

Phase angle, arm fat mass, and arm fat area were predictive factors of muscle strength and muscle quality of people living with the human immunodeficiency virus: exploratory cross-sectional study

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Abstract

Background aims: Skeletal muscle mass and quality are compromised by fat infiltration, but gold standard assessments are often inaccessible. This study examined whether phase angle, arm fat mass, and arm fat area are associated with skeletal muscle strength and quality in adults living with HIV (PLWH).

Methods: This is a cross-sectional study with a non-probabilistic sample composed of PLWH. Handgrip strength (HGS) was evaluated with a Jamar® dynamometer. Appendicular lean mass (ApLM) and arm fat mass (AFM) were assessed with Dual-energy x-ray absorptiometry (DXA). The phase angle (PhA) was evaluated with Bioelectrical Impedance. The arm fat area (AFA) was estimated with mid-upper arm circumference- and triceps skinfold thickness-derived equation. Muscle quality was assessed with the ratio of HGS and ApLM and HGS with body mass index (BMI).

Results: Thirty-eight PLWH, 30 men (78.9%), and 8 women (21.1%) were evaluated. PhA was positively associated ($b = 3.52$; CI 95% 0.39 - 6.66) with HGS. The AFM was negatively associated with HGS ($b = -3.64$; CI 95% -5.69 to -1.60), MQI_{ApLM} ($b = -0.15$; CI 95% -0.24 to -0.07), and MQI_{BMI} ($b = -0.22$; CI 95% -0.30 to -0.13). Finally, AFA was negatively associated with HGS (-0.22; CI 95% -0.35 to -0.05), MQI_{ApLM} (-0.009; CI 95% -0.01 to -0.002), and MQI_{BMI} (-0.01 CI 95% -0.02 to -0.002). **Conclusion:** Among people living with HIV, PhA, AFM, and AFA were predictors of muscle strength and quality.

Introduction

Lowered skeletal muscle (SM) strength and mass have been established as a critical predictor of health outcomes [1–4]. Sarcopenia, a muscle-related disease [5], is defined by a reduction of both, and recently, according to the European consensus on the definition and diagnosis of sarcopenia, the algorithm to diagnose sarcopenia was modified, and SM strength was established as the first criterion to define sarcopenia [6].

Beyond SM strength, muscle function can be assessed by SM quality, which is measured according to SM density from image tests (i.e., magnetic resonance, MRI and computer tomography, CT) [7]. The SM density is affected by fat infiltration (myosteatosis), an ectopic fat, which can influence the ability to generate power and strength [8]. Moreover, SM fat infiltration was positively associated with inflammation and insulin resistance [9, 10].

Given the complexity and difficulty of assessing MRI and CT, other methods of evaluating SM quality, such as the muscle quality index (MQI), have been used [8, 11]. The MQI can be obtained from field- and laboratory-based methods, such as calculating the ratio between SM strength by body mass index (BMI) or appendicular lean mass (ApLM), respectively [11].

Considering that SM quality is affected by fat mass [10], parameters derived from body composition-assessed methods, such as bioelectrical impedance analysis (BIA) and Dual-energy X-ray

absorptiometry (DXA), are studied [12, 13]. For instance, the phase angle (PhA), a parameter derived from BIA, has been used to verify the integrity of the cell membrane structure, and previous studies suggest that lower PhA is related to lower cell membrane integrity [14]. Moreover, PhA has been applied to determine SM function and strength [15]. For example, a low PhA indicates lower SM strength [15] and some studies have applied PhA as a sarcopenia screening parameter [16–19].

Likewise, arm-fat mass (AFM) and arm fat area (AFA) derived from DXA and anthropometry, respectively, can be considered a proxy for arm fat infiltrate. Thus, more accessible methods for evaluating SM quality and predictive factors contribute to better diagnosis and premature interventions, enabling a better prognosis.

Several populations showed body composition abnormalities that can affect SM strength and quality, such as aged people, obese and type 2 diabetes mellitus persons, and people living with HIV (PLWH) [20–23]. PLWH presents changes in body composition resulting from HIV-related residual effect, antiretroviral therapy (ART), and the persistent activation of the immune system, which favors chronic systemic inflammation [20, 24, 25]. In accordance with these characteristics, studies have shown that PLWH has a high amount of infiltrated fat and poor SM quality [26, 27].

The investigation of the relationship between BIA-, DXA-, and anthropometry-related parameters and SM function has been widely investigated [15, 28–33]. However, little is known about PLWH [34]. As such, we aimed to verify the relationship between PhA, AFM, and AFA with SM strength and quality of adult PLWH.

Methods

Study design and Participants

This is a cross-sectional study with a non-probabilistic sample composed of men and women living with HIV. The Ethical Committee XXX[removed for peer review], and all the participants signed a consent form. The PLWH were recruited from the XXX[removed for peer review]. The study divulgation was carried out on-site through folders and by workers (i.e., doctors and nurses). The inclusion criteria were being ≥ 18 years old, being male or female, residing in the state of São Paulo, Brazil, and being free of Hepatitis C, chronic kidney disease, or cancer. Still, participants needed to maintain an undetectable viral load (< 50 copies/mL) and to be under any ART therapy. Data were collected between August 2021 and May 2022.

Muscle Strength and quality

SM strength was evaluated with a Jamar® handgrip strength (HGS) dynamometer. This dynamometer features a static indicator for easy reading, with a 0–90 kg scale and a resolution of 2 kg. HGS was measured in both hands in a seated position with the arm at a 90-degree angle, according to the National Health and Nutrition Examination Survey (NHANES) guidelines for hand dynamometry. HGS was

measured three times, with 1-minute intervals between measurements. We used the highest value of the dominant hand [35]. From HGS, we estimated the SM quality. The SM quality was assessed by dividing HGS by ApLM and BMI to obtain the MQI_{ApLM} and MQI_{BMI} , respectively [11, 36].

Body mass index and arm fat area

We assessed the body weight using a digital balance with a 100 g scale accuracy. Height was measured using a portable stadiometer with 0.1 cm accuracy. The subjects were instructed to stand close to the stadiometer, with their head in the Frankfurt position. Measurement was taken at the end of a deep, inward breath. From body weight and height, we calculated the BMI, dividing the body weight by squared height.

All anthropometric measures were obtained according to standardized protocols and by highly trained Nutritionists [37]. The mid-upper arm circumference (MUAC) was measured to the nearest 0.1 cm on the right arm midway between the acromion and olecranon processes of the ulna with the use of anthropometric tape. The mean value of three measurements was utilized. The triceps skinfold thickness (TSFT) was measured with a Lange® adipometer using the same anthropometric reference as the MUAC. Three measurements were taken, and the mean value was used. From these measurements, the arm muscle circumference (AMC), arm muscle area (AMA) and the arm fat area (AFA) were calculated based on a previous publication by Frisancho [38].

Appendicular lean mass and arm-fat mass

We assess body composition with DXA (Lunar iDXA, GE Healthcare, with incore Software Platform®). All DXA's previous recommendations were followed [39]. We used the following data in this study: (i) fat mass, (ii) lean body mass, (ii) appendicular lean mass, and (iv) AFM. The DXA-derived ApLM was used to calculate MQI_{ApLM} .

Phase angle

We used tetra polar BIA (450 Byodynamics®) to assess PhA. BIA provided resistance (R), reactance (Xc), and Impedance (Z) data from a high-frequency, low-amplitude alternating electric current (50 kHz) [40]. They stay in a supine position for 10 minutes (during preparation for DXA). Then, the BIA was carried out. All participants were instructed to follow the pre-test recommendations, including fasting for at least four hours, wearing proper clothing, being barefoot, refraining from wearing earrings and/or rings, abstaining from intense physical activity on the previous day, avoiding beverages with high caffeine content in the last 12 h and not be on their menstrual period [40].

Sociodemographic characteristics

Age (in years), sex at birth (female or male), educational status (primary course, high school, college, postgraduate course [master's or doctorate] or never studied), and ethnicity (white and non-white) were referred by the participants. According to Brazilian minimum wages, we asked about monthly income: < 1 minimum wage; 1 to 2 minimum wages; 2 to 3 minimum wages; 3 to 4 minimum wages; 4 to 9 minimum wages; 10 or more.

Statistical Analysis

The Shapiro-Wilk test investigated data normality. For descriptive data, continuous and normally distributed data are presented as mean and standard deviation, while continuous and non-parametric data are presented as the median, minimum, and maximum values. The categorical data were presented as absolute and relative values. Respectively, Pearson's correlation and chi-square for continuous and categorical variables were applied if necessary.

To investigate the associations between each independent variable (PhA, AFM, and AFA) and outcomes (HGS, MQI_{APLM} , MQI_{BMI} , AFM and PhA), we performed linear regression models, considering the Gaussian distribution. Regarding PhA as the primary independent variable, models were developed as follows: Model 1: adjusted for arm fat; Model 2: adjusted for arm fat and lean body mass; Model 3: Adjusted for arm fat, lean body mass, and age; Model 4: Adjusted for arm fat, lean body mass, age and sex. Considering the AFM as the primary independent variable, models were developed as follows: Model 1 was adjusted by lean body mass, Model 2 was adjusted for lean body mass and age, and Model 3 was adjusted by lean body mass, age, and sex. Regarding AFA as the primary independent variable, models were developed as follows: Model 1: adjusted by LBM; Model 2: adjusted for LBM and age; Model 3: adjusted by LBM, age, and sex. The variables to compose the models were selected based on biological plausibility. Data expressed as mean and 95% confidence interval. Multivariate linear regression with Gaussian distribution of the dependent variable. Durbin-Watson autocorrelation test was applied. The alpha of 5% was used to reject the null hypothesis of the independent variable. Considering that our study had a non-probabilistic process, the sample calculation was not done *a priori*. The sampling power value was calculated with G*Power 3.1 for each regression, considering the sample size obtained, the alpha value of 5%, the number of predictor variables for each model, and the effect size of each model to avoid type 1 statistical error. All statistical analyses were performed with JAMOV[®] version 2.2.5 Solid Version for macOS.

Results

Table 1 presents the general characteristics of the sample. Thirty-eight PLWH, 30 men (78.9%), and 8 women (21.1%) were evaluated. The mean age was 45.7 ± 7.89 years. The sample includes 12 people with normal weight (31.6%), 18 with overweight (47.4%), and 8 with obesity (21.1%). The average values of LBM, FM, and HGS were 51.2 ± 7.11 kg, 24.3 ± 9.49 kg and 31.5 ± 9.01 kg, respectively. In our sample, according to EWGSOP^{II}, only 4 men have low muscle strength (13.3%), while only 2 women have low muscle strength (25%). The PhA was $7.47 \pm 0.73^\circ$. We verified a positive correlation between PhA and HGS ($r = 0.428$; $p = 0.007$).

Table 1
Characteristics of PLWH (n = 38)

Variables	Mean±SD or n; %
Age (years)	45.7±7.89
Sex at birth (n; %)	
Male	30 (78.9)
Female	8 (21.1)
BMI (kg/m ²)	27.7±5.05
BMI (n; %)	
Normal weight	12 (31.6)
Overweight	18 (47.4)
Obesity	8 (21.1)
LBM (kg)	51.2±7.11
ApLM (kg)	24.2±4.14
FM (kg)	24.3±9.49
AFM (kg)	2.56±1.21
HGS (kg)	31.5±9.01
MQI _{ApLM}	1.29±0.33
MQI _{BMI}	1.19±0.406
PhA (°)	7.47±0.73
MUAC (cm)	32.8±3.68
TSFT (mm)	14.5 (4–49.7)
AMC (cm)	27.5±3.04
AMA (cm ²)	54.5±13.6
AFA (cm ²)	30.7±13.9

Legend: BMI: Body mass index; LBM: Lean body mass; ApLM: Appendicular lean mass; FM: Fat mass; HGS: Hand grip strength; MQI: Muscle quality index; PhA: Phase angle. MUAC: mid-upper arm circumference; TSFT: triceps skinfold thickness; AMC: arm muscle circumference; AMA: arm muscle area; AFA: arm fat area. Minimum wage: The 2022 minimum wage in Brazil was 1202 reais (BR\$). The mean value of 1 dollar (\$) in Brazil during the period was ~ 5.20 reais (BR\$). Data are presented in mean, standard deviation, or absolute and relative frequencies.

Variables	Mean±SD or n; %
Schooling level (n; %)	
Complete basic education	5 (13.2)
Complete high school	11 (28.9)
Complete college	22 (57.9)
Monthly income (n; %)	
1–2 minimum wage	19 (54.3)
2–3 minimum wage	7 (20.0)
3–4 minimum wage	4 (11.4)
4–9 minimum wage	5 (14.3)
Smoking (n; %)	
Yes	12 (32.4)
No	25 (67.6)
Alcohol (n; %)	
Yes	29 (78.4)
No	8 (21.6)
Legend: BMI: Body mass index; LBM: Lean body mass; ApLM: Appendicular lean mass; FM: Fat mass; HGS: Hand grip strength; MQI: Muscle quality index; PhA: Phase angle. MUAC: mid-upper arm circumference; TSFT: triceps skinfold thickness; AMC: arm muscle circumference; AMA: arm muscle area; AFA: arm fat area. Minimum wage: The 2022 minimum wage in Brazil was 1202 reais (BR\$). The mean value of 1 dollar (\$) in Brazil during the period was ~ 5.20 reais (BR\$). Data are presented in mean, standard deviation, or absolute and relative frequencies.	

Insert Table 1.

Table 2 depicts the multivariate linear regression data considering HGS, MQI_{ApLM} , and MQI_{BMI} as dependent variables and PhA as the primary independent variable. For HGS as an outcome, PhA was positively associated in the univariate regression ($\beta = 5.21$; CI 95% 1.40–8.94; small to medium effect: 0.18; power: 0.73) and in model 1 ($\beta = 3.52$; CI 95% 0.39–6.66; medium to large effect: 0.43; power: 0.94). For the other outcomes, the PhA was not a significant predictor.

Table 2

Multiple regression model considering muscle-related parameters as dependent variables and phase angle as independent variable (n = 38).

Muscle-related parameter	β (CI 95%)	R	Adjusted R ² (Sample power)	p-value
HGS				
PhA	5.21 (1.40–8.94)	0.428	0.183 (0.73)	0.007
Model 1	3.52 (0.39–6.66)	0.656	0.430 (0.94)	0.028
Model 2	1.98 (-1.19–5.16)	0.720	0.519 (0.95)	0.214
Model 3	1.54 (-1.71–4.80)	0.734	0.539 (0.93)	0.342
Model 4	1.51 (-1.78–4.81)	0.737	0.543 (0.91)	0.357
MQI_{ApLM}				
PhA	0.09 (-0.05–0.24)	0.204	0.041 (0.23)	0.225
Model 1	0.02 (-0.10–0.15)	0.589	0.347 (0.88)	0.693
Model 2	0.07 (-0.06–0.21)	0.641	0.411 (0.89)	0.265
Model 3	0.06 (-0.07–0.20)	0.649	0.421 (0.86)	0.365
Model 4	0.06 (-0.08–0.20)	0.650	0.423 (0.82)	0.377
MQI_{BMI}				
PhA	0.16 (-0.01–0.34)	0.294	0.086 (0.41)	0.073
Model 1	0.06 (-0.07–0.19)	0.739	0.546 (0.98)	0.345
Model 2	0.02 (-0.12–0.16)	0.756	0.572 (0.97)	0.745
Model 3	-0.01 (-0.15–0.12)	0.797	0.636 (0.97)	0.831
Model 4	-0.01 (-0.15–0.12)	0.804	0.647 (0.95)	0.804
Legend: HGS: Handgrip strength; FM: Fat Mass; ApLM: Appendicular Lean Mass; BMI: Body Mass Index; PhA: Phase Angle; Model 1: adjusted for AFM; Model 2: adjusted for AFM and lean body mass; Model 3: Adjusted for AFM, lean body mass, and age; Model 4: Adjusted for AFM, lean body mass, age, and sex. Data expressed as mean and 95% confidence interval. Multivariate linear regression with Gaussian distribution of the dependent variable. Durbin-Watson autocorrelation test was applied. The alpha of 5% was used to reject the null hypothesis of the independent variable. The sampling power value was calculated with G*Power 3.1.				

Insert Table 2.

Table 3 shows the multivariate linear regression data considering HGS, MQI_{ApLM} , and MQI_{BMI} as dependent variables and AFM as the primary independent variable. The AFM was negatively associated with HGS ($\beta = -3.64$; CI 95% -5.69 to -1.60; medium to large effect: 0.53; power: 0.93), MQI_{ApLM} ($\beta = -0.15$; CI 95% -0.24 to -0.07; medium to large effect: 0.40; power: 0.85), and MQI_{BMI} ($\beta = -0.22$; CI 95% -0.30 to -0.13; medium to large effect: 0.64; power: 0.97).

Table 3

Multiple regression model considering muscle-related parameters as dependent variables and arm-fat mass as independent variable (n = 38).

Muscle-related parameter	β (CI 95%)	R	Adjusted R² (Sample power)	p-value
HGS				
AFM	-4.15 (-6.13 - -2.18)	0.585	0.342 (0.94)	< 0.001
Model 1	-3.93 (-5.69 - -2.16)	0.704	0.496 (0.96)	< 0.001
Model 2	-3.93 (-5.67 - -2.19)	0.725	0.525 (0.95)	< 0.001
Model 3	-3.64 (-5.69 - -1.60)	0.728	0.530 (0.93)	< 0.001
MQI_{ApLM}				
AFM	-0.16 (-0.23 - -0.08)	0.586	0.344 (0.93)	< 0.001
Model 1	-0.16 (-0.24 - -0.09)	0.623	0.388 (0.91)	< 0.001
Model 2	-0.16 (-0.24 - -0.09)	0.637	0.406 (0.92)	< 0.001
Model 3	-0.15 (-0.24 - -0.07)	0.638	0.408 (0.85)	< 0.001
MQI_{BMI}				
AFM	-0.24 (-0.32 - -0.16)	0.731	0.534 (0.99)	< 0.001
Model 1	-0.24 (-0.32 - -0.16)	0.756	0.571 (0.98)	< 0.001
Model 2	-0.24 (-0.31 - -0.17)	0.797	0.635 (0.98)	< 0.001
Model 3	-0.22 (-0.30 - -0.13)	0.804	0.642 (0.97)	< 0.001
Legend: HGS: Handgrip strength; FM: Fat Mass; ApLM: Appendicular Lean Mass; BMI: Body Mass Index; Model 1: adjusted by LBM; Model 2: adjusted for LBM and age; Model 3: adjusted by LBM, age, and sex. Data expressed as mean and 95% confidence interval. Multivariate linear regression with Gaussian distribution of the dependent variable. Durbin-Watson autocorrelation test was applied. The alpha of 5% was used to reject the null hypothesis of the independent variable. The sampling power value was calculated with G*Power 3.1				

Insert Table 3.

Table 4 shows the multivariate linear regression data considering HGS, MQI_{ApLM} , MQI_{BMI} , and Arm fat mass from DXA and PhA as dependent variables and AFA as the primary independent variable. The AFA was associated with muscle strength, except in model 3. In model 2, AFA was negatively associated with muscle strength (-0.22; CI 95% -0.35 to -0.05; medium to large effect: 0.34; power: 0.82). Likewise, in MQI_{ApLM} , AFA was associated with MQI_{ApLM} , except in model 3. In model 2, AFA was negatively associated with MQI_{ApLM} (-0.009; CI 95% -0.01 to -0.002; small to medium effect: 0.18; power: 0.54). AFA was negatively associated with MQI_{BMI} (-0.01 CI 95% -0.02 to -0.002; medium to large effect: 0.44; power: 0.88). Finally, AFA was positively associated with DXA-derived AFM (0.06 CI 95% 0.04–0.08; large effect: 0.71; power: 0.98).

Insert Table 4.

Discussion

We aimed to verify the relationship between PhA, AFM and AFA with SM strength and quality of PLWH.

With the start and improvement of ART, PLWH had their life trajectories positively modified. Currently, longitudinal studies suggest that, depending on the region (i.e., low/middle, or high-income countries) and the ability to control viral replication, PLWH have similar life expectancies to uninfected subjects [41–43]. However, due to the residual virus effect, old ART-related persistent adverse effects, and potential current ART-related harmful effects, PLWH can develop non-AIDS-related chronic comorbidities [44]. For instance, obesity, type 2 diabetes mellitus, higher cholesterol and triacylglycerol levels, and fatty tissue-related syndromes (i.e., lipodystrophy) are common in this population [26, 45–47]. Furthermore, PLWH presents negative changes in the gut microbiota that favor the maintenance of persistent immune activation and systemic inflammation [48]. More recently, SM changes in PLWH have been studied in depth [25, 49].

Our main findings revealed that PhA, AFM and AFA were significant predictors of parameters related to SM strength and quality. However, it is essential to verify the effect size, as well as the power of the analysis to avoid incorrect extrapolations [50].

With a small to moderate effect size, we found that PhA was positively associated with HGS. Nevertheless, this association disappears when adjusted for LBM, age, and sex. Previous studies showed that PLWH presents lower SM strength and quality than HIV-negative subjects [27, 51]. The use of PhA as a health marker increased in the last few years [52]. PhA indicates the geometric relationship between resistance and reactance and is a good indicator of cellular health [52]. PhA values are positively associated with higher cellularity, membrane integrity, and more appropriate cellular function [52].

Earlier publications showed a positive correlation between PhA and SM strength in different population [15, 19]. However, this relationship was poorly investigated in PLWH. Corroborating our data, Martins et al. [34] verified in a cross-sectional study with 62 adolescents with HIV that PhA was positively

associated with HGS. Moreover, PhA has been associated with malnutrition in PLWH. Values below 5.45° for men and 4.95° for women can predict (with sensitivity and specificity > 70%) malnutrition in this population [53]. Besides, PhA was positively associated with bone mineral density [54] and negatively associated mortality risk [55]. Interestingly, SM strength is linked to all of these measurements [56–58]. Thus, a higher PhA value in PLWH indicates a better health status, and to evaluate and monitor changes in SM strength, especially in response to strength training, PhA can be a good predictor [59, 60]. Akamatsu et al. [19] proposed cutoff points to define sarcopenia by the phase angle of electrical bioimpedance. According to the cutoff points created for non-elderly men (5.95°) and non-elderly women (5.02°), no PLWH in our sample was considered sarcopenic by the PhA.

We found that AFM was a consistent negative predictor of SM strength and quality (medium to large effect size). Likewise, AFA was a negative predictor of HGS (small to medium effect size) and SM quality (small to medium effect size) when HGS was corrected by BMI. It is fundamental to highlight that the assessment of AFA allows, with simple instruments, the association with SM strength and quality. Likewise, AFA was a consistent predictor of AFM by DXA (large effect size), reinforcing that in clinical practice, a simple anthropometric parameter is a predictor of DXA-derived AFM. Although a prior publication has discussed the capacity of AFA to predict arm fat when assessed by MRI [31], it is essential to verify the predictive power in PLWH.

Previous studies have shown that higher fat infiltration can lead to harmful SM-related outcomes [61, 62]. However, evaluating infiltrated fat requires specific equipment (i.e., MRI and CT) [63]. Despite that, DXA and BIA are capable of measuring and estimating fat regionally, respectively [63]. Although the use of these tests is encouraged for PLWH [64], it is necessary to emphasize that most health clinics and hospitals will not have this equipment available. Hence, AFA is a simple instrument that can be used in clinical practice, replacing expensive and inaccessible evaluation methods.

Several adipose tissue-related abnormalities are observed in PLWH, including increased fatty infiltration in SM [65, 66]. Natsag et al. [65] observed a higher decline in muscle density of PLWH compared to people HIV-negative subjects. Likewise, Erlandson et al. [27] with data from the Multicenter AIDS Cohort Study and Women's Interagency HIV Study, observed that lower SM area and density were associated with several measures of impaired physical function.

SM naturally presents intramyocellular lipid droplets that stay in the cytoplasm of myocytes [67]. The excessive increase in SM fat infiltration can negatively affect mitochondrial function, increase inflammatory cytokines and oxygen species, and reduce muscle protein synthesis and insulin sensitivity [67]. These changes lead to poor contractile capacity, mechanotransduction and SM force transmission, which can reduce SM strength and function [67]. Therefore, estimates of arm fat content provide vital information to predict SM strength/quality and associated clinical outcomes.

Our study, however, has limitations: (i) the cross-sectional design, in which causality cannot be assumed with the proposed analyses; (ii) the sample size, although we present the effect size and power values to

avoid misinterpretations; (iii) the absence of objective measurements for arm fat mass infiltration by MRI or CT.

However, our study has the potential to add to the scientific literature about SM and sarcopenia of PLWH. Previous studies have not assessed the PhA of adults living with HIV. Likewise, the understanding that a simple measure to obtain, such as the AFA, allows for simple and relevant practical assessments for professional performance.

Thus, we concluded with a small to moderate effect size that PhA was a positive predictor for HGS. Similarly, AFM was a consistent negative predictor of HGS and MQI. Finally, AFA was also a negative predictor of HGS and MQI_{BMI} in PLWH. Studies that evaluate the relationship between these parameters with more objective measurements derived from MRI and CT are necessary for more robust results.

Declarations

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Authors' contribution

Study design – M.V.L.S.Q.; B.M.V.; R.E.B. and S.M.LR.; data collection – M.V.L.S.Q.; B.M.V.; R.E.B.; G.R.; data analysis – M.V.L.S.Q.; manuscript preparation and review – M.V.L.S.Q; projetct principal investigator- SMLR.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Consent for publication

All authors approved the final version of the manuscript and consented to its publication.

Ethical approval

The University of São Paulo, SP, Brazil approved the study (protocol number: 4.938.460)

Availability of data and materials

Data will be made available upon request.

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Table 4

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