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DEVELOPMENT AND VALIDATION OF EQUATIONS TO ESTIMATE VISCERAL ADIPOSE TISSUE IN MILITARY MEN

DESENVOLVIMENTO E VALIDAÇÃO DE EQUAÇÕES DE ESTIMAR O TECIDO ADIPOSO VISCERAL EM MILITARES

DESARROLLO Y VALIDACIÓN DE ECUACIONES PARA ESTIMAR EL TEJIDO ADIPOSO VISCERAL EN MILITARES

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ABSTRACT

Introduction: It has been suggested that visceral adipose tissue (VAT) is associated with several non-communicable chronic diseases, but measuring it is difficult. Thus, anthropometry could be used because is easily applied in clinical practice. Objectives: The present study aimed to develop and validate VAT estimation equations (Eq) in military men. Methods: The sample consisted of 409 (mean age, 36.5 ± 6.7 years) military men in the Brazilian Army (BA) divided into an equation group (EG) (n = 270; mean age, 37.0 ± 6.3 years) and a validation group (VG) (n =139; mean age, 36.0 ± 7.2 years). Anthropometric, hemodynamic and DXA body composition evaluations (*GE iLunar*) were performed. The Student's t test, Pearson's correlation, and stepwise general linear regression were applied. Bland-Altman graphics were used to assess the concordance between VAT by Eq and by DXA. The level of significance was 95% ($p < 0.05$). Results: Age, waist circumference (WC), hip circumference and body mass index presented the main significant positive correlations with the VAT-DXA. Four Eq were created Eq1 ($r^2 = 0.793$), Eq2 ($r^2 = 0.810$), Eq3 ($r^2 = 0.817$), and Eq 4 ($r^2 = 0.823$) ($p < 0.05$). No differences were observed between VAT by DXA and VAT by Eq ($p = 0.982$, $p = 0.970$, $p = 0.495$ and $p = 0.698$). Bland-Altman analysis also presented good concordance as the bias was close to zero and was not statistically significant. Conclusion: Eq2 (age*13.0 + WC*60.0 - 4975,.5) was more suitable because it is easier to apply, has a higher predictive power (81.0%), less bias (1.86) and validation yielded average VAT values close to those found in DXA. It may still be considered a valuable tool for other extensive epidemiological studies in military men in the BA and can be used in adult men. ***Evidence Level I: Development of diagnostic criteria on consecutive patients (with universally applied reference "gold" standard).***

Keywords: X-Ray Absorptiometry, Visceral adipose tissue; Estimation; Military personnel.

RESUMO

*Introdução: A literatura científica tem sugerido que o tecido adiposo visceral (TAV) está associado a doenças crônicas não transmissíveis, mas é difícil fazer sua mensuração. Assim, a antropometria pode ser empregada por ser de fácil aplicação na prática clínica. Objetivos: Este estudo teve como objetivo desenvolver e validar equações de estimativa (Eq) do TAV em militares. Métodos: A amostra consistiu em 409 (média de idade 36,5 ± 6,7 anos) militares do Exército Brasileiro (EB) divididos em Grupo equação (GE) (n = 270; média de idade 37,0 ± 6,3 anos) e Grupo validação (GV) (n = 139; média de idade 36,0 ± 7,2 anos). Foram realizadas avaliações antropométricas, hemodinâmicas e de composição corporal por DXA (GE iLunar). O teste t de Student, a correlação de Pearson e a regressão linear geral Stepwise foram aplicados. Os gráficos de Bland-Altman foram usados para avaliar a concordância entre os resultados de TAV pela Eq e por DXA. O nível de significância adotado foi de 95% (p <0,05). Resultados: Idade, circunferência da cintura (CC), circunferência do quadril e o índice de massa corporal apresentaram as principais correlações positivas e significativas com TAV-DXA. Foram criadas quatro equações: Eq1 (r^2 = 0,793), Eq2 (r^2 = 0,810), Eq3 (r^2 = 0,817) e Eq 4 (r^2 = 0,823), p < 0,05. Não foram observadas diferenças entre o TAV por DXA pelas Eq (p = 0,982, p = 0,970, p = 0,495 e p = 0,698). A análise de Bland-Altman também apresentou boa concordância, porque o viés foi próximo de zero e não estatisticamente significativo. Conclusões: A Eq2 (idade*13,0 + CC*60,0 - 4975,5) foi mais adequada, porque é mais fácil de aplicar, tem maior poder preditivo (81,0%), menor viés (1,86) e a validação forneceu valores médios de TAV próximos aos encontrados no DXA. Além disso, pode ser considerada uma ferramenta valiosa para outros estudos epidemiológicos extensos em militares do EB e pode ser usada em homens adultos.* ***Nível de Evidência I; Teste de critérios diagnósticos desenvolvidos anteriormente em pacientes consecutivos (com padrão de referência "ouro" aplicado).***

Descritores: Absorciometria de Raios X*; Tecido Adiposo Visceral; Estimativa; Militares.*

RESUMEN

Introducción: La literatura científica ha sugerido que el tejido adiposo visceral (TAV) está asociado a enfermedades crónicas no transmisibles, pero es difícil hacer su medición. Así, la antropometría puede ser empleada por ser de fácil aplicación en la práctica clínica. Objetivos: Este estudio tuvo como objetivo desarrollar y validar ecuaciones de estimativa (Ec) del TAV en militares. Métodos: La muestra consistió en 409 (promedio de edad 36,5 ± 6,7 años) militares del Ejército Brasileño (EB) divididos en Grupo de ecuación (GE) (n = 270; promedio de edad 37,0 ± 6,3 años) y Grupo validación (GV) (n

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= 139; promedio de edad 36,0 ± 7,2 años). Fueron realizados análisis antropométricos, hemodinámicos y de composición corporal por DXA (GE iLunar). Fueron aplicados el teste t de Student, la correlación de Pearson y la regresión linear general Stepwise. Los gráficos de Bland-Altman fueron usados para evaluar la concordancia entre los resultados de TAV por la Ec y por DXA. El nivel de significancia fue de 95% (p <0,05). Resultados: Edad, circunferencia de cintura (CC), circunferencia de la cadera y el ***índice de masa corporal*** *presentaron las principales correlaciones positivas y significativas con TAV-DXA. Fueron creadas cuatro ecuaciones: Ec1 (r^2 = 0,793), Ec2 (r^2 = 0,810), Ec3 (r^2 = 0,817) y Ec4 (r^2 = 0,823), p <0,05. No fueron observadas diferencias entre el TAV por DXA por las Ec (p = 0,982, p = 0,970, p = 0,495 y p = 0,698). El análisis de Bland--Altman también presentó buena concordancia, porque el sesgo fue próximo de cero y no estadísticamente significativo. Conclusiones*: La Ec2 (edad*13,0 + CC*60,0 - 4975.5) fue más adecuada, porque que es más fácil de aplicar, tiene mayor poder predictivo (81,0%), menor sesgo (1,86) y la validación suministró valores promedio de TAV próximos a los encontrados en el DXA. Además, puede ser considerada una herramienta valiosa para otros estudios epidemiológicos extensos en militares del EB y puede ser usada en hombres adultos. ***Nivel de Evidencia I: Test de criterios diagnósticos desarrollados anteriormente en pacientes consecutivos (con patrón de referencia "oro" aplicado).***

Descriptores: Absorciometría de Rayos X, *Tejido Adiposo Visceral; Estimativa; Personal militar.*

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INTRODUCTION

Obesity is one of the biggest public health challenges in the world, contributing to the increased risk of many chronic non-communicable diseases (CNCDs), such as hypertension, type 2 diabetes, cardiovascular disease and other comorbidities.[1] In Brazil, each annual survey on frequency and distribution of CNCDs, conducted by federal government, shows that the prevalence of obesity has been skyrocketing from 11.8% in 2006 to 19.8% in 2018.[2] Characterized by an excessive increase in adipose tissue (AT), obesity is an independent predictor of coronary artery disease.[3]

Current scientific literature indicates that the regional distribution ratio of AT is as important, then total fat prediction of CNCDs complications traditionally related to obesity.[3,4] Visceral adipose tissue (VAT) has higher metabolic activity when compared to subcutaneous adipose tissue, secreting a larger amount of adipokines, such as Leptin, causing chronic systemic inflammation associated with insulin resistance and hypertriglyceridemia.[4] Thus, quantifying VAT may be the key to controlling the development of CNCDs.[3-7]

Different methods are capable of measure VAT such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Ultrasound (USG), Dual energy x-ray Absorptiometry (DXA) which are more accurate methods.[7-10] However, these imaging techniques, though very reliable, are expensive, exposes individuals to x-ray risks and require skilled personnel, making their use difficult on a large scale.[8,10]

In contrast, anthropometry, easy to apply in clinical practice can be used to estimate body composition components.[6,11] This technique is based on the two-compartment model, which segments the human body into fat mass (FM) and fat free mass (FFM). Anthropometric measurements can estimate the amount of AT, such as waist circumference (WC) and skin folds.[11-13]

Some studies have proposed predictive equations for measuring FM in several groups.[6,9,12-15] However, five studies were found on the development of VAT estimation equations using anthropometric measurements, age and VAT assessment by CT, MRI, USG and DXA.[6,9,14-16] It's known that the distribution of VAT varies according to race, age and gender, so it isn't possible to choose a generalized equation (Eq) to evaluate the entire population.[5] Brazilian Army (BA) personnel, for example, have professional characteristics that require them to perform frequent physical training, enabling them to have better health indicators when compared to the civilian population.[17] Consequently, the development of a military specific Eq has as its main advantage its accuracy for this group, provided as they are validated.[18]

Thus, this study aimed to develop and validate VAT estimation equations in BA military men, based on easily obtainable and low-cost variables, seeking to create fast strategies for CNCDs control, improving health and quality of life of the militaries.

METHODS

Study design and population

The present cross-sectional study evaluated 409 (36.5 ± 6.7 years) BA military men, in convenience sampling, divided into two groups. The first named group of the Eq (GE), composed of 270 (37.0 ± 6.3 years) military men and second so-called validation group (GV), consisting of 139 (36.0 ± 7.2 years) military men. The selection was made by volunteers who participated in the Metabolic Syndrome (MetS) Monitoring Program, conducted by the Army Physical Training Research Institute (IPCFEx) between 2017 and 2019.

Active-duty male military personnel that were students at the Army Command and General Staff School (ECEME), the Officer Improvement School (EsAO) and the Sergeants School of Logistics (EsLog) were included. In addition, militaries selected to integrate individual peacekeeping missions of the United Nations, militaries from BA Organizations in the city of Rio de Janeiro were included. Military personnel who underwent any type of recent abdominal surgery and retirees were excluded. As well as female military personnel were excluded due to the small number evaluated.

All the participants signed the Informed Consent Form when they became aware of the procedures and risks to which they would be submitted. This research was registered in the National Research Ethics System, submitted and approved by the Ethics Council of the Naval Marcílio Dias Hospital, nº 1.551.242, CAAE nº 47835615.5.0000.5256.

Data Collect

Data collection took place in the IPCFEx laboratories in three stages during the same day in the morning and was conducted by researchers of the same Institute.

Initially, the systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured following the VII Brazilian Guidelines on Hypertension for Ambulatory Blood Pressure Monitoring of the Brazilian Society of Cardiology.[19]

Afterwards, they were submitted to an anthropometric evaluation to measure the total body mass (BM), height, WC, abdominal circumference (AC), hip circumference (HC) and neck circumference (NC) following the Fernandes Filho's guidelines.[11] Height was measured with a *Sanny* metal stadiometer (2 mm). The subjects were standing in Orthostatic Position maintaining contact with the device by the heel. The head adjusted to the Frankfurt plane. Body mass index (BMI) was calculated.

To measure the circumferences, an anthropometric tape, *Sanny* model, *SN4010* was used and the subjects kept the abdomen relaxed. WC was obtained at the point of lowest circumference between the last rib and iliac crest, AC was measured at the umbilical scar line, HC at the medial part between the two trochanteric points, at the most prominent region of the buttocks. The NC was measured at the midpoint of the neck (midpoint of the cervical spine and anterior neck). The average of technical errors of measurement, inter and intra, were considered acceptable, being 1.35% and 0.97%, respectively.[20]

Body composition was performed by a radiology technician using DXA (GE, *iLunar*, *Healthcare, Madison* WI) and following standard quality control procedures, according to the manufacturer.[8,10] Fat mass (FM) and Lean mass (LM) was derived from total body analyze with an *enCore* 12.20 software. TAV was measured in a region-of-interest defined as between the top of the iliac crest and 20% of the distance from the top of the iliac crest to the base of the skull and expressed as absolute values (g and cm^3).[8,10] Measurements in the calibration block (daily) and the calibration column phantom (weekly) provided by the manufacturer presented acceptable coefficients of variation (1.0%).[8,10]

Statistical Analyses

The *Shapiro Wilk* Test confirmed the normal distribution of the data. Descriptive statistics techniques with measures of location (mean) and dispersion (standard deviation) characterized the sample. *Student t test* of independent samples was applied to compare the mean values of the variables between groups. *Pearson's* Correlation was used to verify associations with VAT. *Multiple Linear Regression Stepwise* was used to development the equations and Student's t-test of dependent samples applied to validate. *Bland-Altman Graphics*, with Linear Correlations, were plotted to verify the agreement between methods.[18] All analysis were performed in SPSS 17.0. Significance level adopted was 95% ($p<0.05$).

RESULTS

Descriptive analysis with both groups evaluated and comparisons between EG and VG are presented in Table 1. The groups showed significant differences in mean WC, AC, NC, FM, LM, SBP and DBP ($p < 0.05$). The mean BMI was categorized as overweight in both groups.

All variables except height were positively associated with VAT-DXA. WC presented the strongest association, followed by BMI, BM, WC, NC and AC, respectively. (Table 2)

Four equations were developed using the variables age, WC, HC and BMI. (Table 3) For first equation (Eq1) only WC was used. Aggregating the Age in Eq1, it was created the second equation (Eq2). For the development of the third equation (Eq3) was included in HC to Eq2. Finally, the fourth equation (Eq4) was produced adding the BMI variable to Eq3. All equations reached the minimum value of "r", r >0.80.[18] Standard Error Estimative (SEE) presented the same trend in the four equations, ranging from 285.0 to 307.1 grams. (Table 3)

Comparisons between the mean value of VAT-DXA and VAT by equations are present in Table 4 and no significant differences were observed between them. (Table 4)

The associations between VAT measured by DXA and VAT estimated by all equations were very strong ($r>0.877$; $r^2>0.770$). (Figures 1A to 4A) The graphic representations (Figures 1B to 4B) showed the agreement between the two different methods. On the "Y" axis, the difference between the VAT values by DXA and equations were plotted. The "X" axis

Table 1. Comparisons of anthropometric data and body composition between Equation Group (EG) and Validation Group (VG).

	EG	VG	*p*
n	**270**	**139**	
Age	37.0 ± 6.3	36.0 ± 7.2	0.223
Body composition			
Height (cm)	177.4 ± 6.1	177.0 ± 7.1	0.632
BM (kg)	86.1 ± 13.5	88.8 ± 8.8	0.178
BMI (kg/m²)	27.4 ± 3.6	26.8 ± 3.5	0.181
WC (cm)	90.9 ± 9.7	88.8 ± 8.8	0.011*
AC (cm)	99.2 ± 10.6	93.1 ± 10.1	0.015*
HC (cm)	102.8 ± 7.1	101.7 ± 6.9	0.119
NC (cm)	34.3 ± 2.5	39.2 ± 3.5	0.016*
LM (kg)	59.8 ± 6.4	59.2 ± 8.5	0.000*
FM (kg)	23.1 ± 9.2	21.9 ± 9.6	0.000*
%BFDXA	26.0 ± 6.9	24.8 ± 7.0	0.079
FMI (kg/m²)	7.3 ± 2.9	7.0 ± 3.0	0.248
VAT-DXA (cm³)	856.7 ± 49.0	867.4 ± 67.4	0.073
VAT-DXA (g)	816.5 ± 67.0	820.5 ± 63.3	0.078
SBP (mmHg)	117.1 ± 9.7	123.0 ± 11.1	0.018*
DBP (mmHg)	80.0 ± 6.2	77.7 ± 9.1	0.018*

EG: equation group, VG: validation group, VAT-DXA: DXA visceral adipose tissue, BM: body mass, BMI: body mass index, WC: waist circumference, AC: abdominal circumference, HC: hip circumference, NC: neck circumference, LM: lean mass, FM: Fat Mass, % BFDXA: Percentage DXA Fat, SBP: Systolic Blood Pressure, DBP: blood pressure, kg: kilos, g: grams, cm^3: cubic centimeters, cm: centimeters, mmHg: millimeter mercury, * $p < 0.05$.

Table 2. Associations between VAT and independent variables of the equation group ($n = 270$).

Independents Variables	VAT-DXA (g)		
	Person		
	r*	r²*	P*
Age	0.332	0.110	< 0,001**
Height (cm)	0.014	0.000	0.822
BM (kg)	0.756	0.571	< 0,001*
BMI (kg/m²)	0.797	0.635	< 0,001*
WC (cm)	0.890	0.792	< 0,001*
AC (cm)	0.614	0.377	< 0,001*
HC (cm)	0.690	0.476	< 0,001*
NC (cm)	0.676	0.457	< 0,001*
SBP (mmHg)	0.244	0.060	< 0,001*
DBP (mmHg)	0.323	0.104	< 0,001*

BM: body mass, BMI: body mass index, WC: waist circumference, AC: abdominal circumference, HC: hip circumference, NC: neck circumference, SBP: systolic blood pressure, DBP: blood pressure, kg: kilos, g: grams, m^2: squared meters, cm: centimeters, mmHg: millimeter mercury, *p values and coefficients of correlation were obtained by Pearson correlation analyses.

Table 3. VAT predictive equations (g) to military men of Brazilian Army ($n = 270$).

Eq	Equation	*p*	*r*	*r²*	*r²* aj	SEE (g)
1	WC*62.0 - 4684.2	0.000*	0.890	0.793	0.792	307.1
2	AGE*13.0 + WC*60.0 - 4975.5	0.000*	0.900	0.810	0.808	294.7
3	AGE*11.2 - HC*15.6 + WC*69.8-4210.7	0.000*	0.904	0.817	0.815	289.3
4	BMI*37.4 - HC*22.8 + AGE*14.1+ WC*59.6 - 3674.4	0.000*	0.907	0.823	0.821	285.0

Eq: equation, VAT: visceral adipose tissue, WC: waist circumference, HC: hip circumference, BMI: body mass index, g: grams, SEE: standard error of estimation, aj: adjusted, * $p <0.05$.

Table 4. Comparisons of VAT obtained by equations and measured b DXA in Brazilian Army men ($n = 139$).

Eq	Equation	VAT- Eq *(g)*	VAT-DXA (g)	t	*P**
1	WC*62.0 – 4684.2	819.9 ± 549.6	820.5 ± 635.9	0.022	0.982
2	AGE*13.0 + WC*60.0 – 4975.5	819.0 ± 566.4		0.038	0.970
3	AGE*11.2 - HC*15.6 + WC*69.8-4210.7	803.3 ± 563.5		0.684	0.495
4	BMI*37.4 - HC*22.8 + AGE*14.1+ WC*59.6 – 3674.4	810.9 ± 562.8		0.388	0.698

Eq: equation, DXA: X-ray dual emission absorptiometry, VAT: visceral adipose tissue, WC: waist circumference, HC: hip circumference, BMI: body mass index, g: grams, *p values obtained by student's t test.

shows the differences. The limits of agreement were determined by the average level of 1.96. For all predictive equations, the difference between the VAT measured and VAT estimated were close to zero. The Bias for the equations ranging from 1.86 for Eq2 to 15.5 for Eq3. (Figures 1-4)

Analyzing Figures 1A, 2A, 3A, 4A, the VAT by equations showed strong correlations with VAT by DXA, Eq1(r=0.877; $r2$=0.770), Eq2(r=0.880; $r2$=0.774), Eq3(r=0.885; $r2$=0.783) and Eq4(r=0.884; $r2$=0.781) and good agreement, because Bias is close to zero and they aren't statistically significant.[21]

DISCUSSION

The present study developed and validated four VAT estimation equations for military men from BA using simple, easily obtainable as well as low cost applicability anthropometric variables. After statistical testing, the variables Age, WC, HC and BMI were used for the development of the equations and they showed significant concordance with VAT measured by DXA.

The second equation (Age*13.0 + WC*60.0 - 4975.5) was the most indicated to estimate VAT, because it is simple to apply and a high predictive power yet having presented, in its validation, average values of VAT were close to those found in DXA. The strong correlations of WC, BMI and VAT found in the study under discussion (r=0.890 and r=0.797, respectively) confirm their importance in the development of equations.

For Madden et al.,[13] WC and BMI are strongly associated with cardiovascular risk factors, metabolic disorders, changes in lipid profile and hypertension, which in turn is correlated with the amount of VAT.

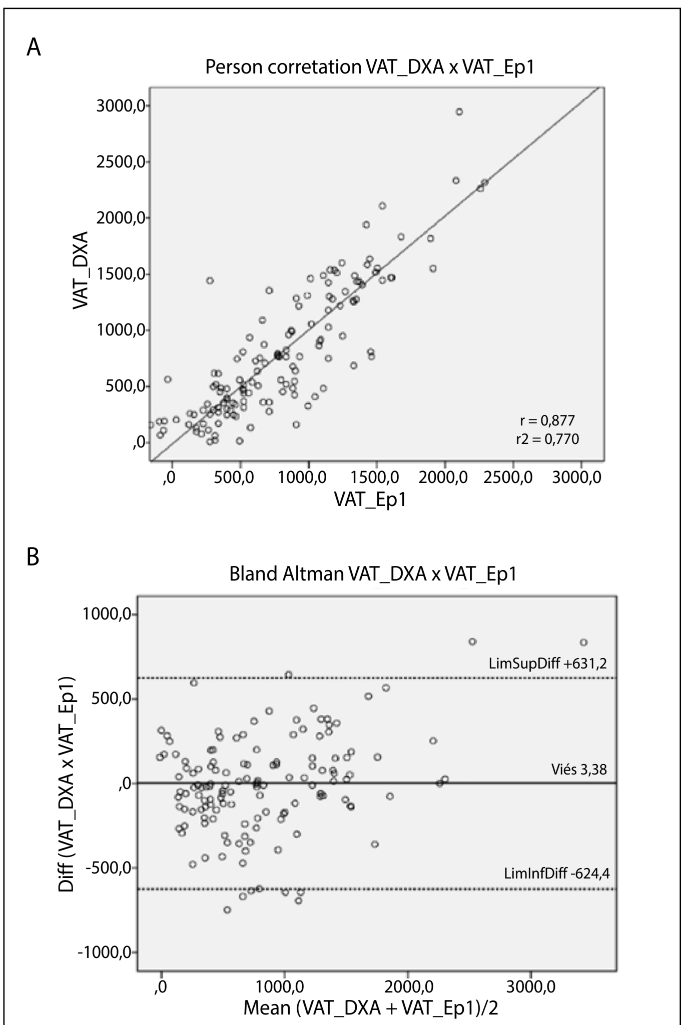

Figure 1. Correlation of equation 1 and VAT-DXA; Bland-Altman for agreement between VAT-DXA and VAT by equation 1.

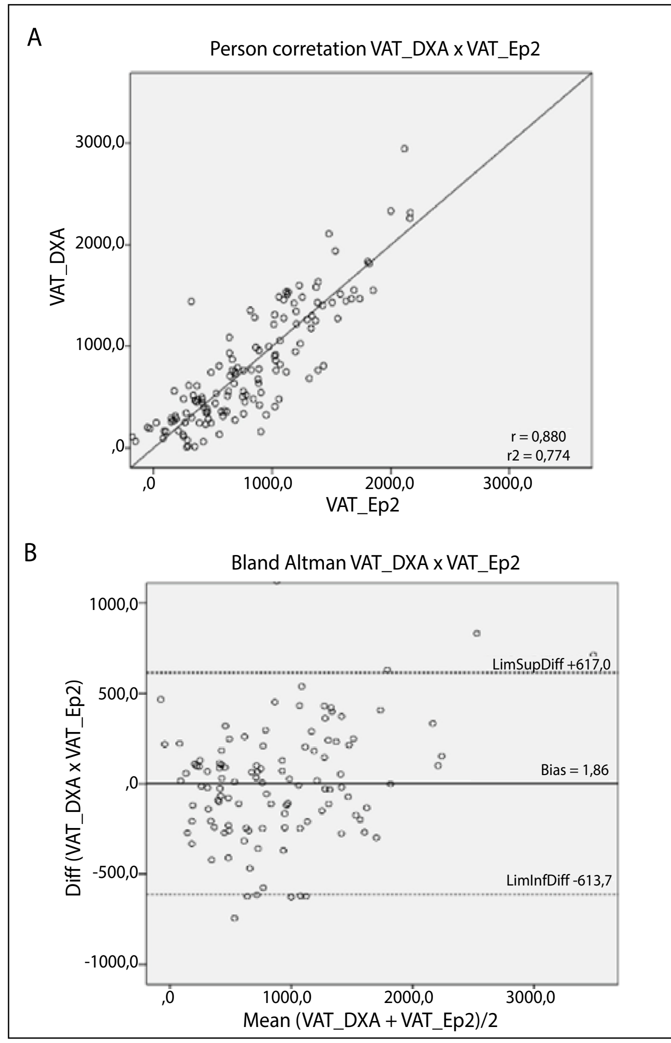

Figure 2. Correlation of equation 2 and VAT-DXA; Bland-Altman for agreement between VAT-DXA and VAT by equation 2.

Recently, Fortes et al.[22] observed strong associations between WC, BMI and risk factors for MetS in BA men, suggesting that both variables are good predictors of the disease strongly associated with VAT.

Regarding HC, findings show that it has an association with AT, but its values for estimating mortality risks are still unclear.[13] A meta-analysis of eighteen studies suggests a significant inverse relationship between HC and the risk of type 2 diabetes mellitus (DM2) in men.[23] HC has also shown good correlations with CNCDs when used with waist hip ratio (WHR), as in a recent study involving obese adolescents, where was found a moderate correlation with VAT.[24] In the present study, HC showed also moderate correlation with VAT and was therefore used in equations.

Despite having a weak correlation with VAT (r=0.332), Age was significant in the construction of the equations. Henry and colleagues[25] also used age to develop predictive AT equations in Asian men but didn't indicate the correlation and significance used. According to Jura e Kozak,[26] FM increases with advancing age, thus being an important variable in the assembly of equations.

It's possible to question the reason why BM, NP and AC didn't enter the construction of equations, even presenting strong and moderate correlations with VAT. The answer may lie in the procedure for selecting/excluding variables that is based on an algorithm that checks their importance from models based on a decision rule, such as Multiple Linear Regression Stepwise.[27] Thus, the most important variable is the one that produces the largest change in the likelihood logarithm, in relation to the model that doesn't contain the variable.[27]

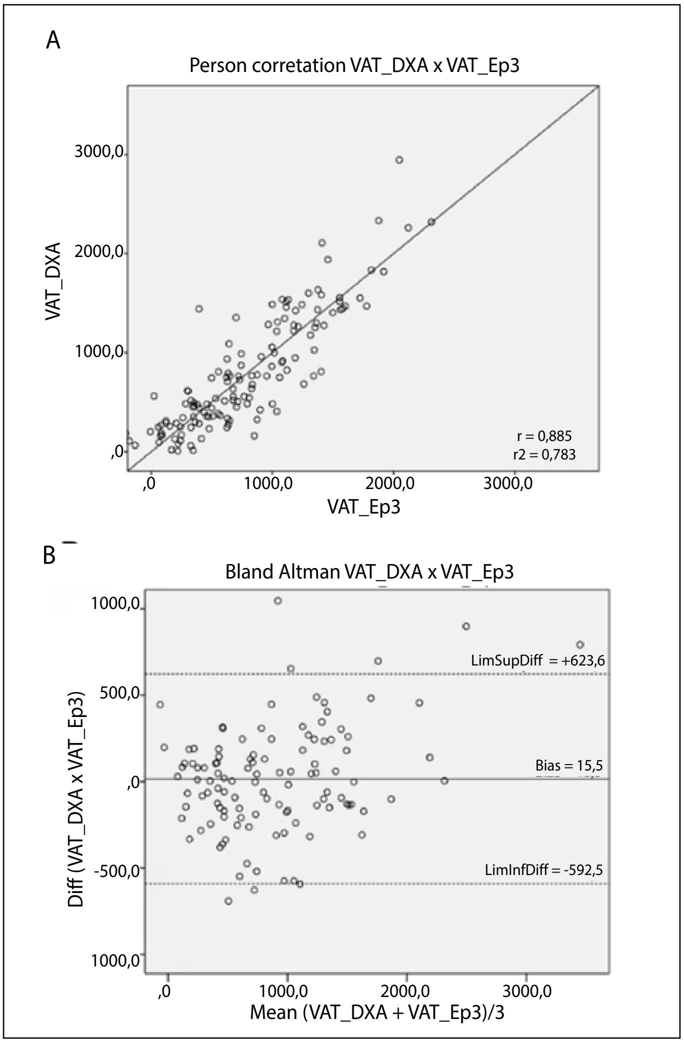

Figure 3. Correlation of equation 3 and VAT-DXA; Bland-Altman for agreement between VAT-DXA and VAT by equation 3.

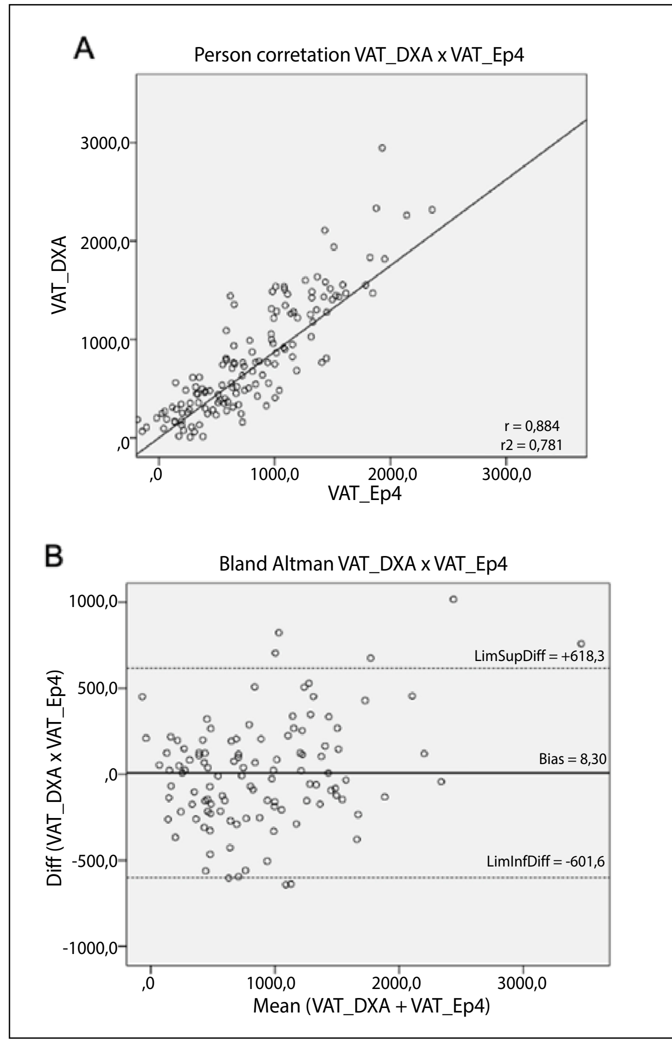

Figure 4. Correlation of equation 4 and VAT-DXA; Bland-Altman for agreement between VAT-DXA and VAT by equation 4.

The hemodynamic variables showed weak and non-significant correlations and weren't used. The same was found by Kotronen et al.,[28] where they suggested that VAT has a significantly weak correlation with SBP (r=0.220) and DBP (r=0.120).

Bland-Altamn Graphics showed that all equations presented good agreement with VAT because the Bias found are close to zero.[19] Also, the agreement limits indicate that the differences between the mean VAT values of the equations are close to 200 grams.[21] The four equations were validated, and no significant difference was found in the results.

Considering what has been researched, there is only one study that developed VAT prediction equations using *GE-DXA*, *ilunar DPX*, and anthropometric variables in the general population.[15] In this finding, the authors evaluated 709 Greek adults (437 women and 272 men; 18 to 80 years, BMI 16.9-40.4 kg/m^2) and used anthropometric measures by skinfolds, height and WC.[15] However, the equation was very long and difficult to apply because it included logarithms but presented high coefficient of determination in men Eq (r^2=0.941).[15] Moreover, in *the Bland-Altman* analysis indicated a non-statistically significant near Bias, the same found in the four equations developed here.[15]

However, other researchers have also developed VAT estimation equations using CT, MRI, USG and DXA. (Table 5)[6,9,14-16]

Pinho et al.[14] created five models (by CT) for men (± 49.9 years) and women (± 50.0 years), BMI 25 kg/m^2 based on anthropometric variables such as BMI, WC, WHR, waist Height Ratio (WHtR), NC, conicity index (CI), sagittal diameter and neck-thigh ratio. Correlations weren't exposed, and the equations presented r^2 from 43.4% to 72.4%.[14]

In another look, Petribú et al.[9] developed three equations to estimate VAT (by USG) in Brazilian women (19-36 years), using WC, HC, BM, BMI, WHtR, CI and glucose. Thus, though HC had a moderate correlation (r=0.409), it wasn't used in the equations and the authors didn't mention the reason.[9] However, they used the MC even presenting a weak correlation.[9] According to the authors, the three equations showed low predictive power to estimate VAT, ranging from 24% to 45%[9]. Already, Brundavani et al.[16] created VAT prediction equations with 120 Indians (40-79 years), WC, regression and CT techniques. In men, the equations explained in 71.9% of the VAT, with a SEE of 28.3%.[16]

The fact that no was found predictive VAT equations by GE-DXA, *iLunar*, specific to the military personnel, made the discussion of this study difficult. However, the equations developed here had a high coefficient of determination (79.3% to 82.3%).

The limitation of the present study includes non-use of biochemical variables such as triglycerides, HDL-C and glucose. Such insertion would be interesting because they are associated with cardiac and metabolic risk factors. Additionally, the equations may present negative values in military personnel with low WC, close to the average of 74.2 cm. This can be explained by the central obesity cutoff point of MetS established in 2009, which associates WC ≥ 90 cm with cardio-metabolic risk factors.[29]

Nevertheless, this study was innovative because it sought to develop CNCDS control strategies the BA personnel has never seen before. Moreover, the VAT estimation equations, specifically for militaries, developed with simple and easily acquired anthropometric measurements, also

Table 5. Estimation equations for visceral adipose tissue (VAT).

References	VAT	VAT Equations	Variables Used	r^2	SEE
Brundavani et al. (2006)	CT (cm^2)	Eq= 400.5 + (6.43 x WC (cm))	WC	0.719	28.6 cm^2
Petribú et al. (2012)	USG (cm^2)	Eq1= 31.888 + (4.044 x BMI)	BMI, WHtR, glucose	0.324	18.5 cm^2
		Eq2= 51.891 + (248.018 x WHtR)		0.239	19.9 cm^2
		Eq3= 130.941 + (198.673 x WHtR) + (1.185 x glucose)		0,446	15.2 cm^2
Pinho et al. (2017)	USG (cm^2)	Eq= -1647.75 + 2.43x(AC) + 594.74(WHR) + 883.40 (CI)	AC, WHR, CI	0.641	296.7 cm^2
Skoufas et al. (2018)	DXA (cm^3)	Eq= -174.177 – (15.247 x height(m)) + (104.503 x LogWC(cm)) + (9907.0 x LogSFSupr(mm)) + (7971.0X LogSFAbd(mm))	Height, Log: WC, SFSupr, SFabd	0.941	NS
So et al. (2017)	MRI (cm^3)	Eq1: 109.39 x WC (cm) – 6.562,6.	Age, BMI, WC	0.380	1.120,3 cm^3
		Eq2: 46.51 x Age + 117.69 x WC (cm) – 9.661,8.		0.456	1.051,3 cm^3
		Eq3: 47.03 x Age + 117.79 x BMI + 74.18 x WC (cm) – 8,792,7.		0.469	1.039,1 cm^3

VAT: visceral adipose tissue, MRI: Magnetic resonance imaging, CT: computed tomography, USG: ultrasound, DXA: dual-emission X-ray absorptiometry device, Eq: equation, **SEE: standard error estimation**, BMI: body mass index, WC: waist circumference, AC: abdominal circumference, WHtR: waist-to-height ratio, WHR: hip-waist ratio, CI: conicity index, DSag: sagittal diameter, DC: skinfold, abd: abdominal, supr: suprailic, log: logarithm, NS: not showed, cm^2: square centimeter, cm^3: cubic centimeter, g: grams, $P < 0.05$.

unpublished, are valuable tools in the identification of cardiometabolic alterations whose impact on the soldier's health. Just applying simple anthropometric techniques, any military man can estimate VAT, no matter where they are. These findings will be presented to the BA in order to include them in the next edition of the Military Physical Training Manual (EB20-MC-10.350) making it easier for access.

CONCLUSION

The present findings suggest that equation that include age and WC seems to be the most suitable for estimating VAT in BA military men because it's simple to apply, has high predictive power (81.0%) and its validation has presented mean values of VAT close to those found by DXA. It can also be considered a valuable tool for other extensive epidemiological studies on VAT and CDNDs. The homogeneity of the members of the BA, made up of adult Brazilians, suggests that this created equation can also be applied to Brazilian men in general.

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