [1, 5].

It has been suggested that obesity be classified based on the composition and distribution of body fat rather than just an increase in body weight and the Body Mass Index because PLHIV on ARVs may have differential fat deposition, which may alter the assessment and classification of obesity. Conventionally, obesity has been assessed by Body Mass Index (BMI), Waist circumference (WC), and Waist-to-Hip (WHR). The merits and demerits of each assessment and classification system have been previously highlighted [10-13]. Understanding how PLHIV should be assessed for obesity as part of their usual care is essential. However, the relative prevalence of obesity based on the various defining criteria and its associations for CVD in PLHIV in our setting has not been thoroughly examined. So, in this study, we looked at obesity in relation to several definable criteria and how these relate to biochemical and inflammatory indicators of CVDs.

## Methods

### Study design

This was a cross-sectional observational study among PLHIV. The study population includes PLHIV who were at least 2 years on ARVs at the time of recruitment.

**Setting**

This study was conducted in Jos, the metropolitan capital city of Plateau State, North Central Nigeria. Participants were recruited from HIV clinics at the Faith Alive Foundation (FAF) and Jos University Teaching Hospital (JUTH) both situated in Jos and among healthcare facilities supported by the AIDS Prevention Initiative in Nigeria (APIN) to provide HIV treatment and care to people living with the virus. The same National AIDS Control Agency treatment protocol is used for HIV care at both clinics.

**Study Population**

The study participants include 140 randomly selected HIV-infected adults on ARV. Selected participants had stable infection with undetectable viral load (plasma HIV-1 RNA < 20 copies per milliliter) within 1 year of the study. Exclusion criteria included severe illness requiring in-patient care, pregnancy, known CVDs, and current use of steroids.

**Data Source and Study Procedure**

A structured questionnaire was used to obtain information such as age, gender, educational status, occupation, cigarette smoking, alcohol intake, physical activity, dietary habits, relevant medical history (see questionnaire in supplementary materials), and family history. HIV-related history was obtained from patients' electronic medical records for APIN and manually from the hospital records at Faith Alive Foundation; known duration of HIV infection, the start date of ART, current ARV regimen, and previous changes in regimen, and the latest CD4+ cell count, and HIV viral load were retrieved. Physical examinations such as Blood pressure and anthropometric measurements such as height, weight, hip, and waist circumference were according to standard procedures [12].

**Blood sample collection and biochemical analysis**

Five millilitres of blood specimens were collected after an 8–12 hour overnight fast into a plain vacutainer for the lipid profile and fluoride oxalate vacutainer for the glucose assay. Serum and plasma were separated after 10 minutes of centrifugation at 4000 revolutions per minute. While samples for aliquots for lipid profile assays were kept at -20°C in a carefully maintained freezer for one month before the analyses, plasma glucose was assessed on the day that samples were collected.

Fasting plasma glucose concentration was measured using the Hexokinase method, triglyceride (TG), and high-density lipoprotein cholesterol (HDLc) were analyzed with standard enzymatic methods and hsCRP by immunoturbidimetric method. All assays were analyzed on a Roche Cobas C111 analyzer (Roche Diagnostics, Germany). Quality control was assured by simultaneous analysis of control specimens.

**Working Definitions**

Obesity was defined as BMI>30kg/$m^2$ (ObesityBMI), waist circumference (male/female): >94/80cm (ObesityIDF) according to IDF criteria, > 102/88cm (ObesityATP) according to ATP criteria, and Waist-Hip-ratio (male/female) > 0.90/0.85 (ObesityWHR) according to WHO [12, 14, 15].

Hypertension (as a component of metabolic syndrome) was defined as systolic blood pressure (SBP) ≥130 mm Hg and/or diastolic blood pressure (DBP) ≥ 85 mm Hg (according to NCEP/ATP and IDF criteria) and/or the use of antihypertensive medication [15, 16]. Impaired fasting glucose was regarded as fasting blood glucose (FBG) between 6.0 to 6.9mmol/L and diabetes mellitus was determined by medical history of confirmed diabetes mellitus (from patients' records), fasting plasma glucose (FPG) ≥ 7.0mmol/L and/or random plasma glucose ≥ 11.1 mmol/L.

Dyslipidaemia was defined as: Triglycerides ≥1.70 mmol/L, HDLc< 1.03mmol/L in males and <1.30mmol/L in females, LDLc ≥ 3.4mmol/L, Non-HDLc (TC-HDLc) ≥ 4.1mmol/L [17]. A sedentary lifestyle was defined as a lack of regular physical exercise (at least 30 minutes three times weekly). The following lipid indices/ratios were assessed: TC/HDLc, LDLc/HDLc, TC-HDLc/HDLc, and Atherogenic Index of Plasma (AIP) which was computed as Log TG/HDLc. AIP > 0.24 was classified as high-risk [18, 19].The age of 40 years was used as cut off to categorise participants based on the European Society of Cardiology (ESC) assessment of increased risk for cardiovascular [20].

**Statistical Analysis**

Data were recorded in Microsoft Excel® version 2.0 (Microsoft Corp., Redmond, Washington, USA) and exported to SPSS® software version 23.0 (IBM Corp., Chicago, Illinois, USA) for analysis. Descriptive statistics were presented as medians with interquartile ranges (IQRs) for non-parametric continuous variables and normally distributed continuous variables were presented as means (SD), Categorical variables were presented as proportions (as percentages). Mann-Whitney U test was used to test the difference in medians of continuous variables between groups and Chi-square and Fisher's exact was used to test relationships among variables. The agreement between the diagnostic criteria for obesity was assessed with the use of kappa statistics. Kappa statistics values were interpreted as poor (kappa ≤ 0.2), fair (0.2 < kappa ≤ 0.4), moderate (0.4 < kappa ≤ 0.6), substantial (0.6 < kappa ≤ 0.8), and very good (kappa > 0.8). The significance level was set at $p \leq 0.05$.

**Ethical consideration**

The ethical committee of Jos University Teaching Hospital and Faith Alive Foundation. approved the study with IRB number (JUTH/DCS/ADM/127/XXV/168). Consent for publication for research purposes was taken from the participant.

## Results

The participant's mean (SD) age was 42.5 (8.8) years and the majority 71.4% were females. The mean (SD) weight was 67.5 (14.4) kg, and this was similar in males and females. Females had significantly higher BMI (26.9±5.5 kg/m$^2$ vs 24.4±3.6 kg/m$^2$), waist circumference (88.3±12.1cm vs 82.5±13.5 cm), and hip circumference (103.7±16.9 cm vs 92.5±11.7 cm) compared to their male counterpart, p< 0.05. The blood pressure, glucose, lipid parameters, and hsCRP are summarised in Table 1 and were not statistically different between males and females, p>0.05. Only 17.9% and 12.9% were sedentary and had a history of alcohol consumption respectively and was also not statistically different in males and females, p>0.05.

**Table 1: General Characteristics of the Study Participants by Gender**

| Variable (Median; IQR) | Total (n=140) | Female (n=100) | Male (n=40) | p-value |
|---|---|---|---|---|
| Age (years; (mean±SD) | 42.5 ± 8.8 | 40.2±7.9 | 48.2± 8.2 | <0.0001 |
| Systolic BP (SBP) mmhg (mean±SD) | 124.5 ± 20.7 | 122.4 ±18.2 | 129.8±25.3 | 0.056 |
| Diastolic BP (SBP) mmhg (mean±SD) | 79.2±10.9 | 78.6 ±10.3 | 80.6±12.2 | 0.338 |
| Weight (mean±SD) | 67.6 ±14.4 | 67.5±15.7 | 67.7±10.6 | 0.937 |
| Height (mean±SD) | 1.6 ±0.1 | 1.6±0.1 | 1.7±0.1 | 0.000 |

| | | | | |
|---|---|---|---|---|
| Waist circumference (cm) (mean±SD) | 86.7 ±12.9 | 88.3±12.1 | 82.5±13.8 | 0.015 |
| Hip Circumference (mean±SD) | 100.5 ±16.3 | 103.7±16.9 | 92.5±11.7 | <0.0001 |
| BMI (kg/m$^2$) (mean±SD) | 26.2 ±5.1 | 26.9±5.5 | 24.4±3.6 | 0.011 |
| Waist-to-hip ratio (WHR) (median; IQR) | 0.87 (0.83-0.92) | 0.85 (0.82-0.91) | 0.89 (0.86-0.95) | 0.002 |
| Fasting Plasma Glucose (mmol/L) (mean±SD) | 5.3 ±1.3 | 5.3±1.3 | 5.4±1.3 | 0.680 |
| Total Cholesterol (mmol/L) (mean±SD) | 5.1 ±1.3 | 5.2±1.3 | 4.8±1.3 | 0.091 |
| Triglyceride (mmol/L) (mean±SD) | 1.2 ±0.9 | 1.2±1.0 | 1.3±0.9 | 0.512 |
| HDL Cholesterol (mmol/L) (mean±SD) | 1.0 ±0.4 | 1.1±0.3 | 0.9 (0.7-1.2) | 0.245 |
| LDL Cholesterol (mmol/L) (mean±SD) | 2.5 ±0.9 | 2.6±0.9 | 2.3±1.0 | 0.104 |
| Non-HDL (mean±SD) | 4.0 ±1.3 | 4.1 ±1.4 | 3.8 ±1.2 | 0.175 |
| TC/HDL (mean±SD) | 5.4 ±2.4 | 5.4 ±2.3 | 5.6 ±2.4 | 0.639 |
| LDL/HDL (mean±SD) | 2.6 ±1.3 | 2.6 ±1.2 | 2.7 ±1.6 | 0.865 |
| TC-HDL/HDL (mean±SD) | 4.4 ±2.3 | 4.4 ±2.3 | 4.6 ±2.6 | 0.639 |
| Atherogenic Index of Plasma (AIP) (median; IQR) | 0.01 (-0.19-0.22) | -0.02 (-0.23-0.22) | 0.07 (-0.12-0.29) | 0.236 |
| HsCRP (median; IQR) | 2.9 (0.8-5.9) | 2.9(1.1-5.8) | 2.4(0.5-9.8) | 0.583 |
| HIV Duration | 5 (3.0 - 10.0) | 5 (3.0 - 9.0) | 8.0 (4.0 - 11.0) | 0.025 |
| ARV Duration | 4 (3.0 - 9.8) | 4 (3.0 – 8.0) | 7.0 (4.0 - 11.0) | 0.025 |
| Latest CD4 count (cells/ul) (Median; IQR) | 441.0 (293.0-614.5) | 479.5(311.0-674.5) | 387.0 (274.3-494.5) | 0.015 |

The prevalence (95% CI) of obesity based on BMI, IDF, ATP, and WHR criteria were 18.6% (12.1% - 25.0%), 50.7% (42.1% -58.6%), 34.3% (26.4% -42.1%) and 45.7% (38.6% -54.3%) respectively.Obesity concordance among the criteria for obesity was highest between IDF and ATP (Kappa= 0.673, p<0.001); this was followed by BMI vs ATP (Kappa= 0.502, p<0.001), IDF vs WHR (Kappa= 0.386, p<0.001) and ATP vs WHR (Kappa= 0.384, p<0.001). The least agreement was between BMI vs WHR (Kappa= 0.124, p<0.073); see Fig 1. Only 13 (9.3%) had obesity by all criteria. The frequency of obesity by a combination of at least two different criteria is illustrated in the Venn diagrams in Figure 1.

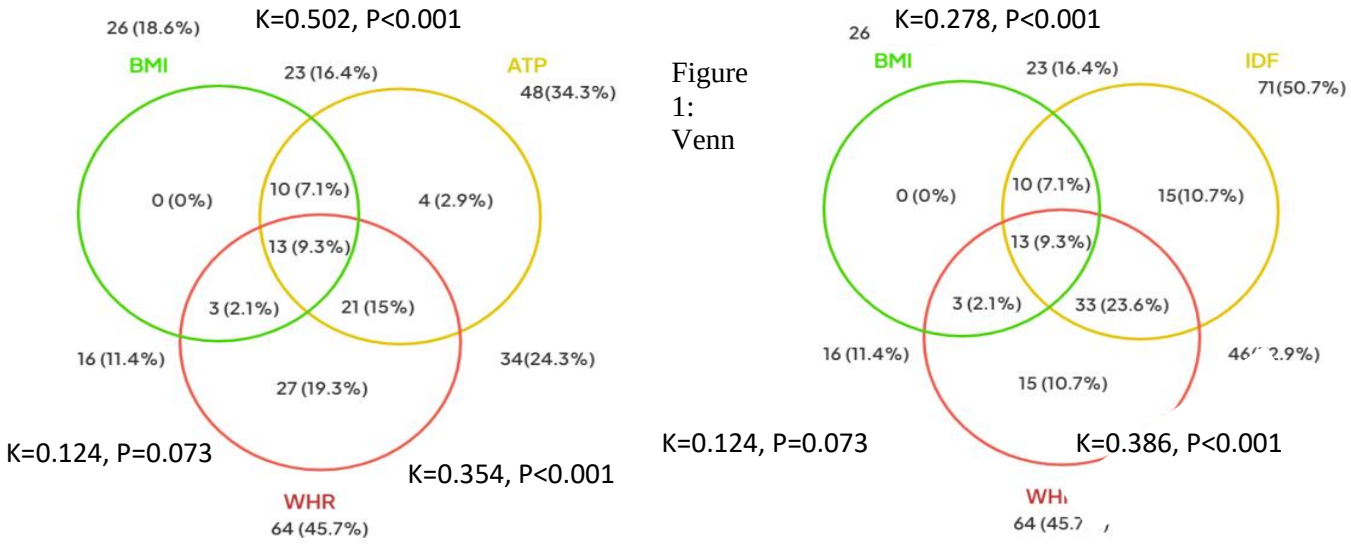


Figure 1: Venn diagram of the prevalence and concordance of Obesity among Diagnostic criteria

The prevalence of obesity was proportionally and significantly higher among females compared to males by BMI criteria 24% vs 5%, p=0.018: IDF criteria 65% vs 15%, p=<0.001 and ATP criteria 47% vs 2.5%, p=<0.001. However, although women had proportionally higher obesity by WHO criteria, this was not statistically significant, p=0.391. There was no statistically significant difference in the prevalence of obesity by age group using BMI, IDF, or ATP criteria. However, participants 40 years or older were more likely to have obesity defined by the WHO criteria, p<0.001, see Figure 2.

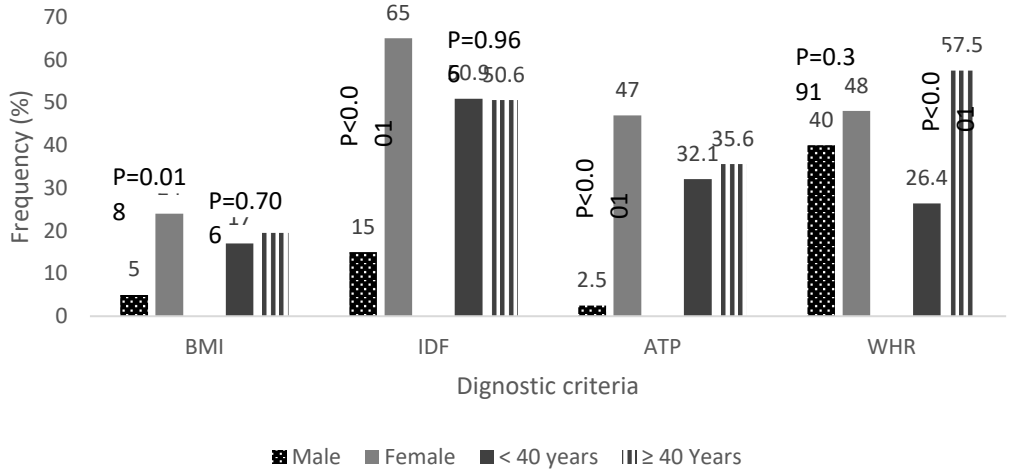


Figure 2: Association between Sex, Age group, and Obesity across four diagnostic criteria

The relationship between obesity and biophysical, biochemical, and HIV-related parameters is illustrated in Table 2. Females were more likely to have obesity by BMI, IDF, and ATP criteria even after adjusting for age. Obesity was significantly associated with hypertension by BMI and WHR criteria and this remained significant after adjusting for sex and age. Obesity was significantly associated with the composite definition of dyslipidaemia by IDF, ATP, and WHR criteria although. This significant association was lost after multivariate analysis controlling for age and sex. Individuals with obesity by

ATP (OR95%CI = 3.0 (1.46-6.18) and WHR (OR;95%CI = 2.79 (1.40-5.56) were more likely to have hypercholesterolemia. This remained significant after adjusting for age and sex. Low HDLC was only associated with obesity by IDF criteria in the bivariate analysis. Obesity by ATP and WHR were significantly associated with increased non-HDLC however, after multivariate analysis only the association with obesity by WHR criteria remained significant. Obesity by BMI and ATP was only associated with elevated hsCRP in the bivariate analysis. There was no significant association between obesity by all the criteria and HIV-related parameters such as the use of second-line ARVs, duration of HIV infection, ARV use, Nadir, and Latest CD4 counts ($p>0.05$), see Table 2.

## Discussion

The result from this study showed that the prevalence of obesity was highest by the IDF criteria and lowest by the BM1 criteria thus the prevalence of obesity in this population of PLHIV ranged from 18.6% to 50.7%.This was much higher than a prevalence of 10.5% and 13.6%by BMI criteria obtained in a recent studies among PLHIV in Nigeria [1, 21]. Also, using BMI criteria, a prevalence of 31% was reported in a peri-urban Nigerian setting while the overall prevalence in sub-Saharan Africa was 34% [5]. The prevalence of central obesity by ATP criteria was slightly higher than 30.6% among PLHIV on ART in Calabar and for obesity byIDF criteria, it was lower than 66.6% in the same study [22]. The prevalence of WHR in this study was also lower than 71.7% found in an Ethiopian population [23]. This suggests that the wide variation of obesity prevalence depends on the population under study. Lifestyle and nutrition may be a plausible reason for this.

The female sex was an independent risk factor for obesity by BMI, IDF, and ATP criteria. However, the WHR criteria were not associated with gender. This may be because, in addition to the different WHR cut-offs used in males and females, the hip circumference included in the WHR varies significantly depending on the gender and serves as a correcting factor for the waist circumference. Our findings agree with several prior studies which showed a significantly higher prevalence of obesity among females [1, 21-23]. The observation may be related to hormonal, sociocultural, and environmental factors [24]. With respect to age, we did not find increasing age to be a risk factor for obesity in our study population (apart from the WHR criteria). This is like previous reports that did not find an association between obesity and age among PLHIV [1, 21, 23, 25]. In other studies, obesity prevalence was associated with increasing age [5, 23]. The association of WHR with age may be due to the adjustment to WC by the fat distribution around the hip which is differentially distributed especially among females.

We found that among the criteria for obesity, obesity concordance was highest between IDF and ATP (Kappa= 0.673, $p<0.001$) showing a substantial agreement. This was expected because they are based on waist circumference although with the only difference in cut-off values. However, the concordance among the more distantly related obesity criteria at best showed moderate agreement between BMI and ATP (Kappa= 0.502, $p<0.001$). The least agreement was between BMI vs WHR (Kappa= 0.124, $p<0.073$) showing these criteria defined nearly two distinct sets of individuals in the study.

**Table 2: The association between obesity (by different criteria) with demographic, Biochemical, and HIV-related factors**

| | **BM1** | | | **IDF** | | | **ATP** | | | **WHR** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | p-value | Unadjusted OR | Adjusted OR | p-value | Unadjusted OR | Adjusted OR | p-value | Unadjusted OR | Adjusted OR | p-value | Unadjusted OR | Adjusted OR |
| Demographic data | | | | | | | | | | | | |
| Sex (Male) | **0.02** | **0.17 (0.04-0.74)** | **0.19 (0.04-0.84)** | **<0.001** | **0.10 (0.04-0.25)** | **0.31 (0.31-0.78)** | **<0.001** | **0.03 (0.01-0.22)** | **0.03 (0.01-0.21)** | 0.391 | 0.72 (0.34-1.52) | |
| Age | 0.706 | 1.19 (0.49-2.90) | | 0.966 | 0.99 (0.50-1.95) | | 0.667 | 1.17 (0.57-2.42) | | **<0.001** | **3.76 (1.79-7.92)** | 1.00 (0.99-1.01) |
| Physical Inactivity | 0.593 | 1.50 (0.53-4.23) | | 0.887 | 1.07 (0.45-2.53) | | 0.791 | 0.88 (0.35-2.22) | | 0.255 | 1.66 (0.69-3.96) | |
| Alcohol Intake | 0.824 | 0.86 (0.23-3.22) | | 0.569 | 0.75 (0.28-2.03) | | 0.927 | 0.95 (0.33-2.72) | | 0.533 | 0.73 (0.26-1.99) | |
| Hypertension | **0.021** | **2.79 (1.15-6.80)** | **3.76 (1.45-9.74)** | 0.086 | 1.80 (0.92-3.53) | | 0.115 | 1.76 (0.87-3.55) | | **0.014** | **2.33 (1.18-4.61)** | **2.34 (1.09-4.59)** |
| Impaired Fasting Glucose | 0.173 | 1.88 (0.75-4.34) | | 0.277 | 1.54 (0.71-3.37) | | 0.887 | 1.06 (0.47-2.38) | | 0.078 | 2.01 (0.92-4.41) | |
| Dyslipidaemia | 0.055 | 5.98 (0.77-46.5) | | **0.033** | **2.76 (1.06-7.21)** | 1.01 (0.99-1.03) | **0.005** | **6.80 (1.52-30.4)** | 1.82 (0.62-5.36) | **0.039** | **2.78 (1.03-7.56)** | 1.22 (0.53-2.81) |
| Elevated Total Cholesterol | 0.415 | 1.43 (0.61-3.35) | | 0.057 | 1.93 (0.98-3.81) | | **0.002** | **3.00 (1.46-6.18)** | **2.34 (1.66-5.14)** | **0.003** | **2.79 (1.40-5.56)** | **2.22 (1.11-4.44)** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevated LDLC | 0.059 | 2.63 (0.94-7.38) | | 0.266 | 1.71 (0.66-4.43) | | 0.369 | 1.54 (0.60-3.96) | | 0.254 | 1.72 (0.67-4.39) | |
| Low HDL | 0.084 | 2.64 (0.85-8.22) | | **0.031** | **2.26 (1.07-4.78)** | 1.26 (0.56-2.85) | 0.048 | 2.31 (0.99-5.37) | 1.13 (0.46-2.74) | 0.516 | 1.28 (0.61-2.67) | |
| Hypertriglyceridaemia | 0.517 | 0.65 (0.18-2.39) | | 0.074 | 2.37 (0.90-6.24) | | 0.091 | 2.19 (0.87-5.50) | | 0.066 | 2.38 (0.93-2.67) | |
| Elevated Non-HDLC | 0.286 | 1.59 (0.68-3.75) | | 0.080 | 1.84 (0.93-3.64) | | **0.007** | **2.66 (1.30-5.45)** | 2.04 (0.92-4.51) | **0.006** | **2.61 (1.31-5.22)** | **2.14 (1.05-4.34)** |
| Elevated Atherogenic Index | 0.128 | 0.38 (0.11-1.37) | | 0.756 | 1.13 (0.51-2.50) | | 0.990 | 1.00 (0.44-2.31) | | 0.338 | 1.47 (0.67-3.25) | |
| Elevated HsCRP | **0.020** | **2.88 (1.16-7.16)** | 2.38 (0.98-5.78) | 0.395 | 1.33 (0.69-2.59) | | **0.043** | **2.07 (1.02-4.22)** | 2.05 (0.94-4.44) | 0.516 | 1.25 (0.64-2.43) | |
| Use of Second line drugs | 0.771 | 1.27 (0.25-6.52) | | 0.764 | 1.23 (0.32-4.79) | | 0.950 | 0.96 (0.23-4.00) | | 0.046 | 4.54 (0.91-22.71) | 4.05 (0.80-20.46) |
| HIV Duration > 5 years | 0.369 | 0.68 (0.29-1.59) | | **0.037** | **0.49 (0.25-0.96)** | 0.45 (0.20-0.99) | 0.09 | 0.54 (0.27-1.09) | | 0.992 | 0.99 (0.51-1.95) | |
| ARV Duration > 5 years | 0.115 | 0.49 (0.20-1.20) | | 0.238 | 0.67 (0.34-1.31) | | 0.238 | 0.66 (0.32-1.33) | | 0.516 | 1.25 (0.64-2.43) | |
| CD4 Count < 350 cells/$mm^3$ | 0.931 | 0.96 (0.38-2.42) | | 0.909 | 0.96 (0.47-1.96) | | 0.974 | 0.99 (0.47-2.10) | | 0.746 | 1.13 (0.55-2.30) | |

A similar finding was observed by Dimala et al, where no linear association and correlation was observed between the WHR and BMI [24]. The poor agreement in the diagnostic criteria for obesity has been previously highlighted [12, 13, 27]. In this study, only 9.3% of individuals were classified as obese by all four criteria studied. This highlights the possibility that the different parameters if used in the assessment of obesity may relate to varying levels and aspects of cardiovascular risks. The general view is that BMI and WC offer different information for predicting the likelihood of developing diseases and may not be interchangeable [12]. This highlights the paradigms that underlie the various criteria and their alleged shortcomings.

Body mass index (BMI) is the most widely used anthropometric parameter for assessing obesity in clinical settings and population studies given its simplicity. As a measure of adiposity, it enables sub-classification into overweight and obesity categories according to their correlation with cardiovascular risk, however, age, race, and relative proportion of muscle mass are not considered, and body mass may not correlate well with body fat [27]. Waist circumference (WC) and indices derived from it such as waist-to-hip ratio (WHR), are employed as surrogate indicators of visceral obesity to predict morbidity and mortality at the population level [13]. The diagnostic criteria set by different organizations attempt to correct for sex and race [28]. The fat collection in the central abdominal region is thought to be a stronger and independent risk for cardio-metabolic disease and CVD deaths [28, 29]. The Waist-to-hip ratio (WHR) is regarded in some quarters as a more accurate measure of central adiposity and a predictor of cardio-metabolic risk [12]. The poor correlation between obesity measured by BMI and WC-based parameters in this study suggests that some PLHIV with a raised BMI may have significant muscle mass and not necessarily a high body fat mass. Much more prevalent was that many individuals with abdominal obesity because of intra-abdominal visceral adiposity did not present with an elevated BMI. The abnormal fat distribution common in PLHIV on ART may well explain this phenomenon.

In this study, we assessed the obesity criteria in relation to the other cardiovascular risk factors such as blood pressure, biochemical markers as well as HIV-related parameters. We did not observe a significant impact of HIV-related factors such as HIV duration, ARV regimen, and CD4 count on the prevalence of obesity across the various criteria studied. Previous findings present conflicting reports on HIV-related parameters and obesity.

Our result showed that obesity by BMI was independently associated with hypertension after correction for age and sex this is in keeping with the previous report [30]. However, obesity by the BMI criteria did not significantly relate to glycaemic status nor dyslipidaemia but associated with inflammatory marker hsCRP that was lost after correcting for age and sex. The WC-related obesity definition showed some association with dyslipidaemia as a composite definition of its components [25]. The IDF did not show any significant association after adjusting for age and sex. On the other hand, the ATP criteria showed higher odds than the IDF criteria for dyslipidaemia and hsCRP. Dyslipidaemia, elevated total cholesterol, and non-HDL cholesterol and hsCRP were significantly associated with obesity at the bivariate levels although only elevated total cholesterol remained associated with obesity after adjusting for age and sex. This may be related to the higher cut-off values for defining obesity in the ATP criteria compared to the IDF criteria [14, 15].

Our finding showed that obesity by WHR was significantly associated with hypertension and dyslipidaemia. Hypertension, elevated total cholesterol, and non-HDL cholesterol were significantly associated with obesity after adjusting for age and sex. These findings suggest that WHR provided the most consistent association with traditional risk factors for CVD. However, as a tool for assessing risk for CVD, it is not clear if this would translate to better prediction of CVD health outcomes in these individuals. Previous report that suggests that measures of abdominal obesity especially WHR are better than BMI as predictors of CVD risk [12].

BMI has been employed continually in place of WC due to its ease of measurement under the presumption that these two measures have a positive linear connection. Yet, with PLHIV, this favourable relationship may not be substantial enough based on the data from this study. Because antiretroviral therapy is known to cause altered adipose tissue metabolism and distribution, as may very well be the case in our study, the use of WC and especially WHR, which are more reliable and independent predictors of cardio-metabolic risk, is particularly pertinent in HIV-infected patients.

There have been requests to consider the value of combining BMI and WC-based measures [12, 28]. According to the WHO, the effectiveness of measurements like waist circumference and waist-hip ratio, when combined with BMI, may help with the creation of composite indices for use at both individual and population levels [12]. Our study lends credence to this call given that obesity by BMI criteria was independently associated with hypertension whereas obesity by ATP and IDF criteria were not. Further studies are needed to clarify this utility among PLHIV.

The limitation in this study includes the fact that only one-time anthropometric assessment was done, and visceral fat analysis was not assessed. Given the cross-sectional design, there is a need for caution in extrapolating our findings to explain temporal relationships. As a tool for assessing risk for CVDs, it is not clear if obesity definitions by the different criteria would translate to better prediction of CVD health outcomes in these individuals. This would need a prospective study design. Nonetheless, we have highlighted the level of agreement between the different criteria for defining obesity and their potential benefits in HIV-infected individuals. Our study urges a unified assessment of obesity and a more prominent use of parameters of central obesity, particularly WHR for assessing cardiovascular risk in PLHIV.

**What is known about this topic?**

- Obesity is a common risk factor for Cardiovascular risk factors in HIV-infected individuals.
- Obesity is linked to insulin resistance, impaired glycaemia, dyslipidaemia, and hypertension in a constellation of metabolic syndrome.

**What this study adds**

- The study has provided us with the prevalence of obesity based on the various defining criteria in PLHIV.
- We showed how 4 definitions of obesity relate to other risk factors of CVD in PLHIV in our setting. This included biochemical and inflammatory indicators of CVDs.
- Our study urges a unified assessment of obesity and a more prominent use of parameters of central obesity, particularly WHR for assessing cardiovascular risk in PLHIV.

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