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# Metabolic Syndrome Among People Living with HIV Receiving Medical Care in Southern United States: Prevalence and Risk Factors

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## Abstract

Using representative data among 1861 in care people living with HIV (PLWH) in four southern states (Texas, Mississippi, Florida, and Georgia) from the 2013–2014 Medical Monitoring Project (MMP) survey, we estimated the prevalence and odds of metabolic syndrome (MetS) among various demographic and HIV related risk factors. Overall MetS prevalence was 34%, with our participants being mostly black (55%), male (72%), ≥ 50 years old (46%), and overweight or obese (60%) with undetectable viral loads (≤ 200 copies/ml, 69%), and were currently taking antiretroviral medication (98%). Compared to those who were ≥ 60 years, 18–39 year olds had a 79% (95% CI 0.13–0.33) lower odds of having MetS. Women were 2.24 times more likely to have MetS than men (95% CI 1.69–2.97). Age and sex were significant predictors of MetS. Since MetS is a combination of chronic disease risk factors, regular screening for MetS risk factors among aging PLWH is crucial.

**Keywords** HIV · Metabolic syndrome · Medical Monitoring Project · Southern United States

## Resumen

Usando datos representativos entre 1861 personas viviendo con VIH y recibiendo cuidado para VIH en cuatro estados del sur (Texas, Mississippi, Florida y Georgia) de la encuesta del Proyecto de Monitoreo Médico (MMP, siglas en inglés) 2013-2014, estimamos la prevalencia y las probabilidades del síndrome metabólico (MetS) entre varios factores de riesgo demográficos y relacionados con el VIH. La prevalencia general de MetS fue del 34%, y nuestros participantes fueron en su mayoría negros (55%), hombres (72%), ≥ 50 años (46%), con sobrepeso u obesidad (60%), con carga viral indetectable (≤ 200 copias/ml, 69%), y actualmente tomando medicamentos antirretrovirales (98%). En comparación con los que tenían ≥ 60 años, los de 18 a 39 años tuvieron un 79% (IC del 95%: 0.13-0.33) más baja probabilidad de tener MetS. Las mujeres tuvieron 2.24 veces más probabilidad de tener MetS que los hombres (IC del 95%:1.69-2.97). La edad y el sexo fueron predictores significativos de MetS. Dado que el MetS es una combinación de factores de riesgo para enfermedades crónicas, la evaluación regular de los factores de riesgo de MetS a lo largo del proceso de envejecimiento de personas que viven con VIH es crucial.

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## Abbreviations

| | |
|---|---|
| MetS | Metabolic syndrome |
| CVD | Cardiovascular disease |
| HIV | Human immunodeficiency virus |
| PLWH | People living with HIV |
| AIDS | Acquired immunodeficiency syndrome |
| aOR | Adjusted odds ratio |
| CI | Confidence intervals |
| MMP | Medical Monitoring Project |
| IDF | International Diabetes Federation |
| HDL | High density lipoprotein |
| BP | Blood pressure |
| BMI | Body mass index |
| ART | Antiretroviral therapy |

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| | |
|---|---|
| T2DM | Type II diabetes mellitus |
| NFHL | Nutrition for healthy living |
| NHBLI | National Heart, Blood, and Lung Institute |
| AHA | American Heart Association |
| HAART | Highly active antiretroviral therapy |
| ATP | Adult treatment panel |

## Introduction

The success of highly active antiretroviral therapy has led to a dramatic decline in immunodeficiency-related causes of death and improvement in life expectancy among PLWH [1–3]. However, as patients are aging with HIV, the decline in morbidity and mortality has been clouded by the emergence of a number of cardio-metabolic perturbations [4]. Cardio-metabolic perturbations, which are collectively known as the metabolic syndrome, refer to a cluster of coexisting metabolic risk factors, such as abdominal obesity, dyslipidemia, defective glucose metabolism, and arterial hypertension [5], that are associated with increased risk of cardiovascular disease (CVD) and diabetes mellitus [6, 7]. In addition to the cardiovascular outcomes, individuals with MetS are thought to be more susceptible to a range of conditions. This includes, but is not limited to, vascular diseases (e.g., atherosclerotic cardiovascular disease and hypertension), adiposity-related disorders (e.g., sleep disordered breathing and fatty liver disease), insulin resistance conditions (e.g., type 2 diabetes or gestational diabetes and polycystic ovary syndrome), atherogenic dyslipidemia, hormonal dysfunction, and chronic kidney disease [8].

With a wide range of estimates from 11.2 to 45.4%, the prevalence of MetS among PLWH is debatable [9, 10]. These large differences may be attributed to differences in study design, small sample sizes, different demographic characteristics of sample populations, and the several MetS definitions used, which make it difficult to draw consistent and comparable population level conclusions on MetS prevalence among PLWH [9].

Although unhealthy behaviors such as poor diet and low levels of physical activity contribute to chronic diseases such as diabetes [11], the natural course of HIV infection and its treatment further increase the susceptibility to cardio-metabolic disorders among PLWH [12]. HIV infection itself, through chronic deregulated inflammatory response, may also play an important role in the pathogenesis of both diabetes mellitus and atherosclerosis [9, 13]. Moreover, the use of certain antiretroviral therapy regimens that include a protease inhibitor is associated with adipose tissue changes and disorders of glucose and lipid metabolism [14]. These findings have raised concerns that PLWH may be at a higher risk of developing MetS, which subsequently may be linked to an increase in CVD risk and diabetes.

CVD is the number one cause of death in adults worldwide [15]. It has been shown that patients with HIV experience a 2–3 times higher CVD risk compared to those without HIV [16, 17]. Previous studies [18–21] reported gender differences on CVD risk among PLWH, but the results are inconsistent. Cross-sectional data from the Data Collection on Adverse Events of Anti-HIV Drugs study [18] showed that female sex was a protective factor against the risk of myocardial infarction among adults living with HIV. However, two studies reported higher relative risk of acute myocardial infarction in HIV positive women than in HIV positive men [19, 20]. Chow et al. found a similar gender effect for stroke among adults living with HIV, indicating an increased risk of stroke among women with HIV compared to men with HIV [21].

Diabetes is the seventh leading cause of death in the US and one of the major causes of CVD, adult-onset blindness, kidney failure, and lower-limb amputations, affecting 9.4% of the US population [22]. It has been shown that patients living with HIV can have up to a twofold higher risk of diabetes when compared to the general population [23], with the prevalence estimate of up to 14% [24]. The direct influence of HIV on diabetes remains unclear. There is mixed evidence regarding HIV as an independent risk factor for diabetes, with some studies reporting an increased prevalence and incidence of impaired glucose tolerance and diabetes among PLWH [25, 26] and others showing no independent effect of HIV on the development of diabetes [25, 27].

In the US, the South is generally behind other regions in some key HIV prevention and care indicators such as having the highest numbers of people without health insurance [28] and not adopting newer HIV prevention advances such as antigen/antibody HIV tests that can detect acute HIV infection. Consequently, it is important to understand disease prevalence to better allocate resources essential for developing preventive and management strategies, healthcare service planning, and the implementation of specific targeted interventions. Studies indicate that southern states are disproportionately affected by diseases linked with MetS such as obesity [29], diabetes [30], and hypertension [31, 32]. In addition, southern states account for nearly half of all PLWH (44%) in the US, despite making up about one-third (37%) of the overall US population [33, 34]. In 2014, eight of the top 10 states in the US with the highest HIV morbidity rates were in the South and included Texas, Mississippi, Georgia, and Florida [35]. Therefore, understanding the potential overlapping impact of being a PLWH in the South, with respect to cardiovascular and diabetes risk, could lead to better clinical assessments and risk mitigation in this population. With a paucity of data available on CVD and diabetes among southern PLWH, we aimed to estimate the prevalence of metabolic syndrome and to establish its associated risk factors among PLWH in the southern US.

## Methods

Medical record abstraction and interview data from the 2013–2014 MMP survey, which includes statewide surveillance of PLWH for Texas (including the city of Houston), Mississippi, Georgia, and Florida, were used in this study. MMP is a Centers for Disease Control (CDC) supplemental surveillance system that monitors behavioral and clinical characteristics of people living with HIV (PLWH) aged 18 years or older receiving medical care across 23 sites nationwide. MMP is a cross-sectional survey with a three-stage sampling design: (1) At a geographic level for the US and dependent areas, (2) At a facility level through outpatient HIV care facilities, and (3) on an individual level for PLWH aged ≥ 18 years who had at least one medical care visit at a sampled facility between the months of January and April of 2013 and 2014. Data collection occurred between June 2013 and May 2015. The data obtained were weighted to account for the probabilities of selection at each sampling stage and adjusted for nonresponse and multiplicity. Nonresponse adjustments accounted for differing response at both facility and patient levels, and multiplicity adjustments accounted for patient's visits to more than one HIV care facility [36]. After excluding participants for missing data, our sample included 1861 participants representing 80,596 of adults living with HIV in the four southern US states (Texas, Florida, Mississippi, and Georgia).

## Measures

These analyses used the International Diabetes Federation (IDF) definition of metabolic syndrome (MetS) was used for these analyses, which is characterized by central obesity plus two of the following criteria: raised triglycerides, reduced HDL (high density lipoprotein) cholesterol, raised blood pressure (BP), or raised fasting blood glucose [37]. Central obesity for MMP participants was calculated from body mass index (BMI, kg/m$^2$), race/ethnicity, and birth sex-specific equations developed by Bozeman et al. [38]. Multiracial, Asian, Native Hawaiian/Pacific Islander, American Indian/Alaskan Native, and transgender participants (n = 94) were excluded because there were no equations developed for these populations. BMI measurements, as documented in the medical chart within 1 year of the participant interview, were abstracted from medical records. Participants with missing height or weight (n = 275) were excluded.

MMP participants were classified as having the following four MetS criteria if any of the following was documented in the medical record:

*Raised triglycerides* (1) hypertriglyceridemia diagnosis or (2) prescription medications for raised triglycerides treatment as determined by clinician review of all the recorded medications abstracted or (3) most recent fasting triglyceride laboratory (lab) value ≥ 150 mg/dl.
*Reduced high density lipoprotein* (*HDL*) *cholesterol* (1) "low HDL" diagnosis or (2) prescription medications for low HDL (medications which could be used for both hypertriglyceridemia and low HDL such as statins, among others, were not double counted among criteria for raised triglycerides and low HDL) or (3) most recent fasting HDL lab < 40 mg/dl (males) or < 50 mg/dl (females).
*Elevated blood pressure* (*BP*) *or hypertension* (1) hypertension diagnosis or (2) prescription medications for hypertension treatment or (3) most recent systolic BP ≥ 130 or diastolic BP ≥ 85 mmHg.
*Raised fasting blood glucose* (1) Type 2 diabetes diagnosis or (2) most recent fasting blood glucose > 100 mg/dl.

If the participants met the waist circumference criteria, they were further evaluated on whether they had enough non-missing criteria to be considered for the study. Because participants could be seeking non-HIV care and/or receiving prescriptions for non-HIV medications at other medical facilities from which we did not review their medical chart, we assumed that the participant did not meet criteria only if they had labs that fell within normal range at the sampled facility, otherwise the criterion was set to missing for that participant. For this study, we determined that if a participant met the waist criterion but did not meet at least two other criteria for MetS and had two or more criteria missing due to non-availability of lab values or other diagnostic variables, then they were excluded from the analysis (n = 383). Additionally, if a participant met one criteria but had at least one criteria missing, they were excluded from the analysis because it is possible that they could have MetS if the value of the missing criteria was known (n = 110). Figure 1 displays the flowchart of the study sample selection process and highlights the inclusion and exclusion criteria used.

Other variables included were: sociodemographic variables including age, sex at birth, race/ethnicity, education, health insurance type, current smoking status, alcohol use, and poverty level. Length of time on antiretroviral therapy (ART) was determined from patient self-report. Clinical variables measured within the past year included BMI, time since HIV diagnosis, viral suppression status, prescription of ART, and geometric mean CD4+ T-lymphocyte (CD4) count.

### Statistical Analysis

Among PLWH, weighted prevalence and 95% confidence intervals (CI) of MetS were calculated as overall

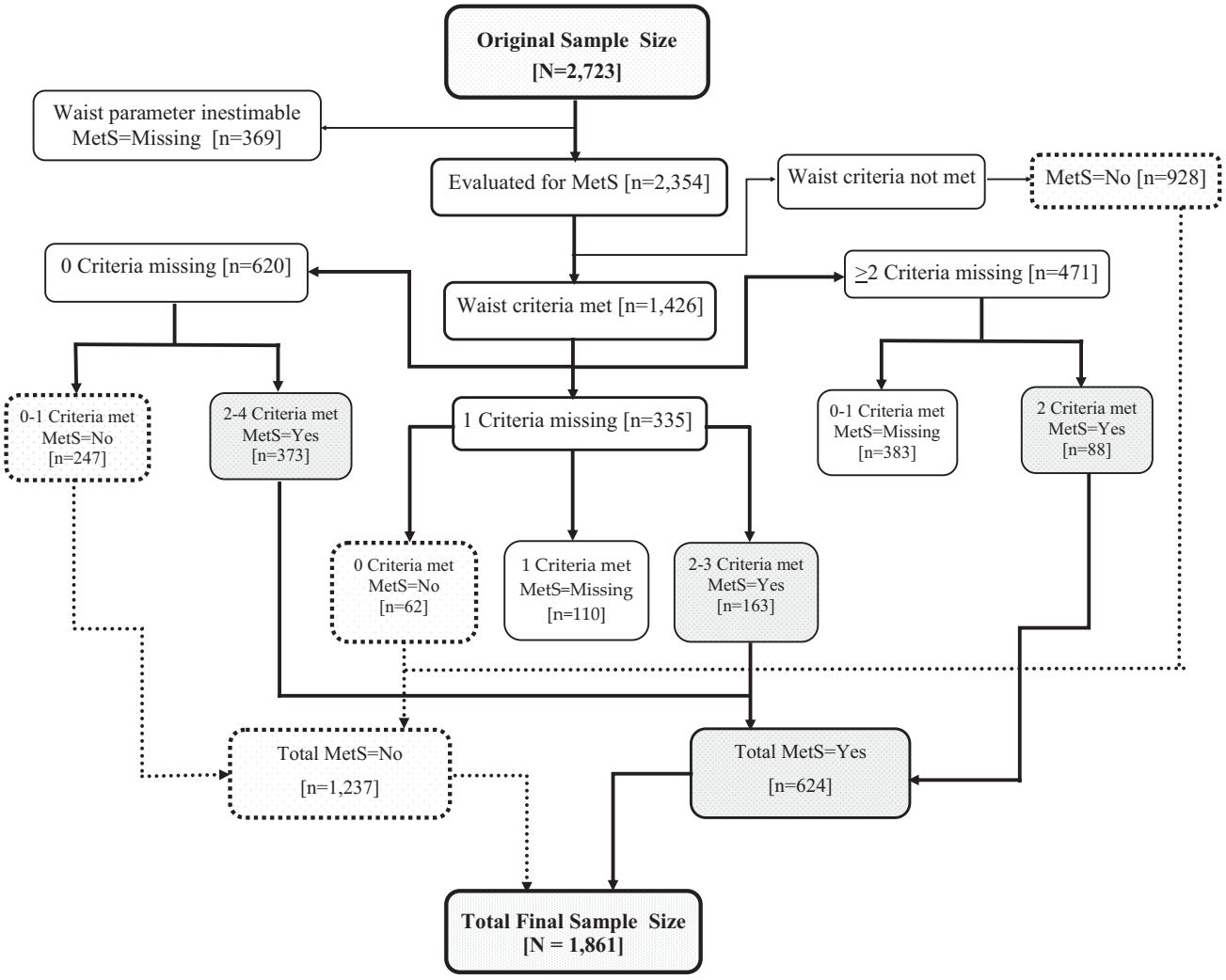


**Fig. 1** Flowchart of study sample selection process

measure and by each of the following categories of sociodemographic and HIV-related characteristics: age (18–39, 40–49, 50–59, or ≥ 60 years), sex at birth, race/ethnicity (non-Hispanic White, Black, Hispanic), education (< high school, high school or equivalent, or > high school), poverty level (at or below federal poverty line and above federal poverty line), BMI (normal weight, overweight, or obese), time since HIV diagnosis (< 5 years, 5–9 years, or ≥ 10 years), and length of time on antiretroviral therapy (ART) (< 5 years, 5–9 years, or ≥ 10 years). To identify factors associated with MetS and to compute adjusted odds ratios (aOR) and corresponding 95% CIs among PLWH, multivariable logistic regression models were used with MetS as the outcome, and all the aforementioned characteristics except for BMI were included as independent predictors. Variables that changed the aOR by > 10% were retained in the multivariable model. All analyses were performed using SAS 9.4 (SAS Institute, Cary, North Carolina, USA) and weighted to account for clustering, unequal selection probabilities, and non-response.

## Human Subjects Protection

MMP has been determined by the National Center for HIV, Viral Hepatitis, STD and TB Prevention's Office of the Associate Director for Science at the CDC to be a non-research, public health surveillance activity used for disease control program or policy purposes. As such, MMP is not subject to human subjects' regulations, including federal institutional review board (IRB) approval. All data collection was Health Insurance Portability and Accountability Act compliant. Informed consent was obtained from all individual participants included in the study.

## Results

Of the 2723 total participants from the four southern US states (Texas, Florida, Mississippi, and Georgia), 862 were excluded from the analysis due to missing data, leaving a final analytic sample of 1861 participants. Table 1 shows the baseline characteristics of these participants by MetS. Thirty-four percent of the total sample (n = 624) had MetS, most of whom were men (62%), black (50%), ≥ 50 years of age (61%), and overweight or obese (97%).

Table 2 shows the aORs and 95% CIs of having MetS by the various predictors. Age, sex, and current smoking were all significantly associated with MetS prevalence ($p < 0.01$ for all). Compared to those ≥ 60 years old, 18–39 year-olds had a 79% lower odds of having MetS (95% CI 0.13–0.33). Similarly, lower odds were observed in males compared to females (aOR: 0.45, 95% CI 0.34–0.59). Current smokers had a 39% reduced odds of having MetS (95% CI 0.46–0.81).

Since sex at birth was a strong predictor of MetS, Table 3 illustrates the sex-stratified aORs of MetS by various sociodemographic factors. Age and smoking remained significant predictors of MetS for men whereas only age remained as a significant predictor for women ($p < 0.01$ for all). In both men and women, those aged 18-39 years had an 81% and 73% lower odds of having MetS, respectively. Male current smokers had a 42% reduced odds of having MetS (95% CI 0.34–0.66).

## Discussion

We found that approximately a third of PLWH living in southern states have MetS. Given the disproportionate impact of diseases linked to MetS in the South, we expected the prevalence of MetS in our study to be higher, but this could be partially explained by demographic differences and our conservative selection process. Additionally, we used the IDF definition rather than the ATP III definition used in other studies. Currently, there are no regional population-based estimates for MetS in the southern US, but our results are within range of several studies among PLWH. A recent systematic review of MetS among PLWH by Paula et al. [9] showed that MetS prevalence ranged from 11% in a Mediterranean multicenter lipodystrophy case definition cohort [39] to up to 45% in an Italian cohort [40]. Differences in characteristics among study participants may contribute to the variability observed in previously published MetS prevalence estimates. For example, a cohort of only men in an international cohort [41] saw a significantly lower MetS prevalence (18%) compared to 25.5% among a cohort of South African men and women [42]. An analysis using the Nutrition for Healthy Living (NFHL) study found MetS prevalence to be 24% among American PLWH [43], which is lower than our current result. Several factors including the use of the National Heart Blood and Lung Institute/American Heart Association (NHBLI/AHA) guidelines (vs IDF), a younger cohort (mean age = 42 vs. 47 years), and a predominantly white sample (52% vs. 25% in MMP) may further explain the reasons for the lower estimate.

Our results show that women have more than double the odds of having MetS than men, which could be explained by more women (75%) meeting the waist criteria compared to men (43%). Cultural factors like different diets in males compared to females may be a possible contributor. According to Freimer et al. cultural variation may play an important role in human nutrition and must be considered in either clinical or public health intervention strategy particularly in areas with large immigrant populations [44]. The increased MetS odds may not only be due to gender differences in traditional risk factors such as body weight [45], abdominal adiposity [46], and genetic biomarkers differences [47], but also to drug exposure, antiretroviral-associated toxicities [45], and combined ARV treatment. Pernerstofer-Schoen et al. [48], in a prospective longitudinal cohort study compared gender-stratified HIV positive individuals initiating a protease inhibitor containing highly active antiretroviral therapy (HAART) regimen with matched HIV negative individuals. The authors found that LDL:HDL was higher among female HIV patients compared to males after initiation of a combined antiretroviral therapy and that circulating levels of E-selectin, an endothelium-associated marker of inflammation and atherosclerotic risk, declined in males whereas they remained elevated in women [48]. This indicates that HAART-suppressed immunological/inflammatory processes are less effective in HIV positive female patients than in males [48]. Furthermore, lower rates of risk factor modification due to lower risk perception in women compared to men [49] can contribute to gender differences in CVD among HIV positive adults. Sobieszczyk et al. in a study of 2393 women (1725 HIV positive and 668 HIV negative), reported that nearly one-third of HIV positive women met criteria for MetS diagnosis, and that MetS prevalence was significantly higher among women living with an HIV diagnosis compared to those with a negative HIV status (33% vs. 22%, $p < 0.0001$) [50]. The authors also reported an increased prevalence of high triglycerides, low HDL, higher BMI, older age, and current smoking status as risk factors associated with higher MetS prevalence among HIV positive women compared to HIV negative women [50]. Prior studies show that estrogen reduction due to menopause is associated with weight gain, insulin resistance and central adiposity, and may contribute to an increased risk of hypertension, dyslipidemia, diabetes, and cardiovascular disease

**Table 1** Baseline characteristics by metabolic syndrome status

| Characteristic | Metabolic syndrome status | | | | | |
|---|---|---|---|---|---|---|
| | No MetS | | MetS | | Test statistics | |
| | N | %[a] | N | %[a] | Rao-Scott Chi-square statistic | *p* value |
| Sex | | | | | | |
| Male | 953 | 70 | 387 | 30 | 35.42 | < 0.001*** |
| Female | 284 | 55 | 237 | 45 | | |
| Race/ethnicity | | | | | | |
| White | 304 | 66 | 164 | 34 | 4.63 | 0.100[ns] |
| Black | 707 | 68 | 313 | 32 | | |
| Hispanic | 226 | 62 | 147 | 38 | | |
| Age group (years) | | | | | | |
| 18–39 | 426 | 87 | 62 | 13 | 96.25 | < 0.001*** |
| 40–49 | 339 | 64 | 182 | 36 | | |
| 50–59 | 329 | 56 | 253 | 44 | | |
| ≥ 60 | 143 | 54 | 127 | 46 | | |
| BMI (kg/m$^2$) | | | | | | |
| < 25 (normal) | 726 | 97 | 21 | 3 | 658.49 | < 0.001*** |
| 25– < 30 (overweight) | 386 | 60 | 255 | 40 | | |
| ≥ 30 (obese) | 125 | 26 | 348 | 74 | | |
| Education | | | | | | |
| < High school | 255 | 62 | 154 | 38 | 5.37 | 0.070[ns] |
| High school/equivalent | 332 | 64 | 179 | 36 | | |
| > High school | 649 | 69 | 291 | 31 | | |
| Insurance | | | | | | |
| Private | 307 | 65 | 160 | 35 | 13.91 | < 0.01** |
| Public | 542 | 63 | 321 | 37 | | |
| Ryan White only | 341 | 73 | 126 | 27 | | |
| Unspecified | 12 | 59 | 7 | 41 | | |
| None | 32 | 83 | 7 | 17 | | |
| Poverty | | | | | | |
| Above | 561 | 65 | 288 | 35 | 0.18 | 0.670[ns] |
| Below | 614 | 67 | 312 | 33 | | |
| Smoking status | | | | | | |
| Never | 550 | 64 | 300 | 36 | 16.48 | < 0.001*** |
| Former | 207 | 59 | 147 | 41 | | |
| Current | 475 | 73 | 172 | 27 | | |
| Binge drinking (30 days) | | | | | | |
| No | 1017 | 65 | 550 | 35 | 3.25 | 0.070[ns] |
| Yes | 199 | 72 | 67 | 28 | | |
| HIV related characteristics | | | | | | |
| ART Use | | | | | | |
| No | 31 | 76 | 12 | 24 | 2.21 | 0.140[ns] |
| Yes | 1170 | 66 | 601 | 34 | | |
| ART use duration | | | | | | |
| Not on ART | 34 | 76 | 9 | 24 | 32.38 | < 0.001*** |
| < 5 years | 3875 | 77 | 121 | 24 | | |
| 5–9 years | 241 | 69 | 109 | 31 | | |
| ≥ 10 years | 465 | 59 | 314 | 41 | | |

**Table 1** (continued)

| Characteristic | Metabolic syndrome status | | | | | |
|---|---|---|---|---|---|---|
| | No MetS | | MetS | | Test statistics | |
| | N | %[a] | N | %[a] | Rao-Scott Chi-square statistic | *p* value |
| HIV diagnosis duration | | | | | | |
| < 5 years | 332 | 77 | 100 | 23 | 37.08 | < 0.001*** |
| 5–9 years | 290 | 71 | 117 | 28 | | |
| ≥ 10 years | 615 | 59 | 407 | 41 | | |
| Mean CD4 count (cells/μl) | | | | | | |
| 0–199 | 128 | 73 | 47 | 27 | 17.99 | < 0.001*** |
| 200–349 | 178 | 75 | 65 | 25 | | |
| 350–499 | 278 | 70 | 110 | 30 | | |
| ≥ 500 | 616 | 61 | 382 | 39 | | |
| Viral load (copies/ml) | | | | | | |
| < 200 (undetectable) | 831 | 65 | 450 | 35 | 2.23 | 0.140[ns] |
| ≥ 200 | 406 | 69 | 174 | 31 | | |
| Total | 1237 | 100 | 624 | 100 | | |

[a]Within a given level of the characteristic, some percentages may not add up to exactly 100 due to rounding

Significance Level: *p<0.05, **p<0.01, ***p<0.001, *ns* not significant (p > 0.05)

among postmenopausal women compared with premenopausal women [51]. Thus, HIV positive postmenopausal women are more likely to develop metabolic disorders not only from HIV related factors such as HAART but also from the consequences of hypoestrogenism. These metabolic changes to some extent may explain the increased risk of MetS among women, especially post-menopausal women [52]. We noted a similar age-related prevalence of MetS in older women in the current study (Table 3). Further research is needed to determine underlying mechanisms of the gender differences in MetS among PLWH.

While there were initial differences noted in the prevalence of MetS by HIV-specific variables, such as longer duration of HIV diagnosis, longer duration of ART use, and higher mean CD4 count, the logistic regression model did not reveal any significant impact of these factors. The initial significance of longer duration of HIV diagnosis and longer ART use may have been explained by age since many of the participants who had been diagnosed and have been taking ART therapy longer were also older. It is also important to note that other conditions or factors not considered in our current study may also be implicated in the odds of acquiring MetS among PLWH.

## Study Limitations and Strengths

Our study had several strengths including the robust MMP sampling methodology, which is designed to achieve generalizability to HIV positive adults receiving medical care with weighted sampling. Medical chart reviews provided in-depth clinical data that allowed the measurement of various demographic and cardio-metabolic parameters. When combined with detailed patient interviews that provided extensive sociodemographic and other behavioral risk factors, we were able to measure and capture a wide array of potential confounders on MetS among PLWH.

Our study has certain limitations. First, MMP was not specifically designed to measure the prevalence of MetS. For our study, labs from abstracted patient charts were considered fasting if they were clearly marked as such in the medical record. A significant percentage of the labs were not used due to abnormal value (e.g., a glucose value of 101 mg/dL) and unknown fasting status. However, the majority of our study participants who met the criteria had either a diagnosis or were on prescription medication for these criteria (77% for glucose, 81% for triglyceride, and 91% for HDL). We tried to overcome this issue with the use of the well-accepted IDF rather than Adult Treatment Panel (ATP) III criteria, which relies less heavily on fasting lab status for the glucose criteria and allows for the inclusion of type II diabetes diagnoses. Another limitation is the extrapolation of waist circumference from BMI measure. Although we used an equation that has been found to be highly predictive of waist circumference from BMI with minimal error [38], its predictive power was less for women than for men. Waist circumference estimates derived from BMI may be less accurate for women than for men due to the shift in body fat distribution in middle-aged/older women [53]. However, the Bozeman et al. [17] equation does try to mitigate these limitations by using age-specific waist circumference equations for women. Several other known risk factors

**Table 2** Odds of metabolic syndrome among PLWH

| Characteristic | aOR | 95% CI |
|---|---|---|
| Sex | | |
| Male (*Ref*) | 1.00 | – |
| Female | 2.24 | 1.69–2.97* |
| Race/ethnicity | | |
| White (*Ref*) | 1.00 | – |
| Black | 0.81 | 0.58–1.14$^{ns}$ |
| Hispanic | 1.52 | 0.98–2.35$^{ns}$ |
| Age group (years) | | |
| 18–39 | 0.21 | 0.13–0.33* |
| 40–49 | 0.80 | 0.55–1.16$^{ns}$ |
| 50–59 | 1.08 | 0.68–1.71$^{ns}$ |
| ≥ 60 (*Ref*) | 1.00 | – |
| Education | | |
| < High school | 1.51 | 1.00–2.27$^{ns}$ |
| High school/equivalent | 1.41 | 0.99–1.99$^{ns}$ |
| > High school (*Ref*) | 1.00 | – |
| Poverty | | |
| Above (*Ref*) | 1.00 | – |
| Below | 0.79 | 0.57–1.10$^{ns}$ |
| Smoking status | | |
| Never (*Ref*) | 1.00 | – |
| Former | 1.07 | 0.68–1.71$^{ns}$ |
| Current | 0.61 | 0.46–0.81* |
| ART use duration | | |
| < 5 years (*Ref*) | 1.00 | – |
| 5–9 years | 1.11 | 0.59–2.09$^{ns}$ |
| ≥ 10 years | 0.84 | 0.42–1.68$^{ns}$ |
| HIV diagnosis duration | | |
| < 5 years | 0.68 | 0.35–1.32$^{ns}$ |
| 5–9 years | 0.62 | 0.33–1.51$^{ns}$ |
| ≥ 10 years (*Ref*) | 1.00 | – |
| Mean CD4 count (cells/μl) | | |
| 0–199 (*Ref*) | 1.00 | – |
| 200–349 | 0.84 | 0.48–1.47$^{ns}$ |
| 350–499 | 1.04 | 0.63–1.73$^{ns}$ |
| ≥ 500 | 1.50 | 0.90–2.50$^{ns}$ |
| Current ART use | | |
| No (*Ref*) | 1.00 | – |
| Yes | 1.09 | 0.44–2.67$^{ns}$ |

*aOR* adjusted odds ratio, *95% CI* 95% confidence interval, *Ref* referent, *ns* not significant

Significance level: *significance based on 95% confidence interval

**Table 3** Odds of metabolic syndrome stratified by sex

| Characteristic | Men | | Women | |
|---|---|---|---|---|
| | aOR | 95% CI | aOR | 95% CI |
| Race/ethnicity | | | | |
| White (*Ref*) | 1.00 | – | 1.00 | – |
| Black | 0.69 | 0.47–1.00$^{ns}$ | 1.33 | 0.67–2.66$^{ns}$ |
| Hispanic | 1.44 | 0.91–2.27$^{ns}$ | 2.17 | 0.82–5.78$^{ns}$ |
| Age group (years) | | | | |
| 18-39 | 0.19 | 0.10–0.35* | 0.27 | 0.12–0.62* |
| 40-49 | 0.94 | 0.60–1.49$^{ns}$ | 0.62 | 0.31–1.25$^{ns}$ |
| 50-59 | 1.22 | 0.72–2.09$^{ns}$ | 0.82 | 0.40–1.68$^{ns}$ |
| ≥ 60 (*Ref*) | 1.00 | – | 1.00 | – |
| Education | | | | |
| < High school | 1.51 | 0.94–2.43$^{ns}$ | 1.52 | 0.82–2.80$^{ns}$ |
| High school/equivalent | 1.53 | 1.00–2.35$^{ns}$ | 1.21 | 0.67–2.18$^{ns}$ |
| > High school (*Ref*) | 1.00 | – | 1.00 | – |
| Poverty | | | | |
| Above (*Ref*) | 1.00 | – | 1.00 | – |
| Below | 0.78 | 0.54–1.11$^{ns}$ | 0.86 | 0.48–1.56$^{ns}$ |
| Smoking status | | | | |
| Never (*Ref*) | 1.00 | – | 1.00 | – |
| Former | 1.05 | 0.61–1.82$^{ns}$ | 1.10 | 0.52–2.32$^{ns}$ |
| Current | 0.48 | 0.34–0.66* | 1.11 | 0.70–1.77$^{ns}$ |
| ART use duration | | | | |
| < 5 years (*Ref*) | 1.00 | – | 1.00 | – |
| 5–9 years | 1.17 | 0.49–2.76$^{ns}$ | 1.16 | 0.42–3.21$^{ns}$ |
| ≥ 10 years | 0.94 | 0.38–2.34$^{ns}$ | 0.68 | 0.27–1.72$^{ns}$ |
| HIV diagnosis duration | | | | |
| < 5 years | 0.74 | 0.31–1.76$^{ns}$ | 0.64 | 0.22–1.84$^{ns}$ |
| 5–9 years | 0.72 | 0.34–1.52$^{ns}$ | 0.41 | 0.16–1.06$^{ns}$ |
| ≥ 10 years (*Ref*) | 1.00 | – | 1.00 | – |
| Mean CD4 count (cells/μl) | | | | |
| 0–199 (*Ref*) | 1.00 | – | – | 1.00 |
| 200–349 | 0.66 | 0.36–1.20$^{ns}$ | 1.29 | 0.40–4.10$^{ns}$ |
| 350–499 | 1.06 | 0.56–2.00$^{ns}$ | 0.81 | 0.32–2.06$^{ns}$ |
| ≥ 500 | 1.42 | 0.83–2.42$^{ns}$ | 1.49 | 0.60–3.71$^{ns}$ |
| Current ART use | | | | |
| No (*Ref*) | 1.00 | – | 1.00 | – |
| Yes | 1.39 | 0.26–7.45$^{ns}$ | 0.85 | 0.26–2.83$^{ns}$ |

*aOR* adjusted odds ratio, *95% CI* 95% confidence interval, *Ref* referent, *ns* not significant

Significance level: *significance based on 95% confidence interval

for MetS were not measured in our data. These include: diet, physical activity, family history for chronic diseases in MetS (hypertension, diabetes, and cardiovascular disease). As with any observational study, residual or uncontrolled confounding associated with these risk factors may have impacted our estimates. Finally, cross-sectional surveillance data was utilized from which causality cannot be inferred from the results.

## Conclusions

Our study addressed the lack of available data on MetS on PLWH in the southern US. Thus, our study is the first population level estimate of the prevalence of MetS among PLWH in these four southern US states. This regional assessment is critical for the understanding of how to prioritize risk mitigation and primary care prevention services in an aging HIV population that is increasingly diagnosed with additional chronic diseases other than HIV itself. Given that PLWH are living longer, longitudinal data are warranted to assess long-term MetS risk and how MetS may impact mortality among PLWH. Since HIV care providers may also provide primary care to PLWH, our study highlights the need for HIV care providers to regularly screen and monitor chronic disease risk factors if not already doing so. Additionally, intervention programs that promote and encourage healthy lifestyle such as physical activity and nutritional counseling should be offered to PLWH as part of an integrated HIV care during clinic visits.

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### Compliance with Ethical Standards

**Conflict of interest** The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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