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Metabolic Syndrome Among People Living with Human Immunodeficiency Virus (HIV) Receiving Antiretroviral Therapy in Mexico

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Abstract: Background/Objectives: In Mexico, there is very little data on the prevalence of metabolic syndrome in people living with human immunodeficiency virus (HIV) receiving antiretroviral therapy (ART), so, determining the number of people with this condition will help to establish measures to treat it promptly. **Methods**: A descriptive, observational, prospective, cross-sectional study was conducted in a cohort of people living with HIV who signed the informed consent form and were stratified according to the criteria established by the Adult Treatment Panel III (ATP-III) and the Latin American Diabetes Association (ALAD) for the diagnosis of metabolic syndrome. **Results**: According to the ATP-III and ALAD criteria, 26.5% and 36.3% of people living with HIV receiving ART were diagnosed with metabolic syndrome, respectively. Metabolic syndrome was more prevalent in men than in women, using both classification criteria (ATP-III: 58 men [67.4%] vs. 28 women [32.6%]; ALAD: 84 men [71.2%] vs. 34 women [28.8%]). The median time since HIV diagnosis of the participants with metabolic syndrome was longer than for the participants without metabolic syndrome, using the ALAD criteria ($p = 0.023$). The time spent on ART among participants with metabolic syndrome was longer than among those without, using the ATP-III criteria ($p = 0.011$). The CD4+ T-cell count and HIV-RNA detection showed no significant difference between participants with and without metabolic syndrome ($p > 0.05$). No statistical significance was found concerning ART and metabolic syndrome; it is noteworthy that for participants with dolutegravir/abacavir/lamivudine (DTG/ABC/3TC), the frequency was similar regardless of the criteria used, and different for those who were taking bictegravir/emtricitabine/tenofovir alafenamide (BIC/FTC/TAF) or were in other schemes (etravirine, darunavir/ritonavir, raltegravir). **Conclusions**: Our results suggested that 26.5% and 36.3% of the people living with HIV receiving ART included in this study had metabolic syndrome according to ATP-III and ALAD criteria, respectively. These results are consistent with results reported in the Latin American population. Interestingly, both criteria showed a higher frequency of metabolic syndrome in men living with HIV compared to women.

Keywords: people living with HIV; AIDS; metabolic syndrome; antiretroviral therapy

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1. Introduction

Metabolic syndrome is a highly prevalent disease in adults and a public health problem with a significant economic impact [1]. Interestingly, the people living with human immunodeficiency virus (HIV) have similar metabolic syndrome prevalence compared with the general population [2]. Due to the use of antiretroviral drugs, the clinical prognosis of people living with HIV has changed, and the mortality of these participants is now related to insulin resistance that contributes to metabolic alterations [3]. A global prevalence of metabolic syndrome in people living with HIV is estimated at approximately 16.7–31.3%, depending on the criteria used to define the syndrome. However, some authors mention that the prevalence can reach up to 48%, with all of them agreeing that Africa is where largest population is found [3,4]. The prevalence of metabolic syndrome in people living with HIV without antiretroviral therapy (ART) is lower than that of the treatment-experienced participants [5–7]. Age, body mass index, physical activity, socioeconomic status, CD4+ T-cell count, and treatment with protease inhibitors are risk factors associated with metabolic syndrome in people living with HIV [8–15]. Moreover, virological failure, female sex, hip circumference, high-sensitivity C-reactive protein, and fasting insulin levels are significantly associated with metabolic syndrome [16].

Regarding antiretrovirals in the contribution to the metabolic syndrome in people living with HIV, dolutegravir (DTG)-based regimen [16], different treatment regimens based on integrase inhibitors [6], and protease inhibitors (indinavir) [17] have been associated with metabolic syndrome. Characterizing metabolic syndrome could help guide the prevention of this disease among people living with HIV receiving ART; however, heterogeneous criteria for defining metabolic syndrome have led to inconsistent prevalence estimates, particularly in low- and middle-income countries. In this study, we estimated trends in metabolic syndrome prevalence in Mexico across two criteria (Adult Treatment Panel III (ATP-III) and the Latin American Diabetes Association (ALAD)). We compared them with the prevalence in other countries. Here, we hypothesized that the prevalence of metabolic syndrome among people living with HIV receiving ART in Mexico varies in comparison with other countries due to the use of the Latin American criterion in this study, ALAD.

2. Materials and Methods

This study was conducted in 2023 using a prospective cohort of people living with HIV from a tertiary-level hospital of the Instituto Mexicano del Seguro Social, Mexico. This protocol was approved (registration number: R-2023-3001-132) by the Ethics and Research Committee CLIS 3001. Of the 2700 people living with HIV and attending HIV control consultations at this hospital, those who met the inclusion criteria were selected. The limit of detection for HIV-RNA by the assays was 40 copies per mL. People aged over 18 living with HIV undergoing antiretroviral treatment (ART) for at least $\geq$ 6 months were included in this study. The exclusion criteria were people with HIV who were not receiving ART or were unable to give informed consent. In addition, people living with HIV with (1) a diagnosis of coronary heart disease before initiation of ART, (2) treatment with corticosteroids, and (3) current infections or previous history of oncologic conditions were excluded.

2.1. Sample Size

The sample size was calculated based on the prevalence of HIV, with the following assumptions: an alpha level of 0.05 and 80% power. According to previous studies, the prevalence of metabolic syndrome is estimated to range from 17.85% to 87.5%, depending on the criteria used. Due to the heterogeneity of the data and the wide distribution for

this work, we decided to use the median prevalence, which corresponds to 29%. The total sample size needed was calculated to be ~325.

2.2. Variables

Data were collected through the laboratory system or electronic files in order to obtain recent and complete lipid values (HDL cholesterol [HDL-C] and triglycerides) and fasting glucose. Variables such as age, sex, currently prescribed ART, time of infection, HIV-RNA, CD4+ T-cell count, and other demographic data (alcohol use and smoking) were collected. The definition of metabolic syndrome was based on the criteria established by the Latin American Diabetes Association (ALAD) consensus [18] and the National Cholesterol Education Program-Adult Treatment Panel III (ATP III) [19] (Table 1).

Table 1. Definition of metabolic syndrome.

Parameter	ALAD	ATP III
Waist circumference	≥94 cm in men and ≥88 cm in women	>102 cm in men and 88 cm in women
Triglycerides	>150 mg/dL or undergoing lipid-lowering treatment	≥150 mg/dL
High-density lipoprotein cholesterol (HDL-C)	<40 mg/dL in men and <50 mg/dL in women, or treatment with an effect on HDL-C	<40 mg/dL in men and <50 mg/dL in women
Blood pressure (systolic blood pressure/diastolic blood pressure)	≥130/85 mmHg or in antihypertensive treatment	≥130/85 mmHg
Fasting glucose	≥100 mg/dL or diabetes	≥100 mg/dL

Abbreviations: ATP-III, Adult Treatment Panel III; ALAD, the Latin American Diabetes Association; HDL-C, high-density lipoprotein cholesterol.

The criteria for the clinical diagnosis of metabolic syndrome included a waist circumference of ≥94 cm in men and ≥88 cm in women, two of the parameters of ALAD, and three or more of the parameters of ATP III. The variables collected (waist circumference, blood pressure, and others) were recoded into binary categorical variables based on the thresholds established for metabolic syndrome according to the ALAD and NCEP/ATP III guidelines.

Diabetes was defined as a fasting plasma glucose (FPG) level of 126 mg/dL or higher or a hemoglobin A1c (HbA1c) level of 6.5% or higher. Hypertension was defined as meeting one of the following criteria: (1) systolic and/or diastolic blood pressure readings ≥ 140 and 90 mmHg, or (2) having a previous clinical diagnosis of arterial hypertension and currently taking any antihypertensive treatment.

2.3. Ethical Aspects

The research was conducted following the General Health Law on Health Research and the Declaration of Helsinki, as amended in 2000, using the current version from 2004. Since this was a prospective study, participants were given an informed consent form, in which, after a clear and complete explanation, they authorized their participation, the use of their data, and the previously mentioned interventions. The individual was free to withdraw their informed consent at any time and had the right not to participate in the study if they chose not to do so.

2.4. Statistical Analysis

Nominal/categorical variables were represented as the number, frequency, or percentage (%), while quantitative variables were expressed as the mean, standard deviation, or median (interquartile range [IQR]). The Shapiro–Wilk test, histograms, and Q-Q plots were used to analyze the data distribution. The sex, time of diagnosis of HIV infection, time of treatment, CD4+ T-cell count, HIV-RNA, and type of ART (bictegravir/emtricitabine/tenofovir alafenamide (BIC/FTC/TAF), dolutegravir/abacavir/lamivudine (DTG/ABC/3TC), and others) were studied for between-group differences. Depending on the assumptions, a comparison between groups was performed using Student's *t*-test, Mann–Whitney U test, Chi-square test (χ^2), or Fisher's exact test. A value of $p < 0.05$ was considered a statistically significant difference. Data were analyzed using IBM SPSS Statistics, Version 29.0.1.0.

3. Results

3.1. Demographic and Clinical Characteristics of the Study Participants

Of the 325 participants, 265 were men (81.5%), and 60 were women (18.5%). The median age of the participants was 41 years. Of the participants, 253 did not smoke (77.8%). Regarding alcohol consumption, 199 mentioned consuming alcohol to date, and 126 (38.8%) said they did not drink it or had stopped (Table 2). Besides diabetes and hypertension, participants had no other comorbidities, liver steatosis, chronic liver disease, chronic kidney disease, or co-infections with HCV and/or HBV. Thirty-two participants had dyslipidemia, which was defined by the presence of both elevated triglyceride (>200 mg/dL) levels and low HDL-C (<40 mg/dL for men and <50 mg/dL for women). Although the participants were older than 61 years of age and had a relatively long exposure to antiretroviral therapy (ART), they did not develop cardiovascular or cerebrovascular events after initiating ART.

Table 2. Sociodemographic characteristics of participants.

Variable		Frequency, *n* = 325 (%)
Sex		
	Male	265 (81.5)
	Female	60 (18.5)
Age, years old		
	18–30	56 (17.2)
	31–40	105 (32.3)
	41–50	64 (19.7)
	51–60	58 (17.8)
	>60	42 (12.9)
Other		
	Smoking	72 (22.2)
	Alcoholism	126 (38.8)

Regarding comorbidities such as hypertension and diabetes, most of the participants did not have a diagnosis of these conditions. Still, of the participants who did have either (or both, *n* = 16 (4.92%), hypertension was the most frequent condition, with 69 (21.2%) vs. 41 (12.6%) who had diabetes. The proportion of participants with overweight and obesity (classes I-III) was 36.9% and 39.1%, respectively (Table 3).

Table 3. Clinical characteristics of participants.

Variable		Frequency, n = 325 (%)
Diseases		
	Hypertension	69 (21.2)
	Diabetes	41 (12.6)
BIM		
	Low weight	4 (1.2)
	Normal	74 (22.8)
	Overweight	120 (36.9)
	Obesity Class I	94 (28.9)
	Obesity Class II	25 (7.7)
	Obesity Class III	8 (2.5)
HIV (time in years)		
	1–5	131 (40.3)
	6–10	117 (36)
	11–15	30 (9.2)
	15–20	25 (7.7)
	>20	22 (6.8)
Time on ART (current)		
	1–5 years	295 (90.8)
	6–10 years	25 (7.7)
	11–15 years	1 (0.3)
	>15 years	4 (1.2)
Antiretroviral treatment		
	BIC/FTC/TAF	299 (92)
	DTG/ABC/3TC	23 (7.1)
	OTHER	3 (0.9)

Abbreviations: BMI, body mass index; HIV, human immunodeficiency virus; ART, antiretroviral treatment; BIC/FTC/TAF, bictegravir/emtricitabine/tenofovir alafenamide; DTG/ABC/3TC, dolutegravir/abacavir/lamivudine; OTHER, etravirine, darunavir/ritonavir, and raltegravir.

Concerning HIV, the mean time from diagnosis was 8.14 ± 6.4 years, and the mean time from diagnosis to current treatment was 3.25 ± 2.2 years (Table 3). Regarding the ART they were taking, 299 (92%) were taking BIC/FTC/TAF, 23 (7.1%) dolutegravir/abacavir/lamivudine (DTG/ABC/3TC), and only 3 (0.9%) were taking another scheme consisting of separate drugs (etravirine, darunavir/ritonavir, raltegravir).

Because not all participants had HIV-RNA and/or a CD4+ T-cell count, estimates were made with lower numbers from the overall sample. Of the 178 participants with a CD4+ T-cell count, the mean was 656.84 ± 341 cells, and of the 205 with HIV-RNA, 191 (93%) were undetectable (Table 4).

Table 4. CD4+ T-cell counts and HIV-RNA levels of the participants.

Variable		Frequency, *n* = 178 (%)
CD4+ T-cell count, cell number		
	100–300	23 (12.9)
	301–500	39 (21.9)
	501–700	54 (30)
	701–900	26 (15)
	901–1100	18 (10.1)
	>1100	18 (10.1)
Variable		**Frequency, *n* = 205 (%)**
HIV-RNA copies per mL		
	Undetectable	191 (93.1)
	40–50	3 (1.5)
	51–100	8 (3.9)
	101–150	2 (1)
	>150	1 (0.5)

Abbreviations: HIV, human immunodeficiency virus; RNA, ribonucleic acid.

3.2. Prevalence of Metabolic Syndrome in the Participants

The proportion of participants living with HIV who met the criteria for metabolic syndrome for each of the variables was analyzed. The frequency of metabolic syndrome, according to the ATP-III criteria, was 86 participants (26.5%), being more prevalent in men (58 [67.4%]) than in women (28 [32.6%]). Regarding the most frequent characteristics of each group, among participants with metabolic syndrome according to the ATP-III criteria, the most common were increased waist circumference and elevated triglycerides, whereas elevated glucose levels were less prevalent.

Concerning the criteria of the ALAD, 118 (36.3%) men and 84 (71.2%) women had metabolic syndrome. All the participants who were diagnosed with metabolic syndrome using ALAD had the circumference criteria. In this group, the glucose criterion was considered the most frequent, with 79 (66.9%) participants, followed by blood pressure, with 77 (65.3%) participants. On the other hand, the least frequently measured criterion was HDL-C, considering the measurements performed in this study.

3.3. Relationship Between Metabolic Syndrome and Participant Characteristics

When the basal characteristics were analyzed between the population with or without metabolic syndrome, we found that the waist circumference, triglycerides, and glucose were significantly elevated ($p < 0.001$) in people living with HIV and metabolic syndrome, regardless of the criteria used, as expected (Table 5). Moreover, the age, BMI, and HbA1c were significantly elevated ($p < 0.05$) in all participants with metabolic syndrome compared to those without, regardless of the criteria used. Interestingly, the median time since HIV diagnosis of the participants with metabolic syndrome was longer than for the participants without metabolic syndrome, using the ALAD criteria. The time spent on ART among participants with metabolic syndrome was longer than among those without, as defined by the ATP-III criteria. There were no significant differences between the ART received when participants with or without the metabolic syndrome were compared. The CD4+ T-cell

count and HIV-RNA detection did not show any significant difference between participants with and without metabolic syndrome ($p > 0.05$) (Table 5).

Table 5. Characteristics of the study population according to the classification of metabolic syndrome.

	ATP-III			ALAD		
Variable	**No (*n* = 239)**	**Yes (*n* = 86)**	***p***	**No (*n* = 207)**	**Yes (*n* = 118)**	***p*-Value**
Age, years old	38 (21)	45.5 (23)	**<0.001** [a]	37 (18)	48 (22)	**<0.001** [a]
Waist Circumference, cm	94 (16)	105 (17.3)	**<0.001** [a]	90.5 (14)	105 (13)	**<0.001** [a]
Weight, Kg	78.1 (±14.5)	85.8 (±17)	0.44 [b]	75.6 (±13.8)	88.4 (±15.2)	0.311 [b]
Height, meters	1.69 (0.1)	1.65 (0.1)	0.05 [a]	1.69 (0.1)	1.66 (0.1)	0.213 [a]
BMI, Kg/m^2	27.28 (6.5)	30.86 (7.3)	**<0.001** [a]	26.19 (5.9)	31.39 (6.3)	**<0.001** [a]
HDL-C, mg/dL	47 (14)	40 (12)	**<0.001** [a]	46 (14)	42 (12)	**0.041** [a]
Triglycerides, mg/dL	116 (61)	180 (109)	**<0.001** [a]	116 (64)	159 (92)	**<0.001** [a]
HbA1c, %	5.71 (0.6)	6.45 (2.9)	**<0.001** [a]	5.8 (1.0)	6.1 (2.2)	**0.023** [a]
Glucose, mg/dL	93 (13)	110 (31)	**<0.001** [a]	92 (11)	104 (17)	**<0.001** [a]
HIV time, years	6 (6)	7 (7)	0.081 [a]	6 (5)	7 (8)	**0.023** [a]
Time on ART, years	3 (1)	4 (1)	**0.011** [a]	3 (2)	3 (2)	0.229 [a]
Type of ART						
BIC/FTC/TAF, %	218 (72.9)	81 (27.1)	0.490 [c]	188 (62.9)	111 (37.1)	0.202 [c]
DTG/ABC/3TC, %	18 (78.3)	5 (21.7)	0.807 [d]	18 (78.3)	5 (21.7)	0.178 [d]
OTHER, %	3 (100)	0	0.569 [d]	2 (66.7)	1 (33.3)	1.00 [d]
CD4+ T-cell count (cell number)	617 (379)	614 (458)	0.924 [a]	621 (387)	614 (448)	0.714 [a]
HIV-RNA, number (%)			0.234 [d]			0.401 [d]
Undetectable	138 (67.3)	53 (25.8)		119 (58.1)	72 (35.1)	
Detectable	8 (3.9)	6 (2.9)		7 (3.4)	7 (3.4)	
Smoking, %	55 (76.4)	17 (23.6)	0.534 [c]	51 (70.8)	21 (29.2)	0.171 [c]
Alcoholism, %	98 (77.8)	28 (22.2)	0.168 [c]	86 (68.3)	40 (31.7)	0.204 [c]

Data are presented as mean ± standard deviation, median (interquartile range), or n (%). *p*-values were calculated using (a) Mann–Whitney U test, (b) Student's *t*-test, (c) Chi-squared test, or (d) Fisher's exact test as appropriate. The bold values pertain to statistical significance ($p < 0.05$). Abbreviations: ATP-III, Adult Treatment Panel III; ALAD, the Latin American Diabetes Association; BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; HbA1c, glycated hemoglobin; HIV, human immunodeficiency virus; ART, antiretroviral treatment; BIC/FTC/TAF, bictegravir/emtricitabine/tenofovir alafenamide; DTG/ABC/3TC, dolutegravir/abacavir/lamivudine; OTHER, etravirine, darunavir/ritonavir, and raltegravir; RNA, ribonucleic acid.

A comparison of the participants' triglycerides, weight, HDL-C, waist circumference, glucose levels, and blood pressure was performed between the different ARTs received. Triglyceride alteration was the only statistically significant variable ($p = 0.020$) among participants who received BIC/FTC/TAF compared to those who did not (Table 6).

Although the frequency of blood pressure alterations was higher in the three groups, these were not statistically significant, in addition to the fact that within this category, there were participants who already had a diagnosis of hypertension, without specifying whether this occurred before or after taking ART.

Table 6. Comparative analysis of the metabolic syndrome variables between the types of antiretroviral treatment.

Variables	BIC/FTC/TAF (*n* = 299)		DTG/ABC/3TC (*n* = 23)		OTHER (*n* = 3)	
	Yes	*p*-Value	Yes	*p*-Value	Yes	*p*-Value
Triglycerides, mg/dL	131 (82)	**0.020** [a]	115 (54)	0.052 [a]	100 (0)	0.172 [a]
Weight, Kg	80.5 ± 15.5	0.563 [b]	76.8 ± 17.1	0.483 [b]	77 ± 14.9	0.81 [b]
HDL-C, mg/dL	46 (16)	0.402 [a]	42 (6)	0.245 [a]	51.5 (0)	0.584 [a]
Waist circumference, cm	97.4 (18)	0.831 [a]	93 (15)	0.619 [a]	102 (0)	0.466 [a]
Glucose, mg/dL	97 (17)	0.493 [a]	92 (17)	0.654 [a]	95 (0)	0.457 [a]
Elevated blood pressure levels (≥130/85 mmHg), n (%)	132 (44)	0.565 [c]	12 (52)	0.449 [c]	1 (33.3)	0.693 [d]

Data are presented as mean ± standard deviation, median (interquartile range), or n (%). *p*-values were calculated using (a) Mann–Whitney U test, (b) Student's *t*-test, (c) Chi-squared test, or (d) Fisher's exact test as appropriate. The bold values pertain to statistical significance ($p < 0.05$). Abbreviations: HDL-C, high-density lipoprotein cholesterol; BIC/FTC/TAF, bictegravir/emtricitabine/tenofovir alafenamide; DTG/ABC/3TC, dolutegravir/abacavir/lamivudine; OTHER, etravirine, darunavir/ritonavir, and raltegravir.

4. Discussion

Here, we suggest that 26.5% and 36.3% of the people living with HIV receiving ART included in this study had metabolic syndrome according to ATP-III and ALAD criteria, respectively. Ortíz et al. reported a metabolic syndrome prevalence of 31.5% in people with HIV, with a median age of 39 years, using the harmonized Joint Scientific Statement criteria combined with the waist circumference cutoffs proposed by ALAD [12]. In contrast, the median age of the participants with metabolic syndrome was 45.5 years and 48 years for ATP-III and ALAD in our study, respectively. These prevalences of metabolic syndrome were higher than those observed in a study from other Latin American countries, which demonstrated an overall prevalence of metabolic syndrome of 20.2% using the ATP-III criterion in people living with HIV receiving ART [20]. A study performed in Mexico revealed a prevalence of metabolic syndrome of 22.3%, using only the ATP-III criterion [21]. Thus, our analysis could be considered the first study to assess metabolic syndrome in people living with HIV receiving ART using ATP-III and ALAD to prioritize diagnostic criteria and guide the selection of appropriate diagnostic criteria for metabolic syndrome in Latin America. Our study revealed that the prevalence of metabolic syndrome was higher in men than in women, following the findings of Ortíz et al. [12]. However, the study of Alvarez et al. suggested that the overall prevalence of metabolic syndrome in Latin American countries was higher in women than in male participants [20].

Regarding other studies conducted outside of the Americas, the overall prevalence of metabolic syndrome among people living with HIV on Dolutegravir and Efavirenz-based ART was 18.6% in Ethiopia [22]. Another study conducted in Ethiopia reported that the prevalence of metabolic syndrome was 23.5%, 20.5%, and 27.6% using the ATP-III, the International Diabetes Federation (IDF), and the Joint Interim Statement-2009 (JIS-2009) criteria, respectively [23]. In southern Italy, the prevalence of metabolic syndrome was 27.5% using the ATP-III criteria [23]. A prevalence of metabolic syndrome of 58% was reported in southwestern Uganda [24], utilizing the definition established by the National Heart, Lung, and Blood Institute/American Heart Association Conference. In contrast, another study in Africa reported a prevalence of 19.2%, defined according to the harmonized Joint Scientific Statement criteria [25]. In this sense, the prevalence of metabolic syndrome varies according to the country and the criteria used for its evaluation. ATP-III has been suggested as the most frequently used criterion for metabolic syndrome [26]. The prevalence of metabolic syndrome among people living with HIV receiving ART ranged from 8.4% to 47% across

the developing regions and was comparable to the overall prevalence across the developed regions [26]. The mean prevalence of metabolic syndrome was 30.5%, 21.5%, and 21.4% in Africa, Asia, and South America, respectively [26]. Nevertheless, research has revealed that the prevalence of metabolic syndrome was highest in the Americas, followed by Europe, Asia, and Africa [2]. A meta-analysis of the global population living with HIV receiving ART demonstrated that the metabolic syndrome prevalence was 16.7%, 18%, 24.6%, 27.9%, 29.6%, and 31.3%, respectively, according to the following criteria: ATPIII-2001, IDF-2005, ATPIII-2004-2005, modified ATPIII-2005, JIS-2009, and the European Group for the Study of Insulin Resistance-2003 [2].

Concerning the ALAD and ATP-III criteria applied to the participants of this study, the median time since HIV diagnosis of the participants with metabolic syndrome was longer than for the participants without metabolic syndrome, using the ALAD criteria. This result is similar to the findings of Ang et al. [13]. Nguyen suggested that a longer interval since HIV diagnosis could be related to the specific effects of prolonged ART or older age, which is a risk factor for metabolic syndrome [2]. The time spent on ART among participants with metabolic syndrome was longer than among those without, as defined by the ATP-III criteria. Bosho et al. demonstrated that the duration of ART regimens for more than 6 years was associated with metabolic syndrome [23]. Because the countries in America follow the worldwide trend of people living with HIV reaching older age due to ART accessibility, this could increase the number of individuals with metabolic syndrome in the future [12]. There were no significant differences between the ART received when participants with or without the metabolic syndrome were compared. However, the type of ART regimens has been significantly associated with metabolic syndrome in people living with HIV [23].

On the other hand, the CD4+ T-cell count and HIV-RNA detection did not show any significant difference between participants with and without metabolic syndrome. Ortíz et al. found that the CD4+ T-cell count was not associated with metabolic syndrome in people living with HIV receiving ART from Guatemala [12]. This issue is controversial because one meta-analysis reported that a low CD4+ T-cell count is associated with metabolic syndrome, while other studies suggested the contrary [2,20,27]. Lower CD4+ T-cell counts in people living with HIV could be related to a pro-inflammatory environment promoting metabolic abnormalities such as low HDL-C and hypertriglyceridemia [12].

In our study, the time on ART showed a significant relationship in the case of the ATP-III but not when participants were classified using the ALAD criteria. This relationship between exposure to ART and metabolic syndrome has been reported by Wu et al., who found that exposure for $\geq$6 years was significantly associated with metabolic syndrome [14]. The biochemical alterations generated by ART, particularly those associated with more prolonged exposure to regimens, increased lipid disturbance, including weight gain, especially with regimens that include the integrase strand transfer inhibitors dolutegravir and bictegravir [28,29]. Although a relationship between ART and metabolic syndrome has been established [2,13,30], our study found no significant differences in ART received when comparing participants with and without metabolic syndrome.

Among the limitations of this study are that, being a single-center study, the sample size is relatively small, and the non-compliance of some participants when requesting laboratory tests makes it difficult for the physician to rule out or confirm any biochemical alterations they may have. Another limitation was that before the incursion of BIC/FTC/TAF (approximately 3 years), some participants had another treatment scheme, so the relationship of certain factors cannot be attributed 100% to this drug. Due to the small number of participants with protease inhibitor drugs, it was not possible to establish a relationship with metabolic syndrome. Nevertheless, our study has some strengths: (1) this study is one of the few studies conducted in Mexico that evaluates the metabolic syndrome in

people living HIV receiving ART; (2) most of the studies on metabolic syndrome were conducted in countries from Europe, Asia, and Africa using the ATP-III generally; thus, the comparison made in this study utilizing the ATP-III and ALAD criteria could be used to prioritize and guide the selection of appropriate diagnostic criteria for metabolic syndrome in Latin America.

5. Conclusions

Metabolic syndrome was diagnosed in 26.5% and 36.3% of the population living with HIV receiving ART in Mexico, according to the ATP-III and ALAD criteria, respectively, the latter being more appropriate for the Latin American population. Both criteria showed a higher frequency of metabolic syndrome in men. This study suggests that promoting monitoring of patients' clinical and metabolic parameters at every visit is ideal.

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